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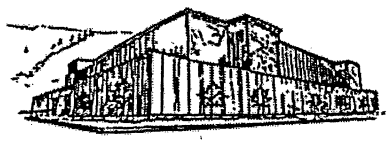
Development of an effective forest fire management strategy for Bhutan

Kinley Tshering
The University of Montana



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DEVELOPMENT OF AN EFFECTIVE FOREST FIRE MANAGEMENT STRATEGY FOR BHUTAN

By

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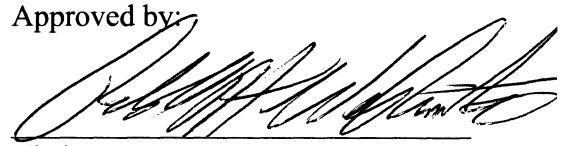

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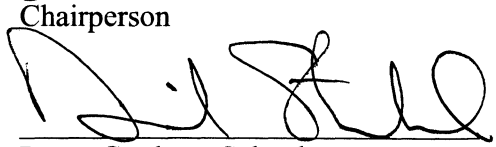

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Development of an Effective Forest Fire Management Strategy for Bhutan

Chairperson: Professor Ronald H. Wakimoto

Forests play an integral role in the overall development of Bhutan by virtue of being the largest renewable natural resource. It is generally believed that forest fire is the primary cause of loss in forest cover and therefore poses the single most important threat to the national objective of maintaining 60 percent forest cover. Catastrophic forest fires also undermine national conservation and developmental efforts. In view of this the development of a national strategy on forest fire management in Bhutan has been identified as a priority need by the Royal Government.

This paper has attempted to broadly assess current status of forest fire management in Bhutan, and recommend ideas for future management efforts and strategies based on this assessment. The assessment is based on review of relevant literature and results of a questionnaire survey conducted among Bhutanese foresters on forest fire management in Bhutan.

Survey results conform to government aspiration that a holistic and integrated forest fire management strategy is highly desirable for Bhutan. There is strong indication that, current policy of fire exclusion in Bhutan should be reviewed and amended based on political will, social acceptability, ecosystem needs and implementation capabilities within the government. There is a decreasing trend of fire incidences since 1999, which may be a result of prevention efforts. The effect of forest fire on the landscape is generally assumed to be negative. Ongoing attempts at management of forest fire in Bhutan are primarily focused on prevention and suppression. There is acute lack of knowledge and expertise on other components of forest fire management, including, fire use and fire fighter safety. Training, education, awareness, resource and organizational needs repeatedly emerge as priority issues and will be key to successful management of forest fires in Bhutan.

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CHAPTER 1. INTRODUCTION

Bhutan is a small country located between China and India, with an area of approximately 38,394 sq. km. The country roughly stretches 300 km. east to west and 170 km. north to south, at their longest dimensions (RGoB NSB 2004). Bhutan is one of the least populated countries in the world and is home to a population of 672,425 people (RGoB OCC 2005), mostly inhabiting river valleys in the 20 *Dzongkhags*[1] (See Appendix A). Being located almost entirely in the great Himalayas, it is one of the most rugged terrains in the world. Elevation varies from 200m in the southern foothills to more than 7600m a.s.l. at highest points bordering China in the north. McKinnell (2000) classifies the country into three broad geographic zones: the high Himalayas in the north above 4000m a.s.l., the central belt from 2000 to 4000m a.s.l., and the southern belt between 200 to 2000m a.s.l. This extreme variation in altitude has created a corresponding range of climatic conditions varying from hot and humid tropical and subtropical conditions in the southern foothills to cold and dry tundra conditions in the north. The south west monsoon, starting in May and lasting for four months, accounts for more than 70 % of annual precipitation. The amount of precipitation ranges widely in various parts of the country. In the temperate central regions, the yearly average is around 1,000 mm. Some locations in subtropical areas in the south register as much as 7,800 mm of rainfall per year. In the severe climate of the north, there is only about 40mm of annual precipitation, primarily occurring in the form of snow (RGoB NSB 2004).

[1] *District*

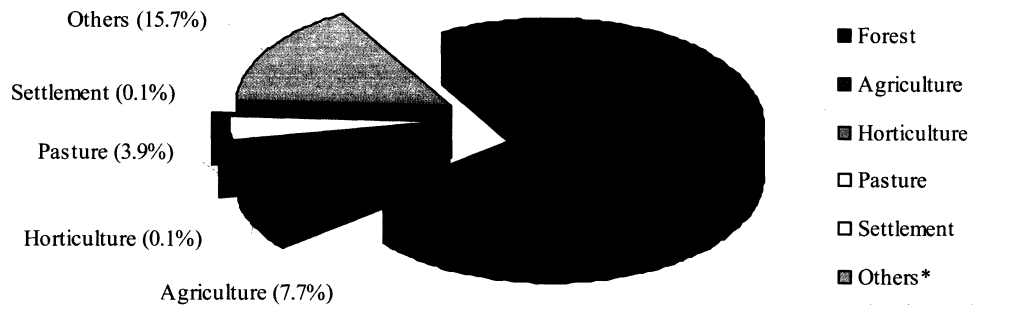
1.1 Overview of Forestry in Bhutan

Bhutan's forest area is estimated at 72.5 %, of which 64.35 % is under tree cover (RGoB DoF 2005, KOL 10.8.2005). The forests are dominated by broadleaf and conifer types, representing 34.3 % and 26.5 % of the total forested area respectively (Table 1):

Table 1. Area and percent of broad forest types in Bhutan. Source from RGoB DoFS 2002

Forest land	Land cover (sq. km.)	% of total land area
Conifer	10,614	26.5 %
Conifer + Broadleaf	1,358	3.4 %
Broadleaf	13,749	34.3 %
Plantation	64	0.2%
Scrub forest	3,258	8.1%

The remaining 27.5 % are agriculture (7.7%), pasture (3.9%), horticulture (0.1%), settlements (0.1%), and others (15.7%) mainly comprised of rock outcrops, snow and water spread (RGoB DoFS 2002). This is illustrated in (Figure 1) below:



**Others include permanent snow, rocks and water spread*

Figure 1. Shows percent of different land-use types in Bhutan. Data source: RGoB DoFS (2002).

The country is rich in biological diversity owing to its location in the eastern Himalayas where two major bio-geographic realms, Palearctic and the Indo-malayan, adjoin. The diverse ecosystems are endemic to more than 5,400 species of vascular

plants, 770 species of birds and 170 species of mammals (RGoB NCD 2004). The floral and faunal species are representative of tropical, subtropical, as well as temperate and alpine regions.

For its size, Bhutan probably has the greatest biodiversity of any country in Asia, and it is for this very reason that the nation has been declared one of the world's 10 most important biodiversity 'hotspots' (RGoB PC 1999). To this end, the Royal Government has formally designated 35 % of the country for protection (RGoB NCD 2004). This protected area network is comprised of 26 % protected areas and an additional 9 % declared as biological corridors in 1999 (RGoB DoF 2002). In contrast the area brought under timber production is only 6 % (RGoB MoA 2002), and these too are operated as per scientific management plans required by law.

Forests play a central role in the overall development of Bhutan by virtue of being the largest renewable natural resource. In addition, a sound forest ecosystem is essential for sustaining agricultural practices. Agriculture contributed more than 26.2 % to Gross Domestic Product (GDP) of the country in 2003 (RGoB NSB 2004) and is the single largest sector that provides livelihood to 79 % of the population (Webb & Dorji 2004). More than 69 % of the Bhutanese population live in rural areas (RGoB OCC 2005) and depend directly on surrounding forests for timber, fuel wood, fodder, leaf litter and water. Subsistence farming and livestock rearing are at the core of the rural farming activity. Livestock is maintained by the rural Bhutanese mainly for dairy and meat production, draught power and production of dung for farmyard manure. Livestock graze freely in forests, which remain the single most important source of fodder. Farmers also depend on an array of non-wood forest produce (NWFP), important as food supplement and

products like mushrooms (*Tricholoma masutaki*), and others (*Cordyseps sinensis*) etc. are now increasingly exported by local communities for considerable cash income.

The conservation of forests and integrity of watersheds is important for success of the hydropower industry. The four major river systems across the country are critical for sustenance of farming activities in the river valleys and more importantly for production of hydro-energy. Hydropower production is recognized as the most promising avenue to economic progress of the country. As of1996, hydropower generation accounted for one-third of the country's total annual revenue and yet less than 2 % of the estimated hydropower potential of 20,000 megawatts, had been harnessed into production. The 1020 MW Tala Hydroelectric Project is currently the biggest hydropower project in Bhutan. The first phase with a capacity of 170 MW commenced production in July 2006 and within the first ten days it reportedly earned revenues over Nu.36 million (KOL August 12 2006). With a ready market in neighboring India, hydropower presents a relatively clean source of foreign revenue (RGoB NEC 1998).

Tourism is another good source of direct foreign revenue in Bhutan. The country's rich biodiversity and spectacular landscapes attract high-end tourists from all over the world. Although tourism in the country has been largely culture-based, scenic natural beauty holds added value and high potential for nature-based tourism and eco-tourism. The policy of "high value, low impact" tourism (RGoB DoT 2002) is complementary to the conservation policy of maintaining pristine environment with minimal impact on the rich culture and traditions of people in the country. Since its inception in 1974, the number of visitors has increased from just 287 in 1974 to more than 7,000 in 1999 (Dorji 2001) and subsequently more than 10,000 in recent years. The

contribution from tourist receipts accounted for as much as 15-20 % of national export of goods and services by the late 1990's. National projections predict revenue from tourism to increase 100 % from current earnings by 2012 (RGoB DoT 2002).

Thus, forests are valued for the critical role it plays in sustaining rural Bhutanese livelihoods, the economic growth of the country and at large maintaining the fragile Himalayan mountain ecosystem. The recognition of these and various other ecological services provided by forests have enabled the country to preserve the environment largely intact to the current time.

1.2 Institutional Set-up

The DoF under the Ministry of Agriculture (MoA) is the legal custodian of all state owned forests, designated as Government Reserved Forests (GRF) in Bhutan. It is the oldest government department, instituted in 1952 at Samtse (RGoB NCD 2004) in southern Bhutan, as a forestry unit under the then Ministry of Trade and Industry. Subsequently, the forestry department was transferred to MoA, under which it grew into its present form. The DoF constitutes four functional divisions (Figure 2) at the headquarters in the capital city of Thimphu. They are Forest Protection and Utilization Division (FPUD), Forest Resources Development Division (FRDD), Nature Conservation Division (NCD) and Social Forestry Division (SFD). These divisions are supported in the field by Territorial Divisions (TDs), Protected Area (PAs) Management, and *Dzongkhag* Forestry Sectors (DzFS) in implementing field activities spread over 20 *Dzongkhags*.

The Bhutan Forestry Institute (BFI) under DoF and the National Resources Training Institute (NRTI) under MoA imparts basic forestry and forestry extension skills to field foresters. The curriculum at BFI and forestry component at NRTI will soon be

dissolved and taken up by Ugyen Wangchuck Institute of Environmental and Forestry Studies, due for opening in 2008 at Bumthang. The plan is to eventually train foresters at all levels at the new institute (McKinnell 2000, KOL 7.17.2006).

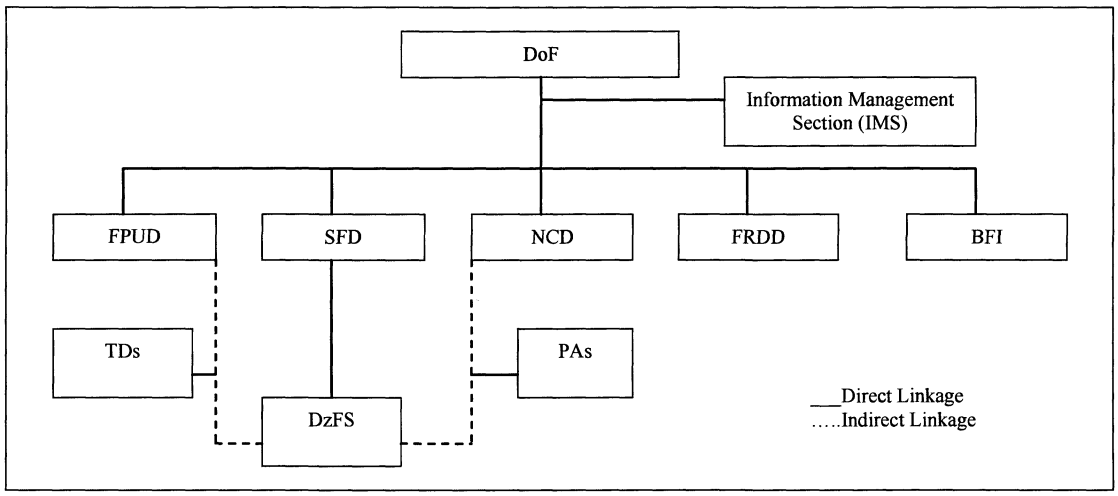


Figure 2. Shows the organizational structure of the Department of Forest in Bhutan. Source: RGoB MoA (2002)

The organization and role of SFD will be elaborated more since it is the focal government agency for providing technical support and guidance on issues related to forest fire and its management in Bhutan. The division evolved from what the then Social Forestry and Extension Division (SFED) established in 1989. Currently SFD has four sections; Social Forestry Section, Plantation and Afforestation Section, Watershed Section, and Forest Fire Section (FFS). Activities include implementing private forestry, community forestry, school social forestry, protection of forest from fire, protection from encroachment into *sokshing*[2] and *tsamdrog*[3], and allocation of rural timer to the public. With the creation of the division and decentralization of forestry activities in 1992

[2] *Leaf litter collection area*
[3] *Grazing area*

(RGoB DoFS 2002), the main role of SFD is to oversee and facilitate these activities in the *Dzongkhags*.

The primary task of FFS at SFD is to provide technical backstopping on forest fire related activities to the DzFS in the field. The DzFS are administratively under the *Dzongkhag* administration and are technically accountable to SFD (Figure 2) in Thimphu. They are instrumental in liaising with local people and influencing their activities related to forest fires. Another priority assignment for the section will be to initiate development of the National Forest Fire Management Strategy, for comprehensive management of forest fires in the country.

1.3 Policy and Legislation

His Majesty the King Jigme Singye Wangchuck's statement succinctly sums up Bhutan's distinctive approach to conservation and sustainable development (RGoB DoF 2002):

> *"Throughout the centuries the Bhutanese have treasured their natural environment and have looked upon it as the source of all life. This traditional reverence for nature has delivered us into the twentieth century with our environment still richly intact; we wish to continue thriving in harmony with nature and to pass on this rich heritage to our future generations"*

The blend of strong political commitment, unique biological diversity and inherent Bhutanese reverence for nature has provided a firm stage for promulgation of strong conservation policies and legislation in the country. The Bhutan Forest Act of 1969 was the first modern legislation enacted, and specifically aimed at protecting the country's natural resources. Since then many of the nearly 100 laws enacted are related, directly or indirectly, to the conservation of the environment (RGoB PC 1999). The formulation of the National Forest Policy in 1974 signified commitment to conservation

at the highest level of the Royal Government. A major objective of the policy was to maintain a minimum of 60 % of the total land under forest cover for all times to come (RGoB DoF 1974). More recently, environmental conservation is recognized as one of the four pillars essential for achieving Gross National Happiness (GNH), a noble concept enunciated by His Majesty the King (Ura & Galay 2004). Further, Article 5 of the draft constitution of the Kingdom of Bhutan upholds the provision of the 1974 policy to maintain a minimum of 60% forest cover (RGoB 2005). Thus, this continues to be a priority mandate for the Department of Forests (DoF).

1.4 Current Forest Fire Situation

Food and Agriculture Organization (FAO) estimate puts the total area damaged by forest fires between 1992 to 2000 at approximately 234,573 acres. Further they report that in 1999, a record 112 cases of forest fires destroyed about 28,664 acres of forests (FAO 2000). These figures are consistent with official fire record data maintained at SFD. The records show that in less than three plan periods from 1993 to 2004, a total of 803 separate incidences of forest fires swept across the country. The mildest fire year was in 1994 with a total of 36 incidences. The worst were in 1999 and 2000 with 112 and 104 incidences respectively (Figure 3). The trend in recent years seems to almost follow a steady decline in the number of incidences.

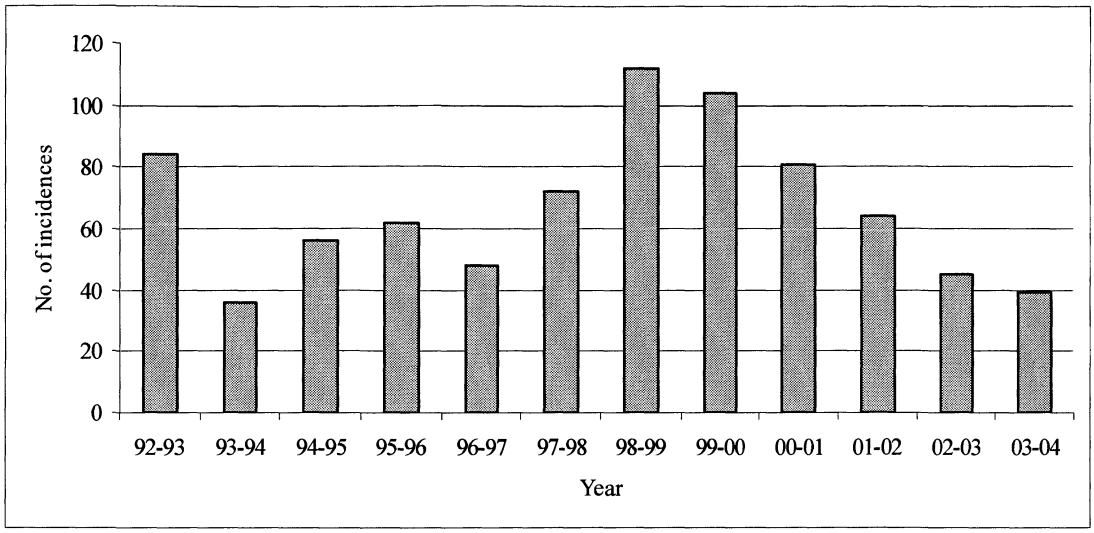


Figure 3. Shows annual forest fire incidences in Bhutan from 1993-2004. Data Source from RGoB SFD (2005).

A total of about 311,147 acres of forest were burnt in a span of a little more than a decade from 1993 to 2004. As shown in (Figure 4) below, annual burnt acreage range approximately between 4,400 acres in 2004 to almost 73,000 in 1993.

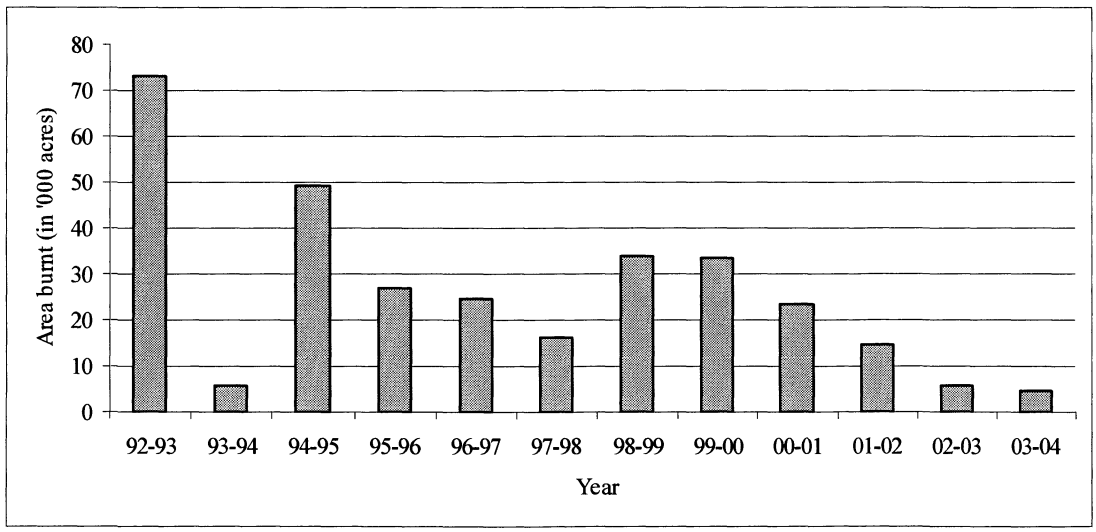


Figure 4. Shows annual acreage burnt by forest fires from 1993-2004 (in thousands of acres). Data Source from RGoB SFD (2005).

It is apparent that trend in area burnt by fires does not necessarily follow a consistent trend with the frequency of fires. This may be a good indication of dependence of incidences on availability of seasonal fuel and climatic conditions.

As shown in (Figure 5) below, analysis of records show that Thimphu had highest cumulative frequency of 115 incidences during the period 1993 to 2004. At the regional level, the eastern region consisting of Mongar, Trashigang, Lhuntse, Trashiyangtse and Samdrupjongkhar *Dzongkhags* had the highest frequency of forest fires during the 12 years. Other areas with more than 25 incidences during the period were Wangdue, Paro and Tsirang *Dzongkhags*.

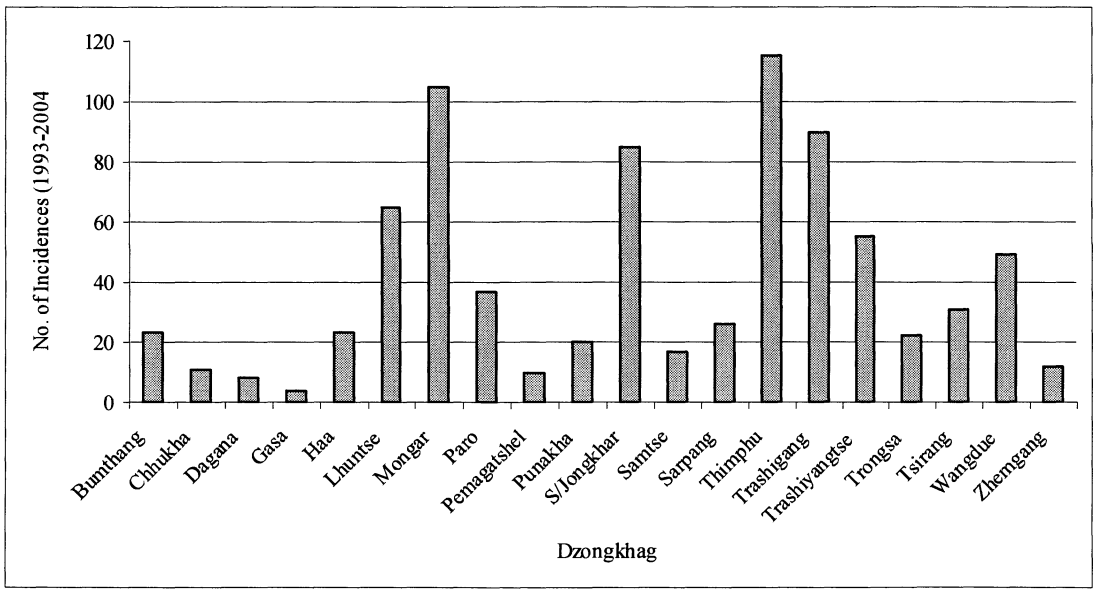


Figure 5. Shows forest fire incidences by *Dzongkhag* in Bhutan from 1993-2004. Data Source from RGoB SFD (2005).

The analysis of burnt areas shows that Mongar (95,630 acres) and Trongsa (70,108 acres) had by far the highest proportion of total burnt area (Figure 6). Trashigang and Trashiyangtse had the next highest burnt area with 38,540 acres and 25,472 acres respectively.

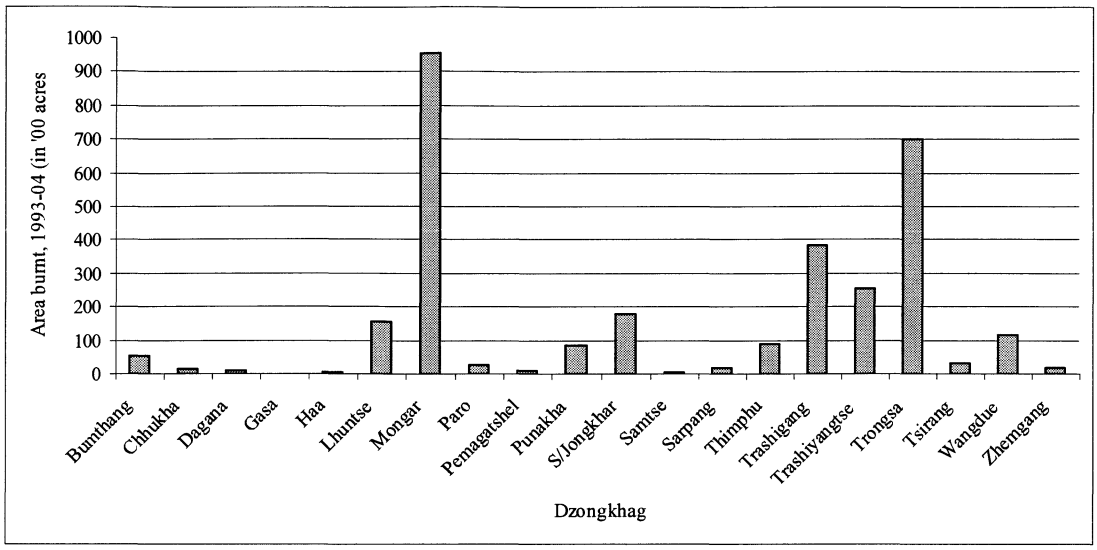


Figure 6. Shows total forest area burnt by forest fire in different *Dzongkhags* in Bhutan from 1993-2004 (in hundreds of acres). Data Source from RGoB SFD (2005).

Forest fires usually occur during the winter months, when the vegetation is very dry, small fuels are abundant and when there is high incidence of outdoor fire use. Chhetri (1994) describes peak fire seasons by four broad regions, based largely on total annual precipitation (mostly during monsoon) and the percentage of incidences (Table 2).

Table 2. Forest fire risk seasons in different regions of Bhutan, based on annual precipitation and percentage of incidences. Reproduced from Chhetri (1994).

	High Risk (p^4 < 1000 mm)		Medium Risk (p=1000-2000 mm)	Low Risk (p > 2000 mm)
	East	West	Central	South
Forest fire season	Jan. – June	Nov. – May	Nov. – April	Feb. – April
Peak fire season	Feb. – March	Jan. – May	Dec. – March	March
Peak fire month	March	January	February	March

[4] *Total annual precipitation*

1.5 Study Objectives

In light of previous research efforts and other information regarding forest fires in Bhutan and the implications it has on national conservation policies, the purpose of this study is to carry out a broad assessment of current status of forest fire and its management in the country, and recommend ideas for future management strategies based on this assessment. This study hopes to:

1. Enhance understanding on ecological, cultural and economical aspects of forest fires in Bhutan;
2. Contribute towards development of sound forest fire prevention and suppression programs; and therefore mitigate negative impacts on environment and communities in Bhutan through reduction of undesired incidences;
3. Emphasize importance of use of fire as a tool for ecosystem and land management practices in Bhutan, and thereby promote a conducive environment for formulation of complementary policy and legislation
4. Promote basic health and safety measures for firefighters and people involved in suppression activities

CHAPTER 2. LITERATURE REVIEW

This broad goal of this study was to assess current status of forest fire and its management in Bhutan and develop ideas for management strategies. In this regard, relevant literature was reviewed, both from Bhutan and from outside. This Chapter is a synthesis of the literature review and will relate current fire management policies and practices in the world with that of Bhutan. Specific examples, mostly from the United States (U.S.), relevant to each component have been highlighted and discussed.

2.1 Fire Policy

Except for Antarctica, practically no region of the world is entirely free from fires in an open environment (Luke and McArthur 1977). Fire is one of the forces of nature that has shaped our world over millions of years. It may be creative or destructive, or both at the same time in its environmental impacts. The occurrence, frequency and intensity of fire, either natural or human caused, or its exclusion either through natural or human intervention are determining forces for maintaining, enhancing, or reducing the health and sustainability of ecosystems (Hamilton et al. 2003). At the turn of the century, many nations initiated policies and programs to protect resources from fire. The negative effects of fires greatly overshadowed their benefits, and thus initial policies were largely centered on fire exclusion. According to Keane et al. (2002), "Fire exclusion' is the defacto policy of trying to eliminate fires from the landscape using fire suppression techniques."

In U.S., The Use Book, published in 1905 for administration and management of Forest Service lands advocated total fire exclusion on both public and private lands

(Biswell 1989). The first national fire policy came after several years of severe fires between 1910 and 1935, in line with accepted theories of the time, fire exclusion was believed to promote ecological stability and in addition reduce commodity damages and economic losses (NWCG 2001). Over several decades, the Forest Service led a multiagency, paramilitary-type program to eliminate forest fires. By 1960s, rapidly expanding knowledge in the young science of ecology revealed that fire plays an important role in natural forests (Arno and Fiedler 2005).

In the years that followed, fire policy in the U.S. saw many changes. By 1977 the Forest Service encouraged fire by prescription. The 1988 Yellowstone fires sparked much debate on such fire policies in the wilderness and national parks. During the season, a total of 248 separate fires raged in the Greater Yellowstone Area; 31 of which were initially designated and allowed to burn as prescribed natural fires under U.S. Departments of Interior and Agriculture policies (Wakimoto 1990). The 1989 review of the 1988 Yellowstone fires affirmed the positive benefits of fire and continued the evolution of fire policy. The 1995 Federal Wildland Fire Management Policy review recognizes the need for landscape-level resource management, the integration of fire into land management planning and implementation, and the involvement of all affected landowners and stakeholders (NWCG 2001).

In the Rocky Mountains, after more than a century of fire suppression, it is now widely accepted that the health of the ecosystems is now in decline because of fire exclusion. According to Keane et al. (2002), at first glance the effects of fire exclusion may seem beneficial to society (for example, preservation of timber resources and watershed protection), but on closer scrutiny, there seems little doubt this policy has

created many unhealthy features on the Rocky Mountain landscape. (Table 3) describes a synthesis of documented effects of fire exclusion in the Rocky Mountain ecosystems:

Table 3. Summary of the documented effects of fire exclusion by organizational level and ecosystem characteristic. Reproduced from Keane et al. (2002).

Scale	Ecosystem attribute	Fire exclusion effect
Stand	Composition	Increased number of shade-tolerant species, decreased number of fire-tolerant species, decreased forage quality, decreased plant vigor, and decreased biodiversity in plant and animals.
	Structure	Increased vertical stand structure, multistoried canopies, increased canopy closure, increased vertical fuel ladders and continuity, greater biomass, higher surface fuel loads, and greater duff and litter depths.
	Ecosystem processes	Slowed nutrient cycling, greater fire intensities and severities, increased chance of crown fires, increased insect and disease epidemics, short term increase in stand productivity, decrease in individual plant vigor, and decreased decomposition. Increased leaf area; increased evapotranspiration, rainfall interception, autotrophic and heterotrophic respiration; increased snow ablation.
	Soil Dynamics	Decreased nutrient (N,P,S) availability; increased pore space, water-holding capacity; lower soil temperatures; increased hydrophobic soils; and increased seasonal drought.
	Wildlife	Increased hiding and thermal cover, increased coarse woody debris, lower forage quality and quantity, increased insect and disease, and decreased biodiversity.
	Resources	Decrease in aesthetics, increased timber production, decreased visitation, increased risk to human life and property, increased fire fighting efforts, and improved air quality.
Landscape	Composition	Decrease in early seral communities, increased landscape homogeneity, increase in dominance of one patch type, and decreased patch diversity.
	Structure	Increase in patch evenness, patch size, patch dominance, and contagion.
	Disturbance	Larger and more severe fires, increase in crown fires, increased insect and disease epidemics, and increased contagion resulting in more severe insect and disease epidemics.
	Carbon and Water Cycles	Increased water use, increase in drought, lower streamflows, higher emissions of carbon dioxide from respiration, increased water quality, and decreased stream sediment.
	Resources	Decreased visitation, visual quality, and viewing distance.

In Bhutan, in tune with nationalization of the forests with the enactment of the Forest Act in 1969, the Royal Government commenced on a policy of strict fire exclusion from all state owned forests. According to Ura (2002), although forest fire is prohibited, a Royal Edict issued in 1981 makes exception to yak herdsmen who are permitted to burn alpine pastures under the supervision of the DoF and Animal Husbandry. This indicates

that provisions on forest fire in the 1969 Act had obvious conflicts with interests of pastoral communities' dependant on yak herding.

The National Assembly of Bhutan, the highest legislative body in the country, has deliberated much on the issue of forest fires in the country. Resolutions on prevention and control of forest fires were passed as early as 1963 at the 19th session of the Assembly. Subsequent sessions dwelt extensively on the subject, which culminated into enactment of provisions on forest fires in the Forest and Nature Conservation Act (FNCA) of 1995. The 77th session held in June 1999 voiced much concern on the destruction of trees and unprecedented accumulation of smog as a result of forest fires during that past season.

The legislation of the FNCA (1995) brought dramatic changes to legal provisions on forest fires. Section 10(ii) of the Act prohibits, "setting of fire, except controlled campfires, or leaving any fire including a campfire burning in such manner as to destroy, damage or endanger trees, any forest produce or wildlife" (RGoB 1995). It also spells out that it is the duty of every citizen to help in suppression efforts and in identifying offenders. Wherever the culprit cannot be identified, it is the responsibility of the nearest community to replant and maintain the burnt area under supervision of the department. In addition, the Revised Forest and Nature Conservation Rules of 2003 further details, "for causing or contributing to the causation of a forest fire, a penalty of imprisonment of not more than 5 years, or a fine, minimum of which shall be Nu.300 and may extend upto Nu.1,000 per acre" (RGoB DoF 2003).

Unlike in the Rocky Mountains, there is hardly any study on effects of fire exclusion on the Bhutanese landscape. Limited research on fire effects on grazing lands

indicate that, since the ban of fires in early 1970s, encroachment of unpalatable shrub species have increased in high altitude grazing lands of western Bhutan (Gyamtsho 2002). Others offer similar views that, certain species of plants and animals whose habitats depend on periodic fires for clearing are dying out due to cessation of burning (Ura 2002). According to the author, in alpine region, there is a well-founded suspicion that diminutive annuals - floral and medicinal plants - are becoming less abundant due to colonization of the meadows by coniferous forest.

Despite a cautious policy on fires, the Act (1995) and Revised Rules (2003) mentions specific provisions for the Ministry (RGoB 1995) or the Department (RGoB DoF 2003) to issue rules and adopt regulations governing the use of fire in GRFs. In recent years the Department is making use of this provision to try out prescribed burns for management of forest stands and NWFPs. A few prescribed burns have already been carried out on trial basis in Chirpine (*Pinus roxburghii*) forests in eastern Bhutan.

2.2 Fire Effects on Ecosystem

Fire affects entire ecosystems – their flora, fauna, the atmosphere, soil and water. Ecosystems have evolved with, and adapted to, specific fire regimes and therefore, it is imperative to define and understand 'fire regimes' when we talk about fire effects on the ecosystem. "Fire regime is defined as patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem" (NWCG 2005).

The inherent abilities of plants to respond to fire depend partially on the fire regime to which plant community has adapted. According to Agee (1993), fire has played and will continue to play a significant role in determining vegetation physiognomy,

structure, and species composition in the world's temperate and boreal ecosystems. He asserts fire has variable but predictable effects on individual plants; and that translating these from the physical to the physiological helps understanding of how fire affects vegetation not only at the level of the individual plant, but also at levels of plant community and the landscape. Fire effects on plants cannot be understood unless their survival and reproductive strategies with respect to fire are understood. Some plants resist fire by characteristics such as thick bark or buds that can withstand scorching temperatures, whereas some plants are almost always killed by fire (Miller and Findley 1994). In many cases fire is a major cause of plant mortality since it preferentially kills trees of short stature or thin bark. Likewise, fire creates gaps that new individuals colonize (Brown and Smith eds. 2000). Anderson (1994) maintains that generalizations regarding fire effects on vegetation can be misleading. Species such as bitterbrush (*Purshia tridentata*) are frequently credited with being so severely harmed by fire, that they should be given complete protection. However, many of them are dependant on fire or some similar disturbance.

Effects of fire on fauna show almost infinite variety. In North America, faunal communities have evolved in the context of particular regimes and show patterns of response to fire itself and changes in vegetation composition and structure that follow fire. Fires affect animals mainly through effects on their habitat. There is often short term increase in productivity, availability and nutrient content of forage and browse. These changes can contribute to substantial increases in herbivore populations. Such increases may be moderated by animals' ability to thrive in the altered, often simplified, structure of the post fire environment (Lyon et al. eds. 2000). Similarly, fire has different effects

on populations of different animal species depending on their habitat, predation habits and home range. The following effects of wildland fire on wildlife are reproduced from Agee (1993):

1. Fire is not detrimental to many species of wildlife; conversely, it is not always beneficial to wildlife beneficial to wildlife or of equal effect on all species.
2. Death of large animals directly due to fire is rare. Death is usually due to suffocation and primarily affects species with small home ranges.
3. Many species ignore the presence of fire, while others are attracted to it because of the availability of prey
4. The major effect of fire is on animal habitat: food, cover, and water.
5. Fire may have different effects over time on an individual species, with immediate beneficial or detrimental effects and later offsetting effects.

Fire, either in the wild or prescribed, may have a large range of effects on the soils, water, and watershed resources of forestlands, shrublands, grasslands and wetlands. The wide range of effects is due to the inherent preburn variability in these resources, and to fire behavior characteristics, season of burning, and prefire and postfire environmental conditions such as timing, amount, and duration of rainfall (Clark 1994). Agee (1993) points out that, much of the rigorous research on soil and water impacts from fire has been conducted on the scale of soil sample, whereas much of the relevant geomorphic and hydrologic impact of fire occurs at the scale of the subbasin or watershed. At this scale there are a variety of confounding impacts associated with weather variation, other aspects of management (logging, roads, salvage operations), and variation in fire severity. In most watersheds of fire dependent or dominated ecosystems, fire impacts to soils and water are significant components and variable backgrounds of cumulative watershed effects (Neary et al. eds. 2005).

The effects of fire on soil resources are induced by soil heating, by removal of protective cover of vegetation, litter and duff, or by concentration of plant material substances in the soil (Clark 1994). Burning and resulting post fire environmental

conditions can alter the functioning of soils physically (e.g. aggregate stability, pore size, distribution, water repellency and runoff response), chemically (e.g. nutrient availability, mineralogy, pH and C:N ratios) and biologically (e.g. biomass productivity, microbial composition and carbon sequestration) (Doerr and Cerda 2005). As a physical event, fires may influence soil temperature, soil structure, and the ability of the soil to absorb and store water. All of these properties are related and depend on how thoroughly the duff and litter are burned. Fire rarely consumes the duff layer completely and almost always some duff remains to protect the soil against raindrop impact and erosion by wind or water (Pyne et al. 1996). One very important effect of fires on soil in the context of this paper is erosion. Observations suggest that various erosion processes may be accelerated by moderate to high severity fires (Agee 1993). Pyne et al. (1996) suggest that areas normally subject to erosion experience erosion rates accelerated temporarily by fire, and those areas with little erosion under normal conditions show little increase as a consequence of fire.

The effects of a fire on a water regime may be physical, relating to movement of water and sediment; chemical, pertaining to array of chemicals and nutrients released by the fire; or biological, relating to changes in aquatic habitat as a result of fire (Pyne et al. 1996). Fires may affect both water quality and water quantity. Annual water yield can be significantly increased after fire due to the reduction of interception loss and transpiring vegetation, compared to generally lower increases in evaporation. This effect is proportional to the amount of watershed area burned and to annual precipitation (Agee 1993). Fire decreases water quality, by increasing

sedimentation and turbidity, increased stream temperatures, and increased concentrations of nutrients resulting from surface runoff (Clark 1994).

Wildland or manager ignited fires emit huge quantities of smoke which contributes to pollution of the atmosphere. In the U.S., the 1977 Clean Air Act (CAA) mandates the protection of human health and the prevention of deterioration of air quality, and establishes acceptable levels of emissions. Amendments to the CAA specify that individual states must consider smoke from wildland fires in their state plans. In addition, states can also establish stringent requirements on prescribed fires (Mahaffey and Miller 1994). Smoke impacts during episodic fire events can threaten public health, cause smoke damage to buildings and materials, and disrupt community activities. Although particulate concentrations in ambient air rarely reach health-threatening levels, particulate matter concentrations from wildfire smoke sometimes exceed accepted levels. Wildfire smoke can also be the dominant cause of visibility reduction in adjoining areas during episodic events like the 1988 Yellowstone fire (Sandberg et al. eds. 2002).

The effect of smoke on air quality has become a critical limitation to use of fire in the wildland and alternatively a basis for suppression of fires. When a fire occurs, about 90% of fire emissions consist of carbondioxide and water vapor. The portion of carbon in smoke not converted to carbondioxide (CO_2) is particulate matter, carbonmonoxide (CO), and volatile organic matter (Agee 1993). These other gaseous components of smoke are considered pollutants. CO is the most abundant and poses major risk to human health. While CO_2 is technically not considered a pollutant, it contributes to global warming. According to Glick (2004), computer models predict that CO_2-induced warming could

eventually raise the incidence of fires by more than half and northern coniferous forests, which become fire prone in hot weather, could be hit hard.

In addition, wildfires have serious social and economic implications. In the U.S., fires in the wildland-urban interface pose serious threat to communities. Large fire episodes in 1910 in northern Idaho and northwestern Montana burnt 1.2 million hectares and resulted in the deaths of 85 people (Agee 1993). Devastating wildfires in western U.S. in 2002 burned more than 3 million acres, and more than 600 homes (Arno and Bunnell 2003). Studies on the economic impacts of the 1988 Yellowstone fires show that there was a big drop in total tourist visitation. Only 1.7 million tourist visits were recorded in 1988, as opposed to the projected 2.3 million based on past figures. Expenditures based on tourism were down about US$ 21 million in 1988, US$ 13 million in 1989, and US$ 26 million in 1990 (Polzin et al. 1993).

In Bhutan, there is little documented research and literature on effects of fire on the ecosystem. Forest fires are perceived as a big threat to national conservation efforts. The effects of forest fires are more pronounced given the highly sensitive nature of the mountainous ecosystem and the time it takes to rejuvenate completely from such incidents. According to Chettri (1994), forest fire is one of the biggest threats to Bhutan's natural resources. Broad leaf and conifer forests which constitute the bulk of Bhutanese forests are most susceptible to frequent wildfires. In addition, scientific forest management plans with high cost inputs can be made quickly obsolete by the occurrence of large fires. From discussions held with foresters, botanists, researchers and academics, McKinnell (2000) has summarized the following general effects of fire on different forest types (Table 4):

Table 4. Effect of forest fire on different forest types in Bhutan. Source from McKinnell (2000).

Forest Type	Effect of forest fire
Fir Forest (*Abies densa*)	Generally not considered to be prone to forest fires. It occurs in higher, cooler and moister elevations and it has an understorey composition that tends to disfavor fire by retaining moisture in the mossy ground layer. Overall, forest fire is not a problem in fir forest.
Mixed Conifer Forest (*Pinus wallichiana, Tsuga Dumosa, Picea spinulosa*)	Highly variable in composition and contains some species that are sensitive to fire, so some parts may be at some risk from wildfire. Much of this type occurs on the more moist sites where fire does not take hold readily, except under drought conditions.
Blue pine Forest (*P wallichiana*)	Moderately prone to fire on moist sites or very prone to fire on dry stony sites with a grass understorey. Has thin bark and it is easily killed by high intensity fire. However, it regenerates strongly after a fire.
Chir pine Forest (*P roxburghii*)	Occurs in a very fire-prone environment of relatively open forest with a grass understorey. It is well adapted to surviving quite intense fires, once seedlings reach the age of about 5 years. In untouched chir forest, fires of low to moderate intensity pass through the forest without causing significant damage to the tree component.
Broadleaf-conifer and Broadleaf Forests	Not prone to fires on sites that are sufficiently moist, while others are moderately prone to fire. Periods of unusually severe drought will make a greater proportion of this forest vulnerable to damage from forest fire. The sal (*Shorea robusta*) forests of southern Bhutan resemble chir pine in their adaptation to fire.
Scrub Forest	Is highly fire-prone, as it usually occurs on steep dry, rocky sites so that it dries out quickly and more completely than other forest types. Its low canopy height and open structure, combined with the steep terrain, mean fires develop rapidly and have a severe impact on this type of ecosystem.

Initial observations by Sangye (2005), from trial burns in chir pine forests show that fire effects on the regeneration of *P. roxburghii* was not as severe as it was commonly assumed. Ground cover percentage was found to be higher in plots with no fire followed by plots with medium and high fire intensities respectively. A strong negative correlation was observed between the density of chir pine seedlings and lemon grass (*Cymbopogon flexuosus*) cover percentages. The author however asserts that it would be too early to interpret on the role of fire in regeneration dynamics of chir pine forests.

Wangchuk (2002) points out that, although little empirical evidence has been published, it is evident from general observation that cumulative impact of forest fires and grazing are the two main sources of environmental degradation. Similarly, many generally agree that large scale fires are the primary cause of loss in forest cover and thereby pose the single most important threat to the national vision of maintaining 60% forest cover. It is felt that the loss and degradation of forests by fires undermines the importance and the role it plays in the socio-economic development process of the country. Damage assessment of the 1999 fire season, one of the most severe fire years in recent times, estimated a loss of more than Nu.140 million in forest resources (RGoB NAS 1999) in a single season.

Large scale forest fires and excessive smoke can also be detrimental to the attractive tourism industry in Bhutan. With expanding wildland-urban interface, fires pose eminent danger to communities and property. In April 1998, *Taktsang* monastery in Paro; one of the most important historical and cultural structure of national importance was razed to the ground. Though the cause of this fire was not linked to forest fire, many of these edifices are located in close proximity to forests, and it is very possible that forest fires can cause similar incidents. In 2005, raging forest fire threatened Basochhu power project, which had to ultimately shut down (KOL 13 April 2005) till the danger passed.

2.3 Prevention of Forest Fire

The logic behind fire prevention programs is obvious: An ounce of fire prevention can be worth many pounds of fire damages and fire suppression expenses. Fire prevention seeks to eliminate unplanned ignition, the accidental fire. By its very nature

such events cannot be removed totally and thus general prevention strategy should be to reduce the probability of fire by separating ignition (risk) from fuels (hazards) (Pyne et al. 1996). Successful fire prevention depends on utilizing "the three E's" – Education, Enforcement and Engineering – in logical, well planned combinations designed to counteract those fires that cause the most damage within the protection area, and not merely those that result from the most obvious or prevalent causes (Chandler et al. 1993).

Effective fire prevention begins with identifying problem fires and their sources of ignition. Wildfires may be either caused naturally by spontaneous combustion, lightning; or by humans either accidentally or intentionally. In many parts of the world, lightning is the primary source of forest fires. In the U.S., less than 2% of annual fire occurrences in the Southeast, Northeast, and Midwest are lightning-ignited, while in the Rocky Mountains 57% and in the Pacific states 37% of all ignitions are from lightning (Agee 1993). In a study of the frequency of lightning fires in an area of about 5 million acres of forest and brushlands from Yosemite National Park, it was found that number of fires between 1948 and 1958 varied from 50 to 300 per year and averaged over 100 (Biswell 1989). The average annual number of lightning fires is greater in the west because less precipitation accompanies the thunderstorms. Simulated studies on ignition of wildland fuels by Latham and Schlieter (1989) shows that ignition probabilities for duff from short needled conifer species were found to depend entirely on the depth of the fuel bed. On the other hand, probabilities in litter and duff from long-needled species depend mostly on the fuel moisture.

The other more pertinent cause of fires in the context of prevention is anthropogenic or human-caused fires. Human caused fires were either deliberate or

accidental. It is common knowledge that natives in many parts of the World used fires for varied purposes. For instance, in Australia, various theories are held about the use of fire by the Aboriginal population before white settlement. Though debated, many consider that fires lit by Aboriginals spread widely in many parts of Australia (Luke and McArthur 1977). Similarly, it is widely accepted that, Native Americans historically used fire for various indigenous purposes throughout North America. In the northwest, natives frequently burned dry Doughlas-fir (*Pseudotsuga menzieiseii*) and Ponderosa pine (*Pinus ponderosa*) forests (Agee 1993). According to Biswell (1989), the Indians of California burned not only to preserve oaks and facilitate acorn gathering, but to reduce fuels and fire hazards. Golia (2002) gives an interesting account of how natives burned off campgrounds for protection from enemy-lit fires, and in some instances deliberately set fire on enemy territory to deprive the home tribe of forage for their game and horses. In later years, with the arrival of early settlers most fires in northwest America were from settler clearing and slashing fires. Pyne et al. (1996) have summarized the causes of fires in the U.S. from 1917 to 1966: Incendiary (26%), Smoking (19%), Debris burning (18%), Miscellaneous (14%), Lightning (9%), Machine use (8%), and Campfires (6%).

An important component of fire prevention is education, a process by which people are informed and persuaded. In this people are instructed in proper fire practices, informed about fire damages and costs, warned about legal responsibilities, and made aware about fire danger at particular places at particular times. The ultimate objective is to rally self-interest and promote self-restraint through awareness campaigns, training, media broadcasts, posters, fire danger warning signs, etc. Suiting the message to the problem and delivering it to the right group is essential (Pyne et al. 1996). Perhaps the

most successful attempt to influence public opinion regarding forest fire prevention has been the creation and manipulation of Smokey Bear in the U.S. (Chandler et al. 1993). Started in 1945 as a poster character produced by the Wartime Advertising Council, Smokey's message was simple and stern, "Only YOU Can Prevent Forest Fires". The message didn't distinguish between beneficial fire and unwanted wildfire and put forth that all fire was bad (Golia 2002). The success of Smokey Bear launched a veritable explosion of fire prevention animals. Australia has koala, Spain a rabbit, France a hedgehog, Chile a coypu, Russia a moose, Alberta a beaver, Quebec a chipmunk, Mozambique an antelope, Turkey a stag, and Mexico its own bear named Simone (Chandler et al. 1993).

Other components crucial for prevention of fires are: engineering to separate risk from hazard by deliberate design in machinery and built environment; and enforcement to regulate behavior under the threat of legal action. Engineering and education are techniques for coping with accidental fire, whereas enforcement targets arson or fires that occur under high risk circumstances that they may be considered incendiary (Pyne et. Al 1996).

In Bhutan, the understanding of the types and frequency of ignition sources is crucial for effectively targeting prevention and awareness programs at known causes. Limited research on causes of forest fire suggests that all forest fire incidences are anthropogenic in nature. According to Chhetri (1994), 100 % of the forest fires are caused by humans, either accidentally or deliberately. McKinnell (2000) reported the following common causes of forest fires in Bhutan:

1. Escapes from agricultural or horticultural burning operations, including *tseri*.
2. Lemon grass harvesters.
3. Electrical faults, mainly along power lines.

4. Cattle herders, both migratory and sedentary.
5. Travelers (mainly cigarette butts thrown from vehicles).
6. Road workers (from fires used to melt bitumen).
7. Campfires and warming fires.
8. Children playing with matches.
9. Deliberate arson, either to scare away damaging wild animals or to take revenge on forest officers for some disagreement.
10. Deliberate arson to kill trees for firewood.

Unlike in the western U.S., the general observation in Bhutan is that lightning does not account for any forest fires. This is a plausible assumption given that lightning strikes are almost always associated with heavy downpours and thus eliminates chances of forest fire incidence. Another reason could be that, especially in blue pine and chir pine forests, due to grazing and other disturbances, the litter layer is not sufficiently thick enough to ignite when lightning strikes. McKinnell (2000) argues that although most people in Bhutan do not accept lightning as a cause of forest fire, lightning-struck trees have been observed, and lightning may account for some of the unexplained forest fire occurrences. Taylor and Davies (2003) agree there is strong anecdotal evidence that the primary ignition sources are humans. They approximate that 75% of the causes of forest fires in the country are not known and therefore lightning and other natural causes cannot be ruled out.

Given shortage of trained people for suppression and inadequate people for law enforcement, active programs on prevention are crucial for the campaign against unwanted forest fires in Bhutan. The reduction of fire incidences in recent years is believed to be mostly due to awareness and prevention programs in the country. Though most of the efforts are currently on prevention, experts are of the opinion that there should be a holistic, more systematic approach to fire prevention in Bhutan (McKinnell 2000). According to him, a fire prevention program is not a matter of a few newspaper

advertisements, but is a carefully planned and multifaceted series of messages received in a variety of ways that inform people about the problem and encourage responsible behavior with respect to wildfire.

2.4 Presuppression Activities and Suppression of Forest Fire

Fire Presuppression refers to any activity undertaken before a fire occurs, that are directed at ensuring safe and effective fire suppression. Given the scope of the paper only a few relevant topics (fuel management, danger rating system) are briefly highlighted in this paper.

Fuel management is receiving increasing attention as a means of modifying wildland fire behavior and mitigating threats to the urban interface (Finney and Cohen 2003). The concept behind fuel management is to modify fuel, to modulate fire behavior, fire effects, and costs of fire suppression. Fuel modification may come through processes of reduction, in which the load of available fuel is decreased; of conversion, by which certain fuels are replaced by others with different flammability; and of isolation, through which large expenses of fuels are broken up with fuelbreaks or greenbelts (Pyne et al. 1996). According to Finney and Cohen (2003), general goals for fuel management in the U.S. as per policy are to: reduce risk of catastrophic fire, protect communities, reduce fuel hazards, reduce wildfire access and costs, and restore fire-adapted ecosystems.

Fire Danger Rating System is another important component of presuppression activity. Forest fire danger rating schemes underlie all contemporary fire management schemes. These systems are the principal means by which scientific knowledge of fire potential is synthesized and integrated with operational experience into practical fire management applications (Taylor and Alexander 2006). The U.S. National Fire Danger

Rating System, the McArthur fire danger rating meters used in Australia and the Canadian Forest Fire Danger Rating System are among the most popular and well developed systems in the world. Weather and vegetation are two factors of fire danger. Weather or current meteorological conditions are a variable factor and a powerful determinant of fire start and spread. In general, most fire danger rating methods have been based on the consideration of meteorological parameters for estimation of fuel status. A number of meteorological indexes combine two or more meteorological parameters to make assessments on daily or hourly basis (Gouma and Sereli 1998). Experience with the Canadian system suggests that four key scientific, technological, and human elements need to be developed and integrated in a national forest fire danger rating system. These include; sustained program of scientific research, development of reliable technical infrastructure, technology transfer and training, cooperation and communication between fire management agencies (Taylor and Alexander 2006).

Fire suppression is aimed at removing any one of the three sides of the fire triangle – fuel, oxygen and heat. Combustion can only proceed when all three are linked and interacting. Chandler et al. (1983) describes in detail how this can be achieved. Oxygen can be excluded by smothering the fuel with dirt, or by diluting the combustible gases either with steam water vapor (steam) or inert gases (N or CO_2). Heat can be removed from a fire either by cooling the flames or by cooling the fuel surface. Water is by far the most common cooling agent used in fire fighting. Breaking the third, or fuel, leg of the fire triangle is by far the most common method of suppressing forest fires. Fuels can be removed, altered, or wetted with moisture or retardants to check advance of fire front.

Prevention and suppression programs are not substitutes, one for the other in mutual exclusion, but complements. Not all fires are preventable even in theory; good fire suppression is necessary to protect gains made by prevention program and, in many areas, to give that program a credible deterrent. Equally no suppression program can hope to be cost-effective or ultimately successful without some means of regulating the number and timing of starts (Pyne et al. 1996). Fire suppression strategy bases itself upon rapid, initial attack of small fires. Chandler et al. (1983) describes the principles of initial attack as; sizing up the fire before attack; determining manpower requirements; attack; and, mop up.

In order to understand fire suppression in the U.S., one should first gain basic understanding of the underlying policies that govern such efforts. In 1935, the USDA Forest Service instituted the "10 AM POLICY". The objective of this policy was to prevent all human caused fires and control any fire that started by 10 a.m. the following day (NWCG 1995). The logic was to put out the fires before the next burning period (the hottest, driest time of the day, when fires burned best). With plentiful cheap labor during the time, total fire suppression seemed attainable and the 10 AM Policy offered new hope (Golia 2002). The active suppression advocated by this policy coupled with the prevention success promoted by Smokey in the years that followed seems to have worked well in suppressing fires. The "10-Acre Policy" started in 1971, set a presuppression objective of containing all fires within 10 acres. In 1977, both these policies were replaced by a more pluralistic approach of fire by prescription. Even for suppression, once initial attack failed, alternatives to full suppression were to be considered. Fire suppression became fire management. Today, the Forest Service generally suppress fires,

only some lightning-ignited fires are allowed to burn within limits spelled out in the fire plan. The 2001 Federal Wildland Fire Management Policy on suppression states, "Fires should be suppressed at minimum cost, considering fire fighter and public safety, benefits, and values to be protected, consistent with resource objectives" (NWCG 1995).

In Bhutan, suppression activities are generally coordinated by DOF and line agencies in the district, including TDs and DzFS. Most often then not, these agencies have neither the expertise nor the resources to tackle forest fires. There is inadequacy of fire fighting and safety equipment necessary during suppression. As such, suppression efforts generally lack fireline organization and consistency, a key element for effectiveness. There are a number of severe constraints on fire suppression operations in Bhutan. The steep and mountainous topography and lack of access make it very difficult for delivery of first response in time to put out fires before they get out of control. Sometimes it may take even days for personnel to just reach the fire scene. This is further exacerbated by the lack of communications network. According to McKinnell (2000), strong afternoon winds are another major problem in fire suppression. During the height of the fire season, March and April, it is normal for there to be very strong (40-60 km/h) up-valley winds from about midday to evening. If a forest fire reaches a mountain slope during that time there is virtually nothing that can be done to arrest its progress as fire behavior becomes very intense. In addition, due to very steep slopes, danger from falling boulders and logs, and frequent occurrence of steep rock outcrops, night operations are very dangerous. Therefore, fire suppression operations have to be postponed until dawn, thus losing several hours of critical suppression and mop-up time.

All citizens are in Bhutan are bound by law to suppress or help suppress forest fires. The FNCA of 1995 (Section 31.a) requires that, "every village head shall organize fire watchers and teams to put out forest fires and every person, to the maximum extent possible, shall help put out any forest fires and identify those who have caused the fire" (RGoB 1995).

2.3 Fire Use

Fire is one of the oldest tools of man, and one of the most powerful. As mentioned in preceding sections, natives and aborigines in many parts of the world used fire for varied domestic purposes for thousands of years. In North America, with the expansion of settlers in the 19th century, countless fires threatened homes and communities. Although a few visionaries recommended prescribed burning of forests to reduce fire threats, forestry leaders, conservationists, and many landowners thought that fires should be suppressed and largely eliminated. In 1907, H.H. Chapman of Yale University began a study of burning of southern pine in the Ozarks and Alabama, which led him to champion prescribed burning around the world (Fuller 1991). In 1943 Weaver advocated fire as a silvicultural tool in ponderosa pine forests (Weaver 1943). Following this, Harold Biswell, who had experience with burning in the Southeast, began demonstrating the use of fire in western pine forests (Biswell 1989). He was one of very few researching prescribed burning in the late 1940s and early 1950s. By 1965, his study of sequoia forests showed that giant sequoias depend on fire to kill the seedlings of competing tree species (Fuller 1991). By the 1970s, natural resource agencies recognized that fire should be used in forest management (Arno and Fiedler 2005).

The 2001 Federal Wildland Fire Management Policy on use of wildland fire states, "Wildland fire will be used to protect, maintain, and enhance resources and, as nearly as possible, be allowed to function in its natural ecological role. Use of fire will be based on approved fire management plans and will follow specific prescriptions contained in operational plans" (NWCG 2005). In the past, policy in the U.S. recognized two types of prescribed fires in the wilderness: those that are started by lightning and those that are ignited by managers (Mutch 1995). Current uses of wildland fire as defined by the National Wildfire Coordinating Group (NWCG) are as follows (NWCG 2005):

1. Use of wildland fire: either wildland fire use or prescribed fire applications to meet resource objectives.
2. Wildland fire use: the application of the appropriate management response to naturally-ignited wildland fires to accomplish specific resource management objectives in pre-defined designated areas outlined in Fire Management Plans.
3. Prescribed fire: any fire ignited by management actions to meet specific objectives, as per a approved prescribed fire plan.

Prescribed burning is based on integrated planning efforts and requires a prescribed fire burn plan. The plan describes the conditions under which the fire may be ignited by hand, ground based vehicle or aerial applications. Biswell (1989) aptly writes on conducting prescribed burns, "Once I was accused of making prescribed burn look too easy. As a matter of fact it is not difficult. But it does require knowledge of basic fire ecology, careful planning, patience, experience, and know-how. It can be hard work, and there may be cases when surrounding fuels and changes in weather make it nerve-racking". Within this framework he suggests; selection and training of personnel, and the prescribed fire management plan as the most important components of effective prescribed fire management planning. The following steps are outlined from Biswell (1989):

1. Selection and training of personnel.
2. Prescribed fire management plans.
    - Objectives in burning.
    - Descriptions of areas to be burned (vegetation type, fuel condition, topographic features, normal wind patterns, size and shape of burn, surrounding fuels and firebreaks).
    - Prescriptions for burning (season, number of days for burning, frequency of burning).
    - Constraints on burning (depending on policy and objectives).
    - Preparations for burning (informing people, permits, equipment, adequate crew).
    - Burn techniques (backing fires, head fires, and flanking fires).
    - Patrolling prescribed fires.
    - Recording burning conditions (fuel moisture, weather conditions, fire behavior).
    - Inspections and mop-up.
    - Monitoring (to evaluate results).

Chandler et al. (1983) describes the following broad categories of uses of prescribed fires: land clearing, type conversion, grassland management, wildlife management, fuels management and ecosystem management. Biswell (1989) gives a similar but a more concise list of prescribed burn objectives; to refuels and fire hazards, restore fire to its proper role in ecosystem functioning, enhance the wildlife habitat, improve ranges for livestock, reduce understorey brush, prepare seedbeds for forest tree planting, stabilize watersheds and improve vegetation-soil-water relationships, or facilitate forest and range management handling practices.

2.4 Fireline Safety

Forest fire fighting is an inherently dangerous occupation. Accidents can happen at any time and from all sources during fire suppression. The common causes of injury or fatality are in some cases due to contact with flames, heat or smoke, and other incidents incidental to the fire. According to Luke and McArthur (1977), on the average about twenty persons per year lose their lives in bushfires in Australia. Many more are temporarily injured or permanently disabled. National statistics in the U.S. consistently show firefighting to be among the most hazardous of all occupations. A fire fighter is ten times as likely to suffer fatal injury and six times as likely to endure a lost- time injury as

the average worker (Pyne et al. 1996). The accident fatality rate for fire fighters is 51 per 100,000 man-years, nearly ten times the average for all work-related fatalities. The lost time accident rate is 6150 per 100,000, six times the average for all occupations (Chandler et al. 1983).

There are numerous cases of fire fatalities and near misses from fire incidences in the U.S. In 1949, the Mann Gulch fire in Helena National Forest in Montana overran 16 firefighters. Only three survived, the foreman who ignited an escape fire into which he tried to move his crew, and two firefighters who found a route to safety. The tragedy was also a severe blow to the Forest Service, and repercussions from this incident were severe and long lasting (Rothermel 1993). The Loop Fire in California (1966) injured 11 men and killed the other 11 of the 22 crew members. The Butte Fire of Idaho (1985) was a near disaster and 73 fire fighters escaped injury by deploying their fire shelters. Perhaps, one of the most publicized incidents in modern times in the South Canyon Fire in Colorado (1994), in which 14 fire fighters lost their lives (Pyne et al. 1996).

The best ways to avoid injury and fatality is to stay out of situation by observing safety principles at all times. According to Chandler et al. (1983), in the U.S, the Ten Standard Firefighting Orders and, and the Thirteen Situations that Shout Watch Out is used to instill the principles of safe firefighting practices. The original Ten Standard Firefighting Orders were developed in 1957 by a task force from the USDA-Forest Service. The Standard Firefighting Orders are organized in a deliberate and sequential way to be implemented systematically and applied to all fire situations (NWCG 2004, USDA-FS 2006):

1. Keep informed on fire weather conditions and forecasts.
2. Know what your fire is doing at all times.
3. Base all actions on current and expected behavior of the fire.

4. Identify escape routes and safety zones and make them known.
5. Post lookouts when there is possible danger.
6. Be alert. Keep calm. Think clearly. Act decisively.
7. Maintain prompt communications with your forces, your supervisor, and adjoining forces.
8. Give clear instructions and insure they are understood.
9. Maintain control of your forces at all times.
10. Fight fire aggressively, having provided for safety first.

Shortly after the Standard Firefighting Orders were incorporated into firefighter training, the 18 Situations That Shout Watch Out were developed. These 18 situations are more specific and cautionary than the Standard Fire Orders and described situations that expand the 10 points of the Fire Orders. If firefighters follow the Standard Firefighting Orders and are alerted to the 18 Watch Out Situations, much of the risk of firefighting can be reduced (NWCG 2004, USDA-FS 2006):

1. Fire not scouted and sized up.
2. In country not seen in daylight.
3. Safety zones and escape routes not identified.
4. Unfamiliar with weather and local factors influencing fire behavior.
5. Uninformed on strategy, tactics, and hazards.
6. Instructions and assignments not clear.
7. No communication link with crewmembers/supervisors.
8. Constructing line without safe anchor point.
9. Building fireline downhill with fire below.
10. Attempting frontal assault on fire.
11. Unburned fuel between you and the fire.
12. Cannot see main fire, not in contact with anyone who can.
13. On a hillside where rolling material can ignite fuel below.
14. Weather is getting hotter and drier.
15. Wind increases and/or changes direction.
16. Getting frequent spot fires across line.
17. Terrain and fuels make escape to safety zones difficult.
18. Taking a nap near the fire line.

The use of protective clothing and other protective devices are also integral part of safety measures in fire fighting. Chandler et al (1983) amusingly remarks, "It is more important to arrive at a fire properly attired than it is at any social function. Going to the opera without a top hat might result in a few scornful looks, whereas going to a forest fire without a hard hat might result in losing the top of your head." In the U.S., the National

Fire Protection Association (NFPA) sets safety standards related to fire clothing and equipment. All clothing and personal protective equipment (PPE) on fires must meet or exceed standards set in NFPA 1977. These include among others, hard hat, fire boots, flame resistant clothing, leather gloves, eye and face protection, fire shelters, hearing protection, etc. In addition, all firefighters should have requisite experience and qualifications and training to be on fire incidents.

CHAPTER 3. METHODS

In addition to literature review on forest fire management discussed in the preceding Chapter, a need was felt to assess current opinion on different aspects of forest fire management in Bhutan. One of the ways to do this was by conducting a survey among field foresters in Bhutan, who are constantly dealing with forest fire issues. The perfect opportunity to carry out the assessment arose when my advisor, Professor Ronald Wakimoto was invited to Bhutan to conduct Forest Fire Ecology and Prescribed Burning Training Course for Bhutanese foresters in February 2006. The course was organized by SFD and jointly funded by Bhutan Trust Fund for Environmental Conservation (BTFEC) and Conifer Research and Training Partnership (CORET) Project.

3.1 Questionnaire Survey

During the above course, a questionnaire survey was conducted among the participants on forest fire management in Bhutan. The purpose of the survey was to get broad insights into issues related to forest fire management in Bhutan, based on opinions of participants who are constantly implementing activities at grass-roots in the field. They possess very good knowledge about forest fire related issues at the local level and within the communities. The participants of the course were all at the rank of deputy rangers or rangers, representing the DzFS, TDs and Research Centers (RCs) from all over the country. There were a total of 44 participants (See Appendix B) and since it was conducted as a session during the above training course, the response rate was 100 %.

A copy of the original survey is attached with the paper (Appendix C), with fonts and layout changed to suit paper. General ideas on design of questionnaire and analysis of response were borrowed from Dunkelberg and Sonquist (1977), and Fowler (1988). A

total of 19 questions were asked of the respondents on various components of forest fire management in Bhutan. Questions were organized around the basic themes of forest fire impacts, causes, prevention activities, suppression activities, fire use, and, health and safety of fire fighters. The final question provided individuals with the opportunity to share their comments and suggestions on the survey or any other issue related to forest fire management in Bhutan.

The format and content of the questionnaire was primarily written by the author, with valuable inputs and suggestions from the graduate committee and other experienced professors and peers at UM. The format is simple with both closed-ended questions (1, 2, 3, 4, 7, 8, 9, 10(i), 11, 15, 16, and 17) and open-ended questions (5, 6, 7, 10(ii), 12, 13, 14, 18, 19, and 20) to encourage response and facilitate ease of response. Responses to closed-ended questions were standardized on likert-scale of 1-4, with an additional 5^{th} for 'no opinion' in all cases, to reduce bias and aid statistical analysis. Individual instructions for all questions were provided to reduce burden on respondents and terminologies were defined based on accepted definitions to suit Bhutanese context.

3.2 Data Analysis and Reporting

The data obtained from the questionnaire survey was coded and compiled in SPSS 14.0. Subsequent analysis was done using SPSS 14.0 and Microsoft Office Excel 2003. The closed-ended questions were analyzed using frequencies and percentages, and illustrated with simple bar graphs wherever appropriate. The open-ended questions were analyzed based on key words and phrases and how often they were expressed by respondents for the same set of questions. All results are analyzed and discussed under the most appropriate topic in Chapter 4.

3.3 Efforts to Reduce Bias

Efforts have been made to reduce response bias by explaining the format of the questionnaire before the respondents were asked to fill it out. The author provided clarifications on the questionnaire as and when required by respondents. Clear instructions were printed that all responses are voluntary and confidential, and that 'there is no right or wrong answer'. The decision to retain respondent anonymity was to counter any response bias arising out official capacity of respondents. Adequate time was given for filling in the questionnaire to reduce non response due to lack of time. In some cases, questions on the same issue were asked in different ways to compare consistency in responses. For all the closed-ended questions, there was a 'no opinion' option when the respondents choose to remain neutral. 'No opinion' and 'non response' cases were assigned unique codes in the analysis and accounted for.

3.4 Limitations of the Survey

As in every survey, there are some limitations to this study. This is the first survey of such nature on forest fire management in Bhutan and in some cases respondents may not be comfortable with all concepts and terms used. Since the survey is conducted among field foresters, results may not necessarily reflect views at all levels and are therefore not representative across the department. Some respondents have suggested that the survey be conducted again among foresters at all levels of service. Given that the survey was aimed at gathering broad general information across the country, the data may lack specifics on any particular place or region. On this too, some respondents suggested that similar survey be refined and conducted at the regional level or if possible in individual *Dzongkhags*.

CHAPTER 4. SURVEY RESULTS

The purpose of conducting this survey was to carry out a broad assessment of current status of forest fire and its management in Bhutan based on opinions of field foresters as discussed in Chapter 3. This Chapter presents the results of the questionnaire survey in simple graph and table formats with appropriate explanations and discussions.

4.1 National Forest Fire Management Strategy

In Bhutan, past efforts on forest fires have largely been on prevention and suppression. With recent emphasis on sustainable resource management, there is need for a holistic approach to management of forest fires in the country. The government gave directives on management of forest fire and exploring potential for its uses during the 9th five year plan (RGoB MoA 2002). Recently, at the 8th annual RNR conference, the MoA passed numerous resolutions on forest fire management in Bhutan. A key resolution was the need to initiate development of the national forest fire management strategy for the country on a priority basis (RGoB MoA 2006). The fact that 99% of the respondents from the survey were overwhelmingly in favor of a national strategy on forest fire management (See 3 under Appendix B) seems to identify well with government objectives.

When asked to rank different components of forest fire management for the proposed national strategy, respondents prioritized them as shown in (Figure 7). It is interesting to note that safety and training of fire fighters were ranked higher than prevention or suppression. A total of more than 75% of the respondents felt it was either 'fairly important' or 'very important' that use of fire as a management tool should be a part of the strategy. (See 4 under Appendix B).

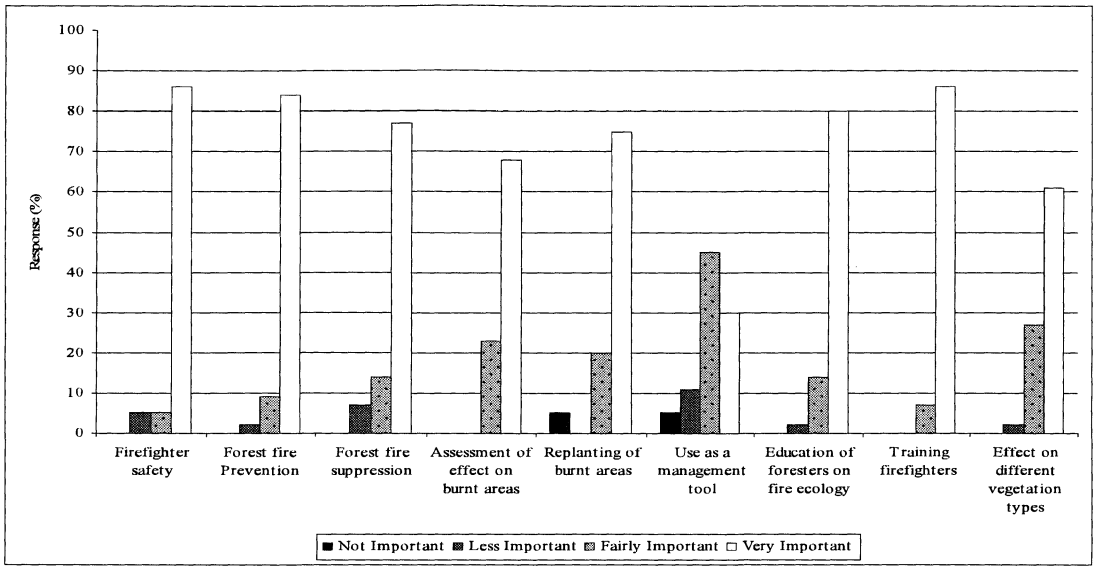


Figure 7. Shows percent response on importance of different components of fire management for inclusion in the national forest fire management strategy for Bhutan.

Respondents felt that training (43%) and education (36%) were the most important issues that should be addressed by the government for promoting forest fire management activities in the country. Other issues included awareness, organization, equipment, fire effects, restoration activities, etc as in (Table 5) below. (See 5 under Appendix B).

Table 5. Percent response on priority of issues to address for promoting forest fire management in Bhutan.

Issues	Frequency of response	Percent response
Training (on all aspects of fire management, emphasis on fire fighting)	19	43
Education (of foresters and public on all aspects of fire management, emphasis on fire effects)	16	36
Awareness (raising awareness on all aspects of fire management, emphasis on prevention)	12	27
Organization (of fire management institutions, emphasis on village level fire management committees)	10	22
Equipment (procurement and effective use of fire fighting equipment)	8	18
Fire Effects (positive and negative effects of forest fires)	4	9
Restoration (of areas burnt by forest fires)	4	9

Analysis of information from the survey show that many respondents consider raising awareness, prevention programs, training, education, etc. as very effective measures on managing forest fires in the country. This is consistent with past and current efforts and inputs by the government on forest fire management. Recommendations for effective measures in future were again mostly on training, education, organization, etc. There were some recommendations for enforcement and penalty, creation of fire lines and provision of incentives for public for collaborating with the department on issues related to forest fires. (See 5 under Appendix B).

Respondents were asked to identify important areas in the field of forest fire management that could be incorporated as part of the curriculum at the upcoming Ugyen Wangchuck Institute of Environmental and Forestry Studies in Bhutan. Responses were highly in favor of curriculum on fire fighting techniques, prescribed burning, practical field exercises on fire, and others as shown (Figure 8) below. (See 18 under Appendix B).

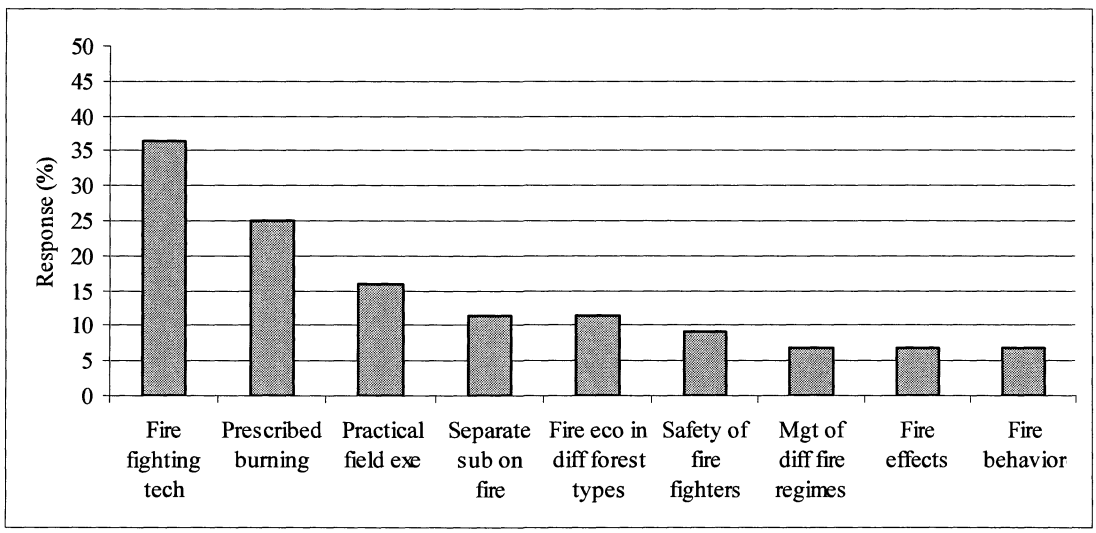


Figure 8. Shows percent response on issues in forest fire ecology and management for incorporation as part of curriculum at Ugyen Wangchuck Institute of Environmental and Forestry Studies in Bhutan.

The concept of forest fire 'management' as opposed to just prevention and suppression is fairly new in Bhutan. It is imperative to promote fire management within a holistic framework, which includes among others fire use, restoration, safety of fire fighters and other science and techniques that has advanced extensively in this field. As shown in (Figure 9) below, more than 30% of the respondents in the survey felt that knowledge on 'fire fighting techniques' is crucial for forest fire management in Bhutan. Other important fields in which knowledge was felt essential were on fire behavior, fire weather, and appropriate fire fighting equipments and how to use them, education and training of communities. Important fields which identify with current advances in forest fire management were prescribed burning, fire fighter safety, fire ecology, etc. (See 19 under Appendix B).

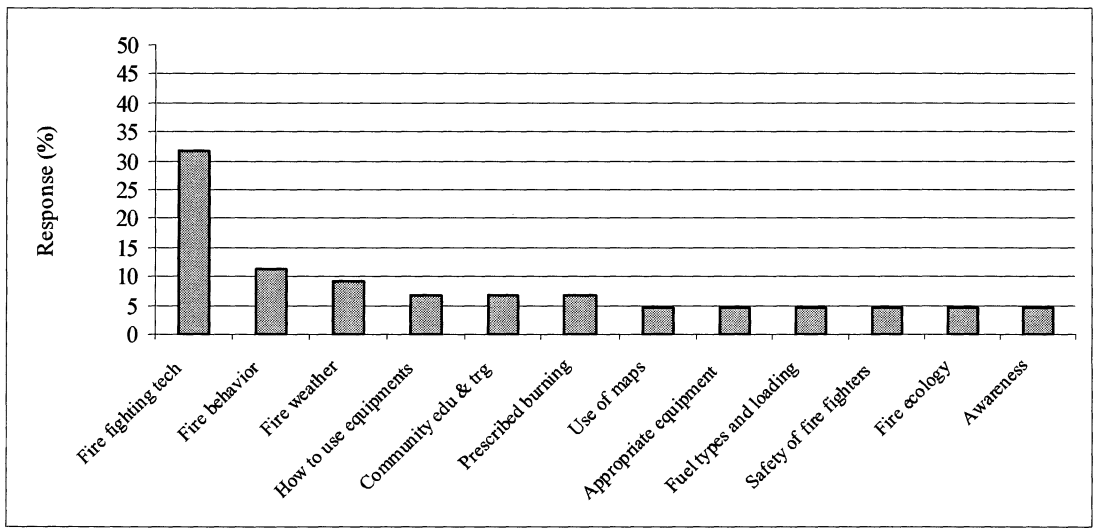


Figure 9. Shows percent response on knowledge needs for successful forest fire management in Bhutan

4.2 Concern on Effects of Forest Fires

The effect of forest fires is perhaps the most important basis for placing high priority on management of forest fires in Bhutan. This is also reflected in response from the survey in which more than 82% of the respondents were 'very concerned' and the rest 18% 'somewhat concerned' with effects of forest fires (See 1 under Appendix B). As shown in (Figure 10), out of a list of the most common effects of forest fires, the highest concern were on the negative impacts of forest fires like; destruction of wildlife habitat (82%), soil erosion (75%) and reduction of forest cover (68%). (See 2 under Appendix B).

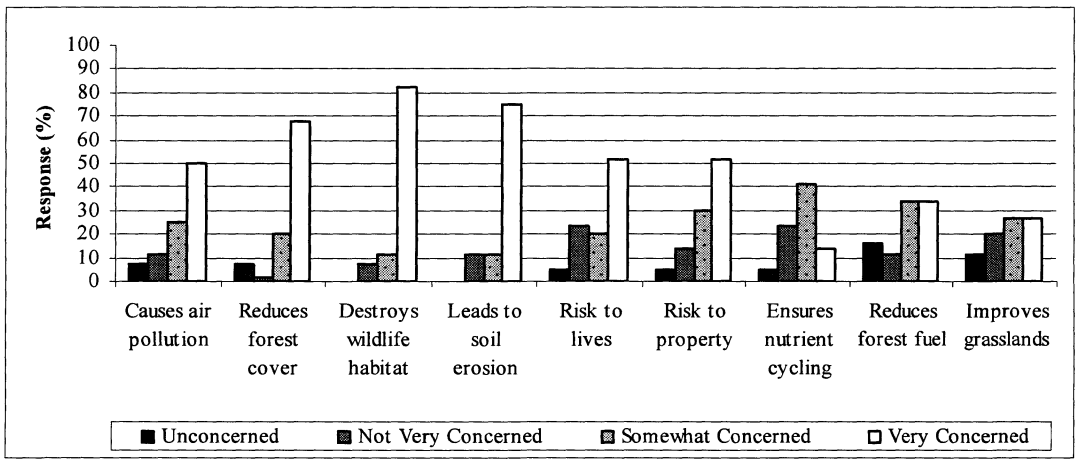


Figure 10. Shows percent response on concern about possible impacts of forest fires in Bhutan.

A significant percentage of people also expressed concern on positive effects of forest fires. The general awareness on usefulness of fire as an option for forest fuel reduction (34%) and improvement of grassland (27%) is a positive change from the conventional outlook on forest fires as just having negative impacts on the landscape.

4.3 Causes of Forest Fires

Many fire experts who worked on fire projects in Bhutan have suggested that there is high uncertainty regarding causes of forest fires in the country. The survey shows that only 36% of the respondents were 'confident' in expressing their familiarity with causes of forest fires in Bhutan (See 7 under Appendix B).

Based on survey data, analysis was done on causes of forest fires by typical forest types in Bhutan, i.e., conifer, mixed conifer, mixed conifer/broadleaf and broadleaf forests. As shown in (Figure 11, 12, 13 & 14), in all these forest types, majority of the fires are anthropogenic in nature.

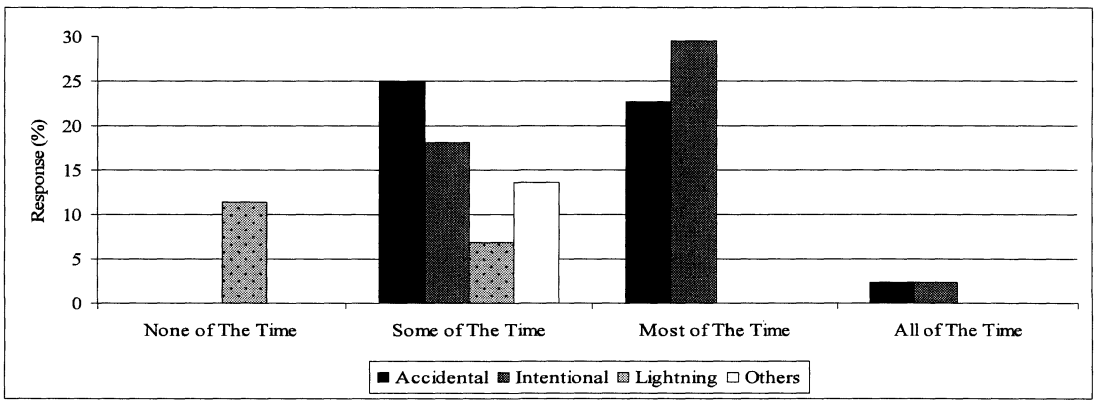


Figure 11. Shows percent response on causes of forest fire by source of ignition in conifer forest type in Bhutan.

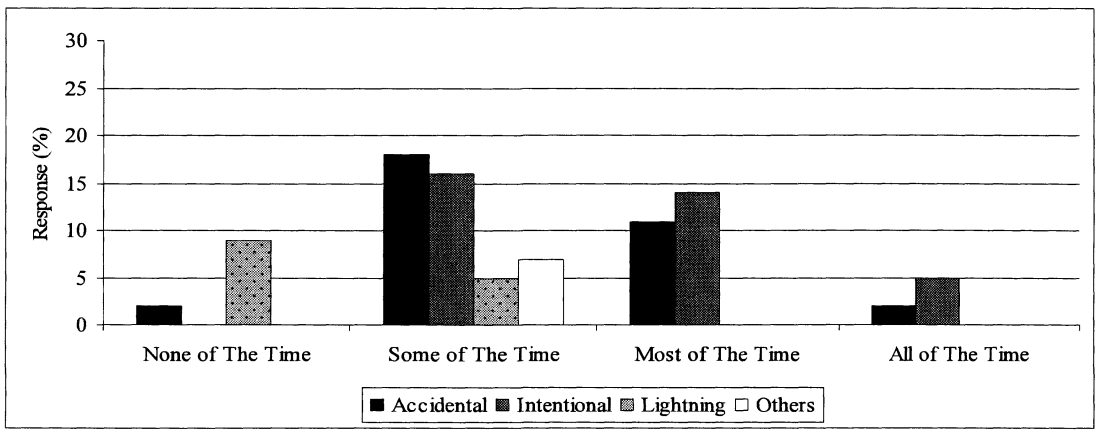


Figure 12. Shows percent response on causes of forest fire by source of ignition in mixed-conifer forest type in Bhutan.

In all cases intentional causes are felt to cause as much forest fires as accidental causes. A significant number of respondents felt that there were other causes of fires; from falling rocks, from power lines, etc. Some respondents felt that lightning caused forest fires 'some of the time', however, a higher number of respondents believe that 'none of the time' lightning caused forest fires in any of the forest types mentioned. (See 8 under Appendix B).

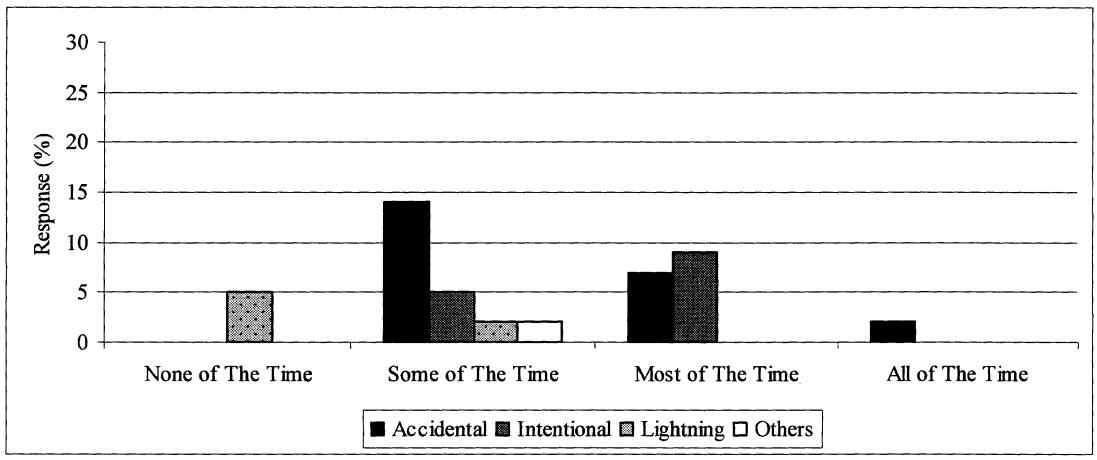


Figure 13. Shows percent response on causes of forest fire by source of ignition in mixed-conifer-broadleaf forest type in Bhutan.

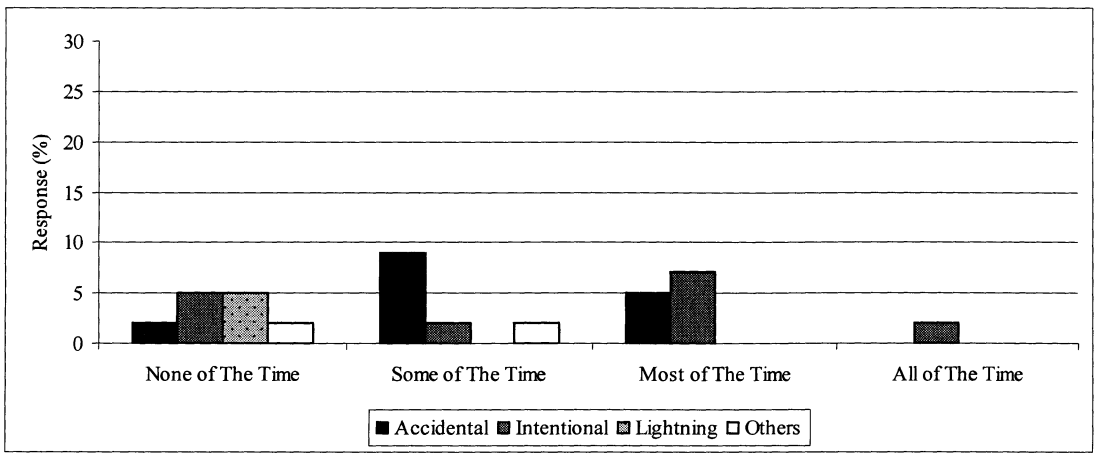


Figure 14. Shows percent response on causes of forest fire by source of ignition in broadleaf forest type in Bhutan.

4.4 Forest Fire Prevention

There is concerted effort by the government to initiate forest fire prevention programmes in recent years. Though no formal studies have been done to ascertain this correlation, it is very likely that steady reduction in incidences of forest fires over the years could mostly be a result of these prevention inputs.

(Figure 15) shows ranking on important prevention components from the survey. Respondents felt that educating communities on negative impacts (84%), enforcing regulations (66%), fire hazard prediction (64%), fire education in schools (62%), identification of causes by locality (62%), etc., are 'very important' and should be given high priority for successful prevention programmes (See 9 under Appendix B).

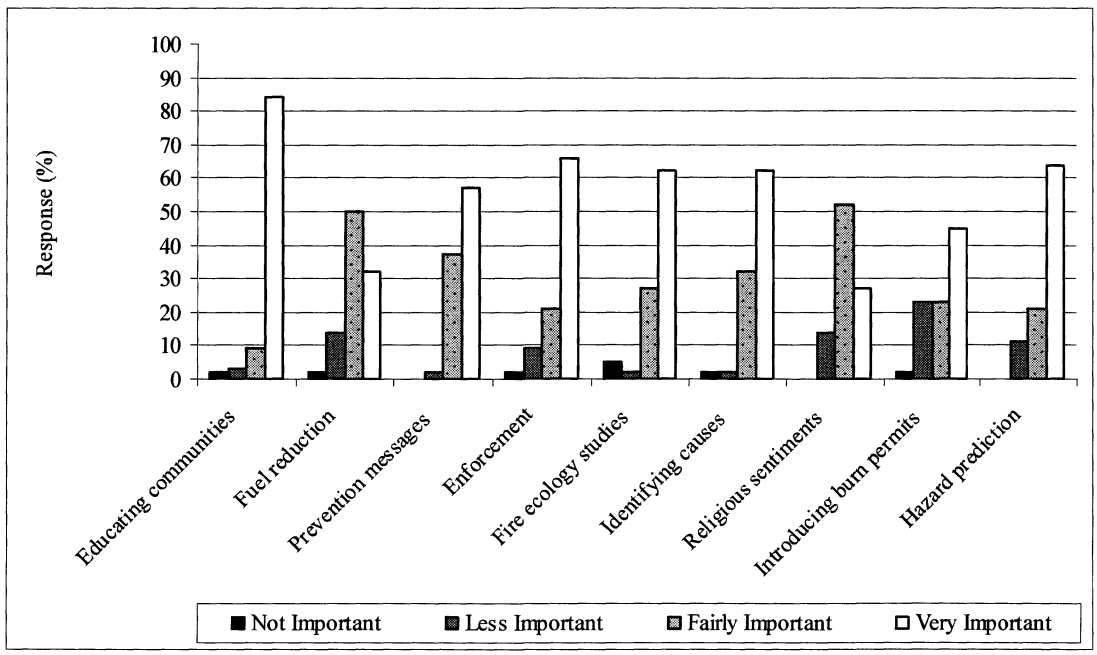


Figure 15. Shows percent response on essential components of a successful forest fire prevention strategy for Bhutan.

The use of a national mascot for prevention like Smokey Bear has seen huge success in the United States. When asked if a similar mascot would be effective for

prevention of forest fires in Bhutan, 55% of the respondents thought it will be effective, only 5% thought it would not work, and the rest either did not offer any opinion or did not respond. (See 10 under Appendix B).

Only a few respondents offered some form of opinion on the choice of a mascot. The suggestions were the national animal takin (*Budorcas taxicolor*), musk deer (*Moschus moschiferus*), and sambar (*Cervus unicolor*). One even suggested the use of the national tree cypress (*Cupressus himalaica*) and the national flower blue poppy (*Meconopsis grandis*). While efforts have been made to on the questionnaire and during the survey to clarify the use of mascots, low rate of response may be because respondents still could not fully comprehend the concept and are therefore not very comfortable in offering any suggestions.

4.5 Forest Fire Suppression

The policy on forest fires in Bhutan is to suppress them as quickly as possible to prevent damage to resources. Results from the survey (Figure 16) show that respondents were not consistent in their views on policies of 'total suppression' on one hand and 'allowing some fires to burn' on the other. They indication seems that there should be total suppression and at the same time allow some fires to burn. (See 11 under Appendix B).

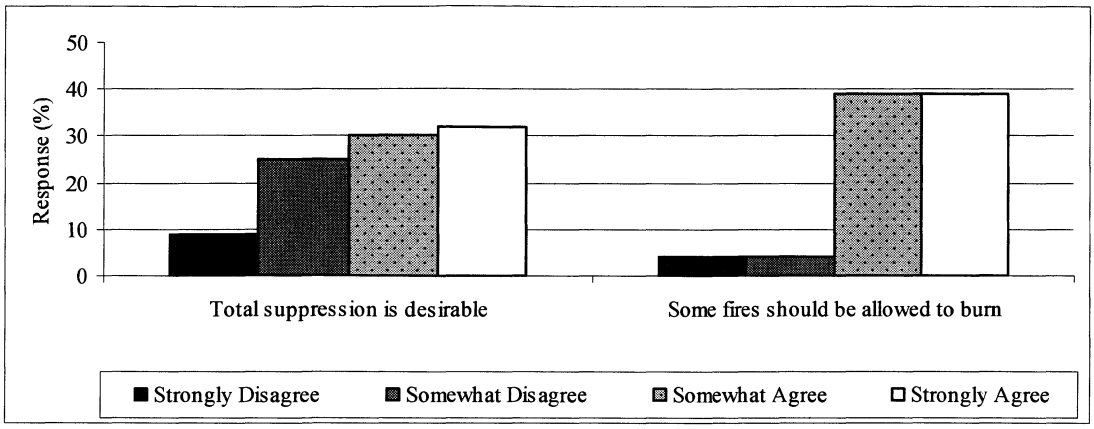


Figure 16. Shows percent response on statements regarding suppression of forest fires in Bhutan.

Prediction services on forest fires are virtually non-existent in Bhutan. Though it is a general notion that prediction services could aid suppress fires before they get out of control, the survey results suggest that many respondents disagree with this idea (Figure 17).

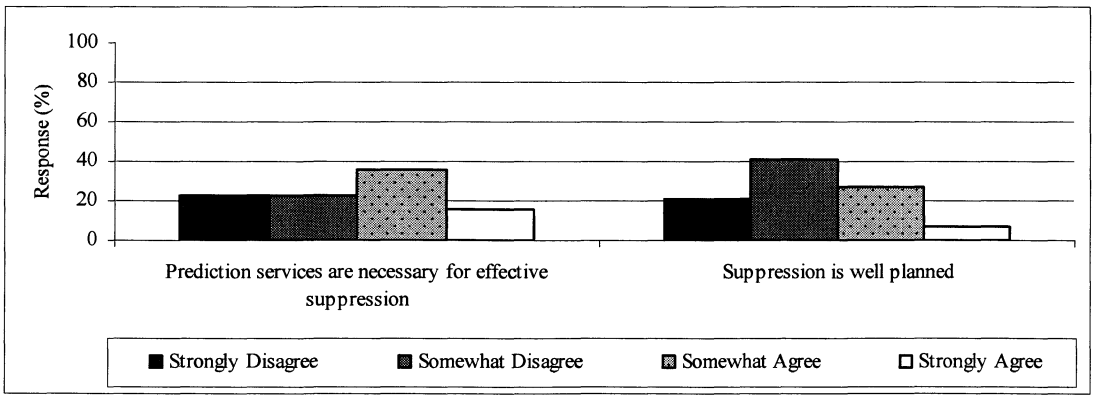


Figure 17. Shows percent response on statements regarding prediction and planning for forest fire suppression in Bhutan.

Suppression of forest fires in Bhutan is often a problem, given the steep topography of the land and constraints on resources required for suppression. Current

suppression efforts are mostly done using limited fire fighting and communications equipment. This is consistent with opinions expressed in the survey (Figure 17), wherein many respondents disagree with the statement that suppression efforts are well planned on forest fire incidents in Bhutan. (See 11 under Appendix B).

The survey results show that armed forces, local communities, staff from *Dzongkhag* administration and local institutions and schools play an active role in the suppression efforts of DoF and DzFS (Table 6).

Table 6. Organizations collaborating with DoF and DzFS for suppression of forest fire in Bhutan

Collaborating organizations	Frequency of response	Percent response
Armed forces (RBG, RBA, RBP)	29	66
Local communities	24	55
Dzongkhag staff	7	16
Local institutions and schools	5	11
Business organizations	2	5

RBG=Royal Body Guards, RBA=Royal Bhutan Army, RBP=Royal Bhutan Police

Many organizations in Bhutan have direct stakes in the integrity of forest resources and the environment at large, it is often felt that all stakeholders should contribute to suppression efforts, in some way. Analysis of information from the survey shows that at least 38% of the respondents disagree to some extent that there is currently effective collaboration among all stakeholder agencies in suppression of forest fires. Further, more than 43% strongly agree that cooperation among such organizations can be improved for successful suppression programs (Figure 18). (See 13 under Appendix B).

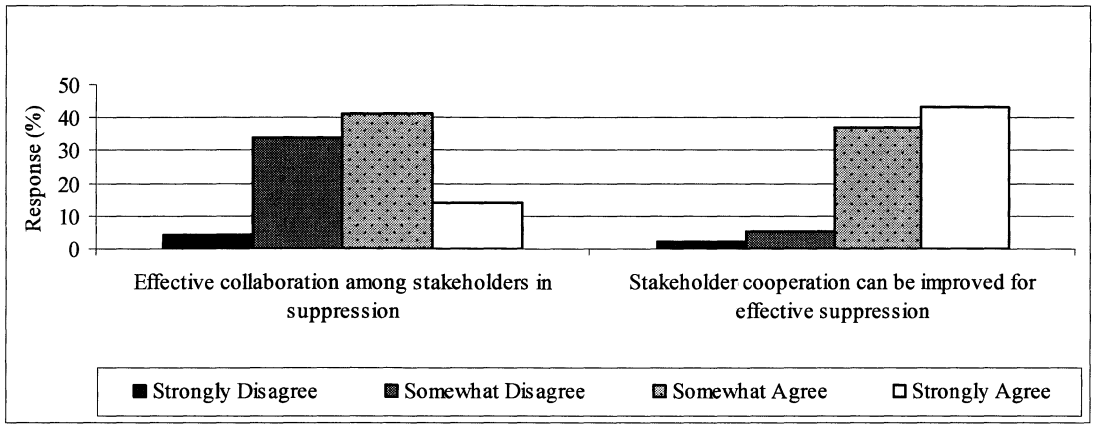


Figure 18. Shows percent response on statements regarding collaboration of stakeholders on forest fire suppression in Bhutan.

It is generally accepted that there are both pros and cons of active forest fire suppression on the landscape. The following were the most common advantages and disadvantages listed by the respondents in the survey. Some advantages are listed in order of importance from the survey (See 12 under Appendix B):

1. Prevents destruction of forest and forest cover
2. Protects wildlife and their habitat
3. Prevents loss of lives of humans, plants and animals
4. Prevents loss of property
5. Prevents soil erosion
6. Prevents air pollution
7. Protects flora and fauna
8. Maintains aesthetic value of the landscape
9. Protects watersheds
10. Promotes good regeneration of certain species
11. Maintains ecological balance

Some disadvantages are listed in order of importance from the survey:

1. Affects regeneration of some species
2. Risk to firefighters
3. Fuel buildup on forest floor
4. Affects grass growth
5. Risk of disease outbreak
6. Change of landscape
7. Cost implications

4.6 Fire Use

There are no dendrochronological studies done to establish if forest fires have historically been a part of the landscape in Bhutan. Traditional land management practices which make use of fire, and which are still actively practiced by people today, strongly favor the assumption that fire may have been a part of the landscape since ancient times. The responses from the survey indicate that at least 80% of the respondents are of the opinion that 'people traditionally used fire for land management'. This is further substantiated by the fact that, more than 70% disagreed with the statement 'use of fire for land management is recent' (Figure 19). (See 11 under Appendix B).

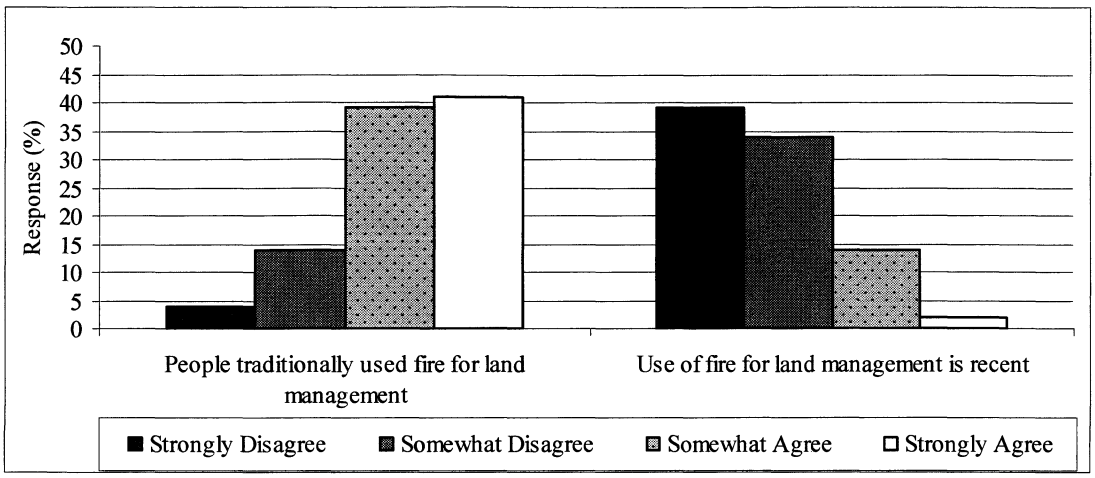


Figure 19. Shows percent response on statements regarding use of fire by people for land management in Bhutan.

From the survey, examples of some land management practices for which people are believed to have 'traditionally' used fires, are listed in (Table 7). The most common traditional uses of fire were for burning agricultural debris, shifting cultivation, burning grassland, burning debris in orchard, etc. These are highly consistent with common causes of forest fires in the past as mentioned in Chapter 1.

Table 7. Traditional practices for which people use/d fire

Traditional use of fire	Frequency of response	Percent response
Burn agricultural debris	26	59
Shifting cultivation	23	52
Burn grassland	14	32
Burn debris in orchard	5	11
Burn lemon grass	2	5
Clearing *sokshings*	2	5
Clearing land	2	5
Destroy wild pests and habitat	2	5
Kill trees for firewood	2	5
For non wood forest produce	1	2
Scare away wild animals	1	2

Analysis also shows that respondents did not consider fire as an agent which shaped the Bhutanese landscape. The view above that fire historically occurred on the landscape and the disagreement that it does not play any role on the state of the landscape are quite contradictory.

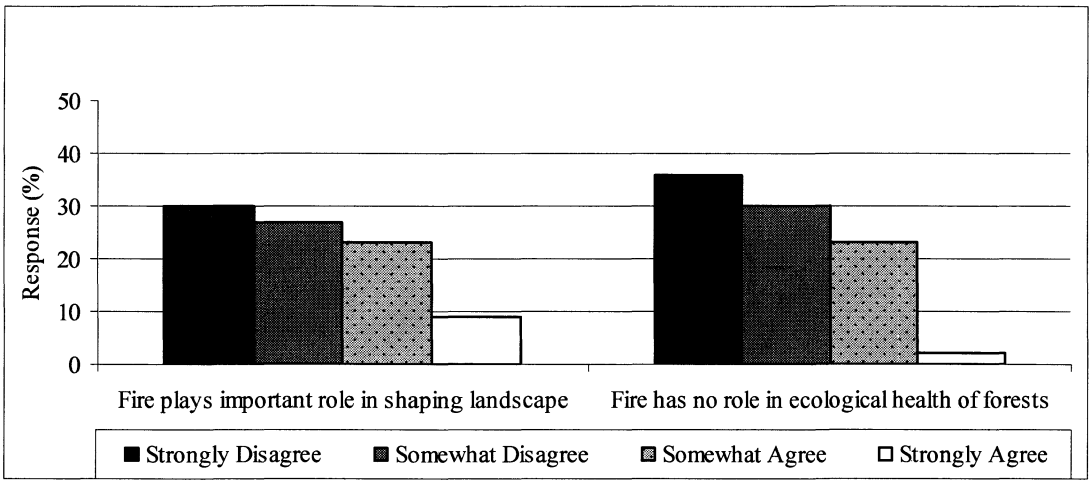


Figure 20. Shows percent response on statements regarding role of fire on landscape and ecology of forests in Bhutan.

There was a strong disagreement with the statement that fire did not play any role in ecological health of the forests. This indicates that respondents consider fire as an essential component of a healthy forest ecosystem. (See 11 under Appendix B).

(Figure 21) illustrates the importance of prescribed fires for different management purposes. The general opinion was that prescribed fire is useful for all the five purposes listed. Rating was highest on use of prescribed fires for wildlife habitat management, rangeland management and for cultural operations in operated forest areas. (See 15 under Appendix B).

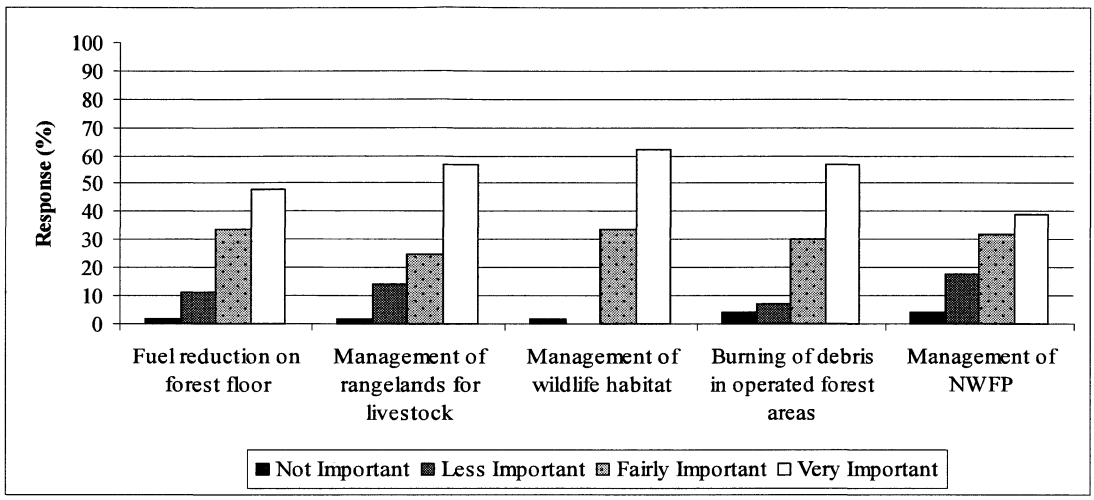


Figure 21. Shows percent response on importance of prescribed fire application for different management purposes in Bhutan.

4.7 Safety of Fire Fighters

On any forest fire incident, fire fighter and public safety warrant utmost consideration and planning. In the Bhutanese situation, these are often overlooked simply because of inadequate training (Figure 22) and lack of personal protective equipment (PPE). As shown in (Figure 22), respondents who are based in the field and are almost always among the first to respond to incidents strongly feel that anyone on a fire should use PPE. (See 11 under Appendix B).

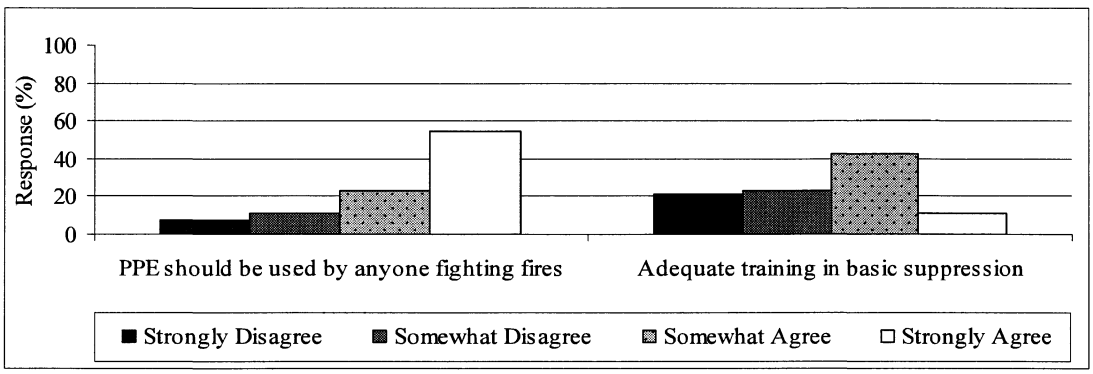


Figure 22. Shows percent response on statements regarding PPE and basic fire suppression training in Bhutan.

As shown in (Figure 23), more than 80% of all respondents were of the opinion that all of the fire fighting and safety equipment listed in the survey were absolutely necessary for fire fighters in Bhutan. In addition a significant percentage mentioned food and refreshment, hand gloves, back pack water pumps, drip torch, etc. as important items during fire fighting operations. (See 17 under Appendix B).

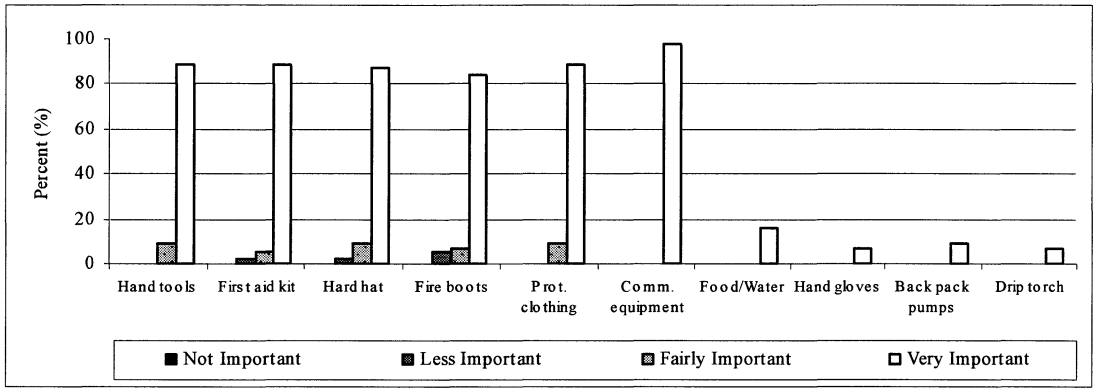


Figure 23. Shows percent response on importance of safety clothing and equipment for fighting forest fire in Bhutan.

When asked if they were aware of any casualties from fire fighting operations, 82% of the respondents were not aware of any casualties (Table 8). About 16% were aware of one or more casualty. About 14% labeled these as cases of serious injury and 2% as fatality cases (table 9).

Table 8. Shows percent response on number of casualties during forest fire fighting in Bhutan.

	Not Aware	One	Two or More	No Opinion	No Response
Casualty during fire fighting	82	7	9	2	0

Table 9. Shows percent response on categories (serious injury or fatality) of casualties during forest fire fighting in Bhutan.

	Serious Injury	Fatality	No Opinion	No Response
Serious injury of fatality	14	2	84	0

CHAPTER 5: DISCUSSION AND RECOMMENDATIONS

This Chapter will discuss findings and provide recommendations on major components of forest fire management in relevance to Bhutan, which were highlighted in preceding Chapters.

1. The Royal Government issued directives for development of a comprehensive National Forest Fire Management Strategy during the 9th five year plan period (2002-2007), to create a strong basis for effective management of forest fires in the country. Despite institutional and resource limitations, DoF has taken numerous initiatives to develop smaller components on prevention, fire fighting, prescribed burning, etc. There has been much emphasis on training professionals to implement these new developments in the field of forest fire and eventually to shoulder responsibilities within the larger framework of the national strategy.

   Past efforts in Bhutan on forest fire management have largely focused on prevention and suppression of forest fires. Similar initial experiences from around the world and the U.S. indicate that management of forest fires should have a holistic approach rather than just prevention and suppression. An effective fire management strategy should adequately address policy, resource, and organizational needs in the context of fire prevention, fire suppression, fire-use, post-fire rehabilitation and public and fire fighter safety.

2. Since the early 1970s, Bhutan pursued a strong policy of fire exclusion on all forested land throughout the country. In Rocky Mountains, studies show that after more than a century of fire exclusion from forests, the health of ecosystems in now in decline.

Scientific researches from around the world indicate similar effects of fire exclusion on the landscape. The conventional idea that, all fires are bad, have been disproved by scientific research and studies worldwide. In many instances lessons has been painfully learnt that total fire exclusion cannot be sustained over time and that when forest fires do occur, as they certainly will, the damage caused by the consequent intense forest fire can be catastrophic.

In Bhutan, after just a few decades of fire exclusion, there are already indications that fire exclusion policy may not be appropriate for all types of forests. In high alpine reaches, pastoral communities are already experiencing impacts like shrub encroachment on traditional grazing lands due to exclusion of fire. Given that fire may be an important natural process in many ecosystems, and that people have traditionally used fire as a land-management tool, the challenge is to develop informed policy that recognizes both the beneficial and traditional roles of fire, while reducing the incidence and extent of uncontrolled burning and its adverse impacts. It is important to understand that protection of forests from catastrophic large scale forest fires is not synonymous with fire exclusion. The current policy on exclusion of forest fires should be reviewed and amended to present a greater flexibility in application of fire for multiple uses on the landscape.

3. The visible negative effects of forest fire on the landscape are the most important reasons for current campaign of active forest fire prevention and suppression in Bhutan. There is high concern that forest fires inherently reduces forest cover, destroys wildlife habitat, causes soil erosion, and in addition to threatens life and property. Fire effects on communities and the ecosystem has received little research

and attention in Bhutan. Views on fire effects are mostly driven by immediate visible impacts. The most common being that forest fires burn down large tracts of forest land, which not only reduce forest cover and destroy wildlife habitat but also triggers soil erosion. Heavy monsoon rains in the aftermath of forest fires can accelerate erosion and increase sediment load in the rivers, which can prove to be detrimental to sustainability of hydropower projects. On the other hand, there are also numerous examples of fire-adapted ecosystems, in which plants show marked preference on frequent fire occurrences, e.g. chirpine-lemon grass ecosystem. The effect of fires on the landscape can be both detrimental and beneficial depending on the fire regime and the ecosystem. There is urgent need to initiate research on the effect of fires on communities and different components of the ecosystem, including flora, fauna, soil, water and air to aid managerial decisions in Bhutan.

4. Results from the survey and other sources indicate that almost all forest fires in Bhutan are anthropogenic in origin. This understanding is crucial for targeting prevention and awareness programs at known causes. Results suggest that a high percentage of forest fires in the country can be avoided to a large extent if local people are effectively educated on the threats large forest fires pose to the environment. Use of mass media for delivery of awareness messages seems to have worked well in the past, and should be promoted more. Publicity and awareness posters are also proven to be quite effective. With fast development and access to internet facilities in the country, use of internet provides a viable opportunity to create awareness and deliver information. Consistency is a key element in ensuring that any prevention message delivered is clear, succinct and relevant. Use of strategic mascot

like Smokey Bear for disseminating messages and influencing public outlook may prove to be useful, but, due consideration should be given to long-term impacts of such prevention strategies. A longer-term approach to prevention can be achieved by augmenting school curriculum with syllabus on forest management and forest fire.

In spite of the impacts of the fires and stringent law and regulations, the use of fire is still an integral part of the traditional farming and rural livelihoods. Any programmes to reduce sources of fire ignition through enforcement need to take into account the local fire usage and the perception of the local people on fire. To this end, introduction of burn permits would be quite useful, as it would allow people to burn under certain conditions and with approval from the forest department. In addition indigenous knowledge of the local people needs to be incorporated into scientific knowledge in an effort to solicit local community support in fire prevention and control. Development of community incentive programs should be considered and the *meesops* (village fire watcher) should be appointed and trained to aid in prevention activities in the villages.

5. Other presuppression methods of forest fire include options for separating fuel from hazard or reducing hazard through management of fuel in the forest. Construction of fire lines prior to fire season is considered to be quite effective but it has high cost implications too. Although managing fuels especially in forests is a complicated process, it may be essential in situations where other prevention methods appear to be ineffective. Local resource allocation could be integrated with fuel management objectives. Similar strategy can be adopted in commercially managed forests (forest

management units), whereby silvicultural thinning should be aimed at multi resource use and fire management objectives.

6. Fire incidence reporting constitutes a major aspect of forest fire management. This is useful for contingency planning as well as forecasting the probability of a fire starting in the future. Forest fire reporting has mostly been through verbal communication and there is no standard format or procedure for reporting a forest fire incident in Bhutan. This makes it difficult to use such uncoordinated information to make any meaningful management decision. A system of fire reporting should be instituted to enable relevant and coordinated reporting of forest fire incidents.

   A simple fire danger risk rating system would also be useful for assessing fire hazard and using the information for forest fire management applications in Bhutan. There is high potential for integration of fire danger rating and early warning system on other natural disasters. However, extensive and complicated fire danger rating systems like the ones employed in U.S. and Canada may not be feasible for Bhutan at the current time, given extensive requirements of meteorological parameters, equipment and infrastructure, and high cost inputs. Alternatively, Geographic Information System (GIS)-based applications using greenness or moisture stress indices, provides a very cost-effective way of predicting fire danger. Possibilities for development of such a system should be explored for Bhutan.

7. The FNCA of 1995 stipulate total suppression of forest fires in Bhutan, given detrimental impacts of forest fires as discussed above. Results from the survey show that more percent of respondents were in favor of 'letting some fires to burn' as opposed to 'total suppression'. Based on fire suppression history in Northwestern

U.S., suppression of fire may lead to more intense fire in the future as a result of accumulated fuel loads. Suppression alone is not always a successful fire management approach. The role of fire in the landscape needs to be carefully assessed.

The DoF is charged with the mandate to suppress forest fires in Bhutan at the national level. The department however does not maintain any formal group or workforce specifically charged with suppression of forest fires. Forestry staff responsible for fire suppression are expected to pick up fire fighting skills through experience and receive very little formal training in fire management, and especially in fire suppression. Recently the SFD in collaboration with the New South Wales Rural Fire Service have developed basic fire fighting training manuals for Bhutan. Training on fire fighting tactics should be regularly imparted to all foresters at national, regional and local levels to train a professional cadre of fire fighters in the country. In addition, the DoF does not possess sufficient equipment, either in terms of quality, type or quantity for effective fire suppression. Adequate equipment should be procured for all *Dzongkhags*, based on frequency of fire incidences and suitability to local conditions. Suppression efforts are mostly weakly organized attempts among multiple collaborating agencies and there is general lack of manpower, suitable equipment and formal fireline organization and suppression procedures. Most large fires often burn out on their own rather than being contained. Results from the survey show that armed forces (RBA, RBP, RBG), local communities, schools and other institutions are the key collaborators during fire incidents. These organizations play important roles in suppression of forest fires in Bhutan. However, many other stakeholders who

have important stakes are currently not linked in any way to fire management efforts in the country. An effective strategy should be developed to coerce a stronger stakeholder representation and support on forest fire management efforts. To start with, negotiations could be initiated with agencies like the Department of Energy, Power Corporations, the Department of Tourism, etc. for a plough-back mechanism on funding suppression activities.

8. Community-Based Fire Management (CBFiM) is emerging as a strategic platform for encouraging community participation in fire management decision making. Recent developments indicate that component of balanced fire management should include an active role for communities. In developing countries like Bhutan, land use activities are often tied to personal livelihood and existences without other choices being available. In view of this, for any CBFiM systems to be sustainable, incentives for fire management must be largely related to the community's needs.

   The key issue is that community based approaches gives local people a sense of ownership, and therefore of stewardship, of their forest or plantation, because their needs have been recognized and accommodated. In Bhutan, preliminary guidelines on formation of CBFiM Committees and their operation mechanism has already been initiated in a few community forests in eastern Bhutan. The existing structure and responsibilities of community-based forest management provides an excellent backdrop for integrated efforts on CBFiM across the country.

9. The use of fires to clear land for permanent agriculture and settlements by local communities is widespread in South East Asia. Though people are believed to have historically used fires for different domestic land management purposes, there are no

studies done to affirm this in Bhutan. Survey results indicate a strong opinion on existence of traditional use of fire on the landscape. Majority of the views describes active traditional use of fire for burning agricultural debris, shifting cultivation, burning grasslands, etc. There is need to immediately initiate research on fire history using documented evidences or dendrochronological techniques.

The percent of naturally ignited fires in Bhutan is very negligible and therefore application of 'wildland fire use' is not elaborated here. The concept of 'prescribed burn' is seen as a more useful management tool for the country. Though contemporary science and techniques on prescribed burn is relatively new to Bhutan, there already exist strong opinions on potential use of prescribed fires for achieving different management objectives in Bhutan. Results from the survey show that people place high priority on uses of prescribed for management of wildlife habitat, management of rangelands for livestock, cultural operations in operated forest areas, fuel reduction and management of NWFPs. As an initial step in this field, the DoF has developed protocols and carried out prescribed burn trials at *Dozam* Community Forest in eastern Bhutan. The studies mainly focused on effect of fire severity on chir pine regeneration and lemon grass production. Immediate applications can be foreseen on wildlife habitat management in Bhutan's protected area system. In this light, feasibility and trial studies should continue and comprehensive guidelines on different uses of prescribed burns should be developed to foster cost-effective fire use.

10. Post fire assessment and rehabilitation techniques are important within the framework of a national strategy. The FNCA of 1995 legally requires that communities residing

in the vicinity of burnt areas should replant burnt areas if the person responsible for the cause of the fire is not identified. Such provisions could potentially raise antagonism against the DoF, and could encourage more arson fires. In any case, this provision is rarely implemented since rural communities neither have the resources, nor have the time to assist DoF in replanting huge tracts of forest land. A more innovative deterrent approach would be to promote investigation of cause of forest fires. A systematic and reliable investigation procedure will also ensure that arsonists are apprehended and charged appropriately and that innocent people are not accused unfairly. The investigation of forest fires would be a specialist job but an important one for Bhutan.

11. Fire fighting and related job is considered one of the most hazardous occupations. In Bhutan, the situation is exacerbated due to of lack of fire fighting training and safety equipment. Results from the survey show that there is significant number of injuries and sometimes death on fire incidents. When a forest fire is reported all available forestry personnel are sent to the site of the fire. There is no fireline organization and often there is big confusion at the scene. There is virtually no use of any PPE including helmets, footwear and clothing. Most people cut off branches to swat out fires. The DoF personnel use walkie-talkie sets to communicate, but again these are extremely limited in number and functionality due to topographic conditions. There is critical need to review and formulate new safety standards and procedures for all fire related operations. It is envisaged that the upcoming labor law will be a strong legal basis for such developments in Bhutan.

CHAPTER 6: CONCLUSIONS

The study shows that management of forest fires in Bhutan is critical for environmental integrity, rural livelihood and economic growth. A holistic and integrated national forest fire management strategy would be instrumental in achieving this goal. To this end, there is strong need for both short term and long term research efforts on all aspects of forest fire management in Bhutan. It is increasingly felt that current policy on exclusion of fire from all state forests may not be appropriate for all forest types and ecosystems. The policy needs to be reviewed and a more flexible approach to application of fire should be developed. It should however be recognized that such a change in policy would be a big challenge given its wider implications for the country. Therefore any policy change on fires should be driven by political will, social acceptability, ecosystem needs and implementation capabilities within the government.

The opinion on effects of forest fires in Bhutan are primarily on immediate and visible negative impacts, i.e. depletion of forest cover, soil erosion, impact on communities. There is urgent need to initiate research on actual effects of fire on communities and different ecosystems. Forest fire prevention activities are seen as being quite effective in reducing fire incidences in Bhutan, given that almost all sources of ignition are anthropogenic in nature. Education of children at school and general public through non formal ways on effects of forest fire is crucial for fire prevention in the longer-term. In addition, any regulation or enforcement should be sensitive to local needs, perception and knowledge.

There is currently lack of any planning and fireline organization during suppression operations in Bhutan. A uniform suppression procedure should be developed

and adopted for the whole country and fire fighters should be well trained and acquainted with this procedure for effectiveness and safety. A big constraint to forest fire suppression is lack of manpower and resources. Stakeholder consultations and analysis should be conducted to identify key stakeholders and their interests in fire suppression, and coerce their involvement and support to future forest fire suppression efforts.

There is a strong feeling that use of fire by communities for traditional land management is a historical practice in Bhutan. This need to be ascertained through a blend of research of documented evidences and relevant scientific methods aimed at understanding the prevalence and role of fire on the Bhutanese landscape. Also, use of prescribed fire has high potential for the country in areas of land, resource and wildlife management. Any efforts in this area should be based on cost implications and prescribed burning protocols specific to the management objective.

Current regulations on replanting fire burnt forest areas are rarely implemented and there is a strong dependence on natural regeneration in these areas. As such rules on rehabilitation of fire affected areas should be amended to retain the element of deterrence while at the same time keeping provisions for quick rehabilitation efforts. Investigative expertise should be developed to identify sources of ignition and prosecute arsonists.

Finally, the study shows that fireline safety feature very poorly during any operation related to forest fires in Bhutan. Safety of fire fighters and people is of utmost importance and should therefore receive top priority in the fire management strategy. There is immediate need to develop safety standards and guidelines specifically for professional fire fighters and the public at large to reduce casualties and prevent fatalities on the fireline.

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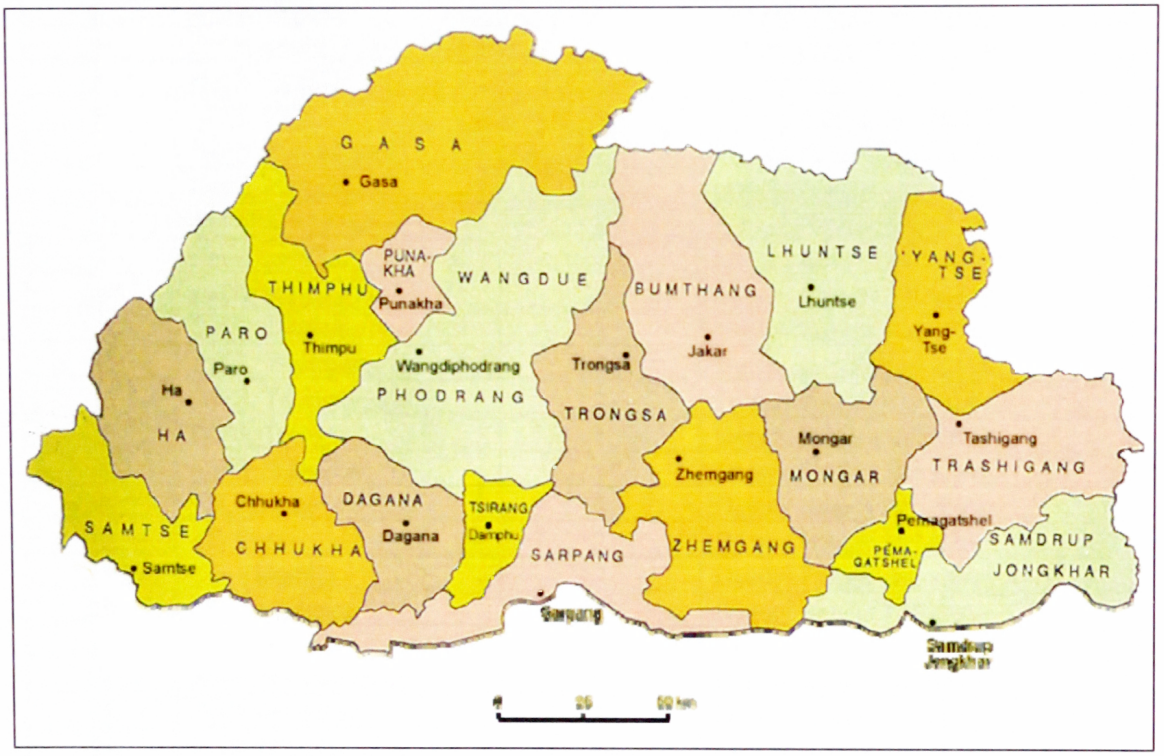
APPENDIX A: Administrative map of Bhutan showing 20 *Dzongkhags*. Source from AMICUS Website (2006).



APPENDIX B: List of respondents in Questionnaire Survey

Sl.No	Agency	Respondent/s	Remarks
1	DzFS, Bumthang	1	Deputy Ranger and above
2	DzFS, Chhukha	1	Deputy Ranger and above
3	DzFS, Dagana	1	Deputy Ranger and above
4	DzFS, Lhuntse	2	Deputy Ranger and above
5	DzFS, Mongar	2	Deputy Ranger and above
6	DzFS, Paro	2	Deputy Ranger and above
7	DzFS, Pemagatshel	1	Deputy Ranger and above
8	DzFS, Punakha	2	Deputy Ranger and above
9	DzFS, S/Jongkhar	1	Deputy Ranger and above
10	DzFS, Samtse	1	Deputy Ranger and above
11	DzFS, Sarpang	1	Deputy Ranger and above
12	DzFS, Thimphu	2	Deputy Ranger and above
13	DzFS, Trashigang	2	Deputy Ranger and above
14	DzFS, Trashiyangtse	2	Deputy Ranger and above
15	DzFS, Trongsa	1	Deputy Ranger and above
16	DzFS, Wangdue	2	Deputy Ranger and above
17	TD, Mongar	2	Deputy Ranger and above
18	TD, Paro	2	Deputy Ranger and above
19	TD, Thimphu	2	Deputy Ranger and above
20	TD, Trashigang	2	Deputy Ranger and above
21	TD, Wangdue	2	Deputy Ranger and above
22	RNR-RC, Bajothang	2	Deputy Ranger and above
23	RNR-RC, Jakar	3	Deputy Ranger and above
24	RNR-RC, Wengkhar	3	Deputy Ranger and above
25	RNR-RC, Yusipang	2	Deputy Ranger and above
Total No. of respondents		44	

DzFS (Dzongkhag Forestry Sector), TD (Territorial Division), RNR-RC (Renewable Natural Resource-Research Center)

APPENDIX C: Questionnaire Survey Results

QUESTIONNAIRE SURVEY ON FOREST FIRE MANAGEMENT IN BHUTAN

(Mongar, 4 February 2006)

AIM: The purpose of this survey is to assess outlook of forestry field staff from Divisions, Dzongkhags and Research on the current situation, and future needs and priorities for forest fire management in Bhutan. The data collected will be used for research work by Kinley Tshering on forest fire management in Bhutan.

All responses are voluntary and confidential. We are interested in your opinion and **there is no right or wrong answers.**

NOTE: Please refer footnotes for intended meaning of selected terms (underlined words) used in the questionnaire.

1. In your opinion, how concerned are you about forest fires in Bhutan? Please circle your choice.

Level of concern	Frequency of response	Percent response
Unconcerned	0	0
Not Very Concerned	0	0
Somewhat Concerned	8	18
Very Concerned	36	82
No Opinion	0	0
No Response	0	0
Total	**44**	**100**

2. We are interested in your opinion regarding possible impacts of forest fires in Bhutan. In this context, please indicate how strongly you are concerned about the following possible impacts of forest fires. In the table below, please circle your choice on a scale of 1 to 5 as per the key provided.

1=Unconcerned, 2=Not Very Concerned, 3=Somewhat Concerned, 4=Very Concerned, 8=No Opinion, 9=No Response

Impacts	1	2	3	4	8	9	Total
	Percent (%)						
Causes air pollution	7	11	25	50	7	0	100
Reduces forest cover	7	2	20	68	2	0	100
Destroys wildlife habitat	0	7	11	82	0	0	100
Leads to soil erosion	0	11	11	75	0	2	100
Risk to lives	5	23	20	52	0	0	100
Risk to property	5	14	30	52	0	0	100
Ensures nutrient cycling	5	23	41	14	14	5	100
Reduces forest fuel	16	11	34	34	0	5	100
Improves grasslands	11	20	27	27	11	2	100
Others							
Loss of endangered flora and fauna	0	0	0	7	0	93	100
Threat to watershed and rivers	0	0	0	11	0	89	100

3. Do you think that Bhutan should have a national forest fire management[5] strategy? Please check your choice.

Response	Frequency of response	Percent response
Yes	43	98
No	0	0
No Opinion	1	2
No Response	0	0
Total	**44**	**100**

[5] ***Forest fire management*** *strategy broadly refers to all aspects of forest fire including prevention, suppression, safety of fire fighters, use of fire, post-fire assessment and replanting of burned areas, education on forest fire ecology, training on fire suppression and other activities relevant to forest fires in Bhutan.*

4. We are interested in your opinion as to what makes a good fire management strategy. In your opinion, please rank the importance of the following components that you think should be in a national forest fire management strategy for Bhutan. In the table below, please circle your choice of rating on a scale of 1 to 5 as per the key provided:

1=Not Important, 2=Less important, 3=Fairly Important, 4=Very Important, 8=No Opinion, 9=No Response

	1	2	3	4	8	9	Total
Components	**Percent (%)**						
Firefighter safety	0	5	5	86	5	0	100
Forest fire Prevention	0	2	9	84	2	0	100
Forest fire suppression	0	7	14	77	2	0	100
Assessment of effect on burnt areas	0	0	23	68	7	0	100
Replanting of burnt areas	5	0	20	75	0	0	100
Use as a management tool	5	11	45	30	9	0	100
Education of foresters on fire ecology	0	2	14	80	2	2	100
Training firefighters	0	0	7	86	5	2	100
Effect on different vegetation types	0	2	27	61	5	5	100

5. What are the most important issues which you think should be addressed by Department of Forest for promoting forest fire management activities in Bhutan?

Issues	**Frequency of response**	**Percent response**
Training		
Provide training to foresters and public on different aspects of forest fire	11	25
Provide training on forest fire suppression	8	18
Education		
Educate public on negative effects and prevention of forest fire	8	18
Educate public on management of forest fires	4	9
Incorporate forest fire ecology in school curriculum	3	7
Educate foresters in forest fire ecology	1	2
Awareness		
Raise awareness about forest fires in communities and schools	6	14
Raise awareness through campaigns and mass media	5	11
Raise awareness through audio visual programs for children	1	2
Organization		
Establish village forest fire management committees	5	11
Establish separate forest fire division	4	9
Establish forest fire suppression committees	1	2
Procure adequate equipment for forest fire fighting	8	18
Study of impacts of forest fires	4	9
Restoration of burnt areas	4	9

6. We are interested in your opinion regarding what you see as effective ways to manage forest fires in Bhutan.

   i. Please list in order of importance to you, the most effective measures which has been or is being implemented.

Effective measures implemented	No of respondents			Total
	a	b	c	
Awareness	14	7	2	23
Public awareness on effects	14	3	1	18
Awareness on importance of forests	0	2	1	3
Use sign boards and posters	0	2	0	2
Prevention	4	5	7	16
Making fire lines	2	2	5	9
General prevention	1	3	1	5
Dialogue with public	1	0	1	2
Training of foresters and public on different aspects of forest fire	3	6	2	11
Public education	8	0	1	9
Suppression	2	5	0	7
General suppression	1	2	0	3
Back firing	0	2	0	2
Public participation	0	1	0	1
Collaboration with armed forces	1	0	0	1
Enforcement of rules and regulations	0	5	1	6
Use of mass media	1	2	2	5

   ii. Please list in order of importance to you the most effective measures that you think should be implemented in future.

Effective measures recommended	No. of respondents			Total
	a	b	c	
Training	7	9	2	18
Provide training to foresters and public on different aspects of forest fire	3	3	2	8
Provide training on forest fire suppression	3	5	0	8
Capacity building for officials and communities	1	1	0	2
Organization	7	6	1	14
Form village level fire management committees	4	1	1	6
Appoint fire committees	0	1	0	1
Form fire management groups	2	1		3
Appoint fire watchers or *meesop*[6] during fire season	0	2	0	2
Fire fighting unit in Dzongkhags	1	1	0	2
Enforcement and penalty	5	4	4	13
Increase fine and penalties	0	0	2	2
General enforcement and penalty	2	1	1	4
Stringent rules	2	1	0	3
Adequate fire fighting equipments	1	2	1	4

[6] *Village Fire Watcher*

Education	4	8	0	12
Educate public on negative effects and prevention of forest fires	2	4	0	6
Incorporate forest fire ecology in school curriculum	2	4	0	6
Create public awareness	5	2	1	8
Fire lines	4	1	1	6
Public incentives	2	0	1	3
Suppression	0	1	1	2

7. We are interested in how confident you feel you are with regard to causes of forest fires in Bhutan. In this context, how confident are you, in your familiarity with causes of forest fires in Bhutan? Circle your choice from the options given below.

1=Not Confident, 2=Less Confident, 3=Moderately Confident, 4=Confident, 8=No Opinion, 9=No Response

Familiarity with causes	Frequency of response	Percent response
Not Confident	0	0
Less Confident	4	9
Moderately Confident	22	50
Confident	16	36
No Opinion	0	0
No Response	2	5
Total	**44**	**100**

8. We are interested in your opinion of the type of forest in your Dzongkhag and what causes fires in these forests. Please rank the causes as you know by filling in the empty columns under 'causes' with any of the numbers from 1-5 as per the key provided:

1=None of The Time, 2=Some of The Time, 3=Most of The Time, 4=All of The Time, 8=No Opinion, 9=No Response
C=Conifer, MC=Mixed Conifer, MCB=Mixed Conifer & Broadleaved, BL=Broadleaved

	1	2	3	4	8	9	Total
Type of cause	**Percent (%)**						
C accidental	0	25	23	2	50	0	100
C intentional	0	18	30	2	48	2	100
C lightning	11	7	0	0	82	0	100
C others	0	14	0	0	86	0	100
MC accidental	2	18	11	2	67	0	100
MC intentional	0	16	14	5	65	0	100
MC lightning	9	5	0	0	86	0	100
MC others	0	7	0	0	93	0	100
MCB accidental	0	14	7	2	77	0	100
MCB intentional	0	5	9	0	86	0	100
MCB Lightning	5	2	0	0	93	0	100
MCB others	0	2	0	0	98	0	100
BL accidental	2	9	5	0	84	0	100
BL intentional	5	2	7	2	84	0	100
BL lightning	5	0	0	0	95	0	100
BL others	2	2	0	0	96	0	100

9. We are interested in your opinion regarding what you think makes a successful forest fire prevention strategy. Please rank the importance you give to the following activities for forest fire prevention program in Bhutan. In the table below, please circle your choice of rating on a scale of 1 to 5 as per the key provided:

1=Not Important, 2=Less important, 3=Fairly Important, 4=Very Important, 8=No Opinion, 9=No Response

Essential component for prevention strategy	1	2	3	4	8	9	Total
	Percent 9%)						
Educating communities on negative impacts of large fires	2	3	9	84	0	2	100
Reduction of fuel in forests	2	14	50	32	0	2	100
Prevention messages in media	0	2	37	57	2	2	100
Enforcing regulations strictly	2	9	21	66	2	0	100
Incorporating fire ecology in school curriculum	5	2	27	62	2	2	100
Identifying causes by locality	2	2	32	62	2	0	100
Link fire effects to religious sentiments	0	14	52	27	7	0	100
Introducing burn permits for agriculture refuse burning	2	23	23	45	5	2	100
Predicting fire hazard in fire prone areas	0	11	21	64	2	2	100

10. Created in 1944, the Smokey Bear campaign continues to be very effective for forest fire prevention in the United States. Smokey's image is used as a national mascot[7] to create awareness on impacts and prevention of forest fire by the United States Forest Service.
    i. Do you think that Bhutan should have a national mascot for prevention of forest fires? Please check your choice.

National Mascot for Forest Fire Prevention	Frequency of response	Percent response
No	2	5
Yes	24	55
No Opinion	17	39
No Response	1	2
Total	**44**	**100**

    ii. What and why in your opinion would be an appropriate choice of national mascot for preventing unwanted forest fires in Bhutan?

Suggested Mascot	Reason
Musk deer	None
Wild Animal	Religious sentiments against mass destruction
Cypress	National symbol
Takin	National symbol
Blue Poppy	National symbol
Sambhar	Habitat loss

[7] ***Mascot*** *means a symbol, character, or emblem that people popularly associate with a cause. For example, in the United States Smokey Bear is the national mascot for fire prevention*

11. Please identify your level of approval with the following statements by circling how strongly you agree with the statement on the left on a scale of 1 to 5 as per the key provided:

1=Strongly Disagree, 2=Somewhat Disagree, 3=Somewhat Agree, 4=Strongly Agree, 8=No Opinion, 9=No Response

Statements	1	2	3	4	8	9	Total
	Percent (%)						
Prediction services are necessary for effective suppression	0	2	57	32	7	2	100
Forest fire suppression in Bhutan is currently well planned	23	23	36	16	2	0	100
Forest Fire suppression operations in Bhutan are currently well organized	21	41	27	7	2	2	100
A systematic forest fire suppression procedure should be implemented uniformly throughout Bhutan	4	14	25	55	0	2	100
Total suppression of forest fire is desirable on the Bhutanese landscape	9	25	30	32	2	2	100
Some forest fires should be allowed to burn under manageable conditions	4	4	39	39	7	7	100
There is effective collaboration among stakeholder organizations in suppression of forest fires in Bhutan	4	34	41	14	7	0	100
Cooperation between stakeholder organizations can be improved for effective suppression of forest fires	2	5	37	43	11	2	100
Adequate training in basic suppression	21	23	43	11	2	0	100
People traditionally used fire for land management	4	14	39	41	2	0	100
Use of fire for land management is recent	39	34	14	2	9	2	100
Fire plays important role in shaping landscape	30	27	23	9	11	0	100
Fire has no role in ecological health of forests	36	30	23	2	7	2	100
PPE should be used by anyone fighting fires	7	11	23	55	2	2	100
Adequate training in basic suppression	21	23	43	11	2	0	100

12. We are interested in your thoughts regarding the advantages and disadvantages of active forest fire suppression in Bhutan. Please list in order of importance to you:

Advantages	No. of Respondents			Total
	i	ii	iii	
Prevents destruction of forest	14	3	0	17
Protects wildlife and their habitat	2	7	4	13
Prevents loss of lives	4	2	5	11
Prevents loss of property	3	4	3	10
Prevents soil erosion	3	5	0	8
Prevents air pollution	2	1	2	5
Protects flora and fauna	2	2	1	5
Maintains aesthetic value	0	0	4	4
Protects watersheds	0	2	1	3
Promotes good regeneration	1	2	3	6
Maintains ecological balance	1	0	2	3

Disadvantages				
Affects regeneration	4	1	2	7
Risk to firefighters	4	0	1	5
Fuel buildup in forest	2	3	0	5
Affects grass growth	3	0	0	3
Risk of disease outbreak	2	1	0	3
Change of landscape	1	0	1	2
Cost implications	1	1	0	2

13. In your opinion, who are the most notable organizations currently collaborating with the Department of Forests in forest fire suppression?

Collaborating organizations	**Frequency**	**Percent**
Armed forces (RBG, RBA, RBP)	29	66
Local communities	24	55
Dzongkhag staff	7	16
Local institutions and schools	5	11
Business organizations	2	5
Dratshangs	1	2

14. In your opinion, what are the ways in which people traditionally[8] use fire on land?

Traditional use of fire	**Frequency**	**Percent**
Burn agricultural debris	26	59
Shifting cultivation	23	52
Burn grassland	14	32
Burn debris in orchard	5	11
Burn lemon grass	2	5
Clearing *sokshings*	2	5
Clearing land	2	5
Destroy wild pests and habitat	2	5
Kill trees for firewood	2	5
For non wood forest produce	1	2
Scare away wild animals	1	2

[8] ***Traditional fire use*** *refers to native or local use of fire which the people have been practicing for various purposes from olden times*

15. The use of prescribed fires for different management purposes is gaining popularity around the world. In your opinion, please rank the importance you give to the following uses of prescribed fires in Bhutan.

1=Not Important, 2=Less important, 3=Fairly Important, 4=Very Important, 8=No Opinion, 9=No Response

	1	2	3	4	8	9	Total
Use of prescribed burn	**Percent (%)**						
Fuel reduction on forest floor	2	11	34	48	5	0	100
Management of rangelands for livestock	2	14	25	57	2	0	100
Management of wildlife habitat	2	0	34	62	2	0	100
Burning of debris in operated forest areas	4	7	30	57	2	0	100
Management of non wood forest produce	4	18	32	39	7	0	100

16. Please describe any casualties you know of that have been caused during forest fire fighting operations in Bhutan. Check either the 'Not aware of any casualty' box or describe casualty as you know in the table below.

	Not Aware	One	Two or More	No Opinion	No Response
Casualty during fire fighting	82	7	9	2	0

	Serious Injury	Fatality	No Opinion	No Response
Serious injury of fatality	14	2	84	0

17. Please rank the importance of the following safety equipment for forest fire fighting in Bhutan.

1=Not Important, 2=Less important, 3=Fairly Important, 4=Very Important, 8=No Opinion, 9=No Response

	1	2	3	4	8	9	Total
Equipment	**Percent (%)**						
Hand tools	0	0	9	89	2	0	100
First aid kit	0	2	5	89	2	2	100
Hard hat	0	2	9	87	2	0	100
Fire boots	0	5	7	84	2	2	100
Protective clothing	0	0	9	89	2	0	100
Communications equipment	0	0	0	98	2	0	100
Food and refreshment	0	0	0	16	84	0	100
Hand gloves	0	0	0	7	93	0	100
Back pack pumps	0	0	0	9	91	0	100
Drip torch	0	0	0	7	93	0	100

18. Please identify the most important issues in fire ecology and fire management, which could be incorporated as part of curriculum at the upcoming Ugyen Wangchuck Institute of Environmental and Forestry Studies.

Issues in fire ecology and management	Frequency of response	Percent response
Fire fighting techniques	16	36
Prescribed burning	11	25
Practical field exercises	7	16
Separate subject on forest fire	5	11
Fire ecology in different forest types	5	11
Safety of fire fighters	4	9
Management of different fire regimes	3	7
Fire effects	3	7
Fire behavior	3	7

19. What areas of knowledge do you think needs to be developed to successfully manage forest fires in Bhutan?

Knowledge needed	Frequency of response	Percent response
Fire fighting techniques	14	32
Fire behavior	5	11
Fire weather	4	9
How to use equipments	3	7
Community education and training	3	7
Prescribed burning	3	7
Use of maps	2	5
Appropriate equipment	2	5
Fuel types and loading	2	5
Safety of fire fighters	2	5
Fire ecology	2	5
Awareness	2	5

20. Please use the space below to share any additional comments or suggestions regarding this survey or forest fire management in Bhutan.

Additional comments on forest fire management
There should be regional training on fire
Regional awareness campaigns
Fire fighting technique for steep terrain
Develop fire management plans
DoF should foster collaboration of all stakeholders in the field
Prevention is important for upholding national policy
Special fire division should be created
Separate fire fighting crews in Dzongkhags
Training and provision on first aid
Fire Hazard mapping
Transboundary fire problems
Additional comments on survey
Survey foresters at all levels
Similar survey at regional level would give more reliable results
Survey will help fire suppression
Conduct survey in all Dzongkhags