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FUELWOOD CONSUMPTION AND PRODUCTION IN ALPINE BHUTAN: A CASE STUDY OF RESOURCE USE AND IMPLICATIONS FOR CONSERVATION AND MANAGEMENT IN WANGCHUK CENTENNIAL PARK

Wangchuk Sangay

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FUELWOOD CONSUMPTION AND PRODUCTION IN ALPINE BHUTAN

A Case Study of Resource Use and Implications for Conservation and Management in Wangchuck Centennial Park

By

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Thesis

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Fuelwood Consumption and Production in Alpine Bhutan: A Case Study of Resource Use and Implications for Conservation and Management in Wangchuck Centennial Park

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Wood has been used since prehistoric times for cooking and heating, and remains the primary energy source for billions of people throughout the world. In Bhutan, fuelwood accounts for 78% of total energy consumption and is the primary energy source for most rural and urban residents. Despite the importance of fuelwood in Bhutan, little is known about household fuelwood consumption, available biomass, or growth and yield.

This study documents fuelwood consumption, standing biomass, and annual growth and yield through a case study in Nasiphel and adjacent hamlets (elevation 2800 m), and a high elevation site (Chajeyna, 4800 m) where Nasiphel residents and others rely on fuelwood for one month each year while gathering a medicinal fungus (Cordyceps). Total annual fuelwood consumption was estimated using the weight-survey method and recording all fuelwood used by 15 households for 15 consecutive days in August and January in Nasiphel and by 12 groups of Cordyceps collectors for ten consecutive days in June in Chajeyna. Total standing biomass was estimated by mapping and calculating the area from which fuelwood was harvested and measuring the height and diameter of trees in randomly established transects and sample plots. Annual biomass accumulation was estimated by measuring growth rings using Measure J2X software in a random sample of fuelwood species in both sites.

Residents of Nasiphel burn exclusively blue pine (*Pinus wallichiana*) and consumed approximately 661 ± 53 metric tons in 2010. Blue pine biomass totaled 901 ± 267 metric tons with an annual biomass increment of approximately 380 metric tons in the designated harvest areas. Harvesting exceeds accumulation rates in the harvest areas in Nasiphel, but forests resources are abundant and expanding in the area. In Chajeyna, Rhododendron (*Rhododendron aeruginosum*) is the only fuelwood species available and approximately 9.2 ± 1.2 metric tons was consumed in 2010. Rhododendron biomass totaled approximately 111 metric tons with an annual biomass increment of just 809 kg. Based on current consumption rates, all Rhododendrons in Chajeyna will likely be consumed in less than 13 years.

I recommend that the Government of Bhutan increase the area from which fuelwood can be harvested in Nasiphel to meet household energy needs on a sustainable basis. In Chajeyna, I recommend that fuelwood harvesting be strictly regulated or eliminated to sustain Rhododendron stands at this high elevation site through reducing the number of Cordyceps collecting permits issued and/or eliminating fuelwood use by requiring the use of alternative fuels (e.g., kerosene).
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**Acronyms and Abbreviations**

AAC - Annual Allowable Cut

AWC – Advanced Wood Consumption

BBS – Bhutan Broadcasting Service

CIFOR – Center for International Forest Research

FAO – Food and Agriculture Organization

FMU - Forest Management Unit

FNCR – Forest and Nature Conservation Rules of Bhutan

FRDD – Forest Resources Development Division

GNH - Gross National Happiness

LPG - Liquid Petroleum Gas

MDG – Millennium Development Goals

MoA – Ministry of Agriculture

NRDCL – Natural Resources Development Corporation Limited

NSB – National Statistical Bureau

NTFP - Non-Timber Forest Products

NWFP – Non-Wood Forest Products

RNR – Renewable Natural Resources

RGoB - Royal Government of Bhutan

RSCN - Resource Conservation

RWEDP – Regional Wood Energy Development Program

UWICE - Ugyen Wangchuck Institute for Conservation and Environment

WCP – Wangchuck Centennial Park

WHO - World Health Organization
**Word Meaning**

**Brokpa** – Alpine nomadic people of Bhutan who are yak herders.

**Bukhari** – Improved wood stove made of tin sheet generally used for space heating.

**Dzongkhag** – Districts

**Forest** – According to FNCR, 2006. Any land or water body, whether or not under vegetative cover, to which no person has acquired a permanent and transferable right to use and occupancy, regardless of whether such land is located within or outside the forest boundary pillars, and includes land registered in a person’s name such as Tsamdrog (grazing land) or sokshing (woodlot for collection of leaf litter).

**Forest Management Unit** – A geographic area of Government Reserved Forest designated pursuant to the Forest and Nature Conservation Rules for scientific management of forest.

**Gewog** – Administrative boundary within a dzongkhag headed by Gup.

**Gup** – Village head man/ head of gewog.

**Household** – People who eats from the same pot.

**Marking Tree** – Hammering a tree at its base with particular sign indicating that permission has been granted to fell that tree.

**Thab** – Out house wood stove made of mud or three stones in triangular shape.
Reflection on the Research

With this research I learned so many new things and real challenges faced by the researchers. The main important lesson I learned is, it is always difficult to gain trust of the people yet it is very important to gain people’s trust in order to obtain factual data/information.

I feel it is of utmost importance for the researchers to have fair knowledge of statistics in order to undertake analysis of the data’s collected. Researchers should also be well versed with un-biased means of sampling procedures as well as various sampling techniques.
CHAPTER 1; LITERATURE REVIEW

1.1. Introduction

Wood energy has been used for thousands of year for cooking and heating and it remains the primary source of energy throughout much of the world (FAO, 2008; Gregory et al., 1999). In addition to wood, agricultural residues including rice husks, straw, bagasse, corncobs, and other forms of biomass are important sources of energy as well (Hulscher, 1998; CIFOR, 2003). Biomass energy is the largest source of renewable energy and accounts for 10.4% of total global energy supply and 77.4% of global renewable energy supply (Carlos and Khang, 2008).

Fuelwood is by far the most important source of biomass energy as it is the primary energy source for more than 2 billion, primarily poor, people (Pattanayak et al., 2004; Troncoso et al., 2007) and because its harvesting contributes to forest degradation in many regions (Pattanayak et al., 2004). Fuelwood extraction does not necessarily lead to forest degradation (FAO, 1997; Palmer and Macgregor, 2009). However, it often leads to forest degradation where demands for fuelwood are high, where forest resources are limited (particularly high elevation and arid environments where plant growth is constrained by climate), and where alternative energy resources such as kerosene or Liquid Petroleum Gas (LPG), are unavailable, (Gregory et al., 1999). It is important to note that fuelwood is used for both domestic and industrial purposes in both rural and urban areas throughout much of the developing world (Dovie et al., 2004).

More than half of global wood production is non-industrial roundwood, most of which is used as fuelwood (Palmer and Macgregor, 2009) and fuelwood harvesting is estimated to account for over 54% of global wood harvest per annum (Bhatt and Sachan, 2003). Approximately 1.7 billion cubic meters of fuelwood and charcoal were produced in the world in 2004, out of which 0.7 billion cubic meters of firewood were produced in developing countries (IEA, 2006). In developing countries, fuelwood accounts for 80% of all household energy consumption (Sharma and Banskota, 2005). The number of people using fuelwood and other biomass fuels in Africa is projected to increase by 40% between 2000
and 2030 to about 700 million, while in Asia approximately 1,700 million people are expected to rely on fuelwood by 2030 (Arnold and Persson, 2003; IEA, 2006).

Fuelwood and charcoal are the primary forest fuel products and comprise approximately 60% of worldwide wood removals (FAO, 1997). This proportion increases to over 80% in developing countries and peaks at over 90% in Sub-Saharan Africa and some South Asian countries, all of which puts considerable pressure on forest (i.e., on farms and around homes) resources (FAO, n.d. a.). Mainly rural populations consume fuelwood, though towns and city dwellers also consume substantial amounts of fuelwood (FAO, 1997).

The primary factors influencing household energy consumption are the number of individuals in the household and household income (Bari et al., 1998; Pandey, 2002). Agro-ecological practices also influence energy consumption, as do socio-cultural factors, and energy consumption differs from place to place. For example, households in temperate regions use more wood for heating (FAO, 1997) than tropical regions where fuelwood is generally used only for cooking (CIFOR, 2003). Fuelwood consumption also tends to be greater in high elevation areas than in lowlands, irrespective of family size (Rawat et al., 2009).

1.2. Implications on Socio-economics and Environment

The environmental effects associated with harvesting fuelwood are highly contentious and inadequately known in many sites. For many years, the conventional wisdom assumed that fuelwood harvesting resulted in widespread forest conversion, soil erosion and land degradation with the Himalayan region often cited as a particularly impacted environment. (Eckholm, 1977). Other assessments do not substantiate assertions that woodfuel demand exceeds sustainable supplies or that it is a major cause of deforestation (Singh et al., 2009). Nevertheless, adverse environmental and socio-economic impacts can arise from unsustainable fuelwood harvesting and lead to fuelwood shortages and the degradation of natural forests (Ghilardi et al., 2009). Regarding socio-economic impacts, fuelwood harvesting that depletes resource supplies can disproportionately impact poor households who are forced to either spend more time collecting fuelwood or pay high prices to buy wood or alternative energy sources. For such households, when fuelwood...
availability is extremely limited or costly, food production and consumption can be adversely affected. Furthermore there are gender-specific impacts. Fuelwood collection is generally considered to be women’s work (FAO, 1997). Thus, when forests are degraded and fuelwood supplies limited, women must spend more time on gathering wood (Macht et al., 2007). Bhatt and Sachan (2003) estimated that on average women in Garhwal Himalayas of India spent 55% of their total labor gathering firewood, energy that would otherwise be spent gathering or producing food.

Although fuelwood extraction may not be a major cause of deforestation, excessive tree cutting is a significant environmental problem in some areas, particularly near large and growing urban centers (Ghilardi et al., 2009). Moreover, wood removal even at low rates, can adversely affect the structure, growth and composition of natural forests (Ghilardi et al., 2009).

1.3. Importance of fuelwood

In rural areas, biomass fuels dominate household energy use, with a high dependence on locally collected fuelwood. In most rural areas, locally gathered fuelwood constitutes the main source of domestic energy. Consequently, these users are vulnerable to changes that affect their access to fuelwood (Singh et al., 2009). Widespread and unmanaged harvesting of vegetation for fuelwood and charcoal exceeds biomass growth in many parts of the world and often results in declining supplies and forest degradation (FAO, n.d. b). Heltberg et al., (2000) note that fuelwood collection can affect future resource availability in two ways; one, directly when fuelwood harvesting exceeds biomass production (i.e., tree growth and yield) and another, indirectly when harvesting practices adversely affect the health and productivity of vegetation (i.e., future growth potentials). In both cases, future harvesting potentials are reduced.

Fuelwood gathered from the forested commons is the most important source of domestic energy in rural areas of many developing countries (Macht et al., 2007), although animal dung and other materials are also used. Fuelwood is collected directly from forests and fields in the Himalayan region and there are cattle, buffalos, sheep and goats which range free on the pastures in these forests whose grazing may reduce tree regeneration and
thereby affect future fuelwood supplies (Rawat et al., 2009). In addition, the lopping of broad-leaved trees in forests for fodder complicates fuelwood availability (Plessis, 1994) as it reduces the potential for fuelwood branches. Fuelwood availability is also constrained by the short growing season in alpine regions of the Himalayas (Rawat et al., 2009).

About half the world’s population cooks with biomass fuels, which provide around 35% of energy supplies in the developing countries (Dovie et al., 2004). Developing countries account for almost 90 percent of the world’s fuelwood consumption with wood being the primary source of energy for cooking and heating (Broadhead et al., 2001). As fuelwood becomes increasingly scarce, households may respond by substituting different fuels or by adopting fuel-saving technologies (Dovie et al., 2004) such as more efficient stoves and perhaps even two or three households cooking together (Dewees, 1989). However, people still need wood to cook and in some areas to heat homes. It is even conceivable that the times spent collecting may act as a "check" on deforestation by inducing greater energy efficiency and substitution (Dovie et al., 2004). This does not mean, however, that declining supplies will save forests from degradation, but rather that once all available fuelwood has been harvested, there is little left in collection areas.

Careful analysis of household fuel substitution and the institutional environment influencing behavior is essential for informed decisions regarding fuelwood and forest management and conservation policies. Household surveys over large areas in India found that wood accounted for 56% of their energy use and that about 55% of household needs for fuelwood were collected for free (Arnold and Persson, 2003). Similar situations may exist in other developing countries where fuelwood is the primary energy source.

Wood as a source of energy is particularly valuable for many indigenous people but is a resource they often do not control (Palmer and Macgregor, 2009). Failure to appreciate resource tenure, access and control could adversely affect household livelihoods and well-being because of the close and profound dependence many people have on natural resources (Palmer and Macgregor, 2009). Thus, it is essential to understand patterns of and variability in household dependence upon forests for fuelwood in developing policies and management. Pattanayak et al., (2004) argues that it is particularly important to have detailed understanding of:

- the contribution of fuelwood to household economies, and
factors influencing household dependence on forests, (including household wealth). In doing so, we can begin to evaluate relationships between poverty and forest use and explore how social and economic issues impact fuelwood use and management.

Shifting cultivation coupled with excessive deforestation for fuelwood has caused severe environmental degradation in northeastern Himalayas of India (Bhatt et al., 2009). This suggests that wood fuel extraction is contributing to forest degradation in areas very near Bhutan. Fuelwood can also be important for religious and cultural reasons. For example, Hindus and Buddhists require wood for cremation on funeral pyres that use approximately 200-300 kilograms of wood each time (FAO, 2010). Studies suggest that demand for wood fuels may increase as countries seek to find clean, green, efficient and cheaper alternatives to fossil fuels (FAO, 2010).

“Perhaps the greatest environmental benefit of woodfuels is that, when produced and harvested sustainably, they provide a renewable source of energy with low net carbon emissions. Woodfuels are derived from vegetation that sequesters atmospheric carbon during growth, releases it to the atmosphere when converted to energy, and takes it back as it re-grows” (FAO, 2010, p.51).

1.4. Woodfuel as source of household Income

The sale of fuelwood provides income for huge numbers of people. In India, the fuelwood sector employs 3-4 million people (FAO, 2010). With easy access to both resources and markets, very large numbers of landless and very poor gather and sell wood for fuel, and large numbers of farmers harvest and sell it as well. Fuelwood related activities are the main source of income for some 10% of the rural population in Asia (Hulscher, 1998). Globally, fuelwood is a major source of income for the poor and a primary forest product collecting activity (Arnold and Persson, 2003). For example, about 125,000 people derive their major source of income from selling charcoal and fuelwood in Tanzania and many more rely on fuelwood and charcoal for supplemental, transitional or seasonal sources of income or as a safety net in times of hardship (Arnold and Persson, 2003).

It is reported that rural people of South Africa earn 44% of their total income by selling charcoal and fuelwood (Dovie et al., 2004). It is also reported that fuelwood is the
main source of income for about 10% of rural households in Nepal and that fuelwood earnings represent about 40% of their total cash income (Sulpya, 1998).

Marketing of biomass in the form of charcoal or fuelwood may contribute to achieving the United Nation’s Millennium Development Goals (MDG) of poverty eradication (RGoB and UNDP, 2008) because biomass harvesting and sales could significantly contribute to many poor families throughout the developing world. In practice, huge numbers of people continue to rely on fuelwood as a source of energy or income, and will continue to do so. Similarly, fuelwood remains one of the largest outputs of the forest sector (Arnold and Persson 2003).

1.5. Data Sources on Fuelwood

Understanding the fuelwood situation has always been hampered by a lack of reliable information as only a small portion of fuelwood production is recorded (Arnold and Persson, 2003). This may be due to the fact that a large portion of fuelwood consumption is by poor households and their use is seldom reported or documented. Pandey (2002) suggests that since fuelwood is gathered free in most places, its consumption is not monitored or recorded by authorities.

Reliably assessing fuelwood consumption is difficult (Arnold and Persson, 2003). In fact, annual fuelwood consumption data for most of Southeast Asia and the Asia-Pacific region are unavailable. Estimates of fuelwood consumption are provided by FAO and are based on estimates of per capita energy consumption which have not changed in over 30 years (FAO, 1997). Thus, the reliability of these data is dubious.

On a global basis, most fuelwood is produced and consumed locally and since much of that is gathered and consumed by private households or traded informally, it is difficult to collect good country-level data (Pandey, 2002; FAO, 2008). Furthermore, empirical studies of fuelwood have focused primarily on consumption. Much less is known about fuelwood supplies (i.e., standing biomass) or growth and yield (i.e., annual growth increments). Despite the tremendous importance of fuelwood, particularly among poor and vulnerable populations, surprisingly little is known about the supply, harvesting, trade, consumption and management of this resource (Koopmans, 2004). There is a clear need for site-specific studies of fuelwood supplies and forest resource extraction and management.
1.6. Factors influencing fuelwood consumption and the associated crisis

More fuelwood is consumed during winter months than summer months in large parts of the world because fuelwood is used for space heating in addition to cooking (Dovie et al., 2004). Fuelwood consumption may also be influenced by wood availability. It is reported that fuelwood consumption in Nepal and Afghanistan was 0.9 and 0.3 m³ per capita, respectively (Dewees, 1989). Afghanistan is largely arid and the amount and growth rate of wood is less there than in Nepal. Thus, finding and collecting wood in Afghanistan could be comparatively more difficult than in Nepal which may reduce consumption. Some authors believe that the availability of fuelwood significantly influences the amount consumed (Pandey, 2002). As Thomson and Warburton (1985) note: “People do not just have needs; they manage them” (p.118). They note that people tend to use more wood when it is readily available and less when supplies are scarce.

Many reports suggest that disputes may arise due to shortages of fuelwood. Mahapatra and Mitchell, (1999) reported that a shortage of fuelwood has been the cause of frequent disputes between villages in Orissa, India and similar conflicts have been reported between Cordyceps (Ophiocordyceps sinensis) collectors and yak herders in alpine areas of Bhutan (Gould, 2007). The apparent growing scarcity of fuelwood in the alpine areas of Bhutan has led Cordyceps collectors to steal wood from yak herders and in some cases even remove and burn the wooden shingles of yak herders’ huts.

Despite the importance and large numbers of people around the world using fuelwood, there are many myths about its use. FAO (1997) compiled a comprehensive list of fuelwood myths and realities. Some of the more significant myths that hamper development of the wood energy sector are first, that fuelwood is generally considered not a relevant source of energy, while in fact it supplies about 30% of total energy consumption in Regional Wood Energy Development Program (RWEDP) (Appendix 1) member countries (FAO, 2000). Secondly, it is often thought that fuelwood is of little value and used only by poor and rural households. But, the fact is the total value of fuelwood amounts to US $ 30 billion per annum for RWEDP countries and studies have shown that fuelwood is consumed by urban populations and even by some industries and commercial sectors. Third a common fuelwood myth is that harvesting results in widespread deforestation. In reality, FAO (1997) reports that numerous surveys reveal that 2/3rd of all fuelwood harvesting
occurs on largely non-forested land which refutes the idea of fuelwood collection leading to loss of forest coverage. Studies have also found that only dead, dying trees and branches are used as fuelwood rather than cutting down live trees in many regions (Ali and Benjaminsen 2004).

1.7. Fuelwood in Bhutan

1.7.1. Bhutan: Country Profile

Bhutan is a small country with an area of 38,394 km$^2$ (Drukair, 2008; National Portal of Bhutan, 2009), located in south Asia and is bordered by the Tibetan Autonomous Region of China to the north and India to the south, east and west (Fig. 1).

In 2008, Bhutan had a population of 671,083 (NSB, 2009) which is projected to increase to around 887,000 in 2030 and to increase by about 40% within the next 25 years (NSB, 2007). Bhutan is mountainous and ranges in elevation from 150 m above mean sea level in the south to 7000 m in the north (MoA, 2009, a.) in a distance of only 170 kilometers (MOA, 2009, b.). Bhutan contains three broad ecological zones (Sub-tropical zone, Temperate...
Zone, and Alpine Scrub), each with very different tree species and biomass growth rates. The diverse and largely intact ecosystems of Bhutan provide habitat to a wide variety of plants and animals and the country is recognized as one of the top 10 global biodiversity hotspots (MoA, 2009a).

Bhutan is an agrarian country with about 69% of the population residing in rural areas (MoA, 2009a). Bhutan is also one of the few countries in the world to feature environmental conservation in its Constitution. Article 5 of the Constitution of the Kingdom of Bhutan identifies specific environmental conservation concerns as it states (MOA, 2009b, p.4):

“The Government shall ensure that, in order to conserve the country’s natural resources and to prevent degradation of the ecosystem, a minimum of sixty percent of Bhutan’s total land shall be maintained under forest cover for all time”

Currently forests cover about 72.5% of the country’s land area and over 51% of the entire country is in some sort of designated protected area or biological corridor (MOA, 2009b). The protected areas stretch from the sub-tropical zone in the south through temperate areas in the central interior region to the alpine zone in the north.

1.7.2. Fuelwood in Bhutan

In Bhutan, fuelwood is the only readily available source of energy for most rural and urban residents. The FAO (1997) reported that 78% of total energy consumption in Bhutan was from wood. During the 9th five year plan of Bhutan (2003-2008), fuelwood was estimated to have supplied 70% of total energy requirements of the country (MoA, 2009b). The Ministry of Agriculture reported in “RNR Sector Tenth Plan” document (MoA, 2009a) that Bhutan’s annual per capita consumption of fuelwood is one of the highest in the world at 1.2 metric tons per capita. Total round wood harvesting reportedly increased by 12% between 1999 and 2000, and most of this is believed to have been for fuelwood (Dhital, n.d). The increase in fuelwood harvesting may reflect increasing demand in urban areas, particularly Thimphu and Paro, where populations are rapidly increasing due to rural to urban migration (BBS, http://www.bbs.com.bt). The Renewable Natural Resources-STAT (RNR-STAT – www.rnrstat.gov.bt) estimated that 45,000 m$^3$ of fuelwood were harvested.
from six Forest Management Units (FMUs) in 2007. It is important to note that this estimate excludes fuelwood harvested outside of FMUs in government reserve forests.

In Bhutan, fuelwood is consumed not only by rural people, but also by urban dwellers, government offices and businesses. Uddin et al., (2006) report that the household sector accounts for 95% of fuelwood consumption, while the Government and commercial sectors consume 3% and the agricultural and industrial sectors 1%. It was reported that in 2007-2008 fuelwood consumption was 50,766 and 77,804 tons for rural and urban areas respectively (NSB, 2009). This report may have ignored most of the fuelwood collected by people in rural areas as it reports only fuelwood harvesting where permits were issued and where the volume harvested was recorded by forestry offices. This is likely to grossly underestimate actual fuelwood consumption and production.

Deforestation in eastern part of Bhutan has been blamed on fuelwood harvesting in some Government reserve and private forests (Norbu and Giri, 2004). Some forest areas in Bhutan are also subject to unsustainable harvesting of fuelwood due to increasing demands by large nearby settlements. For example, fuelwood supplies are reportedly declining around Chumey, Bumthang due to the increase in population and harvesting (Sharma, 2000).

The use of forest resources is an essential component of Bhutanese livelihoods and is intricately woven into the culture of the people. Bhutan’s forest resources contribute significantly to the livelihood of rural households. However, most of the products from the forests are directly consumed by people and thus do not enter the formal economy. For this reason, the role and significance of forest products in general and fuelwood in particular, are overlooked (Uddin et al., 2006).

In one of the few detailed case studies of fuelwood consumption in Bhutan, the residents of the Phobjikha Valley were found to rely on fuelwood for cooking and heating, and they reported consumption to be much greater during winter months (Sharma and Banskota, 2005). Other than this study, very little is known about fuelwood consumption, availability, growth rates or effects associated with its harvesting and use in Bhutan.

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1 Permits to harvest fuelwood are issued by forestry offices after payment of royalty rates
1.7.3. Rules Governing Fuelwood Extraction in Bhutan

In Bhutan, the Forest and Nature Conservation Rules 2006 (MOA, 2006), (henceforth referred to as Rule) regulates fuelwood under the Timber Section (Chapter V – Clause 42(1)) and in supply of Other Forest Produce in Rural Areas (Chapter XI- Clause 101). The Rule states that commercial fuelwood should be supplied through the Natural Resource Development Corporation Limited (NRDCL) and wood lots in Forest Management Units (FMU) are to be the main source of fuelwood throughout most of the country. Chapter V, Clause 42, 1(a) of the Rule, states that,

“In Urban areas, firewood to the Armed Forces, Monk Bodies and other Institutions shall be supplied by NRDCL, subject to payment of royalty and issue of permit by the Department. Supply of firewood to government institutions in rural areas where NRDCL service is not available, permit will be issued by Department/Ministry on payment of Royalty at commercial royalty rate”.

The Rule specifies the need to meet domestic fuelwood demands first and only after that are industrial and other commercial harvesting interests to be met. The Rule allows for the collection of dry fuelwood and tree branches and tops, and for fuelwood to be transported by humans or animals free of royalty payments, whereas any type of fuelwood collected and transported by mechanical devices are levied royalty at commercial rates. One effect of these policies is that fuelwood use by rural communities is not documented or regulated.

Chapter XI, Clause 101 (3) of the Rule clearly specifies that the allowable fuelwood consumption is 16 m$^3$ of stacked firewood per household per year in places where there is no electricity and half of that (8 m$^3$) where electricity is available. In WCP and other national parks, harvesting is prohibited in core zones, but fuelwood harvesting and the collection of Non-Timber Forest Products (NTFPs) are allowed in park buffer zones. Chapter VI, Clause 61 (5-b) of the Rule states that the collection of firewood shall be allowed only to residents of the local area and only for personal domestic use. Implementing and enforcing the Rule has been difficult due to the large and increasing numbers of fuelwood users, the vast area and difficult terrain, and the limited number of forestry personnel in the field.

Fuelwood consumption and management have received very little attention by government officials. In-fact, Uddin et al., (2006) report that fuelwood use and management

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2 Commercial royalty rate is Nu. 90.00 for 8m$^3$ of fuelwood with Nu.10.00 as permit fees. Nu.90.00 is equal to US $2.00.
issues have been largely overlooked. Fuelwood use is not reported in community forestry management plans even though community forests may derive substantial benefits from the sale of fuelwood (Chettri et al., 2009). With the rapid expansion of community forests throughout the country, including within national parks (Chettri et al., 2009), it is essential that fuelwood use, availability, production and management opportunities be investigated.
CHAPTER 2: STUDY OBJECTIVES AND STUDY LOCATION

2.1. Study objectives

Fuelwood consumption, species utilized, areas harvested, availability (i.e., standing biomass), growth and yield, historical changes in fuelwood use, local fuelwood management practices, and ecological effects associated with wood harvesting are poorly documented throughout Bhutan. Fuelwood consumption, management and impact data are particularly lacking from alpine regions of Bhutan where growth and yield are most limited. Reports suggest that fuelwood harvesting by Cordyceps collectors, yak herders and trekkers in high elevation alpine areas has aggravated existing resource scarcities and led to overharvesting of trees and in some cases even uprooting of slow-growing shrubs (Gould, 2007). However, the amount of fuelwood harvested in alpine areas of Bhutan is unknown.

The wood energy sector is overlooked in national planning contexts throughout much of the world, which has led to incomplete and fragmented information, and widespread failure to address fuelwood energy needs (FAO, n.d. c). Given the social, economic and ecological importance of fuelwood harvesting, both globally and in Bhutan, there is a critical need to understand consumption and harvesting rates by residents and seasonal users, to assess ecological effects associated with wood harvesting and to manage resource extraction.

This study seeks to document annual per capita fuelwood consumption\(^3\) and fuelwood availability\(^4\) and production\(^5\) through case study research in one high elevation village and associated fuelwood harvesting areas within Wangchuck Centennial Park (WCP). Most fuelwood studies in Bhutan and elsewhere have focused on consumption, but have ignored resource availability and growth/production rates (Pandey, 2002). I hope this information assists village residents and government officials sustainably manage fuelwood resources in the case study area and serves as a model in assessing fuelwood consumption, resource availability and management elsewhere in Bhutan.

\(^3\) Consumption by both Cordyceps collectors and permanent settlers
\(^4\) Estimate current biomass stock in both the study area
\(^5\) Annual increment of biomass in the study area
Specifically the study will:

1) Identify the fuelwood collection areas (locations) used in one case study village (and associated hamlets) and in the seasonal, high elevation fuelwood harvesting areas used by Cordyceps collectors from the case study village and others.

2) Estimate the area of each fuelwood collection area.

3) Estimate annual per capita fuelwood consumption by local residents and seasonal Cordyceps collectors in the two areas.

4) Estimate the amount of fuelwood currently available in the collection areas (i.e., standing stock) and the annual growth and yield.

5) Provide recommendations for sustainable fuelwood harvesting rates in the two study areas.

2.2. Study Area

The study was carried out in Nasiphel and neighboring hamlets (Sangsangma, Dhokrong and Shabjeythang) and a Cordyceps collection area (Chajeyna) which households from these communities use on a seasonal basis; both are located in Chokor block (Gewog) in Bumthang district (Dzongkhag) within the recently established Wangchuck Centennial Park (Fig. 2). Every year 1 to 3 individuals from each household in Nasiphel and the nearby hamlets are issued a permit to collect Cordyceps in high alpine areas for a period of one month (mid-May to mid-June). Residents of the study area include yak herders as well as non-yak herders. There were 3 yak herders out of a total of 30 households in Nasiphel in 2010. Yak herders spend most of the spring, summer and early fall in the mountains; during the winter they move to lower elevation areas; few of them stay in their homes in Nasiphel.

2.2.1. Bumthang Dzongkhag

Bumthang is one of the twenty districts (Dzongkhag) comprising Bhutan (Fig. 5). Bumthang is the spiritual heartland of Bhutan and home to its most ancient and precious Buddhist sites. It is administered in four blocks, namely Chhoekhor, Chhume, Tang and Ura each located in a glacier-carved valley. Bumthang stretches from 2000 m to 6000 m above mean sea level. Bumthang covers 6.8% of the country’s geographical area or 2610.79 km²
Chokor, the biggest gewog in the district, is approximately 1533 km² and ranges from 2600 m to 5800 m above mean sea level. Chokor gewog has 39 villages with 661 households (Chokor Gup, 2010).

2.3. Wangchuck Centennial Park

Wangchuck Centennial Park (WCP) was formally gazetted as a National Park under Bhutan’s protected area system on June 10, 2008 (NCD, 2008). It is the largest National Park amongst 10 in the kingdom of Bhutan with an area of 4914 km² (NCD, 2008). WCP was declared as a tribute by the Government and people of Bhutan to the Wangchuck Dynasty for selflessly leading Bhutan for 100 years and ensuring her sovereignty, stability and tranquility. The park contains one of the largest and most critical watersheds in the country feeding four major rivers, the Punatsangchhu (Sunkosh), Mangdechhu, Chamkharchhu and Kurichhu (tributaries of Manas). Permanent snow covers many of the mountains located in the park such as Gangkar Puensum, Rinchen Zoegila and Jazayla. In the winter, about 85% of the park is under snow cover for about four months (NCD, 2008).

![Figure 2: Wangchuck Centennial Park in Bhutan map.](image-url)
Wangchuck Centennial Park is located in the central north part of the country. To the east, it is adjacent to Bomdeling Wildlife Sanctuary, and to the west it is adjacent to Jigme Dorji National Park. In the south it is bordered by continuous biological corridor (NCD, 2008). Thus, WCP comprises an integral part of a protected area complex in the country and in the region transcending the boundaries of five political Dzongkhags and nine Gewogs. It encompasses Gasa, Wangdue Phodrang, Trongsa, Bumthang and Lhuntse Dzongkhags (Fig. 2). The following Gewogs falls within the park, namely Chhokhor and Tang under Bumthang, Lunana in Gasa, Sephu, Dangchhu and Kazhi in Wangdiphodrang, Kurtoe Khoma and Gangzur in Lhuntse and Nubi in Trongsa.
CHAPTER 3; FUELWOOD CONSUMPTION BY CORDYCEPS COLLECTORS

3.1. Introduction to Cordyceps

*Cordyceps sinensis* is an Ascomycetes medical fungus with a long and illustrious history. The genus *Cordyceps* is mostly entomophagous flask fungi belonging to the family Clavicipitaceae (Winkler, 2008). Although it is not actually a mushroom in the taxonomic sense, it has been regarded as a medicinal mushroom for centuries. The name Cordyceps comes from the Latin words “cord” and “ceps”, meaning, “club” and “head”, respectively (Holliday et al., 2005). The Latin word accurately describes the appearance of this fungus, whose stroma and fruit body extend from mummified carcasses of insect larvae, usually that of the Himalayan ghost moth belonging to the genus *Thitarodes* (Hepialidae, Lepidoptera; Fig. 3). A recent DNA analysis of the genus *Cordyceps* found that *C.sinensis* was not the same as *C.militaris* thus the genus has been changed to *Ophiocordyceps* (Cannon et al., 2009; Boesi and Cardi, 2009). However, we will refer to the organism as Cordyceps because it continues to be the most common and widespread name. In China, Bhutan and Tibet the literal translation of the name is “summer grass and winter worm” (Holliday et al., 2005).
Cordyceps is harvested over much of the Himalayan plateau and is a highly prized remedy in traditional oriental medicine. Over the past decade its financial value has increased many fold, with collectors being paid as much as US $ 12,500.00 kg\(^{-1}\) (Cannon et al., 2009). The fungus is a coveted medicinal product in traditional Tibetan and Chinese medicine, and is known in the west as “Himalayan Viagra” (Gould, 2007). Cordyceps appears annually between the months of April and August when it is harvested (Holliday et al., 2005; Gould, 2007; Winkler, 2008; Cannon et al., 2009) and thrives only at altitudes above 3800 m in the cold, grassy, alpine meadows on the mountainous Himalayan Plateau of Tibet, Nepal, India, Bhutan and the modern Chinese provinces of Sichuan, Gansu, Hubei, Zhejiang, Shanxi, Guizhon, Qinghai, and Yunnan (Holliday et al., 2005; Winkler, 2008; Cannon et al., 2009; Boesi and Cardi, 2009).

3.2. Cordyceps in Bhutan

Cordyceps has been a resource in Bhutanese traditional medicine for many years (Cannon et al., 2009). In recent years, Cordyceps has become one of the most expensive mushrooms in the world fetching up to US$ 6126.00 – 10,450.00 kg\(^{-1}\) at an auction in Dodena, Bhutan in 2007 (Wangchuk, 2008). The Royal Government of Bhutan legalized Cordyceps harvesting in 2004 (Cannon et al., 2009) and it is now legally harvested extensively throughout alpine areas of the country. Managing Cordyceps harvesting has proved to be extremely difficult because the high alpine areas are very remote with major collection areas near the border of the Tibetan Autonomous Region of China. Many Tibetans illegally cross the border to gather the fungus and there are not enough forest personnel to monitor collection and enforce regulations (Cannon et al., 2009). Enforcing regulation also presents a dangerous situation for forest personal. Bhutanese Cordyceps collectors report that hundreds of Tibetans illegally collect in Bhutan and a RGoB Forestry monitoring team apprehended 13 Tibetan poachers in 2007 (Wangdi, 2008).

Cordyceps harvesting regulations have changed dramatically over the years. In 2003 harvesting was allowed only in the Lunana area of Bhutan (Tshitila, 2009), but in 2004 the policy allowed limited collection by yak herders whose herds traditionally grazed in the pastures where the fungus occurs in other parts of the country (Cannon et al., 2009; Royal Decree, 17th June, 2004- RA Online). Various measures were implemented in an attempt to
manage harvesting, including a ban on any collecting except during the one month period of mid-May to mid-June. In 2008 the policy of allowing one person per household (yak herders as well as those households located within the Cordyceps growing gewog) to harvest the fungus was modified to allow all members of a household permission to collect (Gould, 2007; Wangchuk, 2008; Cannon et al., 2009). In 2009 the rules were revised again permitting up to 3 people per household collection rights.

Very little is known about the biology of Cordyceps, including its abundance, distribution, and effects of harvesting, which raises questions about the sustainability of harvesting. In addition to the direct impacts associated with harvesting Cordyceps, the large number of collectors hiking, camping, cooking, and disposing of human and other wastes in sensitive, high alpine environments undoubtedly have environmental effects. However, none of the potential environmental effects associated with Cordyceps harvesting have been investigated.

3.3. Fuelwood Consumption by Cordyceps Collectors

The large numbers of legal and illegal Cordyceps collectors depend upon and consume significant amounts of fuelwood during the month-long harvesting period. But the amount of fuelwood harvested by Cordyceps collectors in Bhutan is unknown. In fact, even the number of Cordyceps collectors is uncertain. As noted above, in addition to the thousands of Bhutanese granted permits to collect every year, an unknown number of Tibetans sneak across the largely unpatrolled Tibet-Bhutan border. Namgyel and Tshitila (2003) reported encountering over 65 Tibetan Cordyceps poachers in one region and local people reported sighting 200-300 Tibetan poachers at another site and regularly encounter groups of 10 to 25. Namgyel and Tshitila (2003) estimated that about 400 Tibetan poachers are in Bhutan illegally harvesting Cordyceps every day during the collecting season. The amount of fuelwood harvested by Bhutanese and Tibetan Cordyceps collectors for cooking and heating during the month-long harvesting period has never been formally investigated.

According to some Cordyceps collectors, people in the high alpine dwellings (yak herders) of Bhutan have been collecting Cordyceps before it was legal and report having collected for at least 12 years (Ap Tashi, 2010, pers. com.). This implies that both yak herders and others have been burning wood to cook and heat for many years. High alpine
yak herders have expressed concern about dwindling fuelwood supplies near the stone houses where they reside during summer months while tending their herds. One yak herder stated that the number of Cordyceps collectors has been increasing every year and that there is growing evidence of Rhododendron cutting (Namgay, 2010, pers. com.). He expressed concern about the sustainability of Rhododendron harvesting and said that at current exploitation rates, fuelwood supplies will likely be exhausted within the next few years. He also noted that if fuelwood resources are exhausted it will adversely affect his livelihood.

3.4. Research Site

The study of fuelwood consumption by the Cordyceps collectors was conducted in the alpine area of Chajeyna, a three day walk from the nearest road and from the village Nasiphel at 4650m (15,255 ft) above sea level in the Bumthang District of northern Bhutan (Fig. 4). Chajeyna is a seasonal campsite near timberline where the dominant woody
vegetation is *Rhododendron aeruginosum* (henceforth referred as Rhododendron) with scattered dwarf *Juniperus sp.* and dwarf *Salix sp.* Every year Chajeyna and other higher elevation areas in Bhutan attract large numbers of people who come to gather Cordyceps from mid-May through mid-June. Cordyceps collectors and yak herders camp at Chajeyna and other sites near timberline because it is the highest and last available source of fuelwood. The yak herders and Cordyceps collectors rely on Rhododendron for all cooking and drying needs while camping at Chajeyna.

3.5. Methods

Annual fuelwood consumption by Cordyceps collectors and yak herders in Chajeyna was estimated by monitoring daily fuelwood consumption among 12 groups of collectors/yak herders for 10 consecutive days in mid-June, 2010. I selected 12 sample groups relatively near one another to facilitate monitoring. I also recorded the number of individuals in each camp and estimated their daily fuelwood use through the weight-survey method employed by Ali and Benjaminsen (2004). Each day I weighed a stack of fuelwood sufficient to meet all cooking and drying needs in each of the 12 camps. I then returned the following day, reweighed any remaining wood and recorded the weight of fuelwood consumed during that 24 hour period. This was repeated for 10 consecutive days in each of the 12 campsites and an average daily per capita rate of fuelwood consumption was estimated. The Cordyceps collectors proved to be very cooperative and burned wood only from weighed piles throughout the study.

I also interviewed one individual from each of the camps and yak herder groups in Chajeyna and surrounding areas to determine the number of individuals in each group and whether they use any fuel other than wood. All the yak herders and Cordyceps collectors relied on Rhododendron for all cooking and drying needs. Of the 97 collectors, 86 stayed in camps and 11 collectors stayed in stone houses.

The total amount of fuelwood available in Chajenya (i.e., total above ground biomass) was estimated by mapping and calculating the area of all Rhododendron stands in the area, recording the number and size of all Rhododendron plants found in randomly established belt transects in the two largest plots, and by developing diameter: weight relationships from a random sample of Rhododendron plants (n=25). I mapped the area of
all Rhododendron stands (four plots) in Chajenya by walking the perimeter of each with a GPS Garmin eTrek and calculated the area of the plot. I then imported the data into ArcGIS 9.3.1 and calculated the area of each plot in-order to validate the area estimate and to locate the plots on a map. I then randomly established nine 4 m wide belt transects across the two largest Rhododendron stands (five in plot 1 and four in plot 2, Fig. 5) and recorded the number and diameter at the base of all Rhododendrons encountered. I measured diameters of Rhododendron at the base of plants due to the heavy and low branching characteristics of the species. I measured the diameter of 1080 and 795 Rhododendron stems at their base in Plot 1 (2640 m$^2$) and 2 (1840 m$^2$), respectively.

*Figure 5: Study area with Cordyceps collector’s camp sites and fuelwood harvesting plots.*
Lastly, I estimated the mean annual growth rate of Rhododendron (i.e., the annual increment) by randomly selecting ten plants of various sizes, and counting and measuring the number of annual growth rings with the use of “Measure J2X” software. With this software we determined annual diameter increment by measuring the distances between the two annual rings of the plant.

3.6. Results and Discussion

3.6.1. Fuelwood Consumption by Cordyceps collectors

In 2010, 30 groups of Cordyceps collectors totaling approximately 97 people camped for one month in Chajeny. There were also six camps with 13 collectors camping in higher areas than Chajeyna. In addition to Cordyceps collectors, two groups of yak herders also camp in Chajeny for approximately two months each summer to pasture their livestock.

Assessing per capita consumption is vital in fuelwood studies as it is a standard means for estimating total fuelwood consumption (Pandey, 2002). The per capita fuelwood consumed by Cordyceps collectors in Chajeyna varied depending on the number of people in the camp. I found that per capita fuelwood consumption was inversely related to the number of individuals in the group (Fig. 6). This observation is supported by Dewees (1989) who found that household size influences levels of per capita fuelwood consumption, that is, as household size increases, consumption per capita decreases.

![Figure 6: Per-capita fuelwood consumed in relation to number of collectors staying in groups (camps and stone house).](image)
I report average per capita fuelwood consumption by Cordyceps collectors in two groups: 1) those residing in camps and 2) those staying in yak herder’s stone houses. I found that collectors in camps and stone houses consumed 2.3 ± 0.3 kg (standard error) and 4.7 ± 1.2 kg (standard error) of fuelwood per person per day, respectively. Per capita fuelwood consumption was higher for those staying in stone houses as they tended to stay up late at night and burned wood for heating and cooking, whereas collectors in camps typically completed all tasks before dark and did not rely on fires as much for heating.

The total daily fuelwood consumption by all Cordyceps collectors in Chajeyna was estimated to be 248 ± 24 kg. When extrapolated to the entire one month collection period, a total of approximately 7458 ± 732 kg of fuelwood was consumed by Cordyceps collectors in this single area in 2010. It should be noted that in addition to the Cordyceps collectors, two groups of yak herders stay in Chajeyna for about two months after the Cordyceps collection season and they collect and burn Rhododendron as well. Thus, total fuelwood consumption in the area is even greater. Assuming yak herders consume fuelwood at the same rate as collectors who stayed in the huts, fuelwood consumption by yak herders totaled approximately 1700 ± 416 kg in the two month period (assuming 6 yak herders). This implies that approximately 9.2 ± 1.2 metric tons of fuelwood (combined consumption by Cordyceps collectors and yak herders) was consumed in Chajenya in 2010. However, consumption by yak herders may be higher than that of Cordyceps collectors who stay in huts because yak herders remain indoors much of each day making butter, cheese and yogurt. Thus, total annual fuelwood consumption in Chajeyna is likely to be greater than 9.2 ± 1.2 metric tons.

3.6.2. Trend in fuelwood availability and alternative fuels

During the course of this study, I interviewed one individual from all 36 camps (30 in Chajeyna and 6 camps above Chajeyna) to explore their perspectives of fuelwood use and trends and to ascertain if any other fuel sources are used. I found that 7 camps brought kerosene with them, but only 4 camps carried more than 5 liters of kerosene. One camp took cotton dipped in a half liter of kerosene to ease lighting fires. The four camps that carried more than five liters of kerosene carried stoves as well. However, only one camp in Chajeyna had a kerosene stove, the rest were brought by people camping at sites higher than
Chajeyna. Interviews revealed that of the four camps that brought kerosene stoves, three discontinued using kerosene and only one camp regularly used the stove and then only to prepare breakfast. This clearly reveals the near total dependence of Cordyceps collectors in this area on fuelwood, specifically Rhododendron.

Wangchuck Centennial Park officials report that discussions are underway with Cordyceps collectors to shift to kerosene stoves or other fuels. However, encouraging or forcing collectors to shift to other fuels will likely be difficult because stoves and fuel are expensive, a large quantity of fuel would be needed to cook for an entire month, much less to provide heat, and all supplies must be transported long distances to remote collection sites on foot.

About 67% of the collectors reported that fuelwood supplies are a problem. Fifty percent of those interviewed think fuelwood availability has remained constant while 50% say that it has decreased with time. No one reported that fuelwood supplies are increasing. Those who noted that fuelwood supplies are a problem seem to blame themselves, noting that the number of collectors in the area has increased over the years. Interestingly, some of the individuals who said that fuelwood availability had not changed reported burning dead and dry wood rather than cutting live Rhododendron. This may reflect the fact that one of the Rhododendron plots was all dead due to some unknown reason.

I attempted to compare the result of trends in fuelwood availability by segregating the answers of collectors: yak herders and non-yak herders. The yak herders are high alpine nomads who rear large numbers of yaks in alpine areas and non-yak herder are those who live in lower elevation areas and depend on agriculture and other means of livelihood. I found that 80% of the yak herders said that fuelwood availability is decreasing, while 45% of non-yak herders said that fuelwood supplies remain unchanged. This difference may be due to the fact that yak herders have been visiting the area for a longer time (more than 100 years) and know the area well, whereas many of the non-yak herders began collecting Cordyceps only 2-3 years ago.

3.6.3. Estimation of Total Biomass

Based on transect sampling in plots I and II, I estimated the biomass density within
the collection area to be 1.20 ± 0.22 kg/m². When extrapolated across the three plots, the total Rhododendron biomass is estimated to be approximately 111 metric tons.

Rhododendron diameters were converted to approximate woody weights by using the following equation -

\[
\text{Weight of Rhododendron (kg)} = 0.742 \times \text{Diameter of Rhododendron (cm)}^{1.262}
\]

As evident in Fig. 7, there is increasing variability of wood weights when the diameter of Rhododendron exceeds 7 cm. This may be explained by the large and extensive branching characteristic of Rhododendron as it grows and ages.

![Figure 7: Relation between weight and diameter of Rhododendron aeruginosum](image)

3.6.4. Rhododendron Biomass growth increment

The growth rate of Rhododendron (Appendix 5) is, not surprisingly, very slow. Based on the 10 samples, the annual growth increment of Rhododendron in Chajeyna is approximately 0.6 ± 0.04 mm diameter per year or about 0.02 kg per Rhododendron
plant/year. Based on transect sampling in plots I and II, I estimate the yearly increment to be approximately $0.009 \pm 0.0002$ kg/m². This almost negligible growth increment may reflect the fact that there are empty or open areas in all of the plots sampled. When the kg/m² increment is extrapolated across the total area of the three plots/collection areas, the annual increment of Rhododendron biomass is approximately 809 kg. Based on the current rate of fuelwood consumption, standing biomass and annual growth increment, Chajeyna will likely be devoid of woody vegetation in less than 13 years.

3.6.5. Issues Related to Tibetan Collectors

A major concern among Bhutanese Cordyceps collectors is that of Tibetans collecting Cordyceps in Bhutan. About 75% of the Cordyceps collectors interviewed have identified Tibetan collectors as the main threat to continued harvesting. Some collectors (especially yak herders) note seeing Tibetan collectors before Bhutanese collectors arrive in the area and that they remain after Bhutanese collectors’ return to their campsites. The campsites of Bhutanese collectors are about two-hour walk from the Cordyceps collection area. Their reason for camping far from collection sites is due to the dangers posed by Tibetans who camp near the collection area and the fact that at higher elevations woody vegetation gives ways to grasslands.

Bhutanese collectors have expressed their gratitude to forestry and army personal for patrolling the area and trying to reduce the number of illegal collectors. However, collectors noted that it might help if patrolling teams established base camps near the Bhutanese collector’s camp sites or near the collection ground rather than in Tshampa⁶. Some collectors reported that Tibetans, who frequently out-number Bhutanese, would harass them. In 2009 one Bhutanese collector was injured after being attacked by Tibetans with stones. Safety is a big concern among Bhutanese collectors, as it is for forestry officials.

Collectors also expressed concern about not being able to obtain maximum benefits from the collection of Cordyceps primarily because collection is restricted to just one month. Collectors said that Tibetan poachers collect Cordyceps before the Bhutanese are issued permits and continue to collect after the official collection period ends. Collectors note that

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⁶ It is three and half hour walk from collectors’ campsites
Cordyceps are visible and available for harvesting before and after the government allows them to collect and that this is the time when Tibetans are particularly active inside Bhutan.

### 3.7. General Observation and Recommendations

The main source of fuelwood for Cordyceps collectors and Yak herders in Chajeyna is the rapidly dwindling supply of Rhododendron. Rhododendron is preferred as it provides more continuous heat and lasts longer than the only other alternative fuelwood (Ap Tashi, 2010. pers.com.) – dwarf Juniper. Dwarf juniper (*Juniperus sp.*) is frequently used to start fires by those who do not have kerosene. Juniper is also burned by those who camp at higher elevations and by Tibetans. Rhododendron becomes increasingly scarce above 5000 m, or about 200 m above Chajeyna, while small supplies of Juniper are available at higher elevations. Collectors noted the difficulty of carrying kerosene, stove and LPG cylinders. I think it will be a major hardship for collectors to stop burning Rhododendron and shift to alternative sources of energy such as kerosene stove or LPG because it would be costly and because selling Cordyceps is a major portion of their income. However, there are no other options to prevent the elimination of Rhododendron other than encouraging collectors to use alternative energy sources. In order to achieve this goal, park management authorities and the Royal Government of Bhutan need to develop alternative strategies, including subsidizing the purchase of stoves and fuel. This may be necessary because Cordyceps contributes 80-100% of total annual income for about 30% of the collectors interviewed. Since Cordyceps is their only source of income, it may be difficult for them to buy kerosene or stoves. Also it would also seem unfair as illegal Tibetans would undoubtedly not only continue to poach Cordyceps, but be able to continue to exploit Rhododendron as their fuelwood.

I feel that there is no point of estimating the sustained yield extraction of biomass in Chajenya, as the biomass accumulated in a year will likely be insufficient to meet the requirement of the yak herders, much less that of Cordyceps collectors. Thus, if the Rhododendron is to survive it must be left un-disturbed and alternative energy sources used. Consequently, it seems mandatory to reduce the number of Tibetan Cordyceps collectors and Rhododendron harvesters. This could be done by deploying more patrol teams during the Cordyceps collection season, before and after to minimize illegal collecting in Bhutan and by posting Bhutanese Army along the passes and routes used by Tibetans to curtail
poaching. Anecdotal evidence suggests that poachers generally out-number the forest patrol teams which posses risks to forestry officers as well as to Bhutanese collectors. Collectors felt that the situation could be improved if some of the patrolling teams were to camp near the collector’s camp rather than camping in lower elevation and patrol only during the day. I recommend that forestry patrolling teams camp with collectors and encourage them to camp near the Cordyceps harvesting sites with their stoves and kerosene. This would compel the collectors to shift to alternative sources of energy as the availability of wood decreases with altitude. Collectors have expressed interest in camping near the harvesting sites instead of in the current location which is about one and half hour walk if the large number of Tibetan poachers were reduced. This approach may help sustain current Rhododendron stocks and perhaps enable these slow growing plants to re-colonize already denuded sites.

There were 534\(^7\) registered Cordyceps collectors from Chokor Gewog alone in 2010. The increasing numbers of collectors places a great deal of pressure on all resources, not only fuelwood, but also water, trails and disposal of human wastes. The policy of issuing three permits per household to collect Cordyceps may need to be revised and reduced to only one or two individuals per household. This would reduce pressure on biomass to a great extent. Anecdotal reports suggest that the existing policy encourages people from other households with more than three potential collectors to take advantage of those households having only one potential collector. In such cases, former (having more than three potential collectors) gets the permits issued in the name of later (having only one potential collectors). Collectors should also be educated about the environmental and ecological problems, how their impacts can be reduced and that their incomes/earnings would decline significantly if fuelwood resources are exhausted.

In summary, fuelwood consumption by Cordyceps collectors in alpine areas above Nasiphel can be expected to remain the same unless the Government of Bhutan adopts and enforces prohibitions against burning wood in alpine environments, or reduces the number of Cordyceps collectors.

### 3.8. Future Recommended Studies

I recommend a follow-up study of fuelwood consumption and Rhododendron

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\(^7\) Number of permits purchased from WCP
resources after implementing rules requiring collectors to carry and use kerosene or LPG stoves. This would allow park management to assess/monitor the rate and extent of Rhododendron growth and re-establishment. I also suggest that the study be replicated in other Cordyceps collection sites to both obtain information on fuelwood consumption rates and impacts by Cordyceps collectors elsewhere and to refine the methodology.

It is also necessary to document fuelwood consumption and impacts by yak herders and more generally to document the history of land use in alpine areas of Bhutan where human activities have occurred for centuries. Studies of this type could help document ecological changes in alpine environments and the role and importance of historic anthropogenic disturbances, some of which have clearly been compatible with biodiversity conservation objectives and may be necessary to maintain historic plant and animal populations and distributions.

It may also be useful to explore possible alternative income sources for Cordyceps collectors, if Cordyceps populations decline or become extinct.

3.9. Limitations of the Study

The main drawback of this research is that the estimate of fuelwood consumption is based on dried wood (minimum moisture content) while our estimate of biomass is based on the wet weight of the wet wood. I did not develop statistical relationships between the weight of wet and dry woods, but doing so could improve the accuracy of the study. Another limitation is the estimation of current biomass. I could not estimate the biomass of all dead and live Rhododendron because the roots, which are collected and burned, are submerged under moss and or soil. It was also difficult to estimate the total above ground biomass in the area. The result may have been different had I sampled the dead Rhododendron area while people were actually harvesting and then measured/weighed what was extracted. Finally, I was unable to establish transects in one area of Rhododendrons due to the extremely steep terrain on which it was growing. However, I estimated the area of this plot as it will likely be harvested for fuelwood as well.

Since there were no yak herders in the study area during my stay in Chajeyna, I could not measure the amount of fuelwood they consumed. Instead I assumed that their rate of fuelwood consumption is the same as that of Cordyceps collectors who stayed in the yak
herder’s huts. This likely underestimates actual fuelwood consumption because some members of yak herding groups/families typically remain in the huts every day to make cheese, butter and yogurt and thus burn wood all day long. Had I estimated their fuelwood consumption, I would have been able to more accurately estimate total annual fuelwood consumption and the approximate number of years fuelwood supplies are likely to persist in Chajeyna.
CHAPTER 4: FUELWOOD CONSUMPTION BY PERMANENT RESIDENTS IN NASIPHEL AND HAMLETS

4.1 Introduction

4.1.1. Research Sites and Methods:

Fuelwood consumption by permanent residents in Nasiphel and neighboring hamlets (Shabjeythang, Sångsangma, Dhokrong) and current fuelwood supplies and annual growth increments were assessed. Nasiphel is located at about 30 km from the nearest town (Chamkhar) and is located in Chokor Gewog, Bumthang District (Fig. 8). Table 1 shows the number of houses and populations in the villages in 2009 (Chokor Gup’s office. Data)

<table>
<thead>
<tr>
<th>Nasiphel</th>
<th>Sångsangma</th>
<th>Dhokrong</th>
<th>Shabjeythang</th>
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<tbody>
<tr>
<td>Houses</td>
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<td>Houses</td>
<td>Population</td>
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<tr>
<td>30</td>
<td>341</td>
<td>16</td>
<td>181</td>
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<td>04</td>
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Table 1: Number of houses and people in Nasiphel and surrounding villages.

In trying to understand historic pressures on forests and fuelwood resources, I had discussions with key informants in all four villages. From these I learned that the major forest land use for decades, if not for centuries, was shifting cultivation, known in Bhutan as tseri. In practicing tseri, people would clear the land and undertake cultivation for three to five years after which the land would be rested for another 3-5 years (Tenzin, 2011, pers.com.) and cultivation would shift to a new location. Tseri was widely practiced throughout the region and much of Bhutan before it was officially banned in 1969 (Namgyel et al., 2008).

The people of Nasiphel and hamlets include both yak herders and non-yak herders. Yak herders practiced tseri on the slopes around villages in close consultation with the permanent residents of the village who owned the land. Permanent residents practiced tseri in the more level plains and valleys of area (village). People cultivated buckwheat, radish, turnip and potatoes in their tseri. According to village elders, fuelwood was readily available

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8 Shifting Cultivation

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in the past from tseri fields when they were cleared for planting. Twigs and branches were burned in fields which enhanced soil fertility while larger stems were used for fuelwood. Osei (1993) reported that farming provided wood in the process of clearing and burning standing vegetation for cropping space which appears to refer to tseri. The former prevalence of tseri is evident in the uniform age and size class of the blue pine trees (Pinus walliciana) which dominate the slopes around the village today as almost all the trees appear to be in same age and established naturally after tseri was banned.

This study site is in the buffer zone of Wangchuck Centennial Park at an elevation of 2900 m (9514 ft) (Fig. 8). The inhabitants of the area move travel to the mountains every year for a month to collect Cordyceps. The people of Nasiphel and hamlets cultivate potatoes in large scale for sale to India. With the establishment of WCP, 5-10 houses have been identified as farm houses. Many local households rear horses which provide transportation
for tourists and 3-5 households have large numbers of cattle. The residents burn blue pine as their main source of firewood as it is readily available and burns easily.

4.1.2 Methods

Total annual fuelwood consumption by permanent resident in Nasiphel and adjacent hamlets was estimated by monitoring 15 households for 15 consecutive days in mid August, 2010 and again in January, 2011. This was not a random sample because yak herder residents were in high alpine areas tending their yak herds and were not in the village in the summer (3 yak herding households), and six were experiencing family/social turmoil so I decided not to disturb them. Thus, I randomly sampled those residents who were in the village and who were available when the study was initiated in August.

Daily fuelwood consumption was estimated using the weight-survey method employed by Ali and Benjaminsen (2004) and Bhatt and Sachan (2003). Each day I weighed a stack of fuelwood sufficient to meet all cooking and space heating needs in each of the 15 houses. The wood was weighed using a 25 kg spring balance and then left in the kitchen with a request to burn wood only from the weighed bundle. I then returned the following day, reweighed any remaining wood and recorded the weight of fuelwood consumed during that 24 hour period. This was repeated for 15 consecutive days in each of the 15 houses and an average daily per capita rate of fuelwood consumption was estimated. The same procedure was followed for 15 consecutive days in January with the same households. The people of Nasiphel proved to be very cooperative and I was told that they burned wood only from weighed piles throughout the study.

I observed that fuelwood was extracted only from locations where WCP forestry officials designate areas to be harvested. In 2010 residents were allowed to harvest fuelwood from two locations: one near Nasiphel and another five kilometers from Nasiphel adjacent to a road. I surveyed and mapped the collection areas by establishing polygons with the help of Garmin eTrek GPS. The area of the polygons were calculated in Garmin eTrek GPS and in ArcGIS 9.3.1 to cross check the area of polygons drawn with GPS. Sample plots were then established in the two collection sites/polygons. After choosing a random point I established transects and 10 m radius plots at 50 m intervals. I then measured the diameter at breast height (dbh) and height of trees within each sample plot and cored all trees within
each sample plot with an increment borer to determine the age and annual growth increment. The plots contained only blue pine trees, which is the only fuelwood used by local residents. I sampled 9 plots in plot I and 4 plots in plot II and measured the height and dbh of 63 trees and 45 trees from plot I and II, respectively. While I cored all trees in the sample plots, I could analyze the rings of only 11 samples using Measure J2X software as other sample broke during the process of mounting and handling. To estimate the volume of trees in the plots, I consulted volume tables (m³) prepared by the Forest Resources Development Division (MoA, n.d) which are based on blue pine trees. I estimated the volume of daily fuelwood consumption by establishing weight-volume relationships. The weight-volume relationship was obtained by measuring weight against volume for 20, 30, 40, 50 and 60 kgs of wood ten times in each of ten houses.

I randomly interviewed 32 households in the four villages (Nasiphel, Shabjeythang, Sangsangma and Dhokrong). If no one was present in the house selected, another house was randomly selected. I interviewed 18, 6, 4 and 4 households in Nasiphel, Dhokrong, Sangsangma and Shabjeythang, respectively. I also informally gathered information from five key informants.

I used Google Earth to map the area of another potential harvesting site in consultation with residents of Nasiphel and the potential harvesting area of that site was calculated in Google Earth Pro.

4.2. Results and Discussion

I found that 78% of the households interviewed use either tractors or trucks to transport their fuelwood, 6% transport fuelwood on their back, while 16% said that their mode of transportation was rolling logs downhill. The latter households were located at the base of the hill near harvesting sites. These people may have to shift to other modes of transportation when all readily available fuelwood is harvested.

I attempted to identify the different types of energy used to prepare meals. About 41% of the households interviewed said they prepared all meals on Bukharis (improved wood stoves) irrespective of the season, while 59% generally prepared lunches using LPG stoves when the weather was warm. Although all of the houses in the study area had LPG
stoves, some residents used them only to prepare tea or to warm ara\textsuperscript{9} for guests. The main reason stated for not preparing meals on LPG stoves was the difficulty in getting the LPG cylinders filled which can only be done in Chamkhar (approximately: 30 km away). Some interviewees reported that they would prepare meals when they made a fire in the Bukhari wood stove for heating purposes.

People in the study area prefer using a Thab (outdoor wood kitchen) constructed near their house. About 84\% of the households were found to have Thabs. The houses which did not have a Thab were those which were temporarily dismantled for renovation. Thus, all households in the study area will likely have a Thab in coming days. People make use of Thabs to boil water for bathing, brewing alcohol, preparing cheese and while performing rimdos\textsuperscript{10}.

4.2.1. Fuelwood Consumption

Daily per capita consumption of fuelwood in Nasiphel during the summer was approximately 2.6 ± 0.2 kg/day. When extrapolated to the number of people in Nasiphel, a total of about 896 ± 55 kg of fuelwood was consumed daily during the summer. Surprisingly, fuelwood consumption during the winter did not differ a great deal compared to summer (Fig. 9). I found that daily per-capita fuelwood consumption during January was 3.6 ± 0.2 kg/day which when extrapolated suggests that total daily fuelwood consumption by the people of Nasiphel is about 1234 ± 64 kg during winter months. I averaged the two (summer and winter consumption) to estimate annual daily consumption. Based on this, I estimate total annual fuelwood consumption in Nasiphel to be approximately 389 ± 30 metric tons.

Since the four villages (Nasiphel, Sangsangma, Shabjeythang and Dhokrong) collect fuelwood from the same sites, I felt it was necessary to extrapolate fuelwood consumption in Nasiphel to the other villages to derive and estimate total annual fuelwood consumption. Assuming all households in the area consume approximately the same amount consumed by households surveyed in Nasiphel, a total of about 661 ± 53 metric tons of fuelwood is consumed annually in the four villages. Government foresters marked and permitted a total

\textsuperscript{9}Locally brewed alcohol
\textsuperscript{10}Rituals performed by monks/religious head in the house
allowable cut of 207 metric tons of fuelwood in 2010. Thus, actual fuelwood needs and harvesting rates are far greater than the 16 m³/household permitted by the government. Thus, I conclude that a great deal of illegal fuelwood harvesting is occurring and personal observation confirmed this.

![Figure 9: Daily per-capita fuelwood consumed by various households during summer and winter.](image)

![Figure 10: Per-capita fuelwood consumed in relation to average number of people in a household during summer and winter months.](image)
Per capita fuelwood consumption is influenced by the number of people in a household. As found in the earlier study in Chajenya, per capita fuelwood consumption is inversely related to the number of individuals in a household (Fig. 10). This is to be expected since a single person requires the same amount of wood to warm as is required by four people.

4.2.2. People’s Perception of Fuelwood Availability

When respondents were asked their views regarding trends in fuelwood availability, only a few people said that the availability of fuelwood was increasing. The majority of people interviewed (78%) said that fuelwood availability is decreasing, while about 13% felt that fuelwood availability is constant and 9% said it was increasing. Respondents might have answered based on fuelwood sources near their household as forest cover in Nasiphel is likely to have increased since the banning of tseri. When people were asked about fuelwood related problems, approximately 44% said they faced no major problems and 13% reported problems related to its harvest such as associated with chainsaw and tractor availability. Only 3% of respondents expressed problems with fuelwood availability as their main problem.

4.2.3. Current Biomass and Annual Increment

From the sample plots in Plot I and II, I estimated the current biomass to be $315 \pm 95$ metric tons with the biomass density of $3 \pm 0.9 \text{ kg/m}^2$. With the help of Goggle Earth Pro, I estimated the area of the potential fuelwood harvesting site (Fig. 11) to be approximately 17 ha. Based on the estimated biomass density and the harvesting areas, I estimated total current fuelwood biomass available for extraction to be approximately $901 \pm 267$ metric tons.

All the blue pine trees in the study area are 20-35 cm dbh and approximately 30-35 years old. The average diameter growth increment was $0.99 \pm 0.06 \text{ cm}$ ($n=11$). I used the below equation to convert volume to weight (Fig. 12):

Weight of fuelwood (kg) = $235.1 \times \text{Volume of fuelwood (m}^3) + 8.586$
After obtaining the annual increment for one tree, I estimated the annual increment within the sample plots. In order to estimate average increment accumulation in terms of kg/m², I used following equation -

\[
\text{Increment (kg/m²) = \frac{\text{Increment in sample plot (kg)}}{\text{Area of plot (m²)}}}
\]

Based on this equation, I estimated the average increment to be 1.4 kg/m², which when extrapolated to the two current harvesting sites and the potential harvesting site suggests that approximately 380 metric tons of biomass is accumulating each year.

Figure 11: Overview of Nasiphel and surrounding study villages with current harvesting and potential harvesting site.
4.2.4. Illegal Harvesting of Fuelwood

Based on informal conversations with key informants, illegal harvesting of fuelwood appears to have been widespread before the establishment of the park office in Nasiphel. This is corroborated by the abundance of stumps that appear to exceed any likely allowable harvesting guidelines that forestry officials recommended. Despite the establishment of a local park office, illegal harvesting appears to be common as evidenced by the many freshly felled un-marked stumps covered with moss or dried pine needles in an attempt to deceive...
foresters (Fig. 13). I also observed three trees felled and cut into bukhari size logs, but left in the woods after it was noted by foresters that they had been illegally felled. Local residents noted that the establishment of a park office may reduce illegal cutting; 54% of respondents stated that park officials might impose more restriction on fuelwood collection in the future.

4.3. Sustainability of fuelwood in Nasiphel and surrounding villages

Current forestry regulations permit the people of Nasiphel and surrounding villages to burn approximately 207 metric tons of fuelwood annually as there is no electricity in the area. However, electricity will become available in the villages in the near future at which time new fuelwood consumption rules would allow residents to burn only half the current amount of fuelwood (about 103 metric tons/year). As noted previously, in 2010 local residents burned approximately three times what the current rule allows or six times of what will be permitted when electricity becomes available.

The rate of annual biomass accumulation (i.e., growth increment) is greater than what the government permits residents to burn. The designated fuelwood harvesting areas could meet residents fuelwood needs in perpetuity if only 16 m$^3$ of fuelwood were consumed by each household. However, if current (illegal) harvesting rates continue, the sustainability of fuelwood from the designated harvesting areas in Nasiphel and surrounding villages is questionable. On the other hand, fuelwood consumption may decrease with the coming of electricity since much cooking will likely be done using electrical appliances during warmer months. The current Forest and Nature Conservation Rules, 2006 (MoA, 2006) of Bhutan allows only 8m$^3$/year/household of fuelwood in places where electricity is supplied.

4.4. Future Energy of the Study Area (Nasiphel)

With the establishment of the park headquarters office in Nasiphel, residents expect the government or park authorities to complete a paved road between Nasiphel and Chamkhar town. If the road is improved, people noted that easier transportation would encourage them to use LPG rather than wood as energy. The current development activities in Nasiphel may affect future use of fuelwood. But, as reported by An et al. (2002) from a study in China, household willingness to switch to electricity also depends on the cost and the distance of their houses from fuelwood sources. Madubansi and Shackleton (2007) note
that despite an increase in fuelwood scarcity and the availability of electricity, the majority of households continued to use wood as their main source of energy in Limpopo, South Africa. During my research in Nasiphel, most people I spoke with were positive about shifting to electricity to prepare meals, but not for space heating. This suggests that wood burning will continue to be an important source of energy for heating during winter months.

4.5. Recommendations

Fuelwood is likely to remain an important source of energy to residents of Nasiphel. However, per capita fuelwood consumption may decline with the coming of electricity and paved roads to Nasiphel and surrounding villages. Based on fuelwood consumption, growth and standing biomass, I recommend that the Government consider continuing to encourage people to use fuelwood as their major source of energy in Nasiphel and adjacent hamlets. Wood is a renewable source of energy, it is cheaper and more readily available than LPG or other purchased fuels, and its use will help Bhutan achieve its goal of becoming carbon neutral by 2020. In addition, forest cover in the area is greater now according to elderly village residents than it has been for centuries (due to the cessation of tseri and subsequent establishment of forests). Harvesting fuelwood could reduce the buildup of fuel and thereby reduce potential fire hazard around the villages.

Fuelwood supplies (i.e., standing biomass) and annual growth and yield are more than sufficient to meet present and future fuelwood needs in Nasiphel on a sustainable basis. The area has well established, rapidly growing blue pine stands and probably has greater forest cover now than has existed for centuries. Extraction or felling of trees for fuelwood is monitored by WCP forest personal. However, the number and selection of trees to mark is done solely by forestry staff. For some households, three mid-sized trees were marked and for others one or two large trees were marked (Using ocular measurement to obtain 8m$^3$ / 16m$^3$ of firewood). I recommend WCP staff develop local volume tables based on DBH and height for easy calculation of the number of trees to be marked/felled, or use the volume table already prepared by FRDD.

Since current annual fuelwood consumption is approximately four times (51m$^3$) of what the government allows a household to legally burn annually (16m$^3$), I recommend revisiting the 16 m$^3$ annual fuelwood limit per household rule. While fuelwood consumption may decline after electricity becomes available, it is likely to remain far higher than
8m³/household/year that the government permits in communities that have electricity. Current fuelwood harvesting allowed by the government permitting system may meet the needs of people living in sub-tropical regions of the country, but not those of temperate regions. Thus, there is a need to stratify the country, based on ecological zones, and re-consider the volume of annual fuelwood allowed by Forest and Nature Conservation Rules, 2006 of Bhutan (MoA, 2006), rather than issuing the same amount of fuelwood to people irrespective of where they live and their household needs. Since the annual increment of fuelwood is 380 metric tons in the two existing harvesting and potential harvesting sites (29.4 m³ of fuelwood per household), I recommend an annual allowance of 24m³ of fuelwood per household in Nasiphel and hamlets. Following such a strategy may help in reducing fuel buildup and prevent possible future fire hazards.

4.6. Future Recommended Studies

This fuelwood consumption study in Nasiphel and adjacent hamlets was timely. When the study was conducted, electricity was not available, but will be provided to the area in the near future. Thus there is a need to understand and document (i.e., quantify) changes in fuelwood consumption and harvesting patterns in the area and on a household basis after the introduction of electricity (Madubansi, and Shackleton, 2007). Kuensel\footnote{One of the Bhutan’s news paper} reports that institutes and monasteries who shifted to the use of electric cookers and pots reduced their use of fuelwood by 20-30 truckloads (1 truckload = 8 m³) (Dorji, 2010).

There is also a need for the government to study annual fuelwood consumption by Institutes, Monasteries, Industries and other organizations. At present, the Bhutan government does not have data on how much fuelwood is being consumed annually in the country or the available biomass stocks and growth and yield in fuelwood harvesting areas.

Finally, Bhutan is currently more heavily forested than it has been in recent centuries. The slopes around Nasiphel, for example, support dense stands of 30-35 year old trees that were established after the Government of Bhutan prohibited swidden (tseri) farming. The ecological role and importance of tseri and other historic anthropogenic disturbances in maintaining Bhutan’s rich biological diversity is unknown. However, the widespread

\footnote{One of the Bhutan’s news paper}
establishment of dense forests after cessation of tseri cultivation resulted in a significant
reduction in grasses, forbs and other early successional vegetation in Jigme Singye
Wangchuck National Park, which may, in turn, support lower populations of ungulates, such
as sambar and musk deer, and predators, including tigers and leopards (Namgyel, et al.,
2008). The ecological role and importance of historic anthropogenic disturbances in
maintaining native flora and fauna in Nasiphel and other areas of Bhutan is an important
topic that warrants future research.

4.7. Wood as Future Energy Source

Fuelwood has always been and could remain an important source of energy in the
future (Hall and Scrase, 1998). The common mis-conception that “wood is dirty fuel”
(Hulscher, 1998) may be due to the smoke produced while burning wood in traditional
stoves. But, that is a problem, not with wood, but with wood burning technology. Clean
burning stoves are available at household and municipal levels.

Consumers around the world are increasingly shifting to energy that is renewable,
clean and affordable, including solar, wind, hydroelectric, and geothermal. Fuelwood and
biomass in general is the simplest and oldest form of renewable energy (Richter et al., 2009).
In Europe, Advanced Wood Combustion (AWC) is being deployed to supply heat, cooling,
and power, while simultaneously reducing greenhouse gas emissions (Richter et al., 2009).
Many countries around the world are now increasing the use of wood as an energy source.
For example, European Union countries are addressing climate change and the European
Commission is encouraging member countries to increase the use of renewable energy,
specifically that 12% of energy consumption would be from wood by 2010 (Couture et al.,
2009). Bhutan’s per capita forest resources and annual growth rates are far greater than
those of northern Europe (e.g., Austria) where biomass burning is increasingly replacing
fossil fuels. This suggests that there is great potential for Bhutan to meet much of its
residential and community energy needs, including generating heat and electricity, through
burning fuelwood.

Bhutan in general and Nasiphel in particular, are more heavily forested now than any
time over the past several centuries. It makes sense to encourage sustainable fuelwood use to
meet local energy needs, while at the same time addressing growing concerns about forest
fires. Continued or expanded fuelwood use would also lower expenses for households who would otherwise have to purchase costly imported LPG or other fossil fuels.

4.8. Limitations of the Research

A primary shortcoming in this research is that the estimate of fuelwood consumption is based on the dried wood (minimum moisture content) while the estimate of biomass is based on the wet weight of the wood. I did not develop relationships between the weight of wet and dry woods, but that could greatly improve the accuracy of the estimates. Dried wood is obviously lighter than wet wood, thus, current biomass stocks may be less than what has been estimated. The estimate of fuelwood consumption was carried out only during summer and winter months. Had fuelwood consumption been estimated during all four seasons, the estimate of annual fuelwood consumption would have likely been more precise. Another potential shortcoming is that the mapping of the potential harvesting site was done in Google Earth, not in the field (although I did verify the area in the field). Consequently, its accuracy may be questionable. Finally, fuelwood consumption was monitored only in Nasiphel. It is possible that consumption rates differ in the adjacent hamlets and it could be useful to explore any differences in per-capita fuelwood consumption in the four villages.

4.9. Conclusion

Forest biomass is a crucial resource for the rural people of Bhutan. Dependence upon wood energy is not likely to change soon, despite the fact that Bhutan is developing and exporting hydroelectricity (FAO, 2000). Unlike in other countries, most of the fuelwood in Bhutan originates from government owned forests, with a only very small amounts coming from private and agricultural lands (Sharma, 2000).

This study reveals that current fuelwood extraction in high alpine environments is unsustainable, leads to the loss of forest cover, and the degradation of slow growing alpine vegetation, particularly Rhododendron. In contrast, the temperate forests surrounding Nasiphel are abundant, rapid growing and the rate of fuelwood harvesting in this area does not exceed growth and yield. Furthermore, forest cover is increasing in this area, as it is in many other areas of Bhutan and is now far greater than it has been for many centuries. Thus, the discussion on whether fuelwood harvesting leads to forest loss or degradation (Webb and Dhakal, 2010) depends on the area in question and the site-specific rate of amount
fuelwood consumptions in comparison to biomass availability and accumulation (i.e., growth and yield).

Strong patrolling activity needs to be undertaken before, during and after official Cordyceps collection periods in the alpine regions of Bhutan to eliminate fuelwood harvesting Tibetan poachers as well as Bhutanese Cordyceps collectors. In order to prevent the loss of woody vegetation in Chajeyna and similar alpine regions, a policy of encouraging minimum utilization of fuelwood or banning wood burning entirely should be implemented given the slow growth rate of biomass accumulation in this high elevation environment. Given the difficulty of monitoring fuelwood use, complete prohibition may be warranted.

The situation is very different in lower elevation temperate forests. Residents of Nasiphel and adjoining villages will likely continue to burn fuelwood for heating even after electricity becomes available because burning wood in a bukhari generates more heat at much lower cost than electrical appliances. Some reduction in fuelwood consumption may occur during summer months as residents may prepare food with electrical appliances. Fuelwood supplies are abundant in Nasiphel and adjoining villages and could be harvested sustainably in perpetuity even if harvesting rates were increased. Biomass accumulation (i.e., annual growth and yield) in the two designated harvest areas plus the potential harvesting site far exceeds current government allowed harvesting rates. Furthermore, continued or increased use of fuelwood will save household money as wood is less expensive than purchased imported LPG gas or relying upon electricity. Finally, if restrictions are imposed on fuelwood harvesting in Nasiphel and adjoining villages, forest density will likely increase. This may lead to increased risk of fire, insects and disease, and ultimately affect flora and fauna, specifically reducing the abundance and diversity of plant and animal species that prefer early successional, gap and other high light/full sun environments.

Fuelwood consumption far exceeds what the government currently allows residents to burn in a year. It may be useful to evaluate and modify annual allowable fuelwood harvest rates (i.e., to permit increased fuelwood harvesting through either increasing harvesting rates/area and/or increasing the number or size of areas in which fuelwood can be harvested) as annual biomass accumulation is higher than what government rule allows to be burnt annually. Encouraging people to use fuelwood as their main energy source rather than shifting to more expensive non-renewable fuels would help the Royal Government of Bhutan’s desire to achieve its national goal of becoming carbon neutral.
Despite the tremendous importance of fuelwood to households in both rural and urban Bhutan, very little is known about fuelwood consumption or biomass availability and growth and yield (i.e., potential sustainable harvesting rates) in the wide variety of forest types found throughout the country. Additional community and forest-specific studies are needed to better understand fuelwood resource use availability and to develop policies to manage this important and renewable energy resource.
References


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Appendix 1

Member Countries of RWEDP

1. Bangladesh
2. Bhutan
3. Cambodia
4. China
5. India
6. Indonesia
7. Lao PDR
8. Malaysia
9. Maldives
10. Myanmar
11. Nepal
12. Pakistan
13. Philippines
14. Sri Lanka
15. Thailand
16. Vietnam
Appendix 2

This Questionnaire is designed for obtaining the information on fuelwood from the Cordyceps collectors.

A. General Information of the interviewee

1. Name of interviewee ________________________ Sex
   __________________ Age___________
2. Name of interviewer ______________________ Date: __________________
3. Occupation (may include skills like carpentry, masonry, gomchen etc)_____________
4. Number of people in group_____________
5. Number of people from your household____________
6. Village_____________________
7. Gewog ______________________
8. From which year did you start harvesting cordyceps? _____________
9. When did you start collecting this year?____________________
10. For how long will you be collecting?_______________________
11. What did you bring to eat here during the collection time?

B. Fuelwood Information

12. Did you bring any cooking and heating equipments with you? (Includes Kerosene stove, LPG stove or any other)

13. From where do you collect firewood? (Direction and distance from the campsite)

14. Which species of firewood do you prefer? Why?

15. Trend of firewood availability comparing to past years?
   - Increasing ☐
   - Decreasing ☐
16. What are the problems faced during collecting firewood?

17. Did you come across any non-Bhutanese collectors? How many?

C. Marketing of Cordyceps and Income source

18. What do you feel with the present trend of auctioning process followed by the government?

19. What percentage of your income accounts from selling Cordyceps?

20. Besides earning from the Cordyceps, what are your sources of income?

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Income source</th>
<th>Percentage of Income</th>
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<tbody>
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</tbody>
</table>

D. General

21. Did you get permit for Cordyceps collection easily?

22. According to you, is the rule of issuing permits for Cordyceps collection to more than one person from a household good or bad? Why?

23. Availability of Cordyceps from previous years?
   - Increasing □
   - Decreasing □
   - Constant □

Appendix 3

This Questionnaire is designed for obtaining the information on fuelwood from the case study village.

E. General Information of the interviewee

25. Name of interviewee ________________________Sex
_________________________Age___________
26. Name of interviewer ______________________Date:__________________
27. Occupation (may include skills like carpentry, masonry, gomchen etc)_____________
28. Number of people in household___________
29. Village_____________________
30. Gewog ______________________

F. Firewood

31. Which species of wood do you prefer for cooking and heating?

<table>
<thead>
<tr>
<th>Rank</th>
<th>Species</th>
<th>Why?/ Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td></td>
<td></td>
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<tr>
<td>2nd</td>
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<td>3rd</td>
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<td>4th</td>
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<td>5th</td>
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<td>6th</td>
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</table>

32. From where do you collect your firewood? (Direction of firewood collection source)

33. How long does it take you to reach an area to collect firewood?

34. Mode of firewood transportation?
   - Horses
   - Cars
35. Did/do you buy firewood?

36. Reason for buying firewood?

37. Do you sell firewood and where?

38. What are the problems faced while collecting firewood?

39. Who collects firewood?
   - Male
   - Female
   - Children

40. How many times do you go to collect firewood in a week/Month?
   - Week =
   - Month =

41. When do you collect your firewood most?
   - Spring
   - Summer
   - Autumn
   - Winter

42. What do you collect as firewood?
   - Fell live tree
   - Collect live branches
   - Collect fallen trees/shrubs
   - Collect dead and dying trees

43. Do you need to obtain permit from Forest personal to collect firewood?

44. What is the difference of firewood consumption during summer months and winter months? (Rough estimate)
45. Where do you cook your meal?

<table>
<thead>
<tr>
<th></th>
<th>Breakfast</th>
<th>Lunch</th>
<th>Dinner</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas stove</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Kerosene Stove</td>
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<tr>
<td>Bukhari</td>
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<td></td>
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<tr>
<td>Traditional stove</td>
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</tbody>
</table>

46. Trend of firewood availability with time.

- Increasing [ ]
- Decreasing [ ]
- Constant [ ]

47. Are you worried on the future availability of firewood in your community?

48. Have you ever thought of the firewood in your area becoming extinct?

49. How do you ensure the sustainability of firewood in your community?

50. Do you practice any management of the firewood species?

- Yes [ ]
- No [ ] (Skip question 26)

51. How do you go about managing your forest?

52. What is your wish on alternative source of energy?

53. What is your thinking on the establishment of new park in your area? (May include their worries on natural resource extraction scope and problems)

54. What are your expectations from the park?
Appendix 4

Daily Firewood Consumption Assessment for Cordyceps Collectors

Place: Chajeyna                                               Gewog: Chokortoe
Dzongkhag: Bumthang

Household No.1

<table>
<thead>
<tr>
<th>Date</th>
<th>No. of people in group</th>
<th>Initial Weight (kg)</th>
<th>Final Weight (kg)</th>
<th>Addition (If Any) – (kg)</th>
<th>Daily Consumption (kg)</th>
<th>Remarks</th>
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</thead>
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</table>

Appendix 5

Rhododendron Ring Analysis

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Diameter (cm)</th>
<th>Age (Years)</th>
<th>Mean Diameter Increment in a Year (mm)</th>
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</thead>
<tbody>
<tr>
<td>Rhodo 1</td>
<td>8.0</td>
<td>109</td>
<td>0.78</td>
</tr>
<tr>
<td>Rhodo 2</td>
<td>7.9</td>
<td>102</td>
<td>0.78</td>
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<tr>
<td>Rhodo 3</td>
<td>5.0</td>
<td>92</td>
<td>0.54</td>
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<tr>
<td>Rhodo 4</td>
<td>5.1</td>
<td>101</td>
<td>0.54</td>
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<tr>
<td>Rhodo 5</td>
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<td>0.42</td>
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<tr>
<td>Rhodo 6</td>
<td>8.1</td>
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<td>0.51</td>
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<tr>
<td>Rhodo 7</td>
<td>7.0</td>
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<td>0.69</td>
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<td>Rhodo 8</td>
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<td>Rhodo 9</td>
<td>4.8</td>
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<tr>
<td>Rhodo 10</td>
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