Forest Fire Hazard Mapping in Bhutan

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Abstract

The study intends to assimilate data for assessing fire hazards in Bhutan. There has been an increase in fire events over the past few decades, and forest fires have made it urgent to research the issue. Bhutan documented 1,403 instances of forest fires in less than ten years (Kuensel, 11th Jan. 2020). Knowing where there are potential fire hazards is crucial as a result. Many fossil fuels are burned during forest fires, a significant amount of carbon dioxide is produced, which adds to the most prevalent greenhouse gas and changes the regional climate. Moreover, studies have indicated that one of the influential elements contributing to forest fires is climate change. The goal of this research is to consolidate all datasets from multiple sources onto a single GIS platform for the creation of maps that take climatic conditions into account while calculating forest fire threat. To lessen the risk of forest fires, recommendations and adaption methods are offered in this paper. In particular, the Department of Forest and Park Services in Bhutan can benefit from the findings of the research for the development, planning, and implementation works.

Key words: *Forest fire, hazards, GIS*

1. INTRODUCTION

All types of burning caused by industrial emissions, buildings, forest fires, and agricultural all contribute to the radiative gases in the atmosphere, or GHGs (greenhouse gases). Most prominent among these is carbon dioxide, which modifies the local climate. Forest fires have a significant role in the creation of carbon dioxide as a result of the extensive burning of fossil fuels. Globally, there is growing worry about climate change. In 2015, nearly all nations vowed to keep global temperatures well below 2°C by reducing carbon emissions by ratifying the Paris Agreement on climate change.

Bhutan, on the other hand, is regarded as having a carbon negative environment because of its extensive intact forest cover and low level of urbanization. Yet, due to its geological features, precipitation, and steep terrain, Bhutan is extremely sensitive to many climate-related impacts and natural catastrophes (WWF, 2011). If not controlled and mitigated, a large-scale forest fire may have an impact on the carbon balance and result in problems for the environment and society. The forest fire has a negative impact on the climate change and makes a significant contribution to it.

There has been an increase in fire events over the past few decades, and forest fires have made it urgent to research the issue. Bhutan recorded a total of 1,403 forest fire events in less than ten years. Success of forest regeneration is influenced by local geology, fire severity, and weather patterns. The topographical terrain of the country makes it harder to contain fire. 709.27 million tonnes of carbon are stored in Bhutan's forests as biomass, dead organic matter, detritus, and soil organic matter. The forest-urban fire interface is narrowing as urban development encroaches into the forestland, increasing the potential of fire tragedies (Kuensel, 2020, Jan. 11). One of Bhutan's oldest temples, Druk Wangditse Lhakhang, which served as the 8th Druk Desi's residence and had historical significance dating to 1715, was recently destroyed by a forest fire (BBS, May 22, 2021). Although potential climate change effects on forest fires in this region are not well studied, increased wildfire activity in the Himalayan

Mountains could threaten rural livelihoods (Vilà-Vilardell et al., 2020).

***Fig. 1**: Recent Forest Fire Incidences in Bhutan (Source: bbs.bt)*

2. LITERATURE REVIEW:

Forest fires have varying degrees of intensity and effects on people, property, the ecosystem, and the climate. In addition to human activity, environmental, hydrological, and geological elements are cited in literature as having a significant impact on the likelihood of forest fires. The most significant elements influencing fire activity, according to some reports, are weather and climate, both of which are undergoing changes as a result of human-caused climate change. Warmer conditions are predicted to result in more severe fire weather, more area burned, more ignitions, and a longer fire season (Flannigan, M. D., 2006). As evidenced by science and observations, human-induced climate change is the cause of the rise in land burned in Canada during the past 40 years (Gillett et al., 2004). According to reports, areas burned in Canada and Alaska coincided with hotter weather (Duffy et al. 2005; Flannigan et al. 2005). In addition to the temperature and precipitation, factors that contribute to extreme events and fire activity include land use land cover of a region, elevation, slope and aspect. Global fire carbon losses have the potential to play a significant role in the changing climate. There is a chance that a hotter, dryer environment will foster more fire-friendly circumstances. Hence, fires will produce more carbon emissions, which will contribute to global warming (Kurz et al. 1995). As a result, the connection between fire and climate change may have important effects on forests, forestry operations, community safety, and carbon budgets. It was noted that the effects of climate change on fire regimes are having substantial repercussions and may limit the ecosystem's capacity to recover. Where the climate is drier, an increase in fire frequency and intensity is projected. Glenn, N. H., et al. (2008) listed the effects of forest fires, including loss of vegetation in extensively burned areas, increased erosion, increased soil hydrophobicity, loss of organic material, and changes to habitat. This may have an effect on the economy, society, and environment. Moreover, it will take time for stabilization and regeneration. Forest fires modify the physical, chemical, and mineralogical characteristics of soil, affecting its nutritional content, ability to hold water, stability of its aggregates, and hydrophobicity, which changes the ecosystem as a whole (Certini, 2005). Water runoff and a reduction in water infiltration into the soil can be caused by soil erosion brought on by the severity of the fire and the loss of vegetation. Organic substance burns more quickly as the temperature rises. The organic matter in the upper soil layers and on the surface of the soil is reduced or completely removed as a result of combustion (Certini, 2005). Depending on how severe the fire is, organic material exposed to it may become somewhat distilled, charred, or totally oxidized. Forest fires modify the forest's composition and fire regime, according to research and published literature. According to Kofinas et al. (2010), changes in forest cover have a significant impact on human society, wildlife populations, and landscape dynamics. According to Riordan et al. (2006), the

distribution of forests has an impact on water runoff, which causes wetlands to dry up and rivers to flow less freely. Wet land drying also limits habitat and will have negative social and economic effects.

According to the cited literature, forest fires have a significant negative impact on the environment and have harmed Bhutan's rich biodiversity, caused species extinctions, altered soil moisture levels, increased runoff and soil erosion, and decreased infiltration rates that have an impact on the watershed and sources.

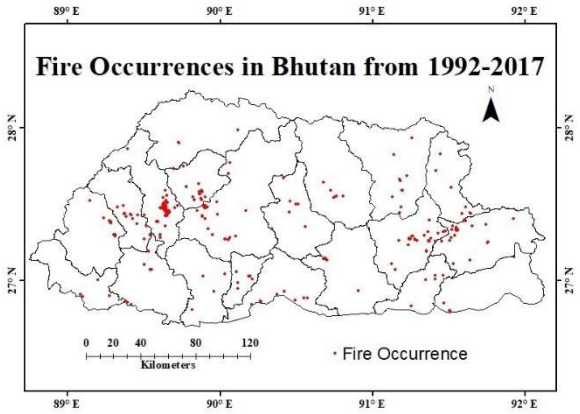

Fig. 2: Forest Fire Occurrence in Bhutan Since 1992-2017

Changes in the fire regime, root injury and a decline in the capacity to regenerate, nutrient losses, loss of organic soil and biomass, and the loss of bacteria and microorganisms are all factors. They have a significant impact on the community's way of life and the soil. It has resulted in fragile, barren, and lost lands, depriving the population of enough and pure water for drinking, irrigation, and important agricultural goods including timber and nonwood forest products. Forest fires impose danger to the lives and property of the community to large-scale. Fig. 2 and Table 1 indicates some of the forest fire occurrences in Bhutan.

Table 1: Forest Fire Incidences Recorded from Kuensel

Year	Location	Fire Hazard	Cause of fire
23-May-21	Druk Wangditse Lhakhang, Thimphu	Forest fire destroyed more than 1,000 acres of forest.	Under investigation. The fire raged on 2 days. The fire was said to be fueled by strong wind and dry vegetation.
11-May-21	Sangaygang, Thimphu	Forest razed to fire.	Not known
25-Apr-21	Tseykha village, Punakha	Forest razed to fire.	Not known
4-Apr-21	Gengkhar Village, Udzorong, Trashigang & Tongmajangsa Gewog, Trashi Yangtse	More than 350 acres of forest destroyed to fire. No casualty reported.	Officials suspected lightening to have caused the fire. Steep terrain and windy weather made it difficult to contain the fire.
3-Apr-21	Darkar Gewog, Wangdue Phodrang	More than 300 acres of forest lost to fire.	Not known. Dried shrubs and heavy wind worsened the battle with fire.
14-Nov-20	Chhubu Gewog, Punakha	Around 800 acres of the forest is lost to the fire.	Officials suspected illegal wildlife poaching in the area to be the cause of the fire. The fire raged for 5 days.
29-Feb-20	Above Bajo town, Wangdue Phodrang	More than 40 acres of forest lost to fire.	Forest officials suspected human error for causing the forest fire.
8-Feb-20	Samkhar Gewog, Trashigang	A cowshed at Pam was burnt down and an ox was injured.	Not known.

Warmer climate conditions, colder winters, and extremely windy autumn seasons will be anticipated as a result of an increase in temperature, the terracing of lands, the inability of ecosystems to recover, the shifting of ecosystems, and changes in relative humidity if the frequency and extent of burning significantly increases, causing major disruptions in the regeneration and loss of forest. This situation is being faced by Bhutanese cities. In order to influence future requirements and needs, and safeguard the woods, forest fire management and policy needs to be given the highest priority.

According to Gyelmo D. (2016), forest fires have destroyed the ecology and had a wide range of negative effects, including the destruction of infrastructure, the threat to wildlife habitat, and even the risk to Bhutan's run-of-river hydropower plants, a key component of Bhutan's growth and development. The average annual loss of forest due to fire is 10,000 acres, with the majority of these fires being caused by human activity due to fast urbanization, climate change, and short circuit.

The goal of this research is to create forest fire hazard map for Bhutan due to the effects of climate change using a GIS platform. Based on the findings, mitigation and adaptation strategies to reduce forest fires are also suggested.

3. METHODOLOGY

The increase in forest fires, wildfires and even urban fires necessitates the development of fire hazards maps for awareness, proper planning and disaster risk reduction. Fire safety measures can be taken in time using the fire risk maps. Among the several factors that contribute to fire hazards, six factors have been chosen in this research for developing the hazard map.

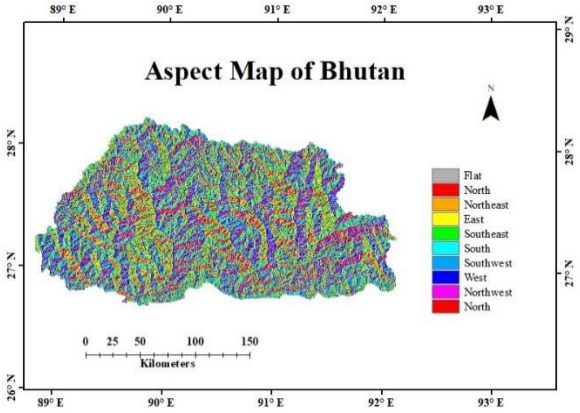

Fig. 3: Aspect Map of Bhutan

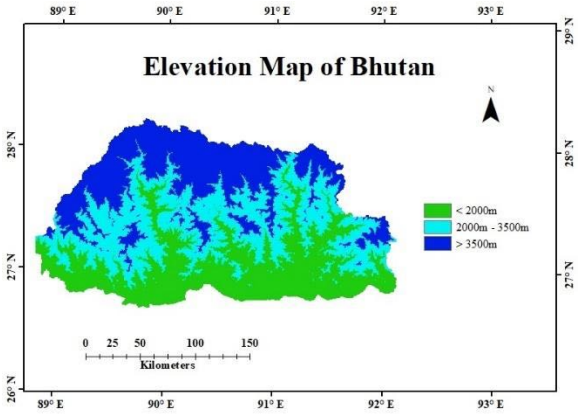

Fig. 4: Elevation Map of Bhutan

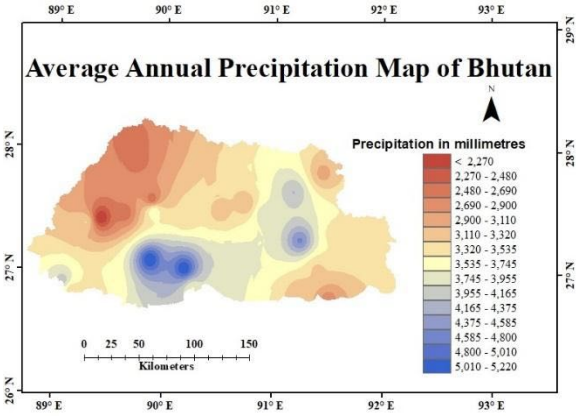

Fig. 5: Average Annual Precipitation Map of Bhutan

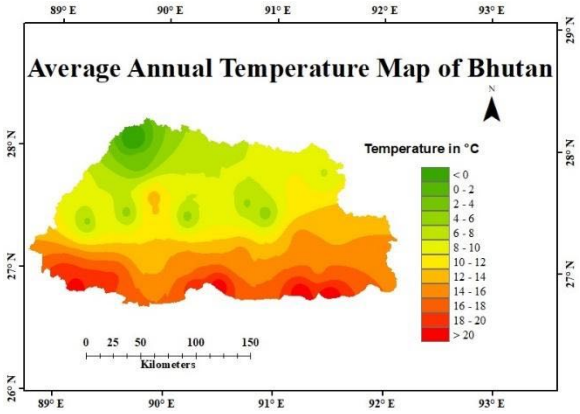

Fig. 6: Annual Average Temperature Map of Bhutan

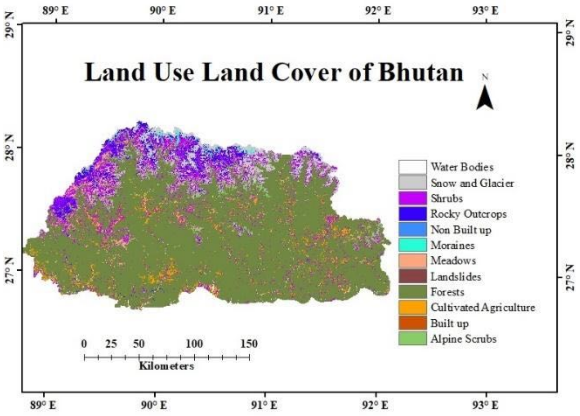

Fig. 7: Land Use Land Cover Map of Bhutan

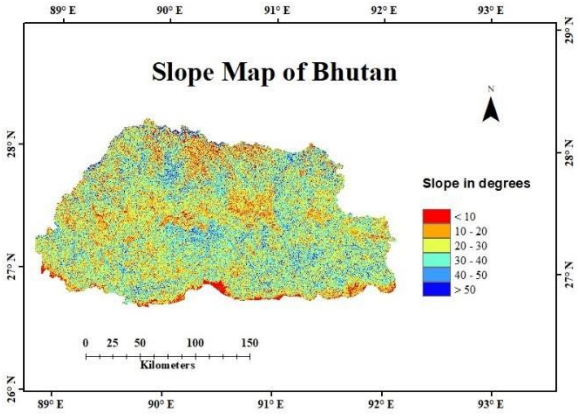

Fig. 8: Slope Map of Bhutan

Land use land cover data, average annual rainfall, average annual temperature, slope, aspect values and elevation have been used as the input data. ArcGIS 10.5 platform has been employed for geoprocessing the data and developing the fire hazard map of Bhutan. GIS can prove to be a very useful spatial tool in forest fire management and early warning system. The procedure involved data collection, spatial analysis using GIS tool and then finally exporting the hazard map. The spatial layers of six factors were generated in the software and reclassified followed by weighted overlaying. Classification was done based on the level of risk of the fire hazard as, High Risk Area, Moderate Risk Area and Low Risk Area. Following are the respective maps developed using the geospatial tool.

4. RESULTS AND CONCLUSION

It has been determined after a thorough research and analysis of the literature that an increase in temperature directly correlates with the occurrence of fire dangers. The risk of fires is decreased by an increase in the yearly average rainfall. It was discovered that as height and slope change, the risk of fire decreases. In a similar vein, fire risks should be lower in the north than in the east, west, or south depending on the aspect. Also, it was discovered that compared to populated areas, water bodies, or agricultural areas, bushes, meadows, and woodlands are more prone to fire.

Following fire incidences, the effects of forest fire on the environment and society are of the utmost importance. It has been noted that fire and heavy rain are unsettling elements that contribute to soil erosion, land degradation, and desertification (M.F.Garcia et. al., 1998). Increases in fire frequency and intensity result in considerable disturbances to forest regeneration and forest loss, which will have a negative impact on the climate. These are the typical conditions that Bhutan's urban centers encounter. In order to influence future requirements and needs and safeguard the woods, this places the highest priority on forest fire management and policy.

According to the cited literature, forest fires have a significant negative impact on the environment and have harmed Bhutan's rich biodiversity, caused species extinctions, altered soil moisture levels, increased runoff and soil erosion, and decreased infiltration rates that have an impact on the watershed and sources. They have a major effect on the land, environment, and way of life in the community.

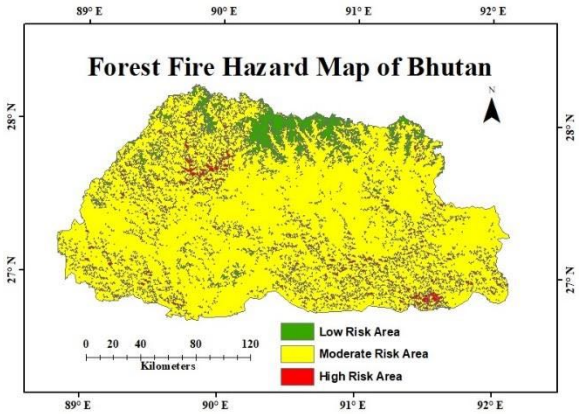

Fig. 9: Forest Fire Hazard Map of Bhutan

Fig. 9 shows the Forest Fire Hazard Map of Bhutan generated included all the possible causative factors. Even though the Department of Forest and Park Services is confident and has sound forest fire management and mitigation strategies with a field data inventory to record the occurrences, more technological improvement is needed to control the fire dangers efficiently. The metropolitan regions of Thimphu, Punakha, Wangduephodrang, and Samdrupjongkhar are high-risk fire zones; the majority of fires there are caused by irresponsible burning and human error, but their effects on Bhutan's forests are alarming. Bhutan places a significant premium on improving data collecting and recording,

inventory sheets, soil tests, and research. The reform and improvement of the main needs and cause will be greatly aided by improvements and investments in laboratories, people resources, technology, and financial support.

According to research findings on causes and occurrence, Bhutan's forest fires can be prevented and protected with the use of advocacy and awareness campaigns, cutting-edge technology, and the creation of forest fire apps. But for the long-term sustainability of the land, the forest, the environment, and the community, it is more important to understand and manage watershed areas and soil conditions. Because this is urgently needed in Bhutan's urban areas, post-forest fire actions should maintain an emphasis on the regeneration of the forest region. Forests have a history of becoming arid in Thimphu.

Some recommendations based on research findings incudes the necessity to maintain and revise the inventory of forest fires, followed by extensive need for research on forest fires for sustainability. Bhutan must improve its use of cutting-edge technologies and data collection. A more effective and efficient redesign is required for the awareness and advocacy programs. To ensure a safer and more sustainable Bhutan, community participation and involvement in forest fire events should be increased.

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