# ASSESSMENT OF CLIMATE RISKS ON FORESTS AND BIODIVERSITY FOR NATIONAL ADAPTATION PLAN (NAP) FORMULATION PROCESS IN BHUTAN

# CONTENTS

## LIST OF TABLES, FIGURES & MAPS

# ACRONYMS

| | |
|---|---|
| BPC: | Bhutan Power Corporation |
| DDM: | Department of Disaster Management |
| DGPC: | Druk Green Power Corporation |
| DHPS: | Department of Hydropower Services |
| DMA: | Disaster Management Act |
| DoFPS: | Department of Forests and Park Services |
| EAA: | Environmental Assessment Act |
| EIA: | Environmental Impact Assessment |
| ENSO: | El Niño-Southern Oscillation |
| FNCA: | Forest and Nature Conservation Act |
| FPED: | Forest Protection and Enforcement Division |
| GBCL: | Green Bhutan Corporation Limited |
| IFFCG: | Inter-agency Forest Fire Coordination Group |
| ISM: | Indian Summer Monsoon |
| MoAF: | Ministry of Agriculture and Forests |
| MoHCA: | Ministry of Home and Cultural Affairs |
| MTBS: | Monitoring Trends in Burn Severity |
| NAP: | National Adaptation Plan |
| NCHM: | National Center for Hydrometeorology |
| NEC: | National Environment Commission |
| NEPA: | National Environment Protection Act |
| NLCS: | National Land Commission Secretariat |
| PDO: | Pacific decadal oscillation |
| PPE: | Personal Protective Equipment |
| RBA: | Royal Bhutan Army |
| RBP: | Royal Bhutan Police |
| RCP: | Representative Concentrative Pathway |
| RGB: | Royal Body Guards |
| RGoB: | Royal Government of Bhutan |
| SOP: | Standard Operating Procedures |
| USDA: | United States Department of Agriculture |
| USAID: | United States Agency for International Development |

## EXECUTIVE SUMMARY

Forests remain central to the wellbeing and prosperity of Bhutan. From providing for water and critical environmental services, forests are inexorably tied to Bhutan's food, water, and energy security. Today, with an estimated 70% of Bhutan's total land under forests, Bhutan continues to remain carbon negative. Being in the eastern Himalayas, Bhutan's forests are also an amazing repository of biodiversity. With climate change, forests will be subjected to multiple threats ranging from novel pests and diseases to diebacks and heat related stress. Forests will also be subjected to increasing risks from forest fires. Fire related damage to forests will imperil biodiversity and severely constrain the provisioning of critical ecosystem services, and fire related loss of forests will significantly reduce Bhutan's carbon sink capacity and endanger Bhutan's ability to remain carbon neutral. Such loss will also, ultimately, compromise Bhutan's constitutional mandate to maintain 60% under forest cover for all times to come.

The objective of the current assignment is to undertake a wildfire risk assessment in Bhutan, by analyzing fire likelihood, fire behavior, and fire impact. The purpose of the assessment is to identify fire-prone areas and quantify the risks to communities, biodiversity, and assets, as well as to inform planners and managers about land management and development in fire prone areas. It will also propose prioritized adaptation options.

We used fire behaviour modelling to characterize fire hazards of Bhutan's forest ecosystems. The analysis of fire hazards, i.e., the physical characteristics of fire, is the first step towards a complete fire risk assessment, which includes fire effects on the biophysical and socioeconomic systems. We used FlamMap 5.0 (Finney et al., 2016), a spatially explicit fire behaviour model, to simulate surface fire behaviour under different representative concentration pathway (RCP) scenarios (Moss et al., 2010). FlamMap strength lies in its potential to show the effect of spatial fuel arrangement and topography on fire behaviour, as environmental conditions are held constant throughout the simulation.

To frame adaptation strategies for the next decade, we focused on highlighting results for the short time frame (now till 2050) under the RCP 4.5 scenario. Detailed results in the main text are mostly limited to projections for RCP 4.5 from now till 2050. Results for other scenarios and time slices are appended in the form of consolidated GIS maps and datasheets. We combined 'high' and 'very high' risk classes together and present results under one single high fire risk category.

Both flame length and rate of fire spread experience an increase as climate becomes more extreme (Figure 6 & 7). According to our simulations, chir pine forests experienced the most severe fire behavior, with flames reaching 2.2 m length and spread of fire at 8.9 m min$^{-1}$ for the RCP 8.5 scenario period 2070-2100. Besides chir pine forests, the highest flame length values were found in mixed conifer forests, with flames reaching also 2.2 m length, and the fastest spread in broadleaf forests below 2000 m, with a fire line moving at 6.4 m min$^{-1}$. Fir forests and broadleaf forests above 2000 m underwent the mildest fire behavior outputs. This means that forest fires will be more intense with increasing possibility of more crown fires. Coupled with a faster rate of spread, the possibility of larger fires burning over longer periods is an eminent possibility.

Almost 90% of Chir pine forests fall under high risk from now till 2050 followed by blue pine with over 60% being subjected to high risk. See Figure 8 and Map 3.

Under RCP 4.5, from now till 2050, an estimated 921 km$^2$ of Chir pine, 626 km$^2$ of Blue pine, 879km$^2$ of mixed conifer forests, and 1175 km$^2$ of fir forests will be at high fire risk (Table 4). Areas under high fire risk increase significantly for mixed conifer forests for all time slices and under both RCP 4.5 and RCP 8.5. Athang and Daga Gewogs in Wangdue and Saleng Gewog in Mongar are at most risk within the Chir pine zone (Table 5) in the short time frame (now till 2050). Two Gewogs of Mewang and Kawang in Thimphu are at most risk followed by Chhoekhor Gewog in Bumtang within the Blue fine forest zone. Kazhi in Wangdue and lower reaches of Lunana Gewog show up as being at most risk followed by Langthil Gewog in Trongsa and Athang in Wangdue within the chir fine forest zone.

Risks to broadleaved forests at lower elevations (<2000) are projected to increase from now to 2050 with over 9000 $km^2$ of broadleaved forests at high fire risk under both RCP 4.5 and RCP 8.5. Pangkhar Gewog in Zhemgang and Jigmichhoeling in Sarpang followed by Trong Gewog in Trongsa and Bongo in Chapcha have the most area at risk from fires within broadleaved forests below 2000 masl.

A total of 18490 households will be at increased risk from forest fires as we move from now to 2050. Houses within the broadleaved belts below 2000 masl will be at most risk from now until 2050, followed by households within Chir pine and Blue pine zone. There are no households and infrastructure at risk within mixed conifer, fir, and broadleaved forests above 2000 masl. An estimated 1747 households will be at a high fire risk within the Chir pine zones under RCP 4.5 as we move from now till 2050. A total of 598 households will be at a high risk within the blue pine zones under RCP 4.5 as we move from now till 2050. About 14867 households will be at a high risk within the broadleaved forests below 2000 masl under RCP 4.5 as we move from now till 2050.

Of the 1774 religious structures currently recorded at the National Land Commission Secretariat, a total of 549 (30%) religious structures will be at risk under RCP 4.5 from now till 2050.

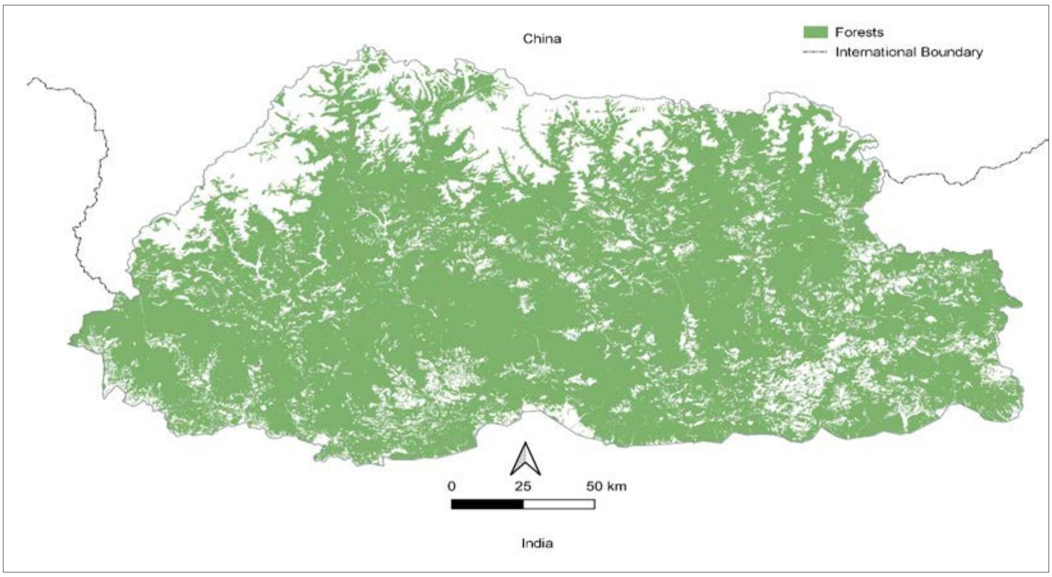
To date, despite the risks posed by the possibility of increasing forest fires, there has not been any significant investment to effectively manage forest fires. We recommend a broad suite of adaptation recommendations from now till 2050, with a focus on chir pine and blue pine forests over the next decade. Adaptation strategies will need to be simultaneously upscaled within broadleaved forests below 2000 masl. Forests at risk should be proactively managed to reduce forest fuel load. This should be supplemented by fuel clearance around key infrastructure and households at risk. Forest surrounding powerlines should also be cleared in addition to fire lines being established within forests most at risk. Importantly, forest institutions should be adequately equipped with basic firefighting equipment. These efforts should then be consolidated through strengthening mechanisms to enhance forest fire fighting response mechanisms. Given that humans are responsible for most fires in Bhutan, education and awareness building programs should be mainstreamed as part of forest fire prevention strategies. And lastly, information management and research should be strengthened to better understand, predict, prevent and manage forest fires.

Our findings which project increasing fire risks under a warming climate align closely with unfolding fire events globally, and warn us, of what may be in store, should we fail to proactively adapt to climate change. Failure to adapt and curtail the risks of future forest fires will entail significant economic and ecological costs for Bhutan. In addition to exacerbated loss of property and rapid disruptions to ecosystems and loss of biodiversity, increased and intensive forest fires will significantly contribute to Bhutan's carbon emissions, thereby – possibly – compromising, Bhutan's carbon neutral status. The consequences of a failure to adapt will be hugely disastrous for Bhutan.

As of now, Bhutan has made no significant long-term financial investment in forest fire management, beyond covering the cost of the DoFPS fire management staff. Given that projected risks are considerable across all forest types, it is imperative that substantive investment be secured to implement a dynamic and proactive fire mitigation and adaptation program. Such an investment will pay itself out in the form reduced carbon emissions, protected infrastructure, and conserved biodiversity.

# CHAPTER I: INTRODUCTION

Forests remain central to the wellbeing and prosperity of Bhutan. From providing for water and critical environmental services, forests are inexorably tied to Bhutan's food, water, and energy security. Today, with an estimated 70% of Bhutan's total land under forests (See Figure 1), Bhutan continues to remain carbon negative. Recent estimates, as of 2015, show that forests sequester a total of 9421.013 Gg of $CO_2e$ emissions (NEC 2020), far exceeding Bhutan's total GHG emissions, estimated at 3,750.563 Gg of $CO_2e$.




*Map 1. Forest cover of Bhutan (extracted from Landuse and Landcover Map for Bhutan prepared in 2016 by the Ministry of Agriculture and Forests)*

Being in the eastern Himalayas, Bhutan's forests are also an amazing repository of biodiversity. From large carnivores to birds to plants, mammals and insects, Bhutan may in fact be the last refugia for biodiversity in the eastern Himalayas (Tempa et al 2013). Furthermore, Bhutan's six agrobiodiversity zones host a wide variety of crop and livestock biodiversity.

Alongside storing biodiversity, forests provision for food, water, and energy, and stem the loss of soil and prevent land degradation (Sears et al 2018). With climate change, forests will be subjected to multiple threats ranging from novel pests and diseases to diebacks and heat related stress. Consequentially, forests will be subjected to increasing risks from forest fires (Vilà-Vilardell, L. *et al*. 2020).

As climate continues to warm, increasing fire related damages will severely reduce the provisioning of critical ecosystem services and fire related forest loss will significantly reduce Bhutan's carbon sink capacity and imperil Bhutan's ability to remain carbon neutral. Such loss will also, ultimately, compromise Bhutan's constitutional mandate to maintain 60% under forest cover for all times to come. Worryingly, fires and fire related destruction are increasing worldwide with damaging consequences on lives, ecology and economic health.

As a matter of critical concern, across the globe, many recent fires have burned ecosystems where fire has historically been rare or absent including the tropical broadleaved forests of southeast Asia and South America (Kelly et al 2019). Tropical broadleaf forests of the Afrotropical, Indomalayan, and Neotropical realms rarely experienced large fires until recently. These changes pose significant challenge for understanding how to sustain biodiversity and protect homes and infrastructure in a new era of large catastrophic fires. It also behooves us to improve knowledge and understanding of the linkages between fire, biodiversity and humans.

Fire regime, a key concept within fire science, describes the type, frequency, intensity, seasonality and spatial dimensions of recurrent fire. Fire regimes determine biodiversity and biodiversity in turn influences fire regime. For instance, plants that require fire to release seeds can be threatened by fire intervals shorter than the time needed for plants to mature and re-establish a seed bank. For animals, changes in the frequency and intensity of fire can reduce foraging and sheltering resources and increase mortality. Abrupt changes in fire regime hold significant consequence for biodiversity persistence.

In Bhutan, as of now, there is limited understanding of the extent to which fires negatively impact forests, associated biodiversity, human property and infrastructure. Furthermore, an appreciation of the extent to which fire risks will escalate into the future under a warming climate is wanting. This lack of understanding hampers the design and implementation of fire related adaptation and mitigation responses.

Given the rampant spread and high frequency of forest fires across the globe – even in previously unburnt ecosystems – it is critical that risks and vulnerabilities to forests from fires be quantified and fire prone areas be identified. Such an assessment will ensure quantification of risks to communities, biodiversity, and assets, and help inform planners and managers about land management and development in fire prone areas.

# CHAPTER II: OBJECTIVES OF THE ASSESSMENT & STRUCTURE OF THE REPORT

The objective of the current assignment is to undertake a wildfire risk assessment in Bhutan, by analyzing fire likelihood, fire behavior, and fire impact. The purpose of the assessment is to identify fire-prone areas and quantify the risks to communities, biodiversity, and assets, as well as to inform planners and managers about land management and development in fire prone areas. It also proposes prioritized adaptation options.

Chapter I provides a brief introduction on the importance of Bhutan's forests and the need to understand fire risks and impacts under a changing climate.

Chapter II provides a review of the nexus between climate, vegetation, fire, and human interactions.

Chapter III provides the objectives of the assignment.

Chapter IV describes the methods used in the study and discusses its limitations.

Chapter V presents the results from the models and spatial risk analyses and highlights risk zones under RCP 4.5 and RCP 8.5 across three-time scales: near (2021 – 2050); mid (2051 – 2070); and long (2071 – 2100).

Chapter VI prescribes adaptation priorities.

Chapter VII concludes the report by highlighting the need to focus efforts on managing forest fuels and improving response systems.

## CHAPTER III: CONTEXT SETTING – FIRES IN A CHANGING WORLD

Emissions from industrial processes, agricultural burning and wildfires are increasing the concentrations of radiatively active gases in the atmosphere, i.e., greenhouse gasses (GHG). Chief among these is carbon dioxide, but water vapor, ozone, methane, nitrous oxide, and various chlorocarbons are also important. Changes in radiative properties, are expected to affect global circulation patterns, significantly altering regional climate (Pattnayak et al. 2017, Fill et al. 2019, Almazroui et al. 2020). The effects on climate are expected to significantly impact Southeast Asia, particularly the Himalayan countries (Dorji et al. 2016, Lamsal et al. 2018).

Climate, the integration of precipitation, temperature and wind has long been recognized as a dominant factor controlling the distribution of vegetation across latitude, elevation, and aspect (Woodward 1987, Ohsawa 2009). Climate is generally defined as the average weather for the previous thirty years. While climate is a major driver of vegetation development that determines the physiognomy and chemistry of the vegetation, short term weather dominates fire potential. Throughout evolution vegetation has developed in response to changes in atmospheric chemistry and climate as well as episodic events including floods, avalanches, extreme weather, and fire (Bond and Keeley 2005, Keeley et al. 2011, McLauchlan et al. 2020). The climate-vegetation-fire dynamic has always been in flux throughout space and time (Ryan and Koerner 2012). Changes in any one element can be expected to have concatenating effects on the other two, and thus feedbacks (Ryan 1991, Ryan and Opperman 2013) (figure 1).

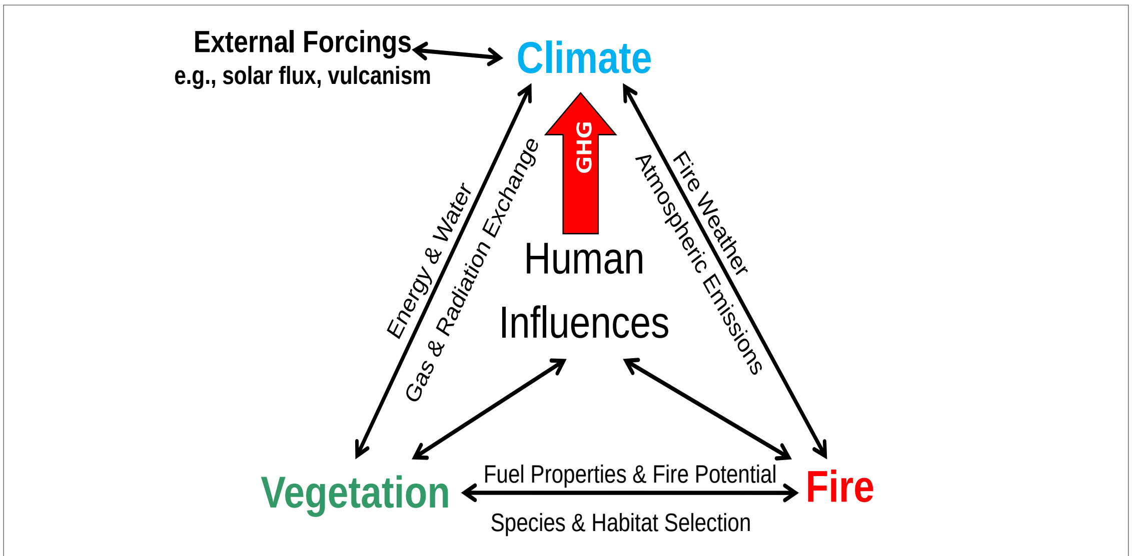



*Figure 1. Climate is dynamically coupled to vegetation, fire, human activities and external forcings (adapted from Ryan et al. 2012).*

Figure 1 illustrates these dynamic interactions and humanity's role in changing the face of the earth. Policy makers and managers need to recognize climate, vegetation and fire are dynamically coupled, and historically deeply linked to human culture (Bond and Keeley 2005; Bowman et al. 2011, 2013; Scott et al. 2015). All aspects of human endeavor can be expected to be affected to some degree.

## 1.1 Climate and Vegetation

Biophysically, vegetative productivity is determined by the available water, energy, and nutrients. Water and energy budgets are affected by latitude, elevation, aspect, slope steepness, and cloud cover. Precipitation and temperature are recognized as the dominant factors affecting the potential vegetation that could grow on a site in the absence of disturbance (LaPiere et al. 2016, Mishra and Maimali 2017, Pareek 2017, Gwal et al. 2020). These also directly impact soil development, which is a critical element of site productivity via a soil's water and nutrient holding capacities. Latitude and proximity to oceans result in macroclimates with relatively reliable temperature and precipitation regimes. Macroclimates experience episodic shifts linked to ocean-atmosphere circulation patterns, (e.g., ENSO, PDO, IOD). Macroclimates are recognized as important elements in vegetation zonation. Warming climate is expected to shift vegetation zones farther from the equator, and up in elevation. This is critical at regional to continental scales (Davies-Barnard et al. 2015).

At sub-regional and landscape scales terrain exerts increasing influence on site productivity (Gwal et al. 2020). Given the adiabatic lapse rate in the atmosphere and the influence of terrain on orographic precipitation, or conversely a rain shadow, elevation has a major effect on mesoclimate. Aspect and slope also affect the energy and water budgets via their influence on solar insolation and water retention, respectively. Likewise, cloud cover has a major influence on water and energy budgets (Scholl et al. 2011). The combined effects of terrain: slope, aspect and elevation, and cloud cover cause vegetation zones to shift in mountainous areas. Terrain complexity therefore has a dominant effect on the species composition, density, physiognomy, and spatial distribution of vegetation. Vegetation zones are expected to migrate to higher elevations under warming climate (Sidgel et al. 2018, Mainali et al. 2020), but existent zones may be extirpated from some mountain ranges leading to habitat fragmentation.

By the end of this century Bhutan is projected to warm by 0.8$^{o}$ C to 2.8$^{o}$ C under the RCP 4.5 scenario and by 0.8$^{o}$ C to more than 3.2$^{o}$ C under the 8.5 scenario. Precipitation is expected to increase by as much 30 percent with wet-season (JJAS) precipitation increasing by 5 to 15 percent (Das et al. 2016, Dorji and Tamang 2019). These changes will affect eco-physiological processes and competitive status of plants and animals, differentially by species and age. Climate change alone can be expected to affect vegetation zonation and the species composition of future plant communities and faunal habitats. Warming can be expected to raise elevation zones. Because species have physiological optimums/tolerances to temperature, precipitation and atmospheric chemistry, inter-specific competitive relationships will change in uncertain ways. Because species have life-cycle attributes that affect their mobility, not all species will be able to migrate to emerging niches. Present-day communities can be expected to disaggregate, and new community associations emerge. Limited knowledge of species physiological requirements and competitive relationships create challenges for future biodiversity projections.

## 1.2 Vegetation and Fire

Living and dead vegetation constitute the fuel essential for combustion (Scott and Burgan 2005, Pickering et al. 2020). Conceptually, the wildfire potential of an area can be viewed as a function of site productivity and the cumulative frequency of moisture deficit. The amount of fuel on a specific site varies with the ratio of productivity to decomposition and with the history of past disturbance and land use. For example, herbivory, particularly by domestic animals removes fine fuels thereby reducing potential for fire to spread. Conversely, storm damage, avalanches, insect outbreaks and logging often create temporary spikes in fuel volume and increased fire potential (Cawson et al. 2018, McColl-Gausden and Penman 2019, Leverkus et al. 2020).

Fire is a major ecosystem process in many of the world's ecosystems (Bond and Keeley 2005; Keeley et al. 2011; He et al. 2012, 2019; Scott et al. 2015). Vegetation and fire integrate across multiple spatial and temporal scales (Ryan and Koerner 2012). Fire has immediate impacts to individual organisms upon exposure to heat and longer-term impacts to organisms' habitats at plot, stand and landscape scales. The behavior (Werth et al. 2016) and effects (Ryan 2002, Lutes and Keane 2017) of a fire are determined by the legacy conditions, actual (real-time) fire weather and suppression activities (Kaufmann et al. 2009) (figure 2). The impact of the fire on the biota, infrastructure, ecosystem services and the like, are also influenced by post fire events (e.g., precipitation, insects, disease, erosion, etc.) acting upon the fire-altered environment (Certini 2013; Iyas and Khan 2005; Neary et al. 2005; Cerda and Robichaud 2009; Ryan and Koerner 2012; Hood and Lutes 2017; Pyke 2017; Hood et al. 2018; Day et al. 2020; Simpson et al. 2020).

Fire regimes emerge over time in response to composition and physiognomy of the vegetation, and the prevalence of ignition sources. An ecosystem's fire regime is characterized by its frequency or fire return interval, the seasonal timing of fire occurrence, typical fire size, fire intensity, and burn severity (aka fire severity). Fire type, i.e., ground fire, surface fire, or crown fire, is also used in fire regime descriptions (McLauchlan et al. 2020). Uniform cycles, implied in the spirals in Figure 2, lead to stable repeatable vegetation-fire response patterns. Changes in climate drivers, land use practices and exotic/invasive species introductions alter vegetation-climate patterns sending sites and ecosystems on new evolutionary trajectories with uncertain futures (Day et al. 2020, Konsam et al. 2020).

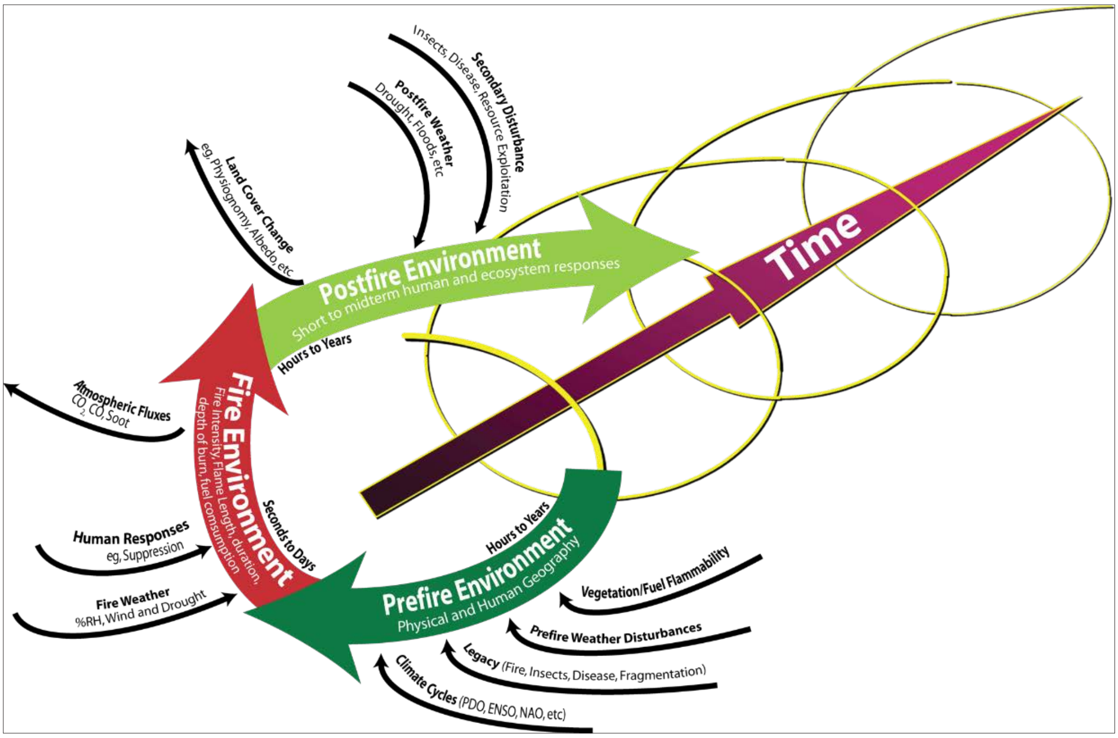



*Figure 2. Fire behavior and the direct effects of fire are driven by the prevailing conditions, fuels and weather. Departures/changes in the mean fire return interval (spirals) affects all aspects of the ecosystem and resultant ecosystem services (adapted from Kauffmann et al. 2009)*

Vegetation types are broad descriptions that are applied in numerous ecological and management contexts. In the context of fire, living and dead vegetation constitute the fuel that is combusted (Cochrane and Ryan 2009, Goldammer 2017). Fires rarely consume all of a site's biomass above the mineral soil interface. Significant combustion of organic matter within the mineral soil is minimal in all but the most severe fires (Ryan 2002, Neary et al. 2005, Keeley 2009). The total fuel is the fuel that can burn in a worst-case fire. For example, sound tree stems remain after intense crown fires. The available fuel is that portion of the biomass that can actually burn in a given fire and are thus not included in total fuel calculations. The science of fire behavior prediction is the science of determining the available fuel and the rate at which its energy will be released by combustion (Rothermel 1972, Finney 2004). The chemical composition of the vegetation and how its mass and particle size distribution are configured in three-dimensional space dictate whether and how vegetation burns. Vegetative physiognomy (e.g., grass, shrub, tree) are general descriptions for conveying information about the types of wildland fuels present. A more specific term “fuel bed” describes the kinds of fuels that are likely to burn (Figure 3). Fuel models are stylized descriptions of fuel bed characteristics that define input variables for computation of fire behavior (Scott and Burgan 2005) or effects (Reinhardt et al. 1997, Lutes and Keane 2017). While there is some guidance for parsing mensurational data from forest inventories or ecological surveys into fuel bed components, it requires seasoned judgement and calibration via expert opinion of fire specialists with local experience (Prichard et al. 2019). Such are in the early stages of development in Bhutan (Vilà-Vilardell et al. 2020).

Fuel beds are commonly divided into strata (Figure 3): ground fuels (mosses, lichens and detritus in contact with the soil, e.g., litter and duff), surface fuels (grasses, forbs, shrubs and saplings nominally < 2 meters high), and aerial fuels (tall shrubs, trees and epiphytes > 2meters high).

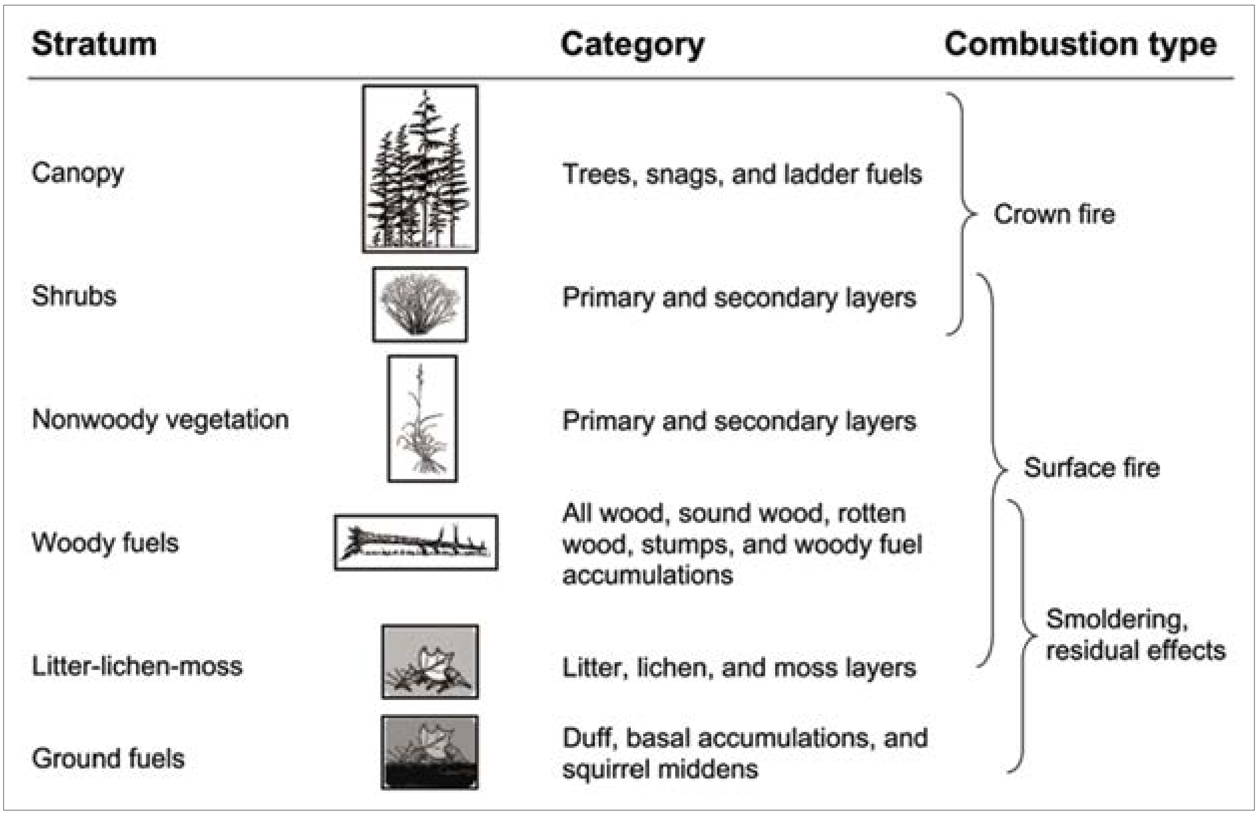



*Figure 3. Fuel bed strata and components (Ottmar 2015)*

However, these are historic conventions. The spatial continuity of fuel beds in three-dimensions is poorly understood and an area of active research (Linn et al. 2002; Parsons et al. 2011, 2017). Fuel bed properties are critical to fire potential. Wetting, drying, and burning rates depend on fuel elements’ particle size distribution (surface area to volume ratio) and spatial arrangement (fuel bed bulk density). Traditionally fuels have been parsed into size classes for field measurements and fire modeling (Rothermel 1972, Scott and Burgan 2005, Wotton et al. 2009) based on the fuel equilibrium moisture ($Mc_e$) time-lag principle (e.g., 1-hr, 10-hr, 100-hr, & 1,000-hr) roughly corresponding to (0 - 0.6 cm, 0.7 - 2.5 cm, 2.6 - 7.5 cm, and 7.6 - 23.0 cm diameter). This is based on the observation that non-humified fuels are nominally cylindrical. The 1- and 10-hour fuels are primarily responsible for a fire’s rate of spread and intensity. Mosses and lichens respond to changes in relative humidity on second to minute time scales. Mosses, lichens, 1-hour, and 10-hour fuels are collectively referred to as fine fuels. These respond rapidly to changes in relative humidity resulting in diurnal changes in fire behavior. The 100-hour and 1,000-hour fuels are collectively referred to as coarse woody debris (CWD) (Keane et al 2013). One-hundred hour and longer-drying fuels play a lessor role in fire behavior but an increasingly important role in determining fire effects (Albini and Reinhardt 1995, Ryan 2002, Neary et al. 2005, Keeley 2009, Cerda and Robichaud 2009, Ryan and Koerner 2012). The dynamic coupling between near-surface organic soil horizons, the capillary fringe and water table (hydroperiod) fluctuations brings into play physics beyond the scope of time-lag-equilibrium moisture content principles. Thus, drought codes, e.g., Palmer Drought Index, better represent moisture relations of these fuels (Wotton et al 2009, Riley et al. 2013).

Fire potential depends not only on the fuel bed properties but also weather and terrain. The energy content of fuel bed biomass varies modestly (Rothermel 1972). The most critical chemical property is the moisture content which varies seasonally (wet season vs. dry season), diurnally, and episodically with ocean-atmosphere circulation (e.g., ENSO, PDO, ISM, etc.) (Myers et al. 2015, Kathayat et al. 2018, Gupta et al. 2020).

In general, the total amount of fuel increases from a grassland to shrubland to forest (Figure 3). However, subtropical grasslands are more productive than semi-arid shrublands, for example. So, variations in fuel volumes are strongly tied to the site's specific climate and the site's inherent productivity. Productive forest sites exposed to frequent fire support available fuels in grasses and shrubs that can burn during most dry seasons leading to altered fire regimes (Goldammer 2017). Grassland fuels are fully exposed to sunlight and wind. As a result, they are frequently in a burnable condition. When grass fuels are plentiful and continuous rapid rates of spread are possible, particularly on steep slopes and with brisk winds. However, because the mass of fuel is quickly consumed most of the fire's energy is transferred to the atmosphere and little soil heating occurs (Ryan 2002). Shrublands are fully exposed to sun and wind and often exhibit extreme fire behavior at higher stand densities. However, shrubs beneath forest canopies are sheltered from sun and wind. Thus, favorable burning conditions occur less frequently. When conditions are favorable these fuels play an important role in the transition from surface fire to crown fires as so called "ladder fuels." Transitions from surface fire to crown fire in coniferous forests result in rapid spread rates, high intensity and long-range broadcasting of burning embers (spotting) (Albini 1976, Finney 2004, Wotton et al. 2009). With forest densification primary production shifts to shrub and canopy foliage thereby reducing fine fuels near the surface. Species composition increasingly shifts to shade-tolerant species, fuel wetting and drying cycles shift to longer time frames, and within-canopy wind speed decreases. The modified fuels and microclimate translate into reduced potential for fires to burn extending fire free periods (Cawson et al. 2018, Pickering et al. 2020). However, during drought periods closed evergreen forests exhibit extreme fire behavior and severity resulting in maximum damage to infrastructure and site degradation (Certini 2013; Werth et al. 2011; Lecina-Diaz et al. 2014). Cool-moist forests (e.g., *Abies*, *Picea* and *Tsuga*) typically only burn under late dry season, extreme drought conditions. "Hold-over" fires smoldering in deep duff and rotten logs are then common and present considerable obstacle to fire control. Extreme drought is not, however, a requisite for fire in such forests. They can burn intensely under low humidity and high wind. Such events are infrequent, tend to be of short duration, but are highly lethal to overstory trees (Ryan 2002).

Vegetation and fire dynamics exist at multiple scales. Over evolutionary time scales plants and animals have developed multiple adaptions to fire (Keeley et al. 2011, He et al. 2012). These include thick bark, bud scales, epicormic buds and leaf sheaths that insulate meristematic tissue; sprouting from basal or underground structures (e.g., rhizomes, corms, lignotubers, bulbs); and fire-stimulated flowering and seed dispersal) (He et al. 2012; Pausas and Keeley 2014, Pyke 2017, USDA 2021). Some species store seeds in the soil for long periods and sprout only after fire (Konsam et al. 2020, Keeley and Pausas 2018).

Although fire has been a major ecosystem process throughout recent geological time, some regions show relatively few fire adaptations indicating that natural ignition sources, lightning and vulcanism, were rare (Bowman et al. 2009, Taylor 2010, Goldammer 2017). Such ecosystems are fuel limited either because biomass production is quite low or ample biomass is present but is rarely dry enough to burn. The modern presence of fire in these ecosystems are directly attributable to human land use (Gupta et al. 2009, Hunt et al. 2014, Dorji et al. 2016, Jha et al. 2021). In contrast, some regions have numerous natural fire-adapted species associated with identifiable fire regimes. In some areas lightning is common, but fires are limited by the time necessary to produce sufficient biomass to carry a fire and human ignitions initiate little additional vegetative change. In contrast, subtropical ecosystems throughout the world experience frequent lightning fire (Goldammer 2017). In yet other cases ecosystems have been heavily altered by human activity such that a small number of native species and numerous exotic fire-adapted species have come to dominate the vegetation resulting in human-dominated ecosystems with permanently altered fire regimes. Given the history of land use, steep environmental gradients, diverse microclimates of the Himalayan Mountains, all such conditions are likely to occur over short distances.

Given the long evolutionary history of vegetation development with fire even long-unburned forests have species capable of rapidly responding following fire. Fire behavior ebbs and flows with changes in fuels, weather, and terrain (Ryan 2002, Goldammer 2017). Changes in plant community are commonly accompanied by transition zones where more moderate fire behavior selectively kills susceptible vegetation that subsequently become fuel for the next fire. The modified fuels and microenvironment predispose the new community to another fire. If ignitions are present all elements for a fire regime shift are present. The extent to which climate change increases the frequency and duration of favorable burning conditions will dictate the floral and faunal responses to human and lightning ignitions.

### 1.3 Climate and Fire

Mesoclimate has an overarching influence on vegetation development. Mesoclimates describe in a general way the type of fire weather to expect in a region (c.f., Ryan et al. 2013). Fire Climate Zones indicate the overarching potential of a region to support fire, and thus reflect the relative level of fire business to be expected. Given the absence of vegetation in alpine/glaciated areas, Bhutan appears to have three distinct fire climate zones: subtropical foothills, temperate montane, and high montane-subalpine. These zones can be expected to migrate upwards in response to climate change (Chettri et al. 2018, Mainali et al. 2020).

Although precipitation is generally expected to increase in Bhutan (Das et al. 2016, Doji and Tamang 2019) increases are expected to be less from east to west. Total precipitation is not, however, as critical as the intra- and inter-annual patterns of precipitation. Climate change is expected to increase the frequency of severe storms and lightning (Romps et al. 2014, Veraverbeke et al. 2017). Lightning patterns are, however, uncertain and will likely vary with latitude and terrain (Finney et al. 2018). Increased lightning may result in increased ignitions if fuel beds are dry and receptive. The two highest lightning zones in the United States are the southeast and southwest. In these areas “dry lightning” is common in advance of the Gulf of Mexico and Baja monsoon seasons, respectively. Both regions have high natural fire frequencies and numerable fire-adapted plants. Fires are particularly troublesome in number, duration and severity in drought years. Similar pre-monsoonal patterns occur in Central and South America, Africa, and southern Asia (Goldammer 2017). If lightning precedes wetting monsoon rains, fires in rugged, inaccessible terrain could emerge as major disturbances affecting biodiversity and ecosystem services.

Microclimate near the surface ~< 1 meter is critical for fire initiation and propagation. The most critical meteorological variable affecting fuel moisture is relative humidity (RH). RH directly affects fuel moisture via the time-lag/equilibrium moisture content ($Mc_e$) relationship. $Mc_e$ is little affected by atmospheric temperature per se. However, the intensity of solar radiation does affect fuel temperature at the boundary layer and therefore the ease of ignition. Thus, cloud cover affects fire initiation. Temperature also affects the ease with which lethal temperatures can be reached and, therefore, has a minor effect on fire survival. Wind near the surface is a critical element of fire behavior (Rothermel 1972; Wotton et al. 2009, Werth et al. 2016). Wind speed decreases with increasing forest canopy density.

Wildland fire science and management has a longstanding tradition of defining fire potential as a function of fuels, weather and terrain, i.e., the "fire environment" concept. As previously noted, fuels are a property of the vegetative community (total fuel) and drying trends (available fuel). RH and wind speed are critical drivers of fire behavior (Rothermel 1972; Scott and Burgan 2005, Wotton et al. 2009; Werth *et al* 2016). Terrain (slope, aspect and elevation) affects diurnal temperature, RH, and wind profiles. Slope steepness is a major contributor to a fire's rate of spread. Terrain exerts another influence of critical importance in mountainous regions. In flat or gently-undulating terrain microclimate is more uniform and similar to the mesoclimate. As a result, the entire landscape either is in a burnable or non-burnable condition. Fires tend to be larger on flat terrain. In contrast, in complex terrain, total and available fuel vary over short distances. Warmer exposures are frequently dry enough to burn at least a few hours each day during the dry season. Cooler exposures are infrequently dry enough to burn, and then usually only after extended drying. Fires tend to be smaller in complex terrain, but more difficult to control.

Seasonal drying trends and episodic drought increase the amount of fuel available to burn thereby enhancing real-time fire behavior, increasing the complexity and difficulty of fire suppression and increasing burn severity (Ryan 2002). Delays in the onset of the rainy season or early snow melt potentially lead to extended fire seasons depending on daily drying trends (e.g., RH, fog-drip, and cloud cover). Changes in ocean/atmospheric circulation affect drought cycles. If shifts in the mesoclimate are associated with longer and dryer fire seasons and more frequent droughts, fire regimes will be altered. The increased frequency and severity of fire will impact humans, ecosystem services, and biodiversity. Significant increases in fire can be expected to directly affect biodiversity via habitat destruction and fragmentation. Recently burned landscapes are susceptible to erosion (Cerda and Robichaud 2009). If the frequency and extent of burning increases significantly major disruptions in the timing, flow and quality of water can be expected (Tariq et al. 2021). Given the importance of relative humidity and wind to fire spread and the lack of spatial- and temporal-scale resolution in climate prediction models, policy and management needs to focus on strategic vegetation management and increased fire management capabilities.

### 1.4 Human Interactions with Fire

The observable patterns of human's historical use of fire to promote grazing and agriculture inform our understanding of ancient practices (Casillo et al. 2016, Jha et al. 2021). Roughly 40,000 years ago a new hunter-gatherer/fire-starter emerged on the southern Asia landscape (Miao et al. 2020, Jha et al. 2021). Hunters used fire to drive, attract, and expose game. Gatherers used fire to promote favored plants and improve habitat. As societies developed, traditional ecological knowledge expanded (Jha et al. 2021). Fire was used to improve forage production, clear and fertilize land, manage predators and pests, and provide defensible space. There is evidence of continuous, increasing burning, deforestation and agricultural land uses over the last 2,000 years in south-eastern Bhutan (Miyamoto et al. 2012).

The behavior and effects of fire are of concern to policy makers and managers because of their social-economic consequences (DeFries and Nagendra 2017). Preparation to manage wildfires, or use prescribed fire, is reliant on an understanding of fire behavior, fire effects and risks. All are essential inputs to strategic and tactical planning. Sound risk management requires knowledge of both the values at risk and the potential for fire to harm those values (Calkin et al. 2011; Thompson et al. 2011, Dunn et al. 2021). Fire behavior describes the spread and intensity of a fire and thus the degree of difficulty for suppression. Fire effects are often of greater concern due to the potential long-term impacts on ecosystem services and biodiversity (Kelly et al 2021).

Fire behavior and effects are dictated by the prevailing conditions at the time of fire (Figure 2). Fire chemically alters residual biomass including the release of gases, aerosols, and particulate matter to the atmosphere, and it releases energy. Fire effects occur at both spatial and temporal scales. Some effects are instantaneous while others occur over time. Spatial scales vary from the micro-scale to landscape scale. Fire effects are often considered direct or indirect. As spatial and temporal scales increase, it is increasingly difficult to ascribe an observed change as a direct effect. Fire has few direct effects: it consumes biomass thereby releasing energy and minerals. Over 100 chemical compounds have been identified in wildland fire smoke (Jayarathne et al. 2018). The energy released is dynamically coupled to the atmosphere in the short term, pyro-cumulous clouds being an extreme example (Werth et al 2016).

The energy released also works to change physical and biotic site factors, killing plant and animal tissue, for example (Hood *et al*. 2018). The terms “fire severity” and “burn severity” are commonly used to describe the suite of changes directly affected by fire (Ryan 2002). The primary attributes of burn severity are the amount of biomass consumed and the amount of the biota killed. A plant may be top-killed (direct) yet survive via sprouting from below-ground meristems (indirect). The soil surface might be denuded by fire (direct) then eroded by rain or wind (indirect). Distinctions between direct and indirect effects has little relevance in policy discussions and management activities. However, such distinctions do come into play when designing prescriptions for using fire to manage vegetation, developing post fire rehabilitation actions, and in developing monitoring frameworks to support adaptive management.

# CHAPTER IV: MODELLING FOREST FIRE RISKS & IMPLICATIONS IN BHUTAN FROM A CHANGING CLIMATE

## 4.1 Assessing Current Situation

We compiled fire occurrence data available from the Department of Forests and Park Services (DoFPS) of the Ministry of Agriculture and Forests (MoAF). We tabulated area burnt statistics by location and forest type and created a heatmap in QGIS to visually appreciate the spatial distribution and extent of extant forest fire patterns.

## 4.2 Predicting Future Fires Scenarios Using FlamMap

We used fire behaviour modelling to characterize fire hazards of Bhutan's forest ecosystems. The analysis of fire hazards, i.e., the physical characteristics of fire, is the first step towards a complete fire risk assessment, which includes fire effects on the biophysical and socioeconomic systems. We used FlamMap 5.0 (Finney et al., 2016), a spatially explicit fire behaviour model, to simulate surface fire behaviour under different representative concentration pathway (RCP) scenarios (Moss et al., 2010). FlamMap strength lies in its potential to show the effect of spatial fuel arrangement and topography on fire behaviour, as environmental conditions are held constant throughout the simulation. The model calculates fire behaviour on each pixel independently, by assuming that every pixel from the landscape burns (Finney, 2006). As fire behaviour indicators we used flame length (m) and rate of fire spread (m $min^{-1}$). Simulations were done in 30 x 30 m pixels.

FlamMap input parameters are grouped into three blocks: topography data, fuel data, and weather data. *Topography data* (elevation, slope, and aspect) are input as raster layers. Topography was derived from a Digital Elevation Model at 30-meter resolution.

*Fuel data* include canopy fuels and surface fuels. Forest ecosystems of Bhutan were classified according to the land use land cover categories of DoFPS (2016a) and expert criteria: broadleaf forests below 2000 m, broadleaf forests above 2000 m, chir pine forests, blue pine forests, mixed conifer forests, and fir forests. In FlamMap, *canopy fuels* (canopy cover, stand height, and canopy base height) are used to estimate the amount of radiation and wind reaching surface fuels and the probability of torching. We estimated canopy fuel parameters from previous studies done in Bhutan (Vilà-Vilardell et al., 2020, DoFPS, 2017, Gratzer et al., 2004, Gratzer and Rai 2003) and data of the National Forest Inventory (DoFPS, 2016b) (Table 1). . FlamMap uses canopy bulk density to calculate spread of a crown fire. In this study we focused on surface fire rate of spread and flame length, therefore canopy bulk density was set constant at 0.2 kg $m^{-3}$

*Table 1. Canopy fuel parameters set as input for each forest type.*

| | Blue pine | Broadleaf | Chir pine | Fir | Mixed conifer |
|---|---|---|---|---|---|
| Stand height (m) | 16.9 | 13.9 | 12.2 | 13.5 | 14.1 |
| Canopy base height (m) | 6.9 | 4.6 | 4.4 | 4.5 | 4.7 |
| Canopy cover (%) | 67 | 60 | 30 | 61 | 50 |

Surface fire spread is characterized through fire behaviour fuel models, which are a set of *surface fuel* parameters that define the main carrier of fire and are used for Rothermel's mathematical fire spread model (Rothermel, 1972). A fuel model includes live and dead fuel load, fuel bed depth, surface-area-to-volume ratio, moisture of extinction, and heat content.

Prior to simulation, we analyzed the fire behavior sensitivity of each forest type to different fuel models in order to *(i)* choose the most appropriate fuel model which resembles the behavior of a fire in that forest and *(ii)* take into account an increase in fuel load and change of fuel composition due to climate change (Figure 4). In other words, the fuel model which better mimicked the behavior of a fire in each forest was assigned to RCP 4.5 time slices 2021-2050 and 2051-2069, and to RCP 8.5 time slice 2021-2050. We considered that under these scenarios forest structure and composition would not change significantly nor would the behavior of a fire. In contrast, the rest of time slices for both RCP scenarios were assigned a fuel model which better represented the future composition of the forest given an increase in $CO_2$ into the atmosphere. Main fire carrier of fuel models of the family TL is litter and dead woody fuels, main fire carrier of the family TU is forest litter with herbaceous or shrub fuels (Scott and Burgan, 2005). Fuel models used are those described in Scott and Burgan (2005). Based on expert opinion, the final set of fuel models used is shown in Table 2.

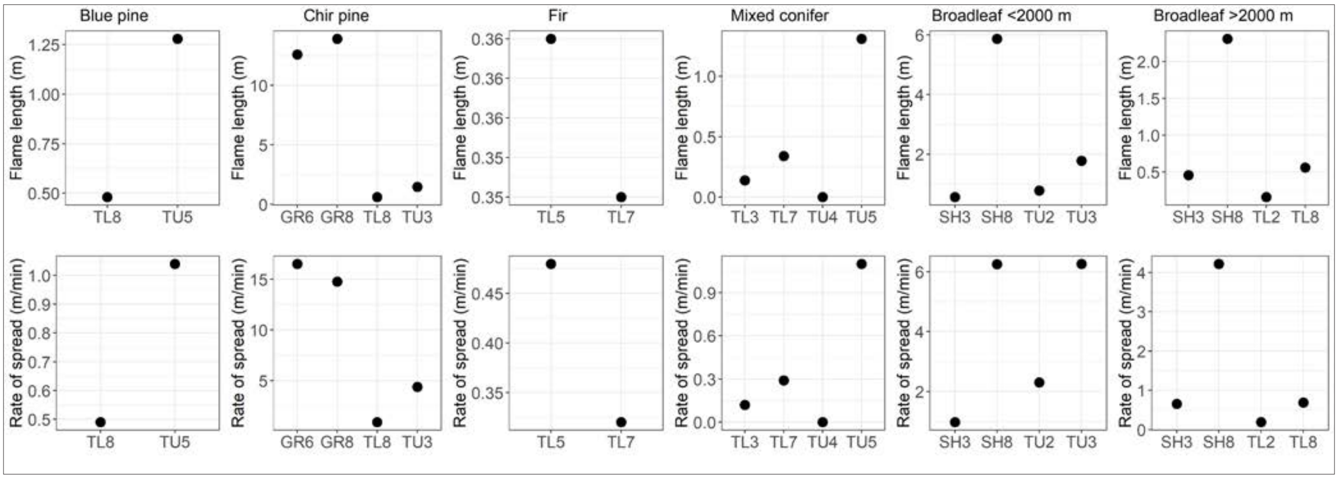



*Figure 4. Outputs of the fuel models tested per forest type.*

*Table 2. Fuel models used to model fire behaviour for each forest type and climate scenario.*

| | Time Slice | Period | Blue pine | Broadleaf <2000 masl | Broadleaf >2000 masl | Chir pine | Fir | Mixed Conifer |
|---|---|---|---|---|---|---|---|---|
| RCP 4.5 | 2021 – 2050 | Short | TL8 | TU2 | TL2 | TL8 | TL7 | TL3 |
| | 2051 – 2069 | Mid | TL8 | TU2 | TL2 | TL8 | TL7 | TL3 |
| | 2070 – 2099 | Long | TU5 | TU3 | TL8 | TU3 | TL5 | TU5 |
| RCP 8.5 | 2021 – 2050 | Short | TL8 | TU2 | TL2 | TL8 | TL7 | TL3 |
| | 2051 – 2069 | Mid | TU5 | TU3 | TL8 | TU3 | TL5 | TU5 |
| | 2070 – 2099 | Long | TU5 | TU3 | TL8 | TU3 | TL5 | TU5 |

Besides fuel structure, another key parameter to model fire behaviour is the moisture content of the fuel particles. Fuel moisture content affects their rate of combustion, influencing fire intensity and spread. Dead fuels moisture content highly depends on daily weather changes, whereas live fuels moisture content is more influenced by seasonal weather changes. We used fuel moisture scenarios defined in Scott and Burgan 2005 as input for the simulation (Table 3), following RCP emissions approach (Moss et al., 2010).

*Table 3. Moisture content of dead and live fuels per climate scenario used for the simulations.*

| | Time Slice | Period | 1h | 10h | 100h | Herbs | Shrubs | |
|---|---|---|---|---|---|---|---|---|
| RCP 4.5 | 2021 – 2050 | Short | 9 | 10 | 11 | 90 | 120 | Moderate |
| | 2051 – 2069 | Mid | 6 | 7 | 8 | 60 | 90 | Low |
| | 2070 – 2099 | Long | 6 | 7 | 8 | 60 | 90 | Low |
| RCP 8.5 | 2021 – 2050 | Short | 9 | 10 | 11 | 90 | 120 | Moderate |
| | 2051 – 2069 | Mid | 6 | 7 | 8 | 60 | 90 | Low |
| | 2070 – 2099 | Long | 3 | 4 | 5 | 30 | 60 | Very Low |

*Weather data* includes measures of temperature, relative humidity, precipitation, wind speed, and wind direction. We modelled fire behaviour using RCP 4.5 and RCP 8.5 scenarios for the intervals 2021-2051 (short-term), 2052-2069 (mid-term), and 2070-2100 (long-term) (Taylor et al., 2012). We used average weather values from January, February, and March, as these are the driest months and the peak of the fire season in Bhutan (Chhetri, 1994). Minimum and maximum temperature were taken from downscaled projections of the MIROC5 climate model. Precipitation was set at 0 for all scenarios. We created relative humidity scenarios using historical records for the period 1989-2019 (Hydromet, 2020). Periods 2021-2051 and 2052-2069 were constructed using the 75$^{th}$ and 85$^{th}$ percentile of relative humidity for both RCP scenarios, respectively, and period 2070-2100 was constructed using the 85$^{th}$ percentile for RCP 4.5 and the 97$^{th}$ percentile for RCP 8.5.

Fire behavior models are a very useful tool to spot areas with higher fire risk. However, some important factors that also affect fire behavior are overlooked by the models, for example mistletoe presence and coarse dead wood, and must be acknowledged when interpreting simulation results.

## 4.3 Quantifying and Prioritizing Risks & Vulnerability

We first classified both ‘flame length’ and ‘rate of spread’ under 4 classes in ArcGIS using the Natural Breaks (Jenks) function which assigns classes to minimize the squared deviation within each class. We then combined the classes of both ‘flame length’ and ‘rate of spread’ to come up with four risk classes: ‘low’, ‘medium’, ‘high’, and ‘very high’.

Using R and ArcGIS, we extracted forest areas under the four risk classes, for both RCP scenarios and the three time slices. We took forest areas as a proxy for risks to biodiversity. And to estimate risks to production circles, we quantified the number of houses which fall under different risk categories.

Rural Household and rural infrastructure locations were obtained from the Population and Housing Census of Bhutan 2005 (PHCB 2005) data collection. The household and rural infrastructure locations have been published in the Atlas of PHCB 2005. We used the 2005 data instead of the more recent 2017 data since GPS points for individual infrastructure is only available for 2005. We assume that using the actual GPS points would render us a much more accurate estimate of actual households under risks in different Gewogs of Bhutan. We also used GPS locations for religious structures and educational institutes available with the National Land Commission Secretariat (NLCS) of the Royal Government of Bhutan.

We ranked Gewogs at higher risk for the 2021-2050 time slice, combining the information about forests and households at risk, to prioritize areas where adaptation measures should be first taken. To focus our presentation of results, we combined ‘high’ and ‘very high’ risk classes and present them as high risk areas.

## 4.4 Implications of 'Fire Environment' Assumptions

Future fire potential in Bhutan will depend on the frequency, timing, and density of ignitions as well as the actual fire environment. The influence of lightning on ignitions will remain uncertain and is largely beyond the influence of policy and management. The potential for human-caused ignitions is the subject of fire prevention programs. In modeling future fire potential, we have looked only at the potential changes in the fire environment. Fire modeling in climate change scenarios involves making assumptions about the future fire environment: climate/weather, vegetation/fuels, and terrain influences. We recognize that daily, seasonal, and decadal variations in precipitation, relative humidity and wind are unknown currently. We have assumed that there will be significant periods of time in future climates where fire weather will be conducive to fire spread under the various RCP scenarios.

A critical element in this assessment is the projection of future fuel beds. We have used general fire regime and vegetation dynamic principles to guide selection of future fuel conditions. The selection fuel models are inherently subjective. The fuel models are mathematical expressions of fuel bed properties. They are an agglomeration of living and dead vegetative elements. Fire potential varies with changes in the chemistry and physical properties of these elements in three-dimensional space, not the species composition per se. Globally, biomes exhibit repeating patterns of vegetation physiognomy and fuel bed properties. The 40 fuel models in Scott and Burgan (2005) represent a robust range of identifiable fuel beds to a level of detail sufficient to support management and policy decisions. Our selection of future fuel beds is consistent with observed patterns elsewhere in the world. They are, however, provisional and should be subjected to place-based synthesis and refinement.

# CHAPTER V: RESULTS – INCREASING RISKS FROM FOREST FIRES & IMPLICATIONS

To frame adaptation strategies for the next decade, we focused on highlighting results for the short time frame (now till 2050) under the RCP 4.5 scenario. Detailed results in the main text are mostly limited to projections for RCP 4.5 from now till 2050. Results for other scenarios and time slices are appended in the form of consolidated GIS maps and datasheets. We combined 'high' and 'very high' risk classes under one single high fire risk category, and present results as such.

## 5.1 Causes, Current and Historical Extent of Forest Fires

Forest fires in Bhutan continue to take a substantial toll on wildlife and biodiversity with annual fire incidences averaging about 57 events (Figure 5) and scarring an average of about 200 ha annually[1]. These forest fires are not evenly distributed across the country (Map 2), with Dzongkhags such as Thimphu, Wangdue Phodrang, Punakha, Mongar, Lhuentse and Trashigang seeing the most fires (Map 3).

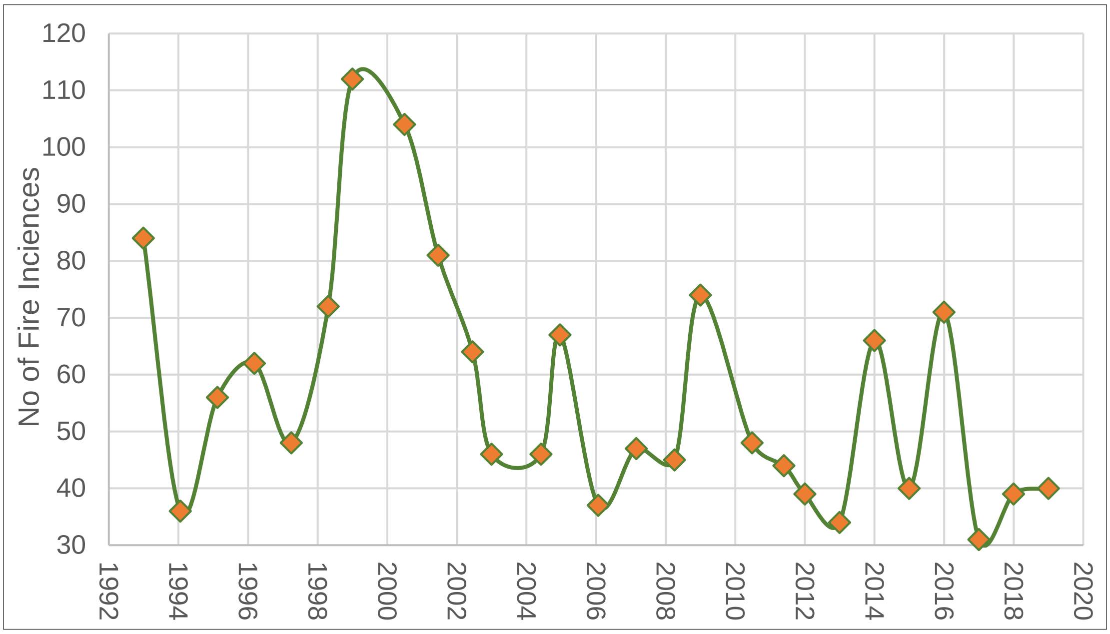
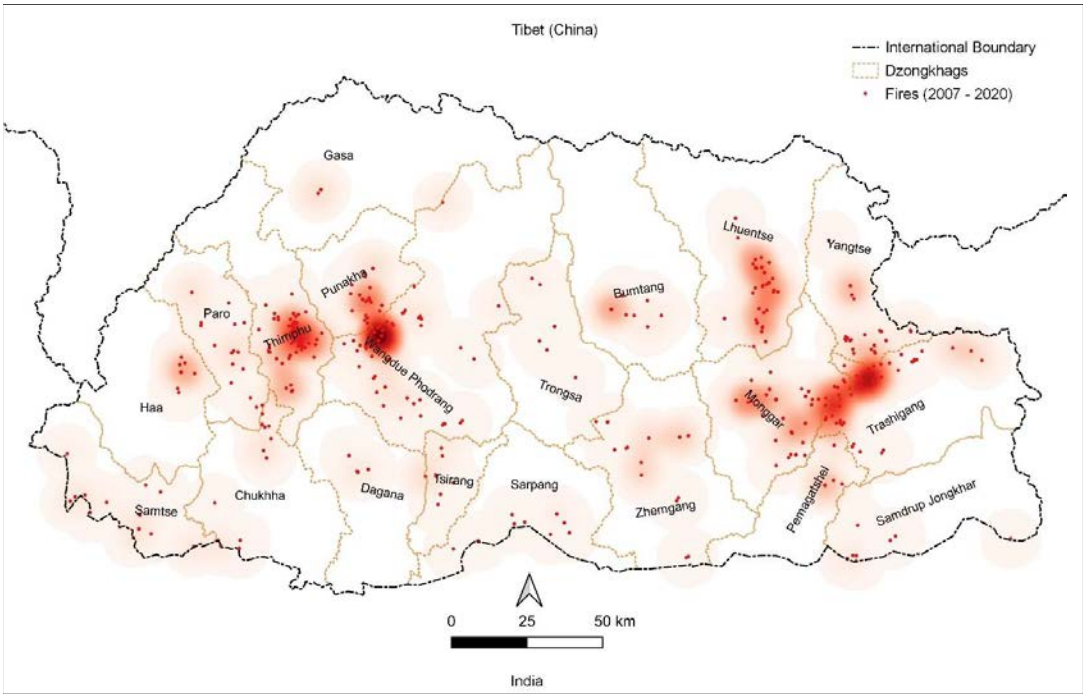



*Figure 5. Number of fire incidences from 1992 till 2019*

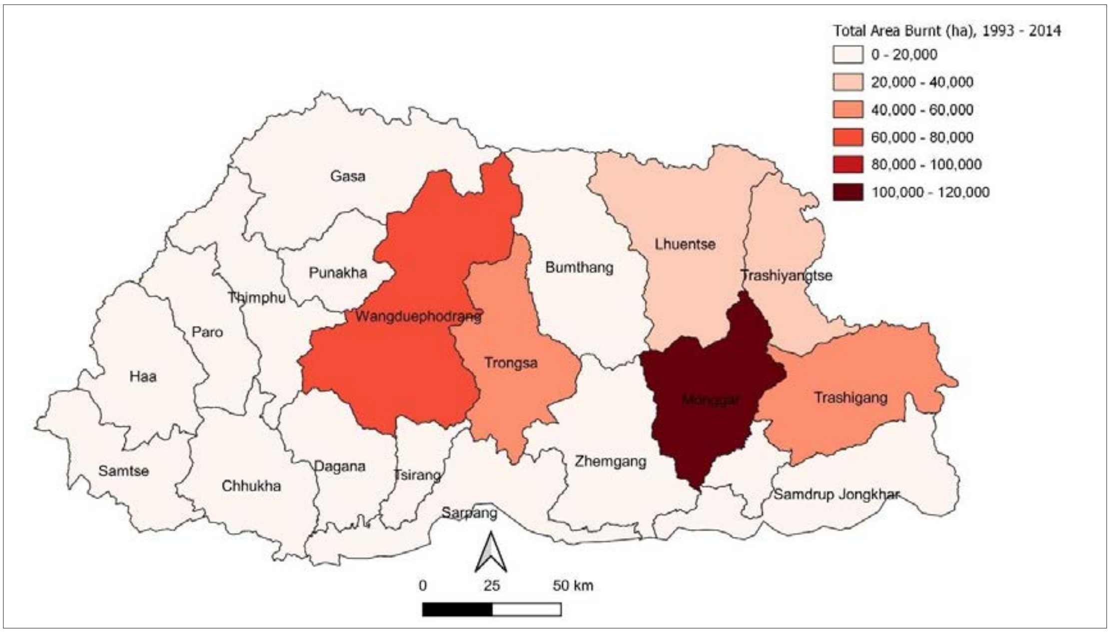
Records maintained at the Department of Forests and Park Services (DoFPS) show the following to be the main cause of forest fires in Bhutan.

- Agriculture debris burning
- Children playing with ignition source (such as matchsticks)
- Lemon grass harvesters
- Smokers
- Cattle herders for new grass
- Roadside workers
- Picknickers
- Campfires
- Electric short circuit

1 Average tabulated for fire events from 1993 to 2014. Data sourced from DoFPS.




*Map 2. Fire occurrence locations (2007 -2020) and current fire risk zones. Darker shades correspond to higher fire occurrences and more area burnt.*




*Map 3. Total forests burnt (hectares) from 1993 till 2014*

Current fires are mostly concentrated in the chir pine and blue pine zones forests, with occasional fires within sub-tropical broadleaved forests.

## 5.2 Forests and Biodiversity at Increased Risk

Both flame length and rate of fire spread experience an increase as climate becomes more extreme (Figure 6 & 7). We chose 'flame length' as a unit of measure for comparing results across different scenarios. The flame length metric also accounts for crown fires, and crown fires are an important factor in determining the rate of spread. Thus, flame length and rate of spread capture the dynamics of expected changes, and indicate fire severity under future climate scenarios. Although, ground fires are an important factor in fire severity, ground fires are not modeled by the current system since we do not have the data to calculate depth of burn. It is, however, important to recognize that depth of burn is important for post fire vegetation dynamics, potential post fire erosion, and for calculating a site's carbon mass.

According to our simulations, chir pine forests experienced the most severe fire behavior, with flames reaching 2.2 m length and spread of fire at 8.9 m $min^{-1}$ for the RCP 8.5 scenario period 2070-2100. Besides chir pine forests, the highest flame length values were found in mixed conifer forests, with flames reaching also 2.2 m length, and the fastest spread in broadleaf forests below 2000 m, with a fire line moving at 6.4 m $min^{-1}$. Fir forests and broadleaf forests above 2000 m underwent the mildest fire behavior outputs.

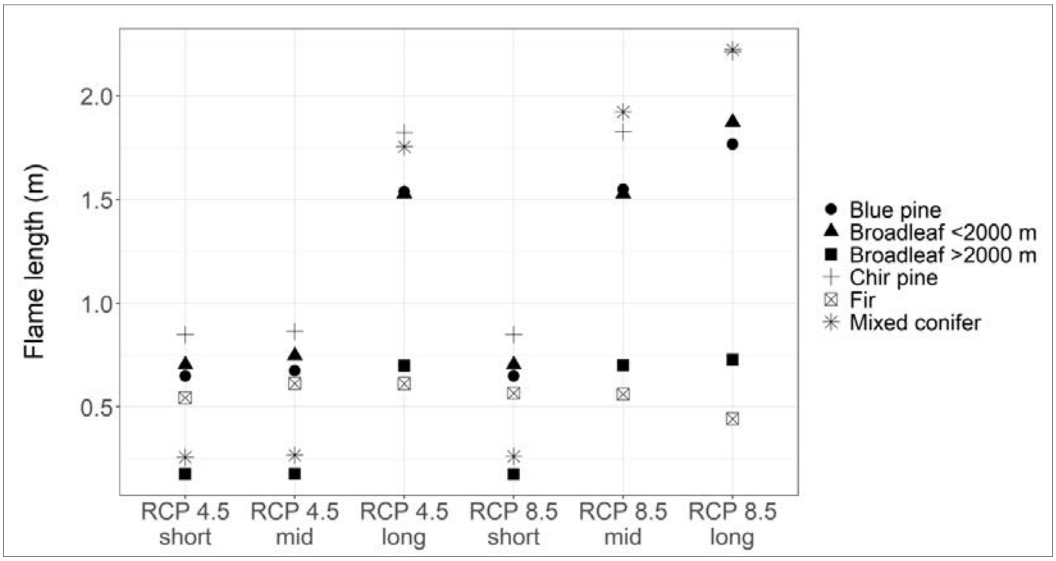



*Figure 6. Predicted flame length (m) under RCP 4.5 and RCP 8.5 across 3 time slices*

Fire behavior spiked in those scenarios where the fuel model accounted for an increase in fuel load because of warmer temperatures and longer growth period (Table 2 and 3).

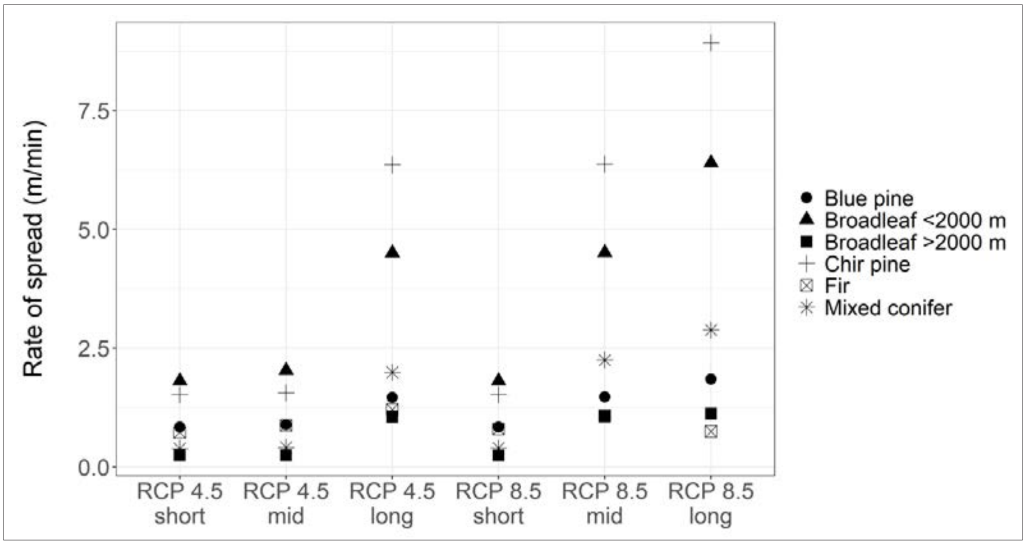



*Figure 7. Predicted 'rate of spread' (m/min) under RCP 4.5 and RCP 8.5 across 3 time slices*

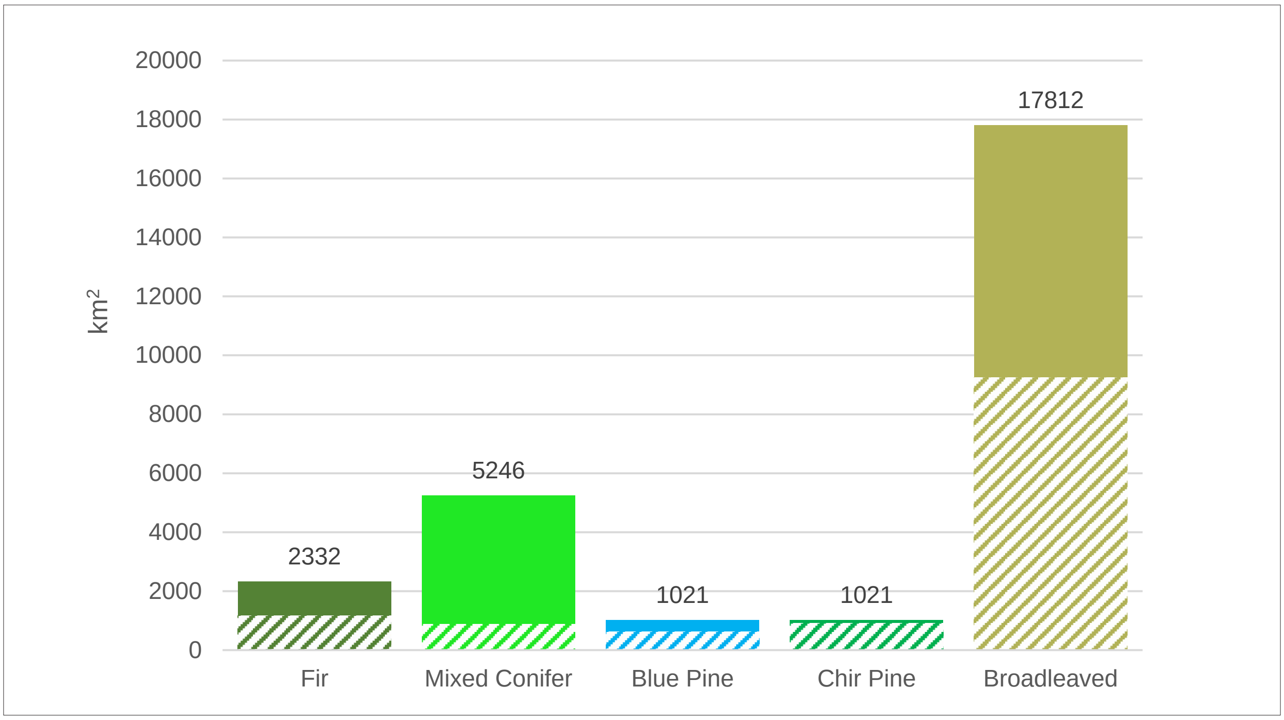
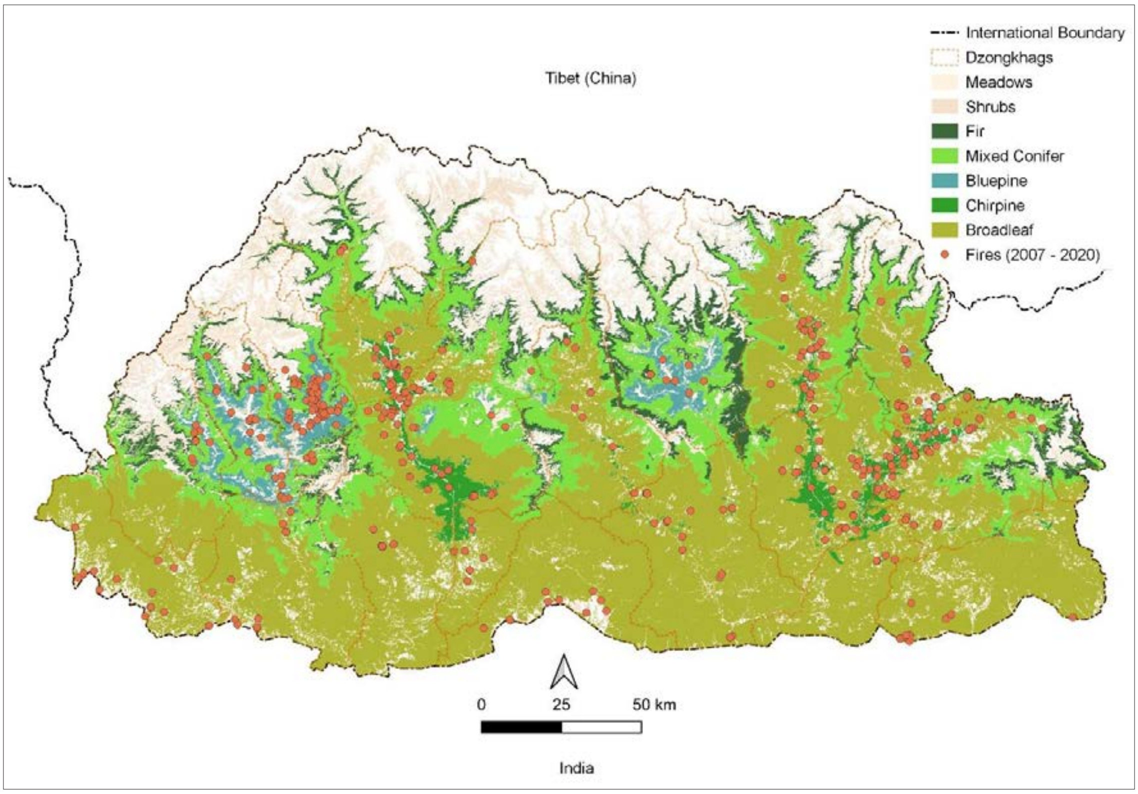



*Figure 8. Forest types, area coverage, and portion under risk (shaded) in each forest type from now till 2050*

Almost 90% of Chir pine forests fall under high risk from now till 2050 followed by blue pine with over 60% being subjected to high risk. See Figure 8 and Map 4.




*Map 4. Forest types and fire locations*

## 5.3 Implications on Biodiversity

Chir pine, blue pine and mixed conifer forests will be the most impacted according to our model projections (Figure 9). Given the size of broadleaved forests (Map 4) and the fuel models we used, broadleaved forests below 2000 masl show up to be at most risk. Given that these broadleaved forests are currently not subject to frequent and intensive forest fires, forest composition and biodiversity in these forests will be severely impacted should fires do occur at the projected rates.

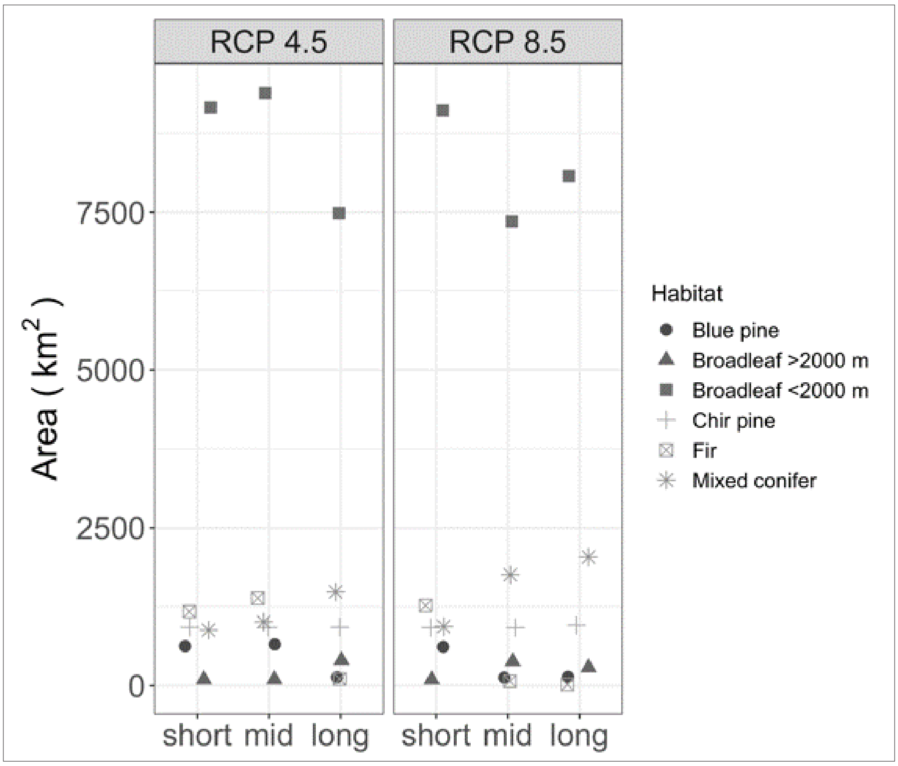



*Figure 9. Forest areas (km2) at risk under RCP 4.5 and RCP 8.5 across 3 time slices*

### *5.3.1 Chir pine, Blue Pine, Mixed conifer & Fir Forests*

Under RCP 4.5, from now till 2050, an estimated 921 km$^2$ of chir pine, 626 km$^2$ of blue pine, 879km$^2$ of mixed conifer forests, and 1175 km$^2$ of fir forests will be at high fire risk (Table 4). Areas under high fire risk increase significantly for mixed conifer forests for all time slices and under both RCP 4.5 and RCP 8.5.

Areas under risk appear to decline and remain constant for blue pine and chir pine forests respectively across time slices and RCP scenarios, yet in mixed conifer forests risk areas increase. See Table 4.

Table 4. Chir pine, blue pine, mixed conifer and fir forests at risk under RCP 4.5 and RCP 8.5 across 3 time slices

| Time Slice | Chir pine (km$^2$) | | Blue pine (km$^2$) | | Mixed conifer (km$^2$) | | Fir (km$^2$) | |
|---|---|---|---|---|---|---|---|---|
| | RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5 |
| short | 921 | 921 | 626 | 616 | 879 | 935 | 1175 | 1271 |
| mid | 924 | 956 | 655 | 128 | 1009 | 1756 | 1387 | 71 |
| long | 926 | 956 | 133 | 139 | 1486 | 2039 | 106 | 17 |

Athang and Daga Gewogs in Wangdue and Saleng Gewog in Mongar are at most risk within the Chir pine zone (Table 5) in the short time frame (now till 2050). A full ranking of Gewogs at risk within the chir pine zone is presented in Annex 1.

*Table 5. Ten Gewogs at most risk (area burnt in km$^2$) from fires within Chir pine forests (now till 2050)*

| Gewog | RCP 4.5 (km$^2$) | RCP 8.5 (km$^2$) |
|---|---|---|
| Athang | 118 | 117 |
| Daga | 81 | 81 |
| Saleng | 66 | 66 |
| Patakla | 37 | 37 |
| Udzorong | 34 | 34 |
| Shumer | 31 | 31 |
| Drepung | 25 | 25 |
| Narang | 25 | 25 |
| Kengkhar | 25 | 25 |
| Ruepisa | 23 | 23 |

Two Gewogs of Mewang and Kawang in Thimphu are at most risk followed by Chhoekhor Gewog in Bumtang within the Blue fine forest zone. See Table 6. A full ranking of Gewogs at risk within the blue pine zone is presented in Annex 2.

*Table 6. Ten Gewogs at most risk (area burnt in km2) from fires within the blue pine forests (now till 2050)*

| Gewog | RCP 4.5 (km$^2$) | RCP 8.5 (km$^2$) |
|---|---|---|
| Mewang | 69 | 68 |
| Kawang | 57 | 56 |
| Chhoekhor | 50 | 49 |
| Naja | 41 | 41 |
| Chhume | 41 | 40 |
| Chang | 39 | 38 |
| Tsento | 37 | 37 |
| Tang | 37 | 36 |
| Doga | 28 | 27 |
| Chapchha | 25 | 25 |

Kazhi in Wangdue and lower reaches of Lunana Gewog show up as being at most risk followed by Langthil Gewog in Trongsa and Athang in Wangdue within the mixed conifer forest zone. See Table 7. A full ranking of Gewogs at risk within the mixed conifer zone is presented in Annex 3.

*Table 7. Ten Gewogs at most risk (area burnt in km2) from fires within the mixed conifer forests (now till 2050)*

| Gewog | RCP 4.5 ($km^2$) | RCP 8.5 ($km^2$) |
|---|---|---|
| Kazhi | 49 | 54 |
| Lunana | 48 | 53 |
| Langthil | 35 | 36 |
| Athang | 35 | 36 |
| Kurtoe | 32 | 37 |
| Bumdeling | 31 | 34 |
| Tseza | 31 | 31 |
| Toewang | 28 | 30 |
| Nubi | 27 | 28 |
| Merak | 26 | 26 |

Within the fir zone, Choekhor and Lunana Gewogs followed by Sephu in Wangdue Phodrang and Tang in Bumtang are projected to be at most risk (Table 8). A full ranking of Gewogs at risk within the fir zone is presented in Annex 4.

*Table 8. Ten Gewogs at most risk (area burnt in km2) from fires within fir forests (now till 2050)*

| Gewog | RCP 4.5 | RCP 8.5 |
|---|---|---|
| Chhoekhor | 78 | 94 |
| Lunana | 66 | 73 |
| Sephu | 65 | 72 |
| Tang | 63 | 67 |
| Kazhi | 56 | 63 |
| Bumdeling | 56 | 58 |
| Sakteng | 55 | 56 |
| Bji | 53 | 58 |
| Laya | 52 | 62 |
| Kurtoe | 51 | 58 |

### *5.3.2 Broadleaved Forests*

Risks to broadleaved forests at lower elevations (<2000) are projected to increase from now to 2050 with over 9000 $km^2$ of broadleaved forests at high fire risk under both RCP 4.5 and RCP 8.5. The area under risk remains fairly constant under both RCPs as we approach the end of this Century. See Table 9.

*Table 9. Broadleaved forests at risk under RCP 4.5 and RCP 8.5 across 3 time slices*

| Time Slice | BL > 2000 ($km^2$) | | BL < 2000 ($km^2$) | |
|---|---|---|---|---|
| | RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5 |
| short | 97 | 97 | 9159 | 9111 |
| mid | 99 | 384 | 9390 | 7355 |
| long | 403 | 287 | 7484 | 8075 |

Pangkhar Gewog in Zhemgang and Athang in Wangdue followed by Jigmichhoeling in Sarpang and Trong Gewog in Trongsa have the most area at risk from fires within broadleaved forests below 2000 masl. See Table 10. A full ranking of Gewogs at risk within the mixed conifer zone is presented in Annex 4.

*Table 10. Ten Gewogs at most risk (area burnt in km2) from fires within the broadleaved forests below 2000 masl (now till 2050)*

| Gewog | RCP 4.5 (km$^2$) | RCP 8.5 (km$^2$) |
|---|---|---|
| Pangkhar | 460 | 457 |
| Athang | 292 | 294 |
| Jigmichhoeling | 288 | 286 |
| Trong | 259 | 258 |
| Saleng | 219 | 218 |
| Bongo | 209 | 208 |
| Nangkor | 202 | 201 |
| Serthig | 199 | 198 |
| Ngangla | 187 | 186 |
| Bjoka | 176 | 175 |

## 5.4 Production Circles at Increased Risk

### *5.4.1 Houses at Risk*

A total of 18490 households will be at increased risk from forest fires under RCP 4.5 as we move from now to 2050 (Table 11).

*Table 11. Households at high fire risk under different RCPs and time slices*

| | Short | Med | Long |
|---|---|---|---|
| RCP 4.5 | 18490 | 19516 | 11782 |
| RCP 8.5 | 18203 | 11347 | 13951 |

Houses within the broadleaved belts below 2000 masl will be at most risk from now until 2050, followed by households within chir pine and blue pine zone. There are no households and infrastructure at risk within mixed conifer, fir, and broadleaved forests above 2000 masl. See Figure 10.

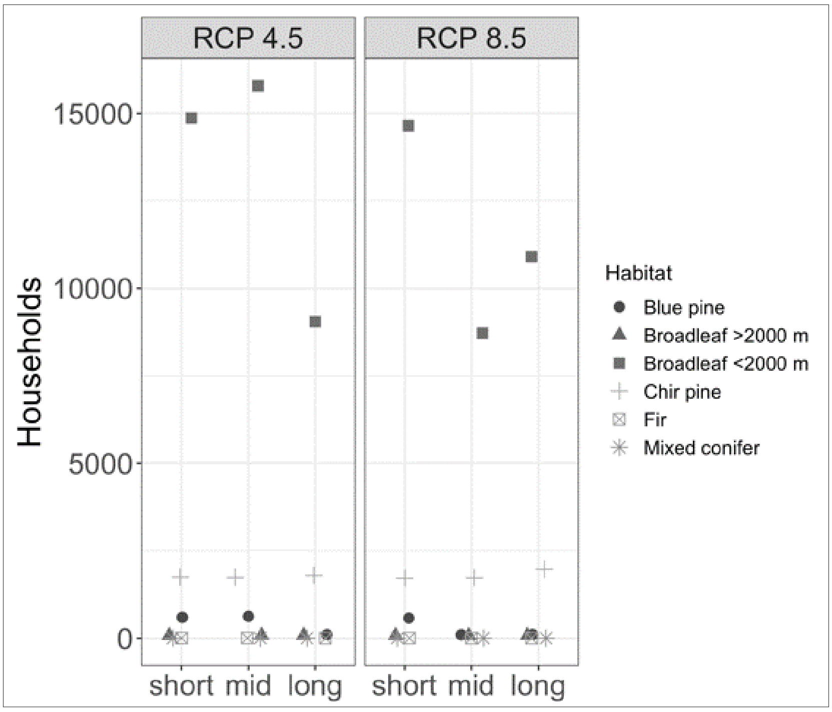
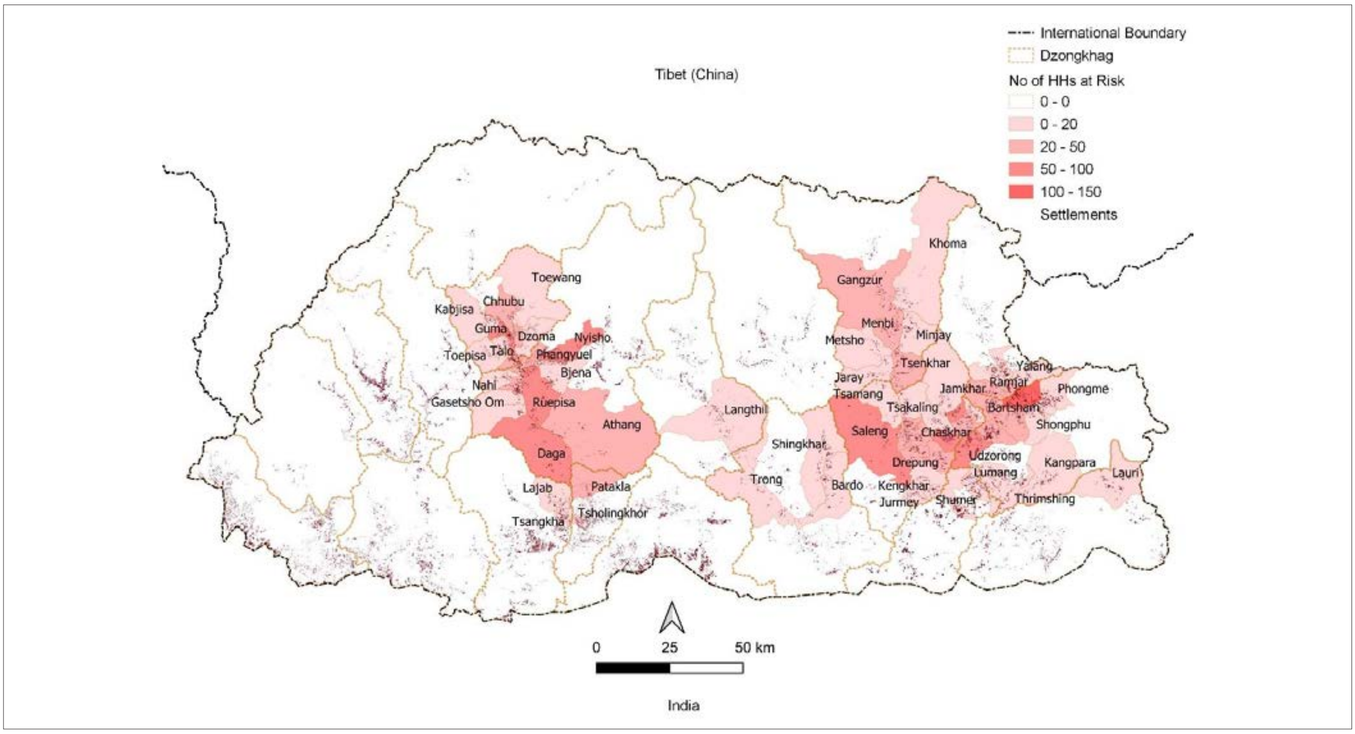



*Figure 10. HHs at risk under RCP 4.5 and RCP 8.5 across 3 time slices*

An estimated 1747 households will be at a high fire risk within the chir pine zones under RCP 4.5 as we move from now till 2050 (Table 12 & Map 5). See Annex 6 for a full list of Gewogs at most risk in chir pine forests.

*Table 12. Gewogs (top 10) at most risk in Chir pine forests under RCP 4.5 from now till 2051*

| Gewog | Dzongkhag | Households |
|---|---|---|
| Bartsham | Trashigang | 112 |
| Bidung | Trashigang | 110 |
| Daga | Wangduephodrang | 91 |
| Ruepisa | Wangduephodrang | 74 |
| Balam | Monggar | 62 |
| Saleng | Monggar | 62 |
| Udzorong | Trashigang | 59 |
| Nyisho | Wangduephodrang | 58 |
| Chaskhar | Monggar | 56 |
| Guma | Punakha | 52 |

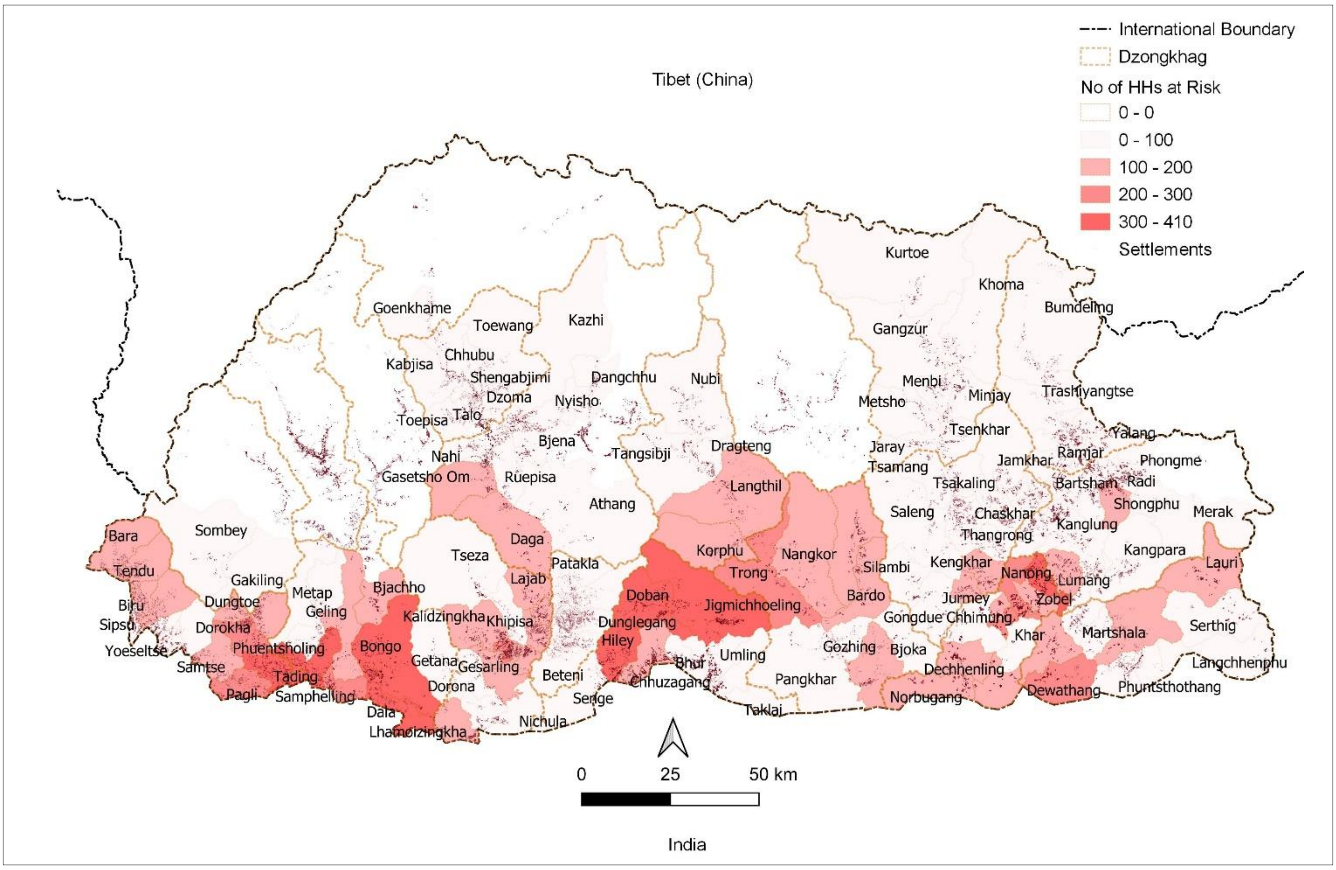



*Map 5. Gewogs with most HHs at risk from fire (from now till 2050) in the Chir pine forest zone*

An estimated 598 households will be at a high risk within the blue pine zones under RCP 4.5 as we move from now till 2050 (Table 13 & Map 6). Refer Annex 7 for a full ranking of Gewogs at most risk under blue pine forests.

*Table 13. Gewogs (top 10) at most risk in blue pine forests under RCP 4.5 from now till 2051*

| Gewog | Dzongkhag | Households |
|---|---|---|
| Kawang | Thimphu | 108 |
| Chhoekhor | Bumthang | 54 |
| Chang | Thimphu | 44 |
| Chapchha | Chhukha | 43 |
| Naja | Paro | 38 |
| Tsento | Paro | 38 |
| Mewang | Thimphu | 26 |
| Uesu | Haa | 22 |
| Tang | Bumthang | 21 |
| Gangte | Wangduephodrang | 19 |

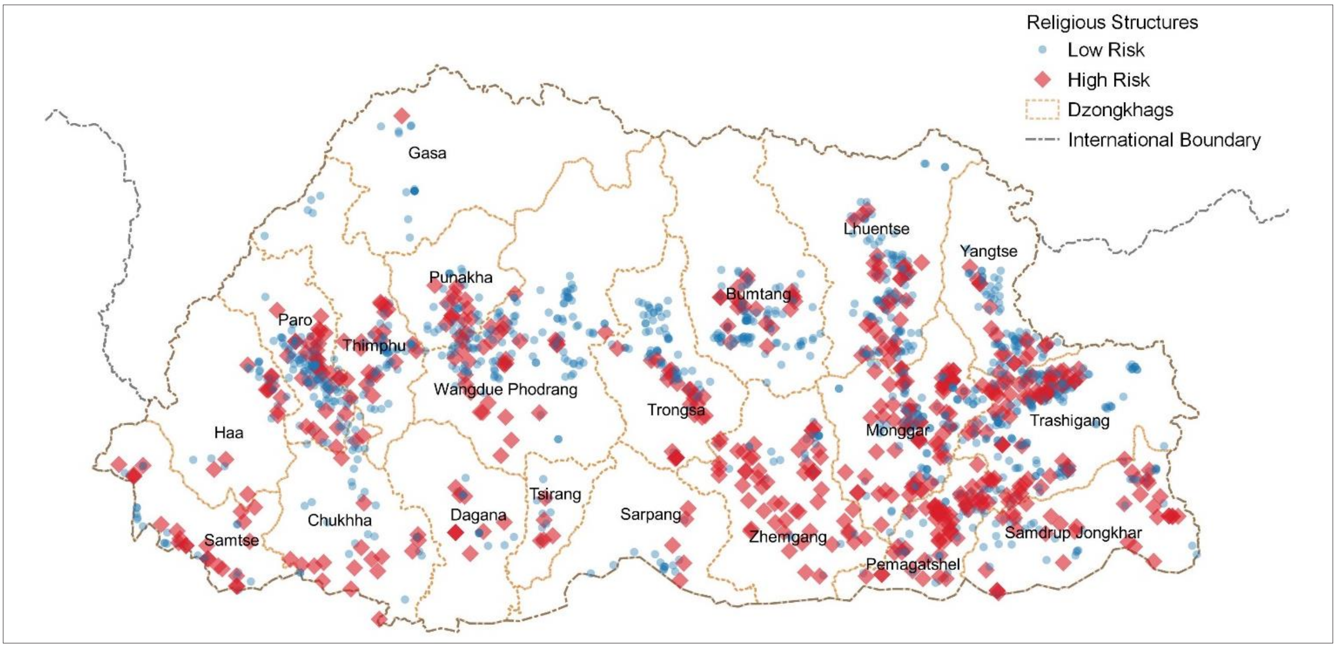



*Map 6. Gewogs with most HHs at risk from fire (from now till 2050) in the blue pine forest zone*

About 14867 households will be at a high risk within the broadleaved forests below 2000 masl under RCP 4.5 as we move from now till 2050 (Table 14 and Map 7).

*Table 14. Gewogs (top 10) at most risk in broadleaved forests below 2000 masl under RCP 4.5 from now till 2051*

| Gewog | Dzongkhag | Households |
|---|---|---|
| Jigmichhoeling | Sarpang | 408 |
| Hiley | Sarpang | 395 |
| Bongo | Chhukha | 373 |
| Phuentsholing | Chhukha | 373 |
| Dala | Chhukha | 362 |
| Tading | Samtse | 362 |
| Doban | Sarpang | 304 |
| Nanong | Pemagatshel | 301 |
| Shumer | Pemagatshel | 292 |
| Dewathang | Samdrupjongkhar | 278 |



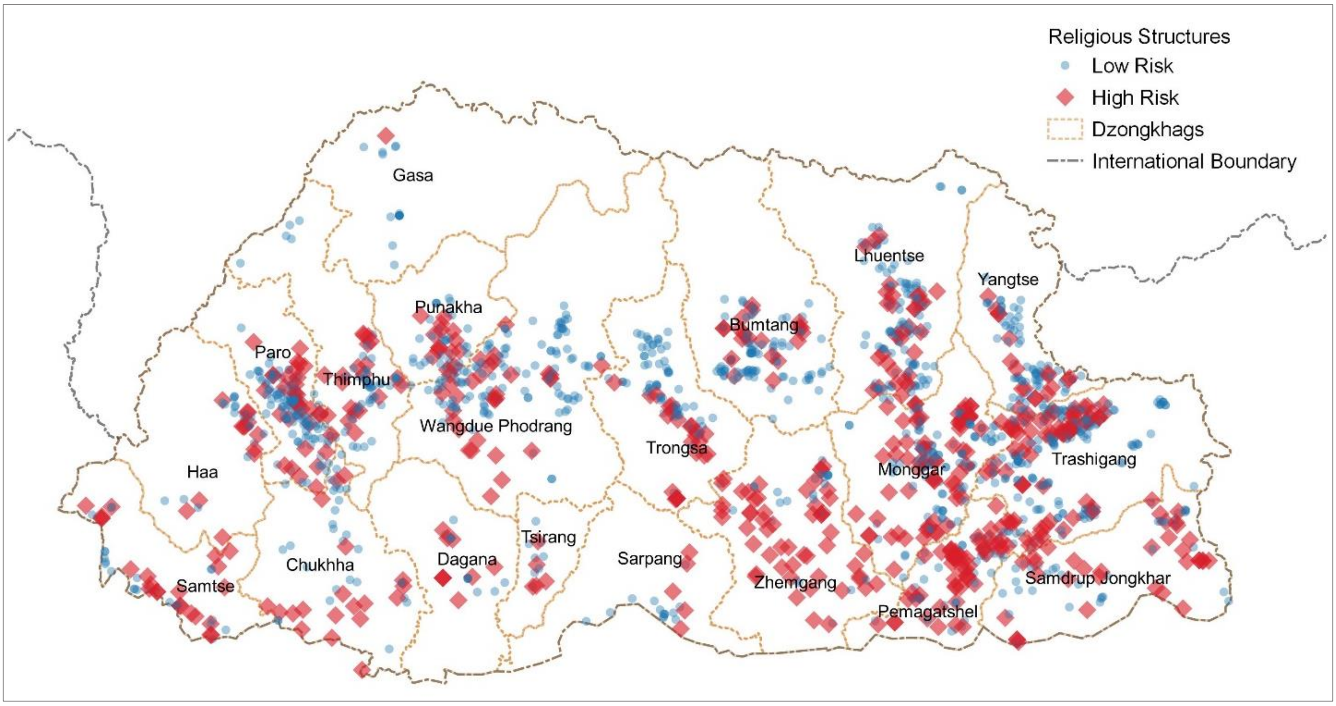

*Map 7. Gewogs with most HHs at risk from fire (from now till 2050) in the broadleaved forests below 2000 masl*

### *5.4.2 Religious Structures at Risk*

Of the 1774 religious structures currently recorded at the National Land Commission Secretariat (NLCS), a total of 549 (30%) religious structures will be at risk under RCP 4.5 from now till 2050. See Table 15 and Map 8.

*Table 15. Gewogs (top 10) with most religious structures at risk under RCP 4.5 from now till 2051*

| Gewog | Dzongkhag | Number | Forest Type |
|---|---|---|---|
| Nangkor | Zhemgang | 13 | Broadleaved (<2000 masl) |
| Shongphu | Trashigang | 12 | Broadleaved (<2000 masl) |
| Chhoekhor | Bumthang | 10 | Blue pine |
| Shermung | Monggar | 10 | Broadleaved (<2000 masl) |
| Yurung | Pemagatshel | 10 | Broadleaved (<2000 masl) |
| Bardo | Zhemgang | 10 | Broadleaved (<2000 masl) |
| Serthig | Samdrupjongkhar | 9 | Broadleaved (<2000 masl) |
| Zobel | Pemagatshel | 8 | Broadleaved (<2000 masl) |
| Kawang | Thimphu | 8 | Blue pine |
| Langthil | Trongsa | 8 | Broadleaved (<2000 masl) |




*Map 8. Religious structures at risk under RCP 4.5 from now till 2050*

Annex 9 shows gewogs with the most religious structures at risk, while Annex 10 presents details of individual structures at risk by gewogs and dzongkhags.

# CHAPTER VI: ADAPTING TO INCREASED FOREST FIRE RISKS

## 6.1 Risk Summary, Recommendation Time Frame and Priority Adaptation Areas

As per the findings presented prior, in the short-term, the risk of forest fire is most at the mid-altitudes in the temperate montane forests. The risk extends to the subtropical vegetation zone in the mid to long-term. Under RCP 4.5, in the next 30 years, in the temperate zone, an estimated 626 $km^2$ of blue pine, 921 $km^2$ of chir pine and 879 $km^2$ of mixed conifer forests will be at high risk. Risks to broadleaved forests at lower elevations (<2000) are projected to increase from now to 2050 with over 9000 $km^2$ of broadleaved forests at high fire risk under both RCP 4.5 and RCP 8.5.

These temperate and broadleaved forests mostly occur along mid and interior valleys and remain vital as sources for timber and other forestry resources. These forests are also home to a significant portion of the eastern Himalayas' rich biodiversity. Concurrently, since settlements within these valleys are located close to forest areas, forest fires pose increased threat to people and property.

Both flame length and the rate of fire spread are expected to increase in all forest types (except for fir) under both RCP 4.5 and RCP 8.5, and for all time slices. This means that forest fires will be more intense with increasing possibility of more crown fires. Coupled with a faster rate of spread, the possibility of larger fires burning over longer periods is an imminent possibility.

In the short (10 years) to medium-term (30 years), given the impending risks, adaptation efforts should be ramped up in high-risk forest types and settlements identified in the analyses and mentioned in the following table (Table 15).

*Table 15. A summary of Gewogs at most risk in terms of forest areas and settlements exposed to high fire risk*

| No | Forest Types/ Settlements | Focus Gewogs |
|---|---|---|
| 1 | Chir pine forest | Athang, Daga, Saleng, Patakla, Udzorong, Shumer, Drepung, Narang, Kengkhar, Ruepisa |
| 2 | Blue pine forest | Mewang, Kawang, Choekhor, Naja, Chhume, Chang, Tsento, Tang, Doga, Chapchha |
| 3 | Mixed conifer forest | Kazhi, Lunana, Langthil, Athang, Kurtoe, Bumdeling, Tseza, Toewang, Nubi, Merak |
| 4 | Broadleaved forest | Pangkhar, Jigmichhoeling, Trong, Bongo, Serthig, Ngangla, Bjokha, Nangkhor, Langchhenphu, Senge |
| 5 | Settlements in chir pine forests | Bartsham, Bidung, Daga, Ruepisa, Balam,, Saleng, Udzorong, Nyisho, Chaskhar, Guma |
| 6 | Settlements in blue pine forests | Kawang, Chhoekhor, Chang, Chapchha, Naja, Tsento, Mewang, Uesu, Tang, Gangte |
| 7 | Settlements in broadleaved forest | Jigmichhoeling, Hiley, Bongo, Phuentsholing, Dala, Tading, Doban, Nanong, Shumer, Dewathang |

## 6.2 Strengthen Adaptative Fire Management

Pro-active management within high risk areas such as chir pine, blue pine and broadleaved forests (< 2000 masl) is an immediate requirement. The advent of formal forestry institutions and active enforcement of regulations which restricted resource use and favored formal suppression efforts has led to steady fuel load accumulation in the forests since the early 1950s. See Plate 3. Under a warming climate, such accumulation of fuel load will continue to put Bhutan’s forests at an increased risk to forest fires.

*Plate 1. Fuel build-up one year after fire in a blue pine forest*

### *6.2.1 Fuel Load Management*

An adaptive framework for forest fuel management at the national scale will be useful to mitigate severe fire risks across all time-scales. Reduction of available fuel can be achieved either through controlled concessionary rights (rural resource collection plans, regulated grazing), through silvicultural thinning, or through application of cost-effective prescribed burn techniques. All such measures should be outlined within Local Forest Management Plans (LFMP’s).

We recommend fuel load management in both chir pine and blue pine forests. Within chir pine forests, controlled burning should be encouraged particularly within lemon grass growing areas. Research into optimal burning cycles, seedling recruitment, burn intensity, mortality and recovery rates, should be initiated immediately to provide management recommendations. The National Forest Policy of 2011 allows for active use of fire as an ecosystem management tool.

Within blue pine forests, scientifically determined thinning prescriptions should be implemented to reduce forest flammability and encourage tree growth to meet economic purposes. Traditional forest management systems which encouraged multiple-use of forests by rural communities for food, fodder, fue, timber, and grazing, would have reduced available forest fuel, thereby averting severe and catastrophic fires. Research should also be initiated on how grazing practices mediate forest fuel availability.

### *6.2.2 Forest Fire Line Creation*

Fuel load management should be supplemented by the creation of large-scale spatial breaks of fuel complexes. Projected flame lengths could be used to guide the design and dimensions of such breaks.

These discontinuities/breaks can be established in the forest periphery and urban interface or inside the forest. Such arrangement will stop low and medium intensity fires from spreading to larger landscapes. However, it should be noted that creation of fire lines, in and of itself, is not a full-on solution to combating forest fires. High intensity fires may jump over these breaks and strong winds can reduce the effectiveness of such breaks, as flying embers carried by the wind easily cross over, and light a spot fire on the other side.

However, fuel breaks and fire breaks can be very effective if properly installed, maintained and used. The design and maintenance of these fire lines should carefully noted, and their impact on wildlife, access to the forest by people, and potential erosion, should be considered. A comprehensive fire line creation plan should be developed and mainstreamed within the DoFPS's five year plans.

#### *6.2.3 Post Fire Habitat Management*

In most cases, post fire, burnt areas are left to recover through natural regeneration. However, in areas where the burn severity is high, vegetation does not regenerate at all or takes a long time to do so. Given our predictions of higher intensity and longer burn durations, it will be necessary to intervene and ensure adequate regeneration of burnt areas.

Post fire, technical assessments of burn severity should be mandatory. The DoFPS has conducted preliminary works on burn severity assessments using the MTBS (Monitoring Trends in Burn Severity) framework developed by the USDA Forest Service. The MTBS program should be mainstreamed within annual workplans of the DoFPS, and implemented routinely, as and when fires occur, to define and prescribe rehabilitation measures.

### 6.3 Secure Infrastructure at Risk

As forest fire intensity, size, and duration of burn increases, there is imminent danger to rural settlements and expanding urban infrastructure. The need for ensuring fire-safe communities is ever more relevant in Bhutan, given that over 70% of Bhutan's land area remains under forest cover. Majority of the human settlements interface directly with forested areas, and important cultural and historical national assets (i.e. Dzongs, Lhakhangs) are almost always located in far-flung forested areas. See Plates 4 and 5.

*Plate 2. Wildland-urban interface*

*Plate 3. Fire below Wangditse Dzong above Thimphu in 2021*

Adaptation and fire risk mitigation measures should be actively pursued to protect communities and important national infrastructure, where risk of ignition or spread from adjoining forest areas is high. The DoFPS has already initiated some preliminary measures in this area by clearing risk trees and bushes around important religious and cultural sites such as the Semthokha Dzong.

In all such cases, woody fuels should be removed for 10 meters around these structures. In addition, remaining trees and large shrubs should be pruned carefully to raise the crowns 1-2 meters above the ground surface. Water storage systems and fire hydrants should be built around key infrastructure supported by solar powered systems, incase of breakdown in energy supply systems. Fire safety protocols to minimize risk and contain fire outbreaks should be developed and distributed to all facilities at risk.

## 6.4 Reduce Forest Fire Causes

Any adaptation measure, especially in the shorter timeframe should also give due recognition to the causes of forest fires in Bhutan. One of the major causes of forest fire is sparks generated by electrical short circuits from powerlines and old transformers. See Plates 6 and 7.

*Plate 4. Transformers cause fire*

*Plate 5. A fire close to Tashichhodzong sparked by electrical short circuit*

Throughout Bhutan, cross-country electrical transmission and distribution corridors have not been maintained properly and cleared of woody vegetation. These corridors need to be systematically maintained and cleared of trees and shrubs over 2 meters tall. In major wind events, arising from climate change in future, electrical wires can swing wildly, cross and short-out or touch adjacent vegetation, leading to a wildland ignition or multiple fires all along the route of a blown-down line. These fires can spread quickly and become thousands of hectares in size. A systematic maintenance program for such corridors needs to be established in consultation with relevant stakeholders including DGPC, DHPS and BPC. Simple interventions on choice of dwarf fire resistant tree/shrub species in powerline corridors and use of modern drone aircraft can make regular inspections affordable and doable.

Apart from the cases relating to electrical short circuits, almost all fires are caused by people and their activities. The DoFPS continues to pursue public awareness and education campaigns. These campaigns should be aimed at eliciting behavioral changes in addition to disseminating information on ecosystem consequences and legal implications. The programs should also educate and train communities to get prepared for, and mitigate, risks from wildfires.

## 6.5 Strengthen Response Capability

### *6.5.1 Forest Fire Suppression Equipment*

As forest cover increases in Bhutan due to wide scale planting of conifers and fire exclusion, fuels will increasingly become woody fuels, not grasses, rendering pine boughs essentially useless for fire suppression. The longer flame lengths predicted due to climate change will hasten their uselessness. This will increasingly become more apparent when hardwood forests begins to burn more readily as climate change intensifies. The ability to effectively contain and fight forest fire needs to be strengthened, firstly, by equipping the DoFPS, and related fire fighting partner agencies, with a basic set of fire fighting equipment.

In the suppression of forest fires, the biggest risk is often the health and safety of firefighters. In the absence of proper firefighting equipment and PPE, personnel on fire incidents are exposed to life-threatening risks, and end up becoming more of a liability, than a help. During any fire incident, the health and safety of firefighters should remain the foremost concern. Therefore, PPE is a mandatory requirement as per the SOP developed by DoFPS for all firefighters. Furthermore, the SOP has listed equipment required for Rapid Response Teams (RRTs or first responders) and for group responders from various agencies in the IFFCG. A basic set of equipment required is provide in Table 16. The DoFPS should secure budget to procure adequate stock to be distributed across DoFPS once every five years, coinciding with the beginning of the Government's five-year planning period. Five year requirements should be estimated based on a stock take and needs assessment review conducted prior to the end of a five-year plan period.

*Table 16. PPE, RRT and Group Equipment Requirement*

| No | Individual PPE | No | RRT Equipment | No | Group Equipment |
|---|---|---|---|---|---|
| 1 | Fire mask | 1 | Shovel | 1 | Communication sets |
| 2 | Fire gloves | 2 | Flappers | 2 | Rakes |
| 3 | Safety goggles | 3 | Rake | 3 | Shovels |
| 4 | Whistle | 4 | Spade | 4 | Pulaskis |
| 5 | Safety helmet | 5 | McLeod | 5 | Flappers |
| 6 | Torch | 6 | Water Bag | 6 | Power chainsaw |
| 7 | Water bottle | 7 | Drip torch | 7 | Water bags |
| 8 | Machete (Patang) | 8 | Portable water pump | 8 | McLeods |
| 9 | Safety rope (4m) | 9 | Collapsible water tank | 9 | Portable water pump |
| 10 | Backpack | 10 | Safety ropes (100m) | 10 | Collipsible tank |
| | | | | 11 | Drone (UAV) |
| | | | | 12 | Safety rope (100m) |

As indicated in the IFFCG SOP, firefighters will need to be organized in crews that are trained in the use of the hand tools mentioned in Table 16.

Given the steep terrain across which most fires occur, the DoFPS has recognized that many of the standard firefighting equipment are either too cumbersome to carry or has proven ineffective under Bhutanese conditions. In addition to the basic list of equipment mentioned under Table 16, we recommend, in line with suggestions made by the DoFPS, that equipment be locally improvised and made, to suit local conditions. A set of fire suppression hand tools appropriate for Bhutan by region or fuel-type should be designed and developed to supplement the basic set specified in Table 16.

For example, in Thimphu, swatters have been created by the Forest Fire Section of the FPED, DoFPS. These combine a 1-meter-long bamboo handle 2.5 to 3.5 cm thick with a swatting head made of 2 pieces of 40 cm wide unserviceable cotton jacket fire hose held together with brass screws and nuts. The hose head is held to the handle with a hose clamp. These have been found to be comparatively lightweight, easier to handle, and therefore more effective than using just tree branches.

From field experiences gathered by DoFPS and other firefighting agencies, water backpack pumps are found to be extremely effective, especially on grass fires or when the intensity is not so high. Often, after containing the fire, there are many instances of re-ignition since mop-up is done without using water. In such cases, wide use of water backpack pumps should be made part of the SOP for containing forest fires.

### *6.5.2 Implement an Advance Warning Systems*

To facilitate faster response times and also to minimize risks to humans and property, a daily fire forecasting system based on weather forecasts should be developed and made readily available by region. Such as system should be tied into warning systems which are already being rolled out and implemented by the National Center for Hydro-meteorology (NCHM).

### *6.5.3 Strengthen Support for Large Fires*

The IFFCG SOP requires backup resource and personnel planning for incidents that cannot be contained by the RRT's and may extend for days. However, organized "support function" to aid these suppression forces (operations) on large fires, especially in terms of providing drinking water, food, and, at times, sleeping accommodations on an extended incident is often difficult to make happen. Fires will become larger as the climate warms. In addition, the duration of large fires will increase. Fire suppression on a single fire may take weeks, not just a few days, as the climate warms. This increase in forest fire size and duration has already been seen in the United States, Australia, Africa, South America, and Indonesia.

A national fire cache should be developed to provide tents, sleeping bags, food, and tools for large, long-duration fires. The DoFS should identify, build, and manage about two to three such caches at strategic locations to ensure coverage of all Bhutan and effectively manage and control large fires.

### *6.5.4 Strengthen Communication Systems*

In times of forest fires or any other disasters, access to quick communication is a must for effective first response, as well as managing situations, which lasts for days. Currently, the DoFPS maintains a radio communication network that connects its offices throughout the country on dedicated communication frequencies.

The DoFPS should map out strategic locations for additional relay stations, and estimate budget requirements for installation, and purchase of additional walkie-talkie sets to upscale the current communication system.

### *6.5.5 Strengthen the Interagency Forest Fire Coordinating Group (IFFCG)*

Until 2017, forest firefighting was primarily the responsibility of the DoFPS and its field offices. Other participating agencies during suppression, like the Armed Forces (Royal Bhutan Army, Royal Bhutan Police, Royal Body Guards), fire volunteers, and local villagers were coordinated by the DoFPS. While the Department of Disaster Management (DDM) is the focal agency and leads all efforts related to disasters, the DoFPS has been given the mandate to manage forest fires from smaller incidents to disaster level incidents. Since 2005, the DoFPS in collaboration with the USDA Forest Service and with support from Conifer Research and Training Partnership (CORET) Project and USAID has initiated the institution of the Incident Command System (ICS) for forest fire as well as disaster response in Bhutan. Since then, numerous coordination protocols has been applied and tested under the general principles of ICS by both the DoFPS and DDM.

In 2017, under Royal Command to strengthen inter-agency coordination and to ensure firefighter safety during incidents, an Interagency Forest Fire Coordination Group (IFFCG) was formed for Thimphu Dzongkhag. This is also in line with the provisions of Forest Fire Management Strategy for Bhutan, 2013 to develop operational plans at various levels to define structures and assign responsibilities. The objectives for the group are:

1. To ensure the safety of firefighting personnel during forest fire incidents.
2. To provide for timely, efficient, and effective firefighting action on forest fire incidents.
3. To enhance better coordination among the different stakeholders involved in forest firefighting.
4. To achieve cost-effective and optimal resource distribution for all forest fire fighters.

The IFFCG is comprised of members from DoFPS, RBA, RBP, Desuung, Dzongkhag and DDM and acts as the Incident Commanders for respective agencies during fire incidents. All coordination, direction of crew, backup despatch, resource supply and post fire efforts are directed through the IFFCG. The IFFCG was found to be highly effective, especially in lead time on first incident response and for suppression coordination. Figure 11 below shows the coordination structure.

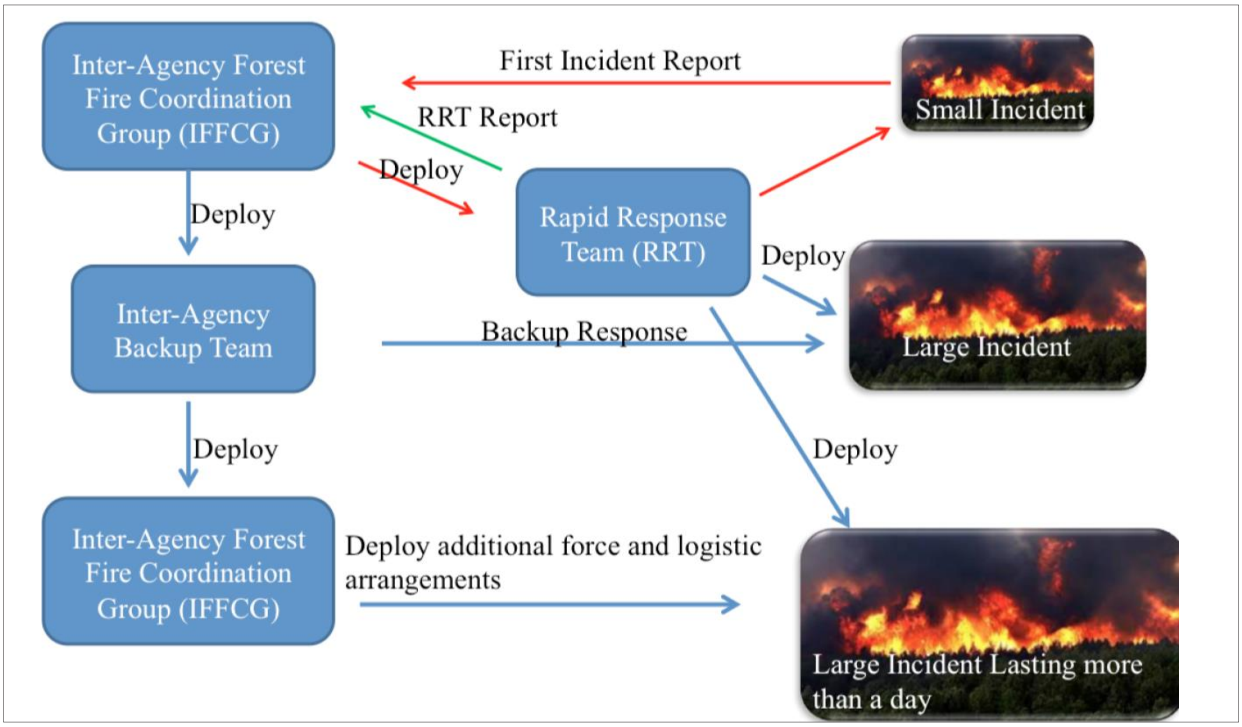



*Figure 11. Operational procedure and coordination structure of the IFFCG.*

The IFFCG has since then been institutionalized in all fire prone Dzongkhags of Haa, Paro, Thimphu, Wangdue, Bumthang, Mongar, Lhuntse, Trashigang and Trashiyangtse.

Immediate support should be provided to form and formalize the IFFCG in hitherto uncovered Dzongkhags. Priority should be placed on instituting the IFFCG in Dagana, Chukha and Tsirang, where fire incidences, although not currently high, are projected to increase. Once formalized in all Dzongkhags, the IFFCG mechanism should be replicated at the Gewog level with the highest fire risks (See Table 15).

### *6.5.6 Integrate Dzongkhag and Local Level Forest Fire Management Plans*

To strengthen community involvement, devolve responsibilities to the local level, and streamline coordination on forest fire management activities, the DoFPS has already initiated formulation of Dzongkhag and Gewog Level Fire Management Plans under funding from the previous NAP Project. The piloting of plan development at both levels has been successfully completed and such plans have already been developed for some fire prone Dzongkhags. However, due to lack of funding support, focused implementation is still lacking. There are also other Gewog level forest plans like that LFMP that is recently being implemented by the DoFPS.

All local level plans should be integrated so that resource management as well as fire protection objectives are achieved in a holistic and coherent manner. More importantly, consistent budgetary support needs to be ensured to successfully implement these plans.

### *6.5.7 Strengthen Legislation*

The management of forest fire is one of the most complex tasks involving a large number of stakeholders, therefore sensitization and information sharing regarding the subject is not always enough; it is also necessary to enforce legislation. The applications of legally bidding instruments should also be coupled with preventive measures to regulate human interventions in the forest or its periphery (agricultural work, picnic, constructions in the forest etc) which will ultimately help to reduce the risks of fire ignitions and spreads.

In the Bhutanese context, the Constitution of Bhutan 2008, specifically Chapter V, provides overarching protection responsibilities by promulgating that "every Bhutanese is a trustee of the Kingdom's natural resources for the benefit of present and future generations and it is the fundamental duty of every citizen to contribute to the protection of the natural environment, conservation, and rich biodiversity of Bhutan and prevention of all forms of ecological degradation including noise, visual, and physical pollution through the adoption and support of environment friendly practices". The Constitution also mandates that 60% of forest cover be maintained for perpetuity, and that the government has the specific responsibility to preserve, conserve, and improve the environment; prevent pollution; secure ecologically balanced sustainable development; and enable a safe and healthy environment. Furthermore, the Forest and Nature Conservation Rules 2017 Chapter XI adequately covers various aspects of forest fire management inside the forests as well as in other land uses. Other relevant legal instrument that could be activated to enforce preventive measures against the forest fire are the National Environment Protection Act 2007 and the Disaster Management Act of Bhutan 2013.

A summary of legal documents that provide preventive, strategic, and regulatory tools to support forest fire prevention is shown in Table 17.

*Table 17. Legislation, policy tools and frameworks to prevent and manage forest fires*

| What | Enactment Year | Pertinent Principles | Relevant Chapters | Implementing Agency |
|---|---|---|---|---|
| Constitution of Kingdom of Bhutan | 2008 | Provides overarching protection of Bhutan's ecosystem. Describes the "… fundamental duty of every citizen to contribute to the protection of the natural environment, conservation, and rich biodiversity of Bhutan and mandates that 60% of forest cover be maintained for perpetuity" | Chapter 5 | RGoB |
| Forest and Nature Conservation Act of Bhutan (FNCA) | 1995 | Provides the legal basis for protection, conservation, and sustainable use of forest resources. Allows for organizational set up at local level to prevent forest fires, impose penalties, and restore burnt areas. | Chapter 8, Article 31 | MoAF |

| | | | | |
|---|---|---|---|---|
| Forest and Nature Conservation Rules of Bhutan | 2017 amended from twice (2006, 2012) | Derived from the FNCA (1995) and provides detailed guidelines on forest fire mitigation and management. | Chapter XI | MoAF |
| National Environment Protection Act of Bhutan (NEPA) | 2007 | Provides the legal basis for the conservation and protection of the environment. | Chapter V and Chapter VII | NEC |
| Environmental Assessment Act of Bhutan (EEA) | 2000 | Specifies regulation and procedures for EIAs | All chapters | NEC |
| Disaster Management Act of Bhutan (DMA) | 2013 | Provides the legal basis to ensure the protection of lives and properties by reducing and managing risk arising out of disasters. Specifies mechanisms for structural and financial aid during disasters. | All Chapters | MoHCA |
| Disaster Management Rules and Regulations of Bhutan | 2014 | Derivatives of DMA 2013 | All Chapters | MoHCA |
| National Disaster Risk Management Framework | Recent | Calls for mainstreaming of disaster risk into national plans and polices. | Chapter 2, Section 2.1 | Disaster Management Division |
| Interagency Forest Fire Coordinating Group (IFFCG) | 2017 | Stipulates frameworks for inter-agency coordination and SOPS for responding to forest fires. | All Chapters | DoFPS |

Extant legal arrangements and provisions should be reviewed and revised to make them more effective.

## 6.6 Strengthen Research and Education

### *6.6.1 Forest Stand Related Information Collection*

For successful predictive modeling or implementation of any fuel management regime, current understanding of forest stand, structure and available fuel will be crucial. Many of these parameters are already included in the National Forest Inventory data collection protocol. Any parameter that is missing in the NFI list but is essential for fuel modeling and management should be reviewed and inserted in the design. Such parameter may include:

- At canopy level: canopy cover, DBH, tree height, canopy tree height
- At understory level (live fuels): shrub and herbaceous cover and height
- At understory level (dead fuels): litter and fine woody debris (1h, 10h, and 100h) load
- Physiognomic characteristics of vegetation - evergreen versus deciduous, angiosperm versus gymnosperm forests.

### *6.6.2 General Information and Research Needs*

The following information and research needs should be addressed as a priority.

- Collate accurate GIS based mapping of village locations, values-at-risk (historic religious sites), water sources, landfill sites, and roads.
- Develop, maintain and manage a forest fire database which stores and analyses information on:
  - Causes of forest fire (cause, date, location and weather conditions). A fire-cause investigation training program will be needed to fill this information accurately into the database.
  - Post-fire statistics based on the MTBS system adopted by the US Forest Service
- Research on the fire ecology of important forest types in Bhutan should be immediately initiated. Parameters related to post-fire fuel recovery, vegetation development, incidences and spread of pests and diseases, and species diversity should be studied. This work should inform the development of controlled burning prescriptions and techniques in forest fuels by forest type.

- Given the projected increased risks, a monitoring program to track flammability of broadleaved and mixed conifer forests should be rolled out.

### *6.6.3 Capacity Building of Fire Fighters*

There is urgent need to educate personnel at all levels that "safety of firefighters always comes first and foremost". The current IFFCG SOP should be reviewed based on field implementation and safety protocol and standards should be further refined to ensure health and safety of frontline firefighters. This will be particularly important given that forest fire intensity and flame lengths are predicted to increase significantly.

The capacity of firefighters to size up a incident and apply appropriate suppression techniques is key to effective suppression of fires and also determines the safety of firefighters. For example, in the US, for any person to be on an active fire incident, s/he must possess a "red card", which is only given to those who have undergone basic firefighting and other requisite course. The type and level of courses that one takes determine the type of crew the firefighter operates on. In Bhutan, such qualification or training is not implicated for a person to be on an active incident. Farmers, volunteers, and many others join fire suppressors in efforts to put out the fire. Under such a scenario, while it helps to have larger suppression forces, safety is often compromised. Under future predicted scenarios, such lack of safety, could result in fatalities. Therefore, proper training and provision of safety equipment will be important.

As per the IFFCG SOP, the responsibility to train forestry and other personnel involved in firefighting is vested with the DoFPS. These include IFFCG Members (DoFPS, RBA, RBP, Desuung, Dzongkhag, DDM) and communities.

The DoFPS should schedule and rollout a multi-year training program covering the following topics:

- Incident management system and coordination
- Equipment handling (including handling of drones, power chainsaws, communication sets, GPS)
- Safety procedures and first aid
- Prescribed burn techniques based on prescribed burn plans
- Smoke jumpers in coordination with the DDM and Royal Bhutan Helicopter Services for first response in areas where there is no/limited access.

While training in basic firefighting can be given by foresters from DoFPS, there is need for external inputs in conducting advanced trainings on suppression as well as in conducting prescribed burns. A critical mass of national trainers should be built through a 'training of trainers' program with inputs from an external expert. Subsequent mass trainings can then be effectively imparted by national trainers.

### *6.6.4 Targeted Sensitization*

The DoFPS should upscale and continue to sensitize and inform the public before and during the fire season. Sensitization programs should cover topics related to the impacts of fire and the need to exercise caution during the dry season, when accidental fires are most likely. Rather than being authoritative, messages should be geared at increasing public appreciation for the multiple benefits of forests (timber and non-timber resources, fodder, medicines, public recreation, aesthetics), and economic and ecological costs of unnecessary fires.

The following target groups needs to be continually sensitized and engaged:

- School going children and teenagers
- Local government officials (Gups and Tshogpas)
- Community forest management groups
- Companies and organization who work in or close to forests

The DoFPS may consider developing a fire prevention mascot, such as Smokey Bear, used in the US, which has been overwhelmingly effective in reducing fires caused by miscreants.

## CHAPTER VII: CONCLUSIONS

Recent events such as the mega fires in Australia and the US, and the fires now raging across Greece and Turkey, leave us in no doubt that rising temperatures will put at risk increasing large swathes of forests across the globe. Of particular concern is the fact that many recent fires have burned ecosystems where fire has historically been rare or absent.

Our findings which project increasing fire risks under a warming climate align closely with unfolding fire events globally, and warn us, of what may be in store, should we fail to proactively adapt to climate change. Failure to adapt and curtail the risks of future forest fires will entail significant economic and ecological costs for Bhutan. In addition to exacerbated loss of property and rapid disruptions to ecosystems and loss of biodiversity, increased and intensive forest fires will significantly contribute to Bhutan's carbon emissions, thereby – possibly – compromising, Bhutan's carbon neutral status. The consequences of a failure to adapt will be hugely disastrous for Bhutan.

Our predictions are however estimated based on climate change scenarios. It has to be noted that there is considerable uncertainty as to the actual weather Bhutan will experience, as we transition into the future. Critical uncertainties relate to the frequency and severity of drought cycles associated with teleconnections with ocean-atmosphere circulation patterns. Relative humidity and wind speed are also major drivers of fire behavior. The seasonal and diurnal patterns of these critical fire weather variables remain highly uncertain into the foreseeable future. Thus, future fire behavior is fraught with uncertainty and modeling future fire potential requires making science-based projections of future climate. Yet, the uncertainty of future weather should not paralyze action.

As of now, Bhutan has made no significant long-term financial investment in forest fire management, beyond covering the cost of the DoFPS fire management staff. Given that projected risks are considerable across all forest types, it is imperative that substantive investment be secured to implement a dynamic and proactive fire mitigation and adaptation program. Such an investment will pay itself out in the form reduced carbon emissions, protected infrastructure, and conserved biodiversity.

Given that climate/weather and terrain are beyond the scope of management to alter, climate response needs to focus proactively on managing the two remaining fire risk factors: forest fuels and human behavior. The proper management of forest fuels, people's attitudes towards fire prevention, and the efficacy of response systems, will determine fire's impact on Bhutan under future climates. It is in this regard that we recommend a robust set of adaptive management strategies coupled with continuing focus on awareness building and community engagement to effectively mitigate and adapt to forest fire in Bhutan.

# ANNEXURES

*Annex 1. Gewogs at risk under chir pine forest*

| Gewog | RCP 4.5 ($km^2$) | RCP 8.5 ($km^2$) |
|---|---|---|
| Athang | 118 | 117 |
| Daga | 81 | 81 |
| Saleng | 66 | 66 |
| Patakla | 37 | 37 |
| Udzorong | 34 | 34 |
| Shumer | 31 | 31 |
| Drepung | 25 | 25 |
| Narang | 25 | 25 |
| Kengkhar | 25 | 25 |
| Ruepisa | 23 | 23 |
| Yangnyer | 23 | 23 |
| Tsamang | 19 | 19 |
| Bartsham | 19 | 19 |
| Thangrong | 19 | 19 |
| Chhubu | 18 | 18 |
| Lajab | 18 | 18 |
| Mongar | 17 | 17 |
| Chaskhar | 14 | 14 |
| Tsenkhar | 14 | 14 |
| Menbi | 14 | 14 |
| Jaray | 13 | 13 |
| Bidung | 12 | 12 |
| Langthil | 12 | 12 |
| Khoma | 11 | 11 |
| Ramjar | 11 | 11 |
| Yalang | 11 | 11 |
| Dzoma | 10 | 10 |
| Jamkhar | 9 | 9 |
| Lingmukha | 9 | 9 |
| Drametse | 8 | 8 |
| Guma | 8 | 8 |
| Samkhar | 7 | 7 |
| Ngatshang | 7 | 7 |
| Kanglung | 7 | 7 |
| Jurmey | 7 | 7 |
| Metsho | 7 | 7 |
| Gangzur | 7 | 7 |
| Tsakaling | 7 | 7 |
| Chhali | 7 | 7 |

| | | |
|---|---|---|
| Toewang | 7 | 7 |
| Thedtsho | 7 | 6 |
| Chhimung | 6 | 6 |
| Phangyuel | 6 | 6 |
| Korphu | 6 | 6 |
| Nahi | 5 | 5 |
| Bapisa | 5 | 5 |
| Minjay | 5 | 5 |
| Lauri | 5 | 5 |
| Nangkor | 5 | 5 |
| Nyisho | 5 | 5 |
| Gasetsho Gom | 4 | 4 |
| Gasetsho Om | 4 | 4 |
| Talo | 4 | 4 |
| Trong | 4 | 4 |
| Nanong | 4 | 4 |
| Toepisa | 3 | 3 |
| Tomzhangtshen | 3 | 3 |
| Shermung | 3 | 3 |
| Balam | 2 | 2 |
| Phongme | 2 | 2 |
| Kabjisa | 2 | 2 |
| Shingkhar | 2 | 2 |
| Khaling | 2 | 2 |
| Kangpara | 2 | 2 |
| Shengabjimi | 1 | 1 |
| Khamdang | 1 | 1 |
| Bjena | 1 | 1 |
| Tsangkha | 1 | 1 |
| Bardo | 1 | 1 |
| Tangsibji | 1 | 1 |
| Gongdue | 1 | 1 |
| Dungmin | 1 | 1 |
| Toetsho | 1 | 1 |
| Shongphu | 1 | 1 |

*Annex 2. Gewogs at risk under blue pine forests*

| Gewog | RCP 4.5 ($km^2$) | RCP 8.5 ($km^2$) |
|---|---|---|
| Mewang | 69 | 68 |
| Kawang | 57 | 56 |
| Chhoekhor | 50 | 49 |
| Naja | 41 | 41 |
| Chhume | 41 | 40 |

| | | |
|---|---|---|
| Chang | 39 | 38 |
| Tsento | 37 | 37 |
| Tang | 37 | 36 |
| Doga | 28 | 27 |
| Chapchha | 25 | 25 |
| Sama | 22 | 21 |
| Doteng | 20 | 19 |
| Shapa | 18 | 18 |
| Lungnyi | 18 | 17 |
| Uesu | 16 | 15 |
| Bji | 14 | 14 |
| Ura | 14 | 14 |
| Lamgong | 12 | 12 |
| Dagala | 7 | 7 |
| Dopshari | 7 | 7 |
| Dungna | 6 | 6 |
| Genye | 6 | 6 |
| Katsho | 5 | 5 |
| Ruepisa | 5 | 5 |
| Tangsibji | 5 | 5 |
| Geling | 5 | 5 |
| Hungrel | 4 | 4 |
| Gangte | 4 | 4 |
| Wangchang | 4 | 4 |
| Sephu | 3 | 3 |
| Bjena | 3 | 3 |
| Trashiyangtse | 3 | 3 |
| Phobji | 2 | 2 |
| Metap | 1 | 1 |

*Annex 3. Gewogs at risk under mixed conifer forests*

| Gewog | RCP 4.5 ($km^2$) | RCP 8.5 ($km^2$) |
|---|---|---|
| Kazhi | 49 | 54 |
| Lunana | 48 | 53 |
| Langthil | 35 | 36 |
| Athang | 35 | 36 |
| Kurtoe | 32 | 37 |
| Bumdeling | 31 | 34 |
| Tseza | 31 | 31 |
| Toewang | 28 | 30 |
| Nubi | 27 | 28 |
| Merak | 26 | 26 |
| Sephu | 25 | 27 |

| | | |
|---|---|---|
| Gangzur | 24 | 27 |
| Khoma | 23 | 24 |
| Tangsibji | 20 | 21 |
| Tsento | 20 | 22 |
| Chhoekhor | 18 | 20 |
| Korphu | 17 | 17 |
| Sombey | 17 | 17 |
| Sakteng | 16 | 18 |
| Goenkhatoe | 16 | 18 |
| Dangchhu | 16 | 16 |
| Kangpara | 15 | 15 |
| Kawang | 15 | 16 |
| Bji | 13 | 15 |
| Dagala | 11 | 13 |
| Laya | 11 | 13 |
| Kabjisa | 11 | 11 |
| Nangkor | 11 | 11 |
| Chhume | 11 | 12 |
| Goenkhame | 10 | 11 |
| Minjay | 10 | 10 |
| Doteng | 10 | 10 |
| Sama | 8 | 9 |
| Ura | 8 | 8 |
| Tang | 8 | 8 |
| Bjachho | 8 | 8 |
| Lauri | 7 | 7 |
| Chapchha | 7 | 8 |
| Gasetsho Om | 7 | 7 |
| Gakiling | 6 | 6 |
| Trashiyangtse | 6 | 6 |
| Phobji | 5 | 7 |
| Shermung | 5 | 5 |
| Shingkhar | 5 | 5 |
| Bongo | 5 | 5 |
| Metsho | 5 | 5 |
| Jigmichhoeling | 5 | 5 |
| Mewang | 4 | 5 |
| Saleng | 4 | 4 |
| Bara | 4 | 4 |
| Ruepisa | 4 | 4 |
| Jaray | 4 | 4 |
| Daga | 4 | 4 |
| Genye | 4 | 4 |
| Dungna | 4 | 4 |

| | | |
|---|---|---|
| Bjena | 4 | 4 |
| Gangte | 4 | 4 |
| Khaling | 4 | 4 |
| Nyisho | 4 | 4 |
| Phuentenchhu | 3 | 3 |
| Uesu | 3 | 4 |
| Metap | 3 | 3 |
| Nahi | 3 | 3 |
| Naja | 3 | 3 |
| Toepisa | 3 | 3 |
| Chang | 3 | 3 |
| Naro | 3 | 4 |
| Tsenkhar | 2 | 2 |
| Shongphu | 2 | 2 |
| Phongme | 2 | 2 |
| Doga | 2 | 2 |
| Getana | 2 | 1 |
| Yalang | 1 | 2 |
| Trong | 1 | 1 |
| Tsakaling | 1 | 1 |
| Geling | 1 | 1 |
| Katsho | 1 | 1 |
| Goenshari | 1 | 1 |
| Tsamang | 1 | 1 |
| Lingzhi | 1 | 2 |
| Lungnyi | 1 | 1 |
| Lamgong | 1 | 1 |
| Chhubu | 1 | 1 |
| Shapa | 1 | 1 |
| Menbi | 1 | 1 |
| Jamkhar | 1 | 1 |
| Serthig | 1 | 0 |

*Annex 4. Gewogs at risk under fir forests*

| Gewog | RCP 4.5 ($km^2$) | RCP 8.5 ($km^2$) |
|---|---|---|
| Chhoekhor | 78 | 94 |
| Lunana | 66 | 73 |
| Sephu | 65 | 72 |
| Tang | 63 | 67 |
| Kazhi | 56 | 63 |
| Bumdeling | 56 | 58 |
| Sakteng | 55 | 56 |
| Bji | 53 | 58 |

| | | |
|---|---|---|
| Laya | 52 | 62 |
| Kurtoe | 51 | 58 |
| Merak | 45 | 46 |
| Khoma | 44 | 48 |
| Nubi | 39 | 41 |
| Tsento | 35 | 39 |
| Ura | 29 | 29 |
| Toewang | 28 | 29 |
| Goenkhatoe | 26 | 28 |
| Chhume | 24 | 26 |
| Dagala | 24 | 26 |
| Tangsibji | 22 | 26 |
| Sama | 18 | 19 |
| Athang | 18 | 19 |
| Doteng | 17 | 18 |
| Gangzur | 17 | 17 |
| Saleng | 15 | 14 |
| Gasetsho Om | 13 | 13 |
| Lingzhi | 11 | 14 |
| Kawang | 11 | 12 |
| Dangchhu | 10 | 11 |
| Nangkor | 9 | 8 |
| Tseza | 8 | 8 |
| Kangpara | 8 | 8 |
| Naro | 8 | 10 |
| Sombey | 8 | 8 |
| Goenkhame | 7 | 8 |
| Mewang | 6 | 6 |
| Trashiyangtse | 5 | 5 |
| Chang | 4 | 4 |
| Langthil | 4 | 5 |
| Shingkhar | 4 | 4 |
| Korphu | 4 | 4 |
| Shermung | 3 | 3 |
| Metsho | 3 | 3 |
| Chapchha | 3 | 4 |
| Kabjisa | 3 | 3 |
| Genye | 3 | 3 |
| Minjay | 3 | 3 |
| Bongo | 3 | 3 |
| Daga | 3 | 3 |
| Lauri | 3 | 3 |
| Jaray | 2 | 2 |
| Bjachho | 2 | 2 |

| | | |
|---|---|---|
| Phobji | 2 | 2 |
| Jigmichhoeling | 2 | 2 |
| Shongphu | 2 | 2 |
| Nyisho | 2 | 2 |
| Dragteng | 2 | 2 |
| Gakiling | 1 | 1 |
| Naja | 1 | 1 |
| Tsamang | 1 | 1 |
| Uesu | 1 | 1 |
| Phongme | 1 | 1 |
| Katsho | 1 | 1 |
| Phuentenchhu | 1 | 1 |
| Goenshari | 1 | 1 |
| Soe | 1 | 1 |
| Gangte | 1 | 1 |
| Tsenkhar | 1 | 1 |
| Yalang | 1 | 1 |
| Khaling | 1 | 1 |
| Lungnyi | 1 | 0 |

*Annex 5. Gewogs at risk under broadleaved forests below 2000 masl*

| Gewog | RCP 4.5 ($km^2$) | RCP 8.5 ($km^2$) |
|---|---|---|
| Pangkhar | 460 | 457 |
| Athang | 292 | 294 |
| Jigmichhoeling | 288 | 286 |
| Trong | 259 | 258 |
| Saleng | 219 | 218 |
| Bongo | 209 | 208 |
| Nangkor | 202 | 201 |
| Serthig | 199 | 198 |
| Ngangla | 187 | 186 |
| Bjoka | 176 | 175 |
| Langchhenphu | 175 | 173 |
| Daga | 167 | 166 |
| Senge | 165 | 162 |
| Dewathang | 159 | 158 |
| Langthil | 159 | 160 |
| Martshala | 158 | 157 |
| Gongdue | 157 | 156 |
| Chhoekhor | 147 | 165 |
| Beteni | 139 | 138 |
| Doban | 136 | 135 |
| Jangchhubling | 136 | 135 |

| | | |
|---|---|---|
| Korphu | 133 | 133 |
| Bardo | 130 | 130 |
| Sombey | 127 | 128 |
| Norbugang | 123 | 122 |
| Shingkhar | 122 | 122 |
| Dechhenling | 119 | 118 |
| Nichula | 118 | 117 |
| Lunana | 115 | 128 |
| Getana | 113 | 112 |
| Hiley | 111 | 111 |
| Chokhorling | 111 | 110 |
| Kazhi | 109 | 121 |
| Gakiling | 108 | 108 |
| Tang | 108 | 112 |
| Toewang | 104 | 106 |
| Gangzur | 103 | 106 |
| Kurtoe | 103 | 114 |
| Dala | 102 | 102 |
| Khar | 98 | 98 |
| Khoma | 98 | 103 |
| Dungmin | 97 | 97 |
| Phuentsholing | 96 | 96 |
| Bumdeling | 95 | 101 |
| Sephu | 94 | 104 |
| Tseza | 94 | 94 |
| Tsento | 93 | 100 |
| Geling | 93 | 92 |
| Lauri | 92 | 91 |
| Phuntsthothang | 90 | 89 |
| Kalidzingkha | 89 | 88 |
| Dorona | 88 | 87 |
| Gozhing | 87 | 87 |
| Merak | 85 | 86 |
| Samtse | 84 | 83 |
| Kawang | 83 | 84 |
| Umling | 82 | 82 |
| Bji | 82 | 88 |
| Taklai | 81 | 80 |
| Mewang | 81 | 80 |
| Lhamoizingkha | 81 | 80 |
| Patakla | 80 | 80 |
| Tangsibji | 79 | 84 |
| Dekiling | 78 | 77 |
| Tsamang | 77 | 77 |

| | | |
|---|---|---|
| Udzorong | 77 | 77 |
| Sakteng | 77 | 79 |
| Chhume | 76 | 78 |
| Tsendagang | 76 | 75 |
| Pagli | 74 | 73 |
| Kengkhar | 73 | 73 |
| Shumer | 73 | 73 |
| Tading | 72 | 72 |
| Nubi | 71 | 74 |
| Deorali | 70 | 70 |
| Dorokha | 70 | 70 |
| Silambi | 69 | 69 |
| Dungna | 67 | 66 |
| Chengmari | 65 | 64 |
| Bara | 64 | 64 |
| Laya | 64 | 76 |
| Namgyel Chhoeling | 64 | 63 |
| Lajab | 63 | 62 |
| Kangpara | 62 | 62 |
| Sherzhong | 62 | 61 |
| Denchhukha | 59 | 58 |
| Lumang | 58 | 58 |
| Phuentenchhu | 57 | 57 |
| Logchina | 54 | 54 |
| Pemathang | 54 | 53 |
| Wangphu | 53 | 53 |
| Nanong | 53 | 53 |
| Ura | 52 | 51 |
| Samphelling | 51 | 51 |
| Khipisa | 50 | 50 |
| Shermung | 49 | 49 |
| Sama | 49 | 50 |
| Chhimung | 48 | 48 |
| Doteng | 47 | 48 |
| Gomdar | 47 | 47 |
| Tendu | 47 | 47 |
| Jurmey | 47 | 47 |
| Chang | 46 | 45 |
| Naja | 46 | 46 |
| Ruepisa | 46 | 45 |
| Thangrong | 45 | 45 |
| Metsho | 45 | 45 |
| Zobel | 45 | 44 |
| Goenkhatoe | 43 | 46 |

| | | |
|---|---|---|
| Dagala | 43 | 46 |
| Gasetsho Om | 41 | 42 |
| Khaling | 40 | 40 |
| Kabjisa | 40 | 40 |
| Jaray | 39 | 39 |
| Trashiyangtse | 38 | 38 |
| Minjay | 37 | 37 |
| Chapchha | 36 | 36 |
| Drepung | 34 | 34 |
| Chhubu | 34 | 34 |
| Biru | 34 | 34 |
| Samrang | 34 | 33 |
| Dungtoe | 33 | 33 |
| Mongar | 33 | 33 |
| Narang | 33 | 33 |
| Bhur | 33 | 33 |
| Yangnyer | 33 | 33 |
| Samkhar | 32 | 32 |
| Ngatshang | 32 | 32 |
| Gesarling | 32 | 32 |
| Drugyelgang | 32 | 32 |
| Doga | 31 | 30 |
| Tsenkhar | 30 | 30 |
| Trashiding | 30 | 30 |
| Bjachho | 29 | 29 |
| Metap | 28 | 28 |
| Gelephu | 28 | 27 |
| Yalang | 27 | 28 |
| Thrimshing | 27 | 27 |
| Kanglung | 27 | 27 |
| Chongshing | 27 | 27 |
| Chaskhar | 27 | 27 |
| Tsakaling | 27 | 27 |
| Tsangkha | 26 | 26 |
| Dangchhu | 26 | 27 |
| Goenkhame | 25 | 25 |
| Yurung | 24 | 24 |
| Goenshari | 24 | 24 |
| Menbi | 24 | 24 |
| Tsirangtoe | 23 | 23 |
| Jamkhar | 22 | 21 |
| Chargharay | 21 | 21 |
| Phongme | 21 | 21 |
| Shongphu | 21 | 21 |

| | | |
|---|---|---|
| Dunglegang | 21 | 21 |
| Uesu | 20 | 20 |
| Bartsham | 20 | 20 |
| Shapa | 20 | 20 |
| Lungnyi | 20 | 19 |
| Bjena | 18 | 19 |
| Rangthangling | 17 | 17 |
| Barzhong | 17 | 17 |
| Nyisho | 16 | 16 |
| Toepisa | 15 | 14 |
| Bidung | 14 | 14 |
| Dragteng | 14 | 14 |
| Lamgong | 14 | 13 |
| Chhali | 13 | 13 |
| Nahi | 13 | 13 |
| Ramjar | 13 | 13 |
| Guma | 13 | 13 |
| Lingzhi | 13 | 16 |
| Genye | 13 | 13 |
| Tomzhangtshen | 12 | 12 |
| Dzoma | 12 | 12 |
| Drametse | 12 | 12 |
| Gozhi | 12 | 12 |
| Shompangkha | 11 | 11 |
| Naro | 11 | 14 |
| Lingmukha | 10 | 10 |
| Phobji | 10 | 11 |
| Ugentse | 9 | 9 |
| Yoeseltse | 9 | 9 |
| Phangyuel | 9 | 9 |
| Balam | 9 | 9 |
| Gangte | 8 | 9 |
| Shemjong | 8 | 8 |
| Thedtsho | 8 | 8 |
| Talo | 8 | 8 |
| Toetsho | 8 | 8 |
| Mendrelgang | 8 | 8 |
| Khamdang | 8 | 8 |
| Katsho | 7 | 8 |
| Gasetsho Gom | 7 | 7 |
| Dopshari | 7 | 7 |
| Bapisa | 7 | 7 |
| Shengabjimi | 7 | 7 |
| Tsholingkhor | 7 | 7 |

| | | |
|---|---|---|
| Kikorthang | 6 | 6 |
| Gosarling | 5 | 5 |
| Sipsu | 5 | 5 |
| Radi | 5 | 5 |
| Hungrel | 4 | 4 |
| Wangchang | 4 | 4 |
| Soe | 1 | 1 |
| Chhuzagang | 1 | 1 |

*Annex 6. Total households at increased fire risk by Gewogs in Chir pine forests under RCP 4.5 from now till 2050*

| Gewog | Dzongkhag | Households |
|---|---|---|
| Bartsham | Trashigang | 112 |
| Bidung | Trashigang | 110 |
| Daga | Wangduephodrang | 91 |
| Ruepisa | Wangduephodrang | 74 |
| Balam | Monggar | 62 |
| Saleng | Monggar | 62 |
| Udzorong | Trashigang | 59 |
| Nyisho | Wangduephodrang | 58 |
| Chaskhar | Monggar | 56 |
| Guma | Punakha | 52 |
| Chhubu | Punakha | 50 |
| Bapisa | Punakha | 46 |
| Jamkhar | Yangtse | 44 |
| Athang | Wangduephodrang | 42 |
| Menbi | Lhuentse | 40 |
| Mongar | Monggar | 39 |
| Gangzur | Lhuentse | 33 |
| Ramjar | Yangtse | 33 |
| Thedtsho | Wangduephodrang | 33 |
| Tsenkhar | Lhuentse | 33 |
| Samkhar | Trashigang | 31 |
| Drepung | Monggar | 30 |
| Kanglung | Trashigang | 29 |
| Phangyuel | Wangduephodrang | 29 |
| Narang | Monggar | 28 |
| Chhali | Monggar | 25 |
| Gasetsho Gom | Wangduephodrang | 25 |
| Patakla | Tsirang | 25 |
| Yangnyer | Trashigang | 25 |
| Dzoma | Punakha | 23 |
| Thangrong | Monggar | 23 |
| Lajab | Dagana | 19 |

| | | |
|---|---|---|
| Nahi | Wangduephodrang | 19 |
| Kabjisa | Punakha | 17 |
| Khoma | Lhuentse | 17 |
| Tsamang | Monggar | 17 |
| Minjay | Lhuentse | 16 |
| Bjena | Wangduephodrang | 15 |
| Shermung | Monggar | 15 |
| Lingmukha | Punakha | 14 |
| Gasetsho Om | Wangduephodrang | 13 |
| Yalang | Yangtse | 13 |
| Tsakaling | Monggar | 12 |
| Ngatshang | Monggar | 11 |
| Radi | Trashigang | 11 |
| Jaray | Lhuentse | 9 |
| Metsho | Lhuentse | 8 |
| Phongme | Trashigang | 8 |
| Talo | Punakha | 8 |
| Drametse | Monggar | 7 |
| Khamdang | Yangtse | 7 |
| Shongphu | Trashigang | 7 |
| Toepisa | Punakha | 7 |
| Jurmey | Monggar | 6 |
| Nanong | Pemagatshel | 6 |
| Shengabjimi | Punakha | 6 |
| Shumer | Pemagatshel | 6 |
| Toewang | Punakha | 6 |
| Tomzhangtshen | Yangtse | 5 |
| Tsangkha | Dagana | 4 |
| Kangpara | Trashigang | 3 |
| Trong | Zhemgang | 3 |
| Bardo | Zhemgang | 2 |
| Langthil | Trongsa | 2 |
| Kengkhar | Monggar | 1 |
| Lauri | Samdrupjongkhar | 1 |
| Lumang | Trashigang | 1 |
| Shingkhar | Zhemgang | 1 |
| Thrimshing | Trashigang | 1 |
| Tsholingkhor | Tsirang | 1 |

*Annex 7. Total households at increased fire risk in Blue pine forests by Gewogs under RCP 4.5 from now till 2050*

| Gewog | Dzongkhag | Households |
|---|---|---|
| Kawang | Thimphu | 108 |
| Chhoekhor | Bumthang | 54 |
| Chang | Thimphu | 44 |
| Chapchha | Chhukha | 43 |
| Naja | Paro | 38 |
| Tsento | Paro | 38 |
| Mewang | Thimphu | 26 |
| Uesu | Haa | 22 |
| Tang | Bumthang | 21 |
| Gangte | Wangduephodrang | 19 |
| Sama | Haa | 19 |
| Dopshari | Paro | 18 |
| Ruepisa | Wangduephodrang | 18 |
| Shapa | Paro | 15 |
| Bjena | Wangduephodrang | 14 |
| Sephu | Wangduephodrang | 14 |
| Doga | Paro | 12 |
| Chhume | Bumthang | 10 |
| Genye | Thimphu | 10 |
| Wangchang | Paro | 10 |
| Lamgong | Paro | 7 |
| Doteng | Paro | 6 |
| Lungnyi | Paro | 6 |
| Dagala | Thimphu | 5 |
| Hungrel | Paro | 5 |
| Bji | Haa | 4 |
| Katsho | Haa | 4 |
| Trashiyangtse | Yangtse | 2 |
| Bji | Haa | 1 |
| Dungna | Chhukha | 1 |
| Geling | Chhukha | 1 |
| Phobji | Wangduephodrang | 1 |
| Tangsibji | Trongsa | 1 |
| Ura | Bumthang | 1 |

*Annex 8. Total households at increased fire risk in broadleaved forests (<2000) by Gewogs under RCP 4.5 from now till 2050*

| Gewog | Dzongkhag | Households |
|---|---|---|
| Jigmichhoeling | Sarpang | 408 |
| Hiley | Sarpang | 395 |
| Bongo | Chhukha | 373 |
| Phuentsholing | Chhukha | 373 |
| Dala | Chhukha | 362 |
| Tading | Samtse | 362 |
| Doban | Sarpang | 304 |
| Nanong | Pemagatshel | 301 |
| Shumer | Pemagatshel | 292 |
| Dewathang | Samdrupjongkhar | 278 |
| Pagli | Samtse | 262 |
| Samphelling | Chhukha | 255 |
| Dorokha | Samtse | 238 |
| Trong | Zhemgang | 214 |
| Gozhi | Dagana | 210 |
| Chongshing | Pemagatshel | 202 |
| Lumang | Trashigang | 195 |
| Trashiding | Dagana | 194 |
| Shongphu | Trashigang | 192 |
| Biru | Samtse | 179 |
| Zobel | Pemagatshel | 178 |
| Kalidzingkha | Dagana | 175 |
| Gesarling | Dagana | 174 |
| Geling | Chhukha | 172 |
| Bara | Samtse | 170 |
| Drugyelgang | Dagana | 170 |
| Bardo | Zhemgang | 168 |
| Dechhenling | Pemagatshel | 166 |
| Shingkhar | Zhemgang | 165 |
| Norbugang | Pemagatshel | 156 |
| Denchhukha | Samtse | 154 |
| Tsangkha | Dagana | 153 |
| Dekiling | Sarpang | 149 |
| Langthil | Trongsa | 149 |
| Lhamoizingkha | Dagana | 149 |
| Lajab | Dagana | 141 |
| Tsendagang | Dagana | 139 |
| Korphu | Trongsa | 134 |
| Ngangla | Zhemgang | 130 |
| Bjachho | Chhukha | 127 |
| Jangchhubling | Samdrupjongkhar | 127 |

| | | |
|---|---|---|
| Chokhorling | Pemagatshel | 126 |
| Gasetsho Om | Wangduephodrang | 125 |
| Dungtoe | Samtse | 124 |
| Tendu | Samtse | 117 |
| Samtse | Samtse | 114 |
| Shompangkha | Sarpang | 112 |
| Namgyel Chhoeling | Samtse | 110 |
| Nangkor | Zhemgang | 108 |
| Yurung | Pemagatshel | 108 |
| Lauri | Samdrupjongkhar | 104 |
| Kengkhar | Monggar | 103 |
| Jurmey | Monggar | 102 |
| Daga | Wangduephodrang | 101 |
| Martshala | Samdrupjongkhar | 101 |
| Mongar | Monggar | 98 |
| Bjena | Wangduephodrang | 97 |
| Chhimung | Pemagatshel | 94 |
| Kabjisa | Punakha | 94 |
| Gozhing | Zhemgang | 89 |
| Udzorong | Trashigang | 84 |
| Kangpara | Trashigang | 81 |
| Dorona | Dagana | 80 |
| Logchina | Chhukha | 80 |
| Kikorthang | Tsirang | 77 |
| Pangkhar | Zhemgang | 76 |
| Gosarling | Tsirang | 75 |
| Serthig | Samdrupjongkhar | 73 |
| Gomdar | Samdrupjongkhar | 72 |
| Shermung | Monggar | 68 |
| Sherzhong | Sarpang | 68 |
| Dragteng | Trongsa | 67 |
| Gelephu | Sarpang | 65 |
| Gangzur | Lhuentse | 64 |
| Bhur | Sarpang | 63 |
| Phuntsthothang | Samdrupjongkhar | 62 |
| Samkhar | Trashigang | 62 |
| Rangthangling | Tsirang | 61 |
| Sipsu | Samtse | 61 |
| Deorali | Dagana | 58 |
| Dungmin | Pemagatshel | 58 |
| Thrimshing | Trashigang | 58 |
| Yalang | Yangtse | 58 |
| Chargharay | Samtse | 57 |
| Phuentenchhu | Tsirang | 56 |

| | | |
|---|---|---|
| Chaskhar | Monggar | 54 |
| Getana | Chhukha | 52 |
| Ngatshang | Monggar | 52 |
| Kanglung | Trashigang | 51 |
| Ruepisa | Wangduephodrang | 50 |
| Dunglegang | Tsirang | 49 |
| Jamkhar | Yangtse | 49 |
| Khaling | Trashigang | 49 |
| Tangsibji | Trongsa | 49 |
| Yoeseltse | Samtse | 49 |
| Beteni | Tsirang | 48 |
| Mendrelgang | Tsirang | 48 |
| Langchhenphu | Samdrupjongkhar | 47 |
| Yangnyer | Trashigang | 47 |
| Goenkhame | Gasa | 46 |
| Tsirangtoe | Tsirang | 45 |
| Wangphu | Samdrupjongkhar | 45 |
| Khoma | Lhuentse | 44 |
| Phongme | Trashigang | 43 |
| Tsamang | Monggar | 43 |
| Bjoka | Zhemgang | 42 |
| Tseza | Dagana | 42 |
| Tsholingkhor | Tsirang | 42 |
| Bumdeling | Yangtse | 41 |
| Chhali | Monggar | 41 |
| Barzhong | Tsirang | 39 |
| Minjay | Lhuentse | 39 |
| Pemathang | Samdrupjongkhar | 39 |
| Radi | Trashigang | 38 |
| Patakla | Tsirang | 37 |
| Nyisho | Wangduephodrang | 36 |
| Toepisa | Punakha | 35 |
| Tomzhangtshen | Yangtse | 35 |
| Saleng | Monggar | 34 |
| Goenshari | Punakha | 33 |
| Senge | Sarpang | 33 |
| Shemjong | Tsirang | 33 |
| Ugentse | Samtse | 32 |
| Umling | Sarpang | 32 |
| Dungna | Chhukha | 30 |
| Khipisa | Dagana | 29 |
| Balam | Monggar | 28 |
| Kurtoe | Lhuentse | 28 |
| Bidung | Trashigang | 27 |

| | | |
|---|---|---|
| Drepung | Monggar | 27 |
| Silambi | Monggar | 27 |
| Tsakaling | Monggar | 27 |
| Gasetsho Gom | Wangduephodrang | 26 |
| Sombey | Haa | 26 |
| Trashiyangtse | Yangtse | 24 |
| Metap | Chhukha | 23 |
| Metsho | Lhuentse | 22 |
| Thangrong | Monggar | 22 |
| Shengabjimi | Punakha | 21 |
| Toewang | Punakha | 21 |
| Chengmari | Samtse | 19 |
| Nahi | Wangduephodrang | 19 |
| Gongdue | Monggar | 18 |
| Jaray | Lhuentse | 16 |
| Phangyuel | Wangduephodrang | 15 |
| Toetsho | Yangtse | 15 |
| Khamdang | Yangtse | 14 |
| Khar | Pemagatshel | 14 |
| Nichula | Dagana | 13 |
| Menbi | Lhuentse | 12 |
| Tsenkhar | Lhuentse | 12 |
| Nubi | Trongsa | 11 |
| Tsholingkhor | Tsirang | 11 |
| Chhubu | Punakha | 9 |
| Taklai | Sarpang | 9 |
| Talo | Punakha | 9 |
| Athang | Wangduephodrang | 6 |
| Chhuzagang | Sarpang | 5 |
| Gakiling | Haa | 5 |
| Kazhi | Wangduephodrang | 5 |
| Narang | Monggar | 4 |
| Bartsham | Trashigang | 3 |
| Guma | Punakha | 3 |
| Lingmukha | Punakha | 3 |
| Merak | Trashigang | 3 |
| Ramjar | Yangtse | 3 |
| Drametse | Monggar | 2 |
| Dzoma | Punakha | 2 |
| Dangchhu | Wangduephodrang | 1 |
| Samrang | Samdrupjongkhar | 1 |

*Annex 9. Religious structures at risk by Gewogs under RCP 4.5 from now till 2050*

| Gewog | Dzongkhag | Number of Structures |
|---|---|---|
| Nangkor | Zhemgang | 13 |
| Shongphu | Trashigang | 12 |
| Chhoekhor | Bumthang | 10 |
| Shermung | Monggar | 10 |
| Yurung | Pemagatshel | 10 |
| Bardo | Zhemgang | 10 |
| Serthig | Samdrupjongkhar | 9 |
| Zobel | Pemagatshel | 8 |
| Kawang | Thimphu | 8 |
| Langthil | Trongsa | 8 |
| Trong | Zhemgang | 8 |
| Tang | Bumthang | 7 |
| Mewang | Thimphu | 7 |
| Thrimshing | Trashigang | 7 |
| Jurmey | Monggar | 6 |
| Kangpara | Trashigang | 6 |
| Phongme | Trashigang | 6 |
| Bjoka | Zhemgang | 6 |
| Shingkhar | Zhemgang | 6 |
| Khoma | Lhuentse | 5 |
| Doteng | Paro | 5 |
| Chongshing | Pemagatshel | 5 |
| Dechhenling | Pemagatshel | 5 |
| Nanong | Pemagatshel | 5 |
| Bidung | Trashigang | 5 |
| Yangnyer | Trashigang | 5 |
| Korphu | Trongsa | 5 |
| Pangkhar | Zhemgang | 5 |
| Kalidzingkha | Dagana | 4 |
| Uesu | Haa | 4 |
| Gongdue | Monggar | 4 |
| Mongar | Monggar | 4 |
| Thangrong | Monggar | 4 |
| Naja | Paro | 4 |
| Dungmin | Pemagatshel | 4 |
| Norbugang | Pemagatshel | 4 |
| Dewathang | Samdrupjongkhar | 4 |
| Gomdar | Samdrupjongkhar | 4 |
| Lauri | Samdrupjongkhar | 4 |
| Martshala | Samdrupjongkhar | 4 |
| Samtse | Samtse | 4 |

| | | |
|---|---|---|
| Bjena | Wangduephodrang | 4 |
| Gangte | Wangduephodrang | 4 |
| Bongo | Chhukha | 3 |
| Phuentsholing | Chhukha | 3 |
| Tseza | Dagana | 3 |
| Metsho | Lhuentse | 3 |
| Ngatshang | Monggar | 3 |
| Saleng | Monggar | 3 |
| Shermung | Monggar | 3 |
| Silambi | Monggar | 3 |
| Tsamang | Monggar | 3 |
| Doga | Paro | 3 |
| Hungrel | Paro | 3 |
| Tsento | Paro | 3 |
| Chhimung | Pemagatshel | 3 |
| Chokhorling | Pemagatshel | 3 |
| Shumer | Pemagatshel | 3 |
| Chhubu | Punakha | 3 |
| Dzoma | Punakha | 3 |
| Talo | Punakha | 3 |
| Langchhenphu | Samdrupjongkhar | 3 |
| Pagli | Samtse | 3 |
| Ugentse | Samtse | 3 |
| Chang | Thimphu | 3 |
| Radi | Trashigang | 3 |
| Udzorong | Trashigang | 3 |
| Yangnyer | Trashigang | 3 |
| Dragteng | Trongsa | 3 |
| Gasetsho Om | Wangduephodrang | 3 |
| Bumdeling | Yangtse | 3 |
| Yalang | Yangtse | 3 |
| Ngangla | Zhemgang | 3 |
| Chhume | Bumthang | 2 |
| Chapchha | Chhukha | 2 |
| Dala | Chhukha | 2 |
| Getana | Chhukha | 2 |
| Katsho | Haa | 2 |
| Sama | Haa | 2 |
| Sombey | Haa | 2 |
| Gangzur | Lhuentse | 2 |
| Jaray | Lhuentse | 2 |
| Khoma | Lhuentse | 2 |
| Kurtoe | Lhuentse | 2 |
| Menbi | Lhuentse | 2 |

| | | |
|---|---|---|
| Tsenkhar | Lhuentse | 2 |
| Tsenkhar | Lhuentse | 2 |
| Chaskhar | Monggar | 2 |
| Chhali | Monggar | 2 |
| Drepung | Monggar | 2 |
| Tsakaling | Monggar | 2 |
| Dopshari | Paro | 2 |
| Lamgong | Paro | 2 |
| Lungnyi | Paro | 2 |
| Wangchang | Paro | 2 |
| Chongshing | Pemagatshel | 2 |
| Khar | Pemagatshel | 2 |
| Bapisa | Punakha | 2 |
| Chengmari | Samtse | 2 |
| Tendu | Samtse | 2 |
| Jigmichhoeling | Sarpang | 2 |
| Bartsham | Trashigang | 2 |
| Kanglung | Trashigang | 2 |
| Khaling | Trashigang | 2 |
| Samkhar | Trashigang | 2 |
| Samkhar | Trashigang | 2 |
| Langthil | Trongsa | 2 |
| Tangsibji | Trongsa | 2 |
| Athang | Wangduephodrang | 2 |
| Bjena | Wangduephodrang | 2 |
| Daga | Wangduephodrang | 2 |
| Nyisho | Wangduephodrang | 2 |
| Tomzhangtshen | Yangtse | 2 |
| Trashiyangtse | Yangtse | 2 |
| Gozhing | Zhemgang | 2 |
| Chhume | Bumthang | 1 |
| Bjachho | Chhukha | 1 |
| Geling | Chhukha | 1 |
| Geling | Chhukha | 1 |
| Samphelling | Chhukha | 1 |
| Samphelling | Chhukha | 1 |
| Drugyelgang | Dagana | 1 |
| Gesarling | Dagana | 1 |
| Laya | Gasa | 1 |
| Bji | Haa | 1 |
| Gakiling | Haa | 1 |
| Gangzur | Lhuentse | 1 |
| Jaray | Lhuentse | 1 |
| Kurtoe | Lhuentse | 1 |

| | | |
|---|---|---|
| Menbi | Lhuentse | 1 |
| Minjay | Lhuentse | 1 |
| Tsenkhar | Lhuentse | 1 |
| Balam | Monggar | 1 |
| Chhali | Monggar | 1 |
| Drepung | Monggar | 1 |
| Jurmey | Monggar | 1 |
| Kengkhar | Monggar | 1 |
| Saleng | Monggar | 1 |
| Silambi | Monggar | 1 |
| Thangrong | Monggar | 1 |
| Tsakaling | Monggar | 1 |
| Tsamang | Monggar | 1 |
| Dopshari | Paro | 1 |
| Shapa | Paro | 1 |
| Chokhorling | Pemagatshel | 1 |
| Nanong | Pemagatshel | 1 |
| Guma | Punakha | 1 |
| Lingmukha | Punakha | 1 |
| Toepisa | Punakha | 1 |
| Gomdar | Samdrupjongkhar | 1 |
| Lauri | Samdrupjongkhar | 1 |
| Phuntsthothang | Samdrupjongkhar | 1 |
| Wangphu | Samdrupjongkhar | 1 |
| Bara | Samtse | 1 |
| Chargharay | Samtse | 1 |
| Dorokha | Samtse | 1 |
| Dungtoe | Samtse | 1 |
| Sherzhong | Sarpang | 1 |
| Sherzhong | Sarpang | 1 |
| Umling | Sarpang | 1 |
| Kawang | Thimphu | 1 |
| Kanglung | Trashigang | 1 |
| Khaling | Trashigang | 1 |
| Lumang | Trashigang | 1 |
| Merak | Trashigang | 1 |
| Samkhar | Trashigang | 1 |
| Udzorong | Trashigang | 1 |
| Dragteng | Trongsa | 1 |
| Tangsibji | Trongsa | 1 |
| Beteni | Tsirang | 1 |
| Kikorthang | Tsirang | 1 |
| Tsirangtoe | Tsirang | 1 |
| Daga | Wangduephodrang | 1 |

| | | |
|---|---|---|
| Daga | Wangduephodrang | 1 |
| Gasetsho Gom | Wangduephodrang | 1 |
| Kazhi | Wangduephodrang | 1 |
| Nahi | Wangduephodrang | 1 |
| Phangyuel | Wangduephodrang | 1 |
| Ruepisa | Wangduephodrang | 1 |
| Sephu | Wangduephodrang | 1 |
| Thedtsho | Wangduephodrang | 1 |
| Thedtsho | Wangduephodrang | 1 |
| Bumdeling | Yangtse | 1 |
| Jamkhar | Yangtse | 1 |
| Jamkhar | Yangtse | 1 |
| Toetsho | Yangtse | 1 |
| Tomzhangtshen | Yangtse | 1 |
| Trashiyangtse | Yangtse | 1 |
| Yalang | Yangtse | 1 |
| Shingkhar | Zhemgang | 1 |

*Annex 10. Details of religious structures at risk by Gewogs and Dzongkhags*

| Name | Gewog | Dzongkhag | Category |
|---|---|---|---|
| Jarogang Lhakhang | Athang | Wangdue Phodrang | Lhakhang |
| Lophokha Lhakhang | Athang | Wangdue Phodrang | Lhakhang |
| Sanga Choekhorling Lhakhang | Baap | Punakha | Lhakhang |
| Dorangthang Peljorcholing Lhakhang | Baap | Punakha | Lhakhang |
| Khepshing Jigme Nidup Lhakhang | Balam | Mongar | Lhakhang |
| Beteni Lhakhang | Bara | Samtse | Lhakhang |
| Rawathang Lhakhang | Bardo | Zhemgang | Lhakhang |
| Phulabi Lhakhang | Bardo | Zhemgang | Lhakhang |
| Umling Lhakhang | Bardo | Zhemgang | Lhakhang |
| Langdurbi Lhakhang | Bardo | Zhemgang | Lhakhang |
| Digala Lhakhang | Bardo | Zhemgang | Lhakhang |
| Bardo Goenpapong Lhakhang | Bardo | Zhemgang | Lhakhang |
| Goenpong Ugyencholing Lhakhang | Bardo | Zhemgang | Lhakhang |
| Kalamti Lhakhang | Bardo | Zhemgang | Lhakhang |
| Relangbi Lhakhang | Bardo | Zhemgang | Lhakhang |
| Donga Moense Drajeling Gomdey | Bardo | Zhemgang | Gomdey |
| Muktangkhar Lhakhang | Bartsham | Trashigang | Gomdey |
| Kumung Lhakhang | Bartsham | Trashigang | Gomdey |
| Chorten | Bartsham | Trashigang | Chorten |
| Dhupi Dangra Mandir | Beteni | Tsirang | Mandhir |
| Lhendup Choling Lhakhang | Bidung | Trashigang | Gomdey |
| Gelong Goenpa Lhakhang | Bidung | Trashigang | Gomdey |
| Kherie Lhakhang | Bidung | Trashigang | Gomdey |

| | | | |
|---|---|---|---|
| Jaipo Lhakhang | Bidung | Trashigang | Gomdey |
| Mani dangray chorten | Bidung | Trashigang | Chorten |
| Zangdhog Pelri | Bjabcho | Chukha | Lhakhang |
| Drak Jangchub Lhakhang | Bjena | Wangdue Phodrang | Lhakhang |
| Khothang Jangsa Dzong | Bjena | Wangdue Phodrang | Lhakhang |
| Balakha Lhakhang | Bjena | Wangdue Phodrang | Lhakhang |
| Gangkalo Lhakhang | Bjena | Wangdue Phodrang | Lhakhang |
| Dungkhor Lhakhang | Bjena | Wangdue Phodrang | Lhakhang |
| Rinchhenling Lhakhang | Bjena | Wangdue Phodrang | Lhakhang |
| Tenchog Samten Choling | Bji | Ha | Choling |
| Gyen saer Lakhang | Bji | Ha | Lhakhang |
| Bjoka Trong Lhakhang | Bjoka | Zhemgang | Lhakhang |
| Barpong  Lhakhang | Bjoka | Zhemgang | Lhakhang |
| Samdrupcholing Lhakhang | Bjoka | Zhemgang | Lhakhang |
| Dalibi Lhakhang | Bjoka | Zhemgang | Lhakhang |
| Kumari Lhakhang | Bjoka | Zhemgang | Lhakhang |
| Bazaguru Lhakhang | Bjoka | Zhemgang | Lhakhang |
| Meritsemo Lhakhang | Bongo | Chukha | Lhakhang |
| Bongo Lhakhang | Bongo | Chukha | Lhakhang |
| Gedu Lhakhang | Bongo | Chukha | Lhakhang |
| Ketokha Lhakhang | Bongo | Chukha | Lhakhang |
| Zhapang Lhakhang | Bumdeling | Trashiyangtse | Lhakhang |
| Phanteng Lhakhang | Bumdeling | Trashiyangtse | Lhakhang |
| Shangyul Lhakhang | Bumdeling | Trashiyangtse | Lhakhang |
| Nganteng Lhakhang | Bumdeling | Trashiyangtse | Lhakhang |
| Shapchi Dungkhor Lhakhang | Chali | Mongar | Lhakhang |
| Charshong Samten Choling Lhakhang | Chali | Mongar | Lhakhang |
| Tshamkhang Tshewang Jamtsho ye Lhakhang | Chali | Mongar | Lhakhang |
| Kuruzam Pemawogling Lhakhang | Chali | Mongar | Lhakhang |
| Tashigang Goenpa | Chang | Thimphu | Goenpa |
| Drupkhana Lhakhang | Chang | Thimphu | Lhakhang |
| Semtokha Dzong | Chang | Thimphu | Shedra |
| Gur Gonpa | Chapcha | Chukha | Goenpa |
| Karsang Lhakhang | Chapcha | Chukha | Lhakhang |
| Chargharey Dratsang | Chargharey | Samtse | Dratshang |
| Bar Dungkhor Lhakhang | Chaskar | Mongar | Lhakhang |
| Hatkhola_Bazar_Chorten | Chengmari | Samtse | Chorten |
| Hatkhola Shivalaya Mandir | Chengmari | Samtse | Shivalaya Mandir |
| Jiligang Lhakhang | Chhubu | Punakha | Lhakhang |
| Jangwakha Lhakhang | Chhubu | Punakha | Lhakhang |
| Bali Lhakhang | Chhubu | Punakha | Lhakhang |
| Sonamgatshel Nye | Chhubu | Punakha | Nye |

| | | | |
|---|---|---|---|
| Chimong Dechenpelri Lhakhang | Chimoong | Pemagatshel | Lhakhang |
| Redingla  Lhakhang | Chimoong | Pemagatshel | Lhakhang |
| Longkholum Lhakhang | Chimoong | Pemagatshel | Lhakhang |
| Nyaskhar Dungkhor | Chimoong | Pemagatshel | Dungkhor |
| Tamshing Lhakhang | Choekhor | Bumthang | Lhakhang |
| Pedseling Lhakhang | Choekhor | Bumthang | Lhakhang |
| Dorjibee Lhakhang | Choekhor | Bumthang | Lhakhang |
| Dendupcholing Lhakhang | Choekhor | Bumthang | Lhakhang |
| Thangbi Lhuendrupchoedey Lhakhang | Choekhor | Bumthang | Gomdey |
| Taga Lhakhang | Choekhor | Bumthang | Lhakhang |
| Shudrag Lhakhang | Choekhor | Bumthang | Lhakhang |
| Thrasphel Lhakhang | Choekhor | Bumthang | Lhakhang |
| Saram Lhakhang | Choekhor | Bumthang | Lhakhang |
| Ugyen Shabchey Lhakhang | Choekhor | Bumthang | Lhakhang |
| Chokorling Dungkhor | Chokorling | Pemagatshel | Dungkhor |
| Deezama Lhakhang | Chokorling | Pemagatshel | Lhakhang |
| Gazawoong Lhakhang | Chokorling | Pemagatshel | Lhakhang |
| Kerong Lopenchorten Lhakhang | Chokorling | Pemagatshel | Lhakhang |
| Chongshing Kuenzang Choling Lhakhang | Chongshing | Pemagatshel | Lhakhang |
| Youmzor Lhakhang | Chongshing | Pemagatshel | Lhakhang |
| Mandi Lhakhang | Chongshing | Pemagatshel | Lhakhang |
| Yuomzor dungkhor | Chongshing | Pemagatshel | Dungkhor |
| Guyum Sangaycholing Lhakhang | Chongshing | Pemagatshel | Lhakhang |
| Zambala Lhakhang | Chumey | Bumthang | Lhakhang |
| Namphur Lhakhang | Chumey | Bumthang | Lhakhang |
| Terzoe Lhakhang | Chumey | Bumthang | Lhakhang |
| Norbugang Lhakhang | Daga | Wangdue Phodrang | Lhakhang |
| Uma Chhoeling Goenpa | Daga | Wangdue Phodrang | Goenpa |
| Gyalpakha Lhakhang | Daga | Wangdue Phodrang | Lhakhang |
| Taksha Norbuding Lhakahang | Daga | Wangdue Phodrang | Lhakhang |
| Pasakha Aamai Neykhang | Darla | Chukha | Neykhang |
| Darla Tashi  choeling Lhakhang | Darla | Chukha | Lhakhang |
| Ynagmalashing Dungkhor | Dechenling | Pemagatshel | Dungkhor |
| Layshingri Dungkhor | Dechenling | Pemagatshel | Dungkhor |
| Shingchongri Dungkhor | Dechenling | Pemagatshel | Dungkhor |
| Kulamanti Dungkhor | Dechenling | Pemagatshel | Dungkhor |
| Gonpawoong Dungkhor | Dechenling | Pemagatshel | Dungkhor |
| Denchukkha Shivalaya Mandir | Denchukha | Samtse | Shivalaya Mandir |
| S/Jongkhar drashang | Deothang | Samdrupjongkhar | Lhakhang |
| Samdrupjongkhar dzongnang | Deothang | Samdrupjongkhar | Lhakhang |
| Zangdopelri Lhakhang | Doethang | Samdrupjongkhar | Lhakhang |
| Maecharkarmalingcholing Lhakhang | Doethang | Samdrupjongkhar | Lhakhang |
| Dokar Tashichoding Lhakhang | Dogar | Paro | Lhakhang |

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| Drakteng Lhakhang | Dogar | Paro | Lhakhang |
| Gemdralog Lhakhang | Dogar | Paro | Lhakhang |
| Kotey Phusisi Lhakhang | Dopshari | Paro | Lhakhang |
| Tading Lhakhang | Dopshari | Paro | Lhakhang |
| Thak Choe Lhakhang | Dopshari | Paro | Lhakhang |
| Sengdhyen Goendhey | Dorokha | Samtse | Gomdey |
| Dorkha School Chorten | Dorokha | Samtse | Chorten |
| Chumo Phu Lhakhang | Doteng | Paro | Lhakhang |
| Goensar Lhakhakhang | Doteng | Paro | Lhakhang |
| Khandro Chedu Goenpa | Doteng | Paro | Goenpa |
| Damthaykha Dechencholing | Doteng | Paro | Lhakhang |
| Doelpo Shedra Lhakhang | Doteng | Paro | Lhakhang |
| Ashi Lhakhang | Doteng | Paro | Lhakhang |
| Para Lhakhang | Doteng | Paro | Lhakhang |
| Tashidingkha L/khang | Drakteng | Trongsa | Lhakhang |
| Chakar zur L/khang | Drakteng | Trongsa | Lhakhang |
| Drakteng Dungkhor L/khang | Drakteng | Trongsa | Lhakhang |
| Refey Khamey Tshag-Jab dungkhor l/khang | Drakteng | Trongsa | Lhakhang |
| Kungarabten Drubday goenpa L/kahng | Drakteng | Trongsa | Lhakhang |
| Laptsa Goenpa Tashicholing | Drepong | Mongar | Lhakhang |
| Namgonepa yoocholing Lhaknag | Drepong | Mongar | Lhakhang |
| Namla memay Chorten Lhakhang | Drepong | Mongar | Lhakhang |
| Namdrup choling | Drujeygang | Dagana | Choling |
| Wongborang Lhakhang | Dungmin | Pemagatshel | Lhakhang |
| Tomi Lhakhang | Dungmin | Pemagatshel | Lhakhang |
| Dungmin Lhakhang | Dungmin | Pemagatshel | Lhakhang |
| Wongborang Gonpa Lhakhang | Dungmin | Pemagatshel | Lhakhang |
| Aomla Lhakhang | Dungmin | Pemagatshel | Lhakhang |
| Lhakhang | Dungtoe | Samtse | Lhakhang |
| Tshogdag Langpoi Nye Lhakhang | Dzomi | Punakha | Lhakhang |
| Jimthang Lhakhang | Dzomi | Punakha | Lhakhang |
| Jojogoenpa Lhakhang | Dzomi | Punakha | Lhakhang |
| Wangchu lo Dzong | Eusu | Ha | Dzong |
| Chorkoling Tshulakhang | Eusu | Ha | Lhakhang |
| Tagchug lungtsho lakhang | Eusu | Ha | Lhakhang |
| Sharkada Lakhang | Eusu | Ha | Lhakhang |
| Gangtey Goenpa | Gangtey | Wangdue Phodrang | Lhakhang |
| Chuchig Zhay Lhakhang | Gangtey | Wangdue Phodrang | Lhakhang |
| Gyela Goenkhang | Gangtey | Wangdue Phodrang | Lhakhang |
| Kuenzang Chhoeling Lhakhang | Gangtey | Wangdue Phodrang | Lhakhang |
| Gesar Lhakhang | Gangzur | Lhuentse | Lhakhang |
| Jangchubling dratshang | Gangzur | Lhuentse | Dratshang |
| Tongling Lhakhang | Gangzur | Lhuentse | Lhakhang |

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| Ngar Lhakhang | Gangzur | Lhuentse | Lhakhang |
| Yodra Gondey Lhakhang | Gangzur | Lhuentse | Lhakhang |
| Matshig Pokto Lhakhang | Gasetsho Gom | Wangdue Phodrang | Lhakhang |
| Shingkhey Lhakhang | Gasetsho Wom | Wangdue Phodrang | Lhakhang |
| Thegchhen Ugyen Drak Lhakhang | Gasetsho Wom | Wangdue Phodrang | Lhakhang |
| Geekha Lhakhang | Gasetsho Wom | Wangdue Phodrang | Lhakhang |
| Gangrim Lakhang | Gaykedling | Ha | Lhakhang |
| Phuntsho Darjaycholing Lakhang | Gaykedling | Ha | Lhakhang |
| Geling Sa-ngag choeling Lhakhang | Geling | Chukha | Lhakhang |
| Kuenga choeling Gonpa | Geling | Chukha | Lhakhang |
| Gesarling Lhakhang | Gesarling | Dagana | Lhakhang |
| Tashigang Lhakhang | Getana | Chukha | Lhakhang |
| Tshebji Lhakhang | Getana | Chukha | Lhakhang |
| Phutsa Lhakhang | Getana | Chukha | Lhakhang |
| Chidungkhar Lhakhang | Gomdhar | Samdrupjongkhar | Lhakhang |
| Aumshing Lhakhang | Gomdhar | Samdrupjongkhar | Lhakhang |
| Phendhecholing Lhakhang | Gomdhar | Samdrupjongkhar | Lhakhang |
| Drongshing Lhakhang | Gomdhar | Samdrupjongkhar | Lhakhang |
| Mandir (Narphung) | Gomdhar | Samdrupjongkhar | Lhakhang |
| Pangthang Lhakhang | Gongdue | Mongar | Lhakhang |
| Phoksa Lhakhang | Gongdue | Mongar | Lhakhang |
| Damkhar Lhakhang | Gongdue | Mongar | Lhakhang |
| Balajangchunbcholing Lhakhang | Gongdue | Mongar | Lhakhang |
| Goshing Trong Lhakhang | Goshing | Zhemgang | Lhakhang |
| Lichibi Lhakhang | Goshing | Zhemgang | Lhakhang |
| Mewangang  Lhakhang | Goshing | Zhemgang | Lhakhang |
| Samcholing Gomdey | Goshing | Zhemgang | Gomdey |
| Choekhorling Goenpa | Guma | Punakha | Lhakhang |
| Zurig Gongma Lhakhang | Hungrel | Paro | ZGL |
| La Teng Lhakhang | Hungrel | Paro | Lhakhang |
| Chudra Lhakhang | Hungrel | Paro | Lhakhang |
| Labar Lhakhang | Jamkhar | Trashiyangtse | Lhakhang |
| Yesehry choling Goenpa | Jamkhar | Trashiyangtse | Goenpa |
| Yumchey Lhakhang | Jarey | Lhuentse | Lhakhang |
| Goenpagang Lhakhang | Jarey | Lhuentse | Lhakhang |
| Kiranang dungkhor | Jarey | Lhuentse | dungkhor |
| Yabi Lhakhang | Jarey | Lhuentse | Lhakhang |
| Jigmecholing Dratshang | Jigmecholing | Sarpang | Dratshang |
| Chungshing Lhakhang | Jigmecholing | Sarpang | Lhakhang |
| Singsiri Chimi drakpa Lhakhang | Jurmey | Mongar | Gomdey |
| Rakta Sonam RinchemLhakhang | Jurmey | Mongar | Lhakhang |
| Dungkhor cholingLhakhang | Jurmey | Mongar | Dratshang |
| Roro nam ugyen gytshel Lhakhang | Jurmey | Mongar | Dratshang |
| Ringphu lungten Gerwang Lhakhang | Jurmey | Mongar | Lhakhang |

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| Bayoul choda Gyerwang Lhakhang | Jurmey | Mongar | Lhakhang |
| Nganphu Yeshay Choiling Lhakhang | Jurmey | Mongar | Lhakhang |
| Chorten | Kana | Dagana | Chorten |
| Chorten | Kana | Dagana | Chorten |
| Chorten | Kana | Dagana | Chorten |
| Tapgang Lhakhang | Kana | Dagana | Lhakhang |
| Rongthung Naktshang Lhakhang | Kanglung | Trashigang | Lhakhang |
| Thukten Chekorling Shedra (Zangdopelri) | Kanglung | Trashigang | Shedra |
| Sanga Dorji Lhakhang | Kanglung | Trashigang | Gomdey |
| Resharlog Namgay Lhakhang | Kangpara | Trashigang | Gomdey |
| Phuntsho Tshering Dungkhor | Kangpara | Trashigang | Dungkhor |
| Merdha Mongdrang Lhakhang | Kangpara | Trashigang | Gomdey |
| Lhendup Samtencholing Lhakhang | Kangpara | Trashigang | Shedra |
| Kuenphen Choling Lhakhang | Kangpara | Trashigang | Gomdey |
| Jarokharshong Chorten | Kangpara | Trashigang | Chorten |
| Jungne drak Lakhang | Katsho | Ha | Lhakhang |
| Katsho Goempa | Katsho | Ha | Goenpa |
| Drolung Gonpa | Kawang | Thimphu | Drubdey |
| Tango Shedra | Kawang | Thimphu | Shedra |
| Chari Drubdey | Kawang | Thimphu | Drubdey |
| Ugyen Dongacholing | Kawang | Thimphu | Lhakhang |
| Paygiri drubdey | Kawang | Thimphu | Drubdey |
| Dodedra shedra | Kawang | Thimphu | Shedra |
| Decheling Gonpa | Kawang | Thimphu | Drubdey |
| Pumla Lhakhang | Kawang | Thimphu | Lhakhang |
| Thujidra Lhakhang | Kawang | Thimphu | Lhakhang |
| Wangditse Lhakhang | Kawang | Thimphu | Lhakhang |
| Bay Langdrag Nye Lhakhang | Kazhi | Wangdue Phodrang | Lhakhang |
| Chagina Lhakhang | Kazhi | Wangdue Phodrang | Lhakhang |
| Leymi Tshering Gyeltshen Lhakhang | Khaling | Trashigang | Gomdey |
| Leymi Gomchen Dorji Lhakhang | Khaling | Trashigang | Dungkhor |
| Jadrung Lhakhang | Khaling | Trashigang | Gomdey |
| Leymi Tashi Choling Lhakhang | Khaling | Trashigang | Gomdey |
| Khawar Lhakhang | Khar | Pemagatshel | Lhakhang |
| Khengzor Lhakhang | Khar | Pemagatshel | Lhakhang |
| Thongphu Gonpa | Khar | Pemagatshel | Lhakhang |
| Gyelmarkhar Thingrab tenling Lhakhang | Khengkhar | Mongar | Lhakhang |
| Memkhar Lhakhang | Khoma | Lhuentse | Lhakhang |
| Zepadhur lhakhag | Khoma | Lhuentse | Lhakhang |
| Sangay lodu Lhakhang | Khoma | Lhuentse | Lhakhang |
| Berpa lhakhqang Lhakhang | Khoma | Lhuentse | Lhakhang |
| Karphu Lhakhang | Khoma | Lhuentse | Lhakhang |
| Samdrubcholing Lhakhang | Khoma | Lhuentse | Lhakhang |
| Nyalamdung Naktshang | Khoma | Lhuentse | Naktsang |

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| Damphu Town Lhakhang | Kikhorthang | Tsirang | Lhakhang |
| Nimshong L/khang | Korphu | Trongsa | Lhakhang |
| Korphu L/khang | Korphu | Trongsa | Lhakhang |
| Korphu Dungkhor | Korphu | Trongsa | Lhakhang |
| Nabji Dungkhor | Korphu | Trongsa | Dungkhor |
| Korphu Gomday | Korphu | Trongsa | Gomdey |
| Ugyenphu Lhakhang | Kurtoe | Lhuentse | Lhakhang |
| Khambu Lhakhang | Kurtoe | Lhuentse | Lhakhang |
| Tsendenpokpa Lhakhang | Kurtoe | Lhuentse | Lhakhang |
| Rin Pung Lhakhang | Lamgong | Paro | Lhakhang |
| Tseto Goenpa Lhakhang | Lamgong | Paro | Lhakhang |
| Bayling Lhakhang | Langthil | Trongsa | Lhakhang |
| Baling Lhakhang | Langthil | Trongsa | Lhakhang |
| Wangkhar L/khang | langthil | Trongsa | Lhakhang |
| Sheling L/khang | langthil | Trongsa | Lhakhang |
| Jangbi L/khang | langthil | Trongsa | Lhakhang |
| Koshala Drolong Dungkhor l/khang | Langthil | Trongsa | Lhakhang |
| Taktsi L/khang | Langthil | Trongsa | Lhakhang |
| Lingtey L/khang | Langthil | Trongsa | Lhakhang |
| Baling Tobgay dunghor l/khang | Langthil | Trongsa | Lhakhang |
| Thrsebee Tashichholing | Langthil | Trongsa | Gomdey |
| Tsephu goenpa Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Batselingdrupdra Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Tashicholing Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Ngoengacholing Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Dungmanma (T-49) Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Woongthigdungkhor Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Sangacholing Lhakhang | Lauri | Samdrupjongkhar | Lhakhang |
| Dompala Lhakhang | Limbu | Punakha | Lhakhang |
| Jarokharshong Chorten | Lumang | Trashigang | Chorten |
| Dunggan Lhakhang | Lungo | Gasa | Lhakhang |
| Gadrak Changchu Lhakhang | Lungyni | Paro | Lhakhang |
| Dingshingzor  Lhakhang | Martsala | Samdrupjongkhar | Lhakhang |
| Thongpashingzor Lhakhang | Martsala | Samdrupjongkhar | Lhakhang |
| Kakani Lhakhang | Martsala | Samdrupjongkhar | Lhakhang |
| Tsholingkhar Lhakhang | Martsala | Samdrupjongkhar | Lhakhang |
| Barkha Lhakhang | Menbi | Lhuentse | Lhakhang |
| Menjabi Lhakhang | Menbi | Lhuentse | Lhakhang |
| Dangling Lhakhang | Menbi | Lhuentse | Lhakhang |
| Takila Lhakhang | Menbi | Lhuentse | Lhakhang |
| Mendrelgang Lhakhang | Mendrelgang | Tsirang | Lhakhang |
| Mendrelgang Hindu Lhakhang | Mendrelgang | Tsirang | Lhakhang |
| Khashiteng Lhakhang | Merak | Trashigang | Gomdey |
| Tongthrong Lhakhang | Metsho | Lhuentse | Lhakhang |

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| Duwazhing Lhakhang | Metsho | Lhuentse | Lhakhang |
| Zhongmay Lhakhang | Metsho | Lhuentse | Lhakhang |
| Tshaluney lhakhaqng | Mewang | Thimphu | Lhakhang |
| Semo Lhakhang | Mewang | Thimphu | Lhakhang |
| Datong Lhakhang | Mewang | Thimphu | Lhakhang |
| Dramisa Lhakhang | Mewang | Thimphu | Lhakhang |
| Khasakha Lhakhang | Mewang | Thimphu | Lhakhang |
| wangzhing naktsang Lhakhang | Minjey | Lhuentse | Naktsang |
| Sengling Lhakhang | Minjey | Lhuentse | Lhakhang |
| Phunchola Lhakhang | Mongar | Mongar | Dratshang |
| Nangling Lhakhang (Pema Dorji) | Mongar | Mongar | Lhakhang |
| Yakgang Sanga Choling Lhakhang | Mongar | Mongar | Lhakhang |
| Wengkhar Ngatshang Lhakhang | Mongar | Mongar | Dratshang |
| Wengkhar Kadam Lhakhang | Mongar | Mongar | Lhakhang |
| Khujula Chhoeling Phodrang Lhakhang | Nahi | Wangdue Phodrang | Lhakhang |
| Tandin Lhakhang | Nahi | Wangdue Phodrang | Lhakhang |
| Tshendu Goenpa | Naja | Paro | Goenpa |
| Tshedra Goenpa | Naja | Paro | Goenpa |
| Jawargoenpa jangchub Choling | Naja | Paro | Choling |
| Nagu Goenpai Lhakhang | Naja | Paro | Lhakhang |
| Tali Thegling dratshang | Nangkor | Zhemgang | Dratshang |
| Buli Goenpa Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Tali Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Duenmang Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Zhobling Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Kikhar Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Goling Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Phuntsh Peling Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Tshaidang Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Tshaidang Gomdey | Nangkor | Zhemgang | Gomdey |
| Dakphai Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Dakphai Gortab Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Kamjong Lhakhang | Nangkor | Zhemgang | Lhakhang |
| Rashigonpa Lhakhang | Nanong | Pemagatshel | Lhakhang |
| Tokari Gari Lhakhang | Nanong | Pemagatshel | Lhakhang |
| Wongchiloo Lhakhang | Nanong | Pemagatshel | Lhakhang |
| Wilegtang Lhakhang | Nanong | Pemagatshel | Lhakhang |
| Tokari (Tshering) Lhakhang | Nanong | Pemagatshel | Lhakhang |
| Thngthung gonpa Lhaknang | Nanong | Pemagatshel | Lhakhang |
| Ngangla Trong Lhakhang | Ngangla | Zhemgang | Lhakhang |
| Rebati Lhakhang | Ngangla | Zhemgang | Lhakhang |
| Panbang Lhakhang | Ngangla | Zhemgang | Lhakhang |
| Yadi sanga choling Lhakhang | Ngatshang | Mongar | Lhakhang |
| Kungacholing :Lhakhang | Ngatshang | Mongar | Lhakhang |

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| Sherubcholing Lhakhang Pema wangchuk | Ngatshang | Mongar | Lhakhang |
| Gashari Lhakhang | Norbugang | Pemagatshel | Lhakhang |
| Tshishingzor Lhakhang | Norbugang | Pemagatshel | Lhakhang |
| Tshishingzor Dungkhor | Norbugang | Pemagatshel | Dungkhor |
| Norbugang Dungkhor | Norbugang | Pemagatshel | Dungkhor |
| Samtengang Lhakhang | Nyisho | Wangdue Phodrang | Lhakhang |
| Nyishokha Lhakhang | Nyisho | Wangdue Phodrang | Lhakhang |
| Gashing gaon Chorten | Pagli | Samtse | Chorten |
| Shiva Mandir (Pvt) | Pagli | Samtse | Shivalaya Mandir |
| Durga Mandir | Pagli | Samtse | Durga Mandir |
| Mamung Trong Lhakhang | Phangkhar | Zhemgang | Lhakhang |
| Tashibi Yukhar Lhakhang | Phangkhar | Zhemgang | Lhakhang |
| Pantang  Lhakhang | Phangkhar | Zhemgang | Lhakhang |
| Pongchula Lhakhang | Phangkhar | Zhemgang | Lhakhang |
| Gujong Dungkhor Lhakhang | Phangkhar | Zhemgang | Lhakhang |
| Tayel Goenpai Dargye Goenpa | Phangyul | Wangdue Phodrang | Goenpa |
| Omshadrem Lhakhang | Phongmey | Trashigang | Shedra |
| Phongmey Hongmen Choling Lhakhang | Phongmey | Trashigang | Gomdey |
| Shokhang Zhabdrung Lhakhang | Phongmey | Trashigang | Gomdey |
| Thongrong Samten Choling Lhakhang | Phongmey | Trashigang | Gomdey |
| Jagngyenma Lhakhang | Phongmey | Trashigang | Gomdey |
| Pengtse Samdrup Choling Lhakhang | Phongmey | Trashigang | Gomdey |
| Dodril Dongaling Shedra | Phongmey | Trashigang | Shedra |
| Rinchending Lhakhang | Phuntsholing | Chukha | Dratshang |
| Pachu Dangra | Phuntsholing | Chukha | Goenpa |
| Nga-sumi Ney Lhakhang | Phuntsholing | Chukha | Lhakhang |
| Namgay Choeling Lakhang | Phuntsholing | Chukha | Lhakhang |
| Thangchu goenpa Lhakhang | Phuntshothang | Samdrupjongkhar | Lhakhang |
| Thekcho Kuenga Choling Lhakhang | Radhi | Trashigang | Nunnery |
| Namdrol Choling Lhakhang | Radhi | Trashigang | Gomdey |
| Jangchub Chorten | Radhi | Trashigang | Chorten |
| Zamding Lhakhang | Rubesa | Wangdue Phodrang | Lhakhang |
| Ulla Lhakhang | Rubesa | Wangdue Phodrang | Lhakhang |
| Tsholing goma Lhakhang | Saleng | Mongar | Lhakhang |
| Thridangbi Lhankhang | Saleng | Mongar | Lhakhang |
| Mangling tokapang Lhakhang | Saleng | Mongar | Lhakhang |
| Kalapang Gadencholing Lhakhang | Saleng | Mongar | Lhakhang |
| Broksa Ugyencholing Lhakhang | Saleng | Mongar | Lhakhang |
| Wama Lhakhang | Salimbi | Mongar | Lhakhang |
| Dakcha laye Lhakhang | Salimbi | Mongar | Lhakhang |
| Zegoen Lhakhang | Salimbi | Mongar | Lhakhang |
| Zegoen jangchub dorji dungkhor Lhakhang | Salimbi | Mongar | Lhakhang |
| Pudup tshuk Lakhang | Samar | Ha | Lhakhang |

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| Balam wang ge Lakhang | Samar | Ha | Lhakhang |
| Khapti Kegphu Gonpa Lhakhang | Samkhar | Trashigang | Gomdey |
| Taling Gonpa Lhakhang | Samkhar | Trashigang | Gomdey |
| Khapti Kadam Lhakhang | Samkhar | Trashigang | Gomdey |
| Pam Drodul Pema Yeling Lhakhang | Samkhar | Trashigang | Gomdey |
| Zhu shing Dingkha Gonpa | Sampheling | Chukha | Lhakhang |
| Pagsam Singye | Sampheling | Chukha | Zangdopelri |
| Guest House Chorten | Samtse | Samtse | Chorten |
| NIE Chorten | Samtse | Samtse | Chorten |
| Tercholing Lhakhang (Lamitar) | Samtse | Samtse | Lhakhang |
| Guru Lhakhang (Bukay) | Samtse | Samtse | Lhakhang |
| Tasim Shiva Mandir | Samtse | Samtse | Shivalaya Mandir |
| Rabgatse Lhakhang | Sephu | Wangdue Phodrang | Lhakhang |
| Samdrupcholing Lhakhang | Sershong | Sarpang | Lhakhang |
| Woedselgang Goenpa | Sershong | Sarpang | Goenpa |
| Deptshang ugyencholing Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Larjab pemagatshel Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Drenphu ugyencholing Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Khandrophung Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Moenmula Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Sangacholing Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Tashithangjay Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Juenmay tashicholing Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Moenmula karchung dongkhor Lhakhang | Serthi | Samdrupjongkhar | Lhakhang |
| Samdro Cholling Lhakhang | Shaba | Paro | Lhakhang |
| Neyphug Tshugla Khang | Shaba | Paro | NL |
| Bemori Lhakhang | Shaba | Paro | Lhakhang |
| Boetam Lhakhang | Shaba | Paro | Lhakhang |
| Nyephu Goem Gonpa | Shaba | Paro | Goenpa |
| Serchong Choling Lhakhang | Shermung | Mongar | Gomdey |
| Sherchong Tsechuphu Phuntsho Lhakhang | Shermung | Mongar | Lhakhang |
| Sherchong Pangtala Lhakhang Dendup | Shermung | Mongar | Lhakhang |
| Sherchong Lhakhang Ngawang | Shermung | Mongar | Lhakhang |
| Sonekhar Riling Lhakhang | Shermung | Mongar | Gomdey |
| Sonekhar Bomay Lhakhang Kelzang Wangdi | Shermung | Mongar | Lhakhang |
| Sonekhar Lhakhang Kinga Raday Lhakhang | Shermung | Mongar | Lhakhang |
| Thiling Lhagong goenpa lop sangay Dorji | Shermung | Mongar | Lhakhang |
| Thiling Barka Lhakhang Karma | Shermung | Mongar | Lhakhang |
| Jabgang pempa Lhakhang | Shermung | Mongar | Lhakhang |
| Jabgang Chorten Lhakhang | Shermung | Mongar | Lhakhang |
| Jabgang Tashi Lhakhang | Shermung | Mongar | Lhakhang |
| Jabgang Bopay Lhakhang | Shermung | Mongar | Lhakhang |

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| Gangmung Lhakhang | Shermung | Mongar | Lhakhang |
| Shingkhar Wambu Lhakhang | Shingkhar | Zhemgang | Lhakhang |
| Radhi Tashiding Lhakhang | Shingkhar | Zhemgang | Lhakhang |
| Zangling Lhakhang | Shingkhar | Zhemgang | Lhakhang |
| Thajong Lhakhang | Shingkhar | Zhemgang | Lhakhang |
| Jatshabi Lhakhang | Shingkhar | Zhemgang | Lhakhang |
| Peseng Zowachador Lhakhang | Shingkhar | Zhemgang | Lhakhang |
| Raha Lhakhang | Shongphu | Trashigang | Gomdey |
| Kuenphen Chekhorling Lhakhang | Shongphu | Trashigang | Gomdey |
| Dungphu Gonpa Lhakhang | Shongphu | Trashigang | Gomdey |
| Neykhang Lhakhang | Shongphu | Trashigang | Gomdey |
| Galing Tshering Dungkhor Lhakhang | Shongphu | Trashigang | Dungkhor |
| Neykhang Dekiling Lhakhang | Shongphu | Trashigang | Gomdey |
| Galing Drongmay Lhakhang | Shongphu | Trashigang | Gomdey |
| Kidpu Choling Lhakhang | Shongphu | Trashigang | Gomdey |
| Sangcham Gonpa Lhakhang | Shongphu | Trashigang | Gomdey |
| Chemari Lhakhang | Shongphu | Trashigang | Gomdey |
| Dramang Ridiser Lhakhang | Shongphu | Trashigang | Gomdey |
| Changmey Lhakhang | Shongphu | Trashigang | Gomdey |
| Dangling Dungkhor Lhakhang | Shongphu | Trashigang | Dungkhor |
| Bartsheri Lhakhang | Shumar | Pemagatshel | Lhakhang |
| Gyelpodrangsa Lhakhang | Shumar | Pemagatshel | Lhakhang |
| Dengtsirawa Lhakhang | Shumar | Pemagatshel | Lhakhang |
| Toepalung Lhakhang | Shumar | Pemagatshel | Lhakhang |
| Serkhegpa Sanag Dorji Lhakhang | Shumar | Pemagatshel | Lhakhang |
| Ana Goempa | Sombaykha | Ha | Goenpa |
| Pelri Dorji Dhen Tshuglakhang | Talo | Punakha | Tshug-lakhang |
| Nobgang Yulkhangna Lhakhang | Talo | Punakha | Lhakhang |
| Dashigang Gyelwa Lhakhang | Talo | Punakha | Lhakhang |
| Nalenda Sona Gatshel Lhakhang | Talo | Punakha | Lhakhang |
| Namkha Lhakhang | Tang | Bumthang | Lhakhang |
| Anu Lhakhang | Tang | Bumthang | Lhakhang |
| Ugyencholing Dzong | Tang | Bumthang | Lhakhang |
| Bumphog Lhakhang | Tang | Bumthang | Lhakhang |
| Rimochen | Tang | Bumthang | Lhakhang |
| Dorjitse Lhakhang | Tang | Bumthang | Gomdey |
| Dechenpelrithang Lhakhang ( HM's) | Tang | Bumthang | Lhakhang |
| Kela L/khang | Tangsibji | Trongsa | Lhakhang |
| Ugyen Thongdra L/khang | Tangsibji | Trongsa | Lhakhang |
| Chendbji Chorten | Tangsibji | Trongsa | Chorten |
| Tendu Dratsang | Tendu | Samtse | Dratshang |
| Tendu School Chorten | Tendu | Samtse | Chorten |
| Chorten (Ap Daw Tshering) | Tendu | Samtse | Chorten |

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| D-Bindu New Lhakhang | Tendu | Samtse | Lhakhang |
| Zimbula Peling Goenpa | Teotsho | Trashiyangtse | Lhakhang |
| Dumang Lhakhang | Teotsho | Trashiyangtse | Lhakhang |
| ThongThong Gonpa | Thangrong | Mongar | Lhakhang |
| Changshing Gonpa Lop Gyeltshen | Thangrong | Mongar | Lhakhang |
| Ri phu Lhakhang (Sangay Drakpa) | Thangrong | Mongar | Lhakhang |
| Tongphuyoung Lhakhang (Karma Dorji) | Thangrong | Mongar | Lhakhang |
| Trebang Nimadorji Dungkhor Lhakhang | Thangrong | Mongar | Lhakhang |
| Changzhong Lhakhang | Thangrong | Mongar | Lhakhang |
| Bajo Thangu Lhakhang | Thedtsho | Wangdue Phodrang | Lhakhang |
| Gashari Lhakhang | Thrimshing | Trashigang | Gomdey |
| Bongzor Lhakhang | Thrimshing | Trashigang | Gomdey |
| Yongderi Lhakhang | Thrimshing | Trashigang | Gomdey |
| Thungkhar Serkem Lhakhang | Thrimshing | Trashigang | Gomdey |
| Tshogphel Lhakhang | Thrimshing | Trashigang | Gomdey |
| Thekshok Pema Yuling | Thrimshing | Trashigang | Gomdey |
| Mani Dangray | Thrimshing | Trashigang | Mani Dangray |
| Gomphu Kora Dratshang | Tongzhangtshen | Trashiyangtse | Dratshang |
| Bainangkhar Ugyen choling Lhakhang | Tongzhangtshen | Trashiyangtse | Lhakhang |
| Druk Drasamdrup choling Lhakhang | Tongzhangtshen | Trashiyangtse | Lhakhang |
| Zatshen Choling Lhakhang | Tongzhangtshen | Trashiyangtse | Lhakhang |
| Dungkhor Lhakhang | Trashiyangtse | Trashiyangtse | Lhakhang |
| Teng Gomdhey Lhakhang | Trashiyangtse | Trashiyangtse | Lhakhang |
| Thamchu Khenpo Dratshang | Trashiyangtse | Trashiyangtse | Lhakhang |
| Tama Goenpa Gomdey | Trong | Zhemgang | Gomdey |
| Tama Lhakhang | Trong | Zhemgang | Lhakhang |
| Gomphu Lhakhang | Trong | Zhemgang | Lhakhang |
| Berti Trong Lhakhang | Trong | Zhemgang | Lhakhang |
| Trong Lhakhang | Trong | Zhemgang | Lhakhang |
| Dangkhar Lhakhang | Trong | Zhemgang | Lhakhang |
| Zurphey Lhakhang | Trong | Zhemgang | Lhakhang |
| Subrang Lhakhang | Trong | Zhemgang | Lhakhang |
| Gunda Dranamling Dungkhor Lhakhang | Tsakling | Mongar | Lhakhang |
| Gunda Penden Choling Dungkhor Lhakhang | Tsakling | Mongar | Lhakhang |
| Changlagang baryousen sum Lhakhang | Tsakling | Mongar | Lhakhang |
| Thumling Tashicholing Dungkhor Lhakhang | Tsakling | Mongar | Lhakhang |
| Nartshe Dungkhor Choling Lhakhang | Tsakling | Mongar | Lhakhang |
| Phangray Lhakhang | Tsenkhar | Lhuentse | Lhakhang |
| Takchu Lhakhang | Tsenkhar | Lhuentse | Lhakhang |
| Tongphugang Lhakhang | Tsenkhar | Lhuentse | Lhakhang |
| Namdrupling Gonpa dratshang | Tsenkhar | Lhuentse | Dratshang |
| Lhading Goenpa | Tsento | Paro | Goenpa |

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| Ugyen Tshemo Tsugla Khang | Tsento | Paro | UTL |
| Droley Phu Lhakhang | Tsento | Paro | Lhakhang |
| Daga Tashi Yangtse Dzong | Tseza | Dagana | Dzong |
| Shakthong goenpa | Tseza | Dagana | Goenpa |
| Samey Lhakhang | Tseza | Dagana | Lhakhang |
| Sarbum Lhakhang | Tshamang | Mongar | Lhakhang |
| Banjar Lhakhang | Tshamang | Mongar | Lhakhang |
| Dramaling Nangar Lhakhang | Tshamang | Mongar | Lhakhang |
| Ganglapong Lhakhang | Tshamang | Mongar | Lhakhang |
| Dauthrey Lhakhang | Tsirangtoe | Tsirang | Lhakhang |
| Boteykharka Shivalaya Mandir | Ugentse | Samtse | Shivalaya Mandir |
| Raigaon Shivalaya Mandir | Ugentse | Samtse | Shivalaya Mandir |
| Ugentse Namgay Khanzang Chorten | Ugentse | Samtse | Chorten |
| Umling Lhakhang | Umling | Sarpang | Lhakhang |
| Throlnang Lhakhang | Uzorong | Trashigang | Gomdey |
| Riegoem Lhakhang | Uzorong | Trashigang | Gomdey |
| Neydhen Gatshel Lhakhang | Uzorong | Trashigang | Gomdey |
| Dhensalo Lhakhang | Uzorong | Trashigang | Gomdey |
| Kir Khu Gonpa | Wangchang | Paro | Goenpa |
| Gomdra Lo Lhakhang | Wangchang | Paro | Lhakhang |
| Yarphu Tsachilu Lhakhang | Wangphu | Samdrupjongkhar | Lhakhang |
| Trashithang Jaling Lhakhang | Yallang | Trashiyangtse | Lhakhang |
| Yalang Gaykar Goenpa | Yallang | Trashiyangtse | Lhakhang |
| Chema Lhakhang | Yallang | Trashiyangtse | Lhakhang |
| Phungyang Tshokhang | Yallang | Trashiyangtse | Tshokhang |
| Durung Ugyen Wangchuk Lhakhang | Yangneer | Trashigang | Gomdey |
| Gomchen Langala Lhakhang | Yangneer | Trashigang | Gomdey |
| Talung Dopo Lhakhang | Yangneer | Trashigang | Gomdey |
| Lama Rinchen Lhakhang | Yangneer | Trashigang | Gomdey |
| Tshenmey Chokhorling Lhakhang | Yangneer | Trashigang | Gomdey |
| Shingkhar Gonpa Lhakhang | Yangneer | Trashigang | Gomdey |
| Durung Lhakhang | Yangneer | Trashigang | Gomdey |
| Chazam Duptho Thongthong Gyelpo Lhakhang | Yangneer | Trashigang | Lhakhang |
| Tokden Choling Dubdey | Yangneer | Trashigang | Choling |
| Thungo Lhakhang | Yurung | Pemagatshel | Lhakhang |
| Tashicholing Lhakhang | Yurung | Pemagatshel | Lhakhang |
| Dungsingma Lhakhang | Yurung | Pemagatshel | Lhakhang |
| Chengri dungkhor Lhakhang | Yurung | Pemagatshel | Lhakhang |
| Phunsumburi Lhakhang (Peljor wangdi) | Yurung | Pemagatshel | Lhakhang |
| Phunsumburi Lhakhang (Jangchu dendup) | Yurung | Pemagatshel | Lhakhang |
| Gomtshang Lhakhang | Yurung | Pemagatshel | Lhakhang |
| Yanglikhoi Lhakhang | Yurung | Pemagatshel | Lhakhang |

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| Gypkha Lhakhang | Yurung | Pemagatshel | Lhakhang |
| Zobel Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Resinang Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Showmarthung Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Layshingkhar Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Chungkhag gonpa Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Bachok Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Leteri Lhakhang | Zobel | Pemagatshel | Lhakhang |
| Gonpasingma Lhakhang | Zobel | Pemagatshel | Lhakhang |

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