

# Status and Practical Implications of Forest Fire Management in Nepal

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## Abstract

Forest fire occurs globally on various scales every year, causing economic, social, ecological, and environmental damage. In a developing country like Nepal, a critical review of policy envisions and its translation concerning the prevailing wildfire scenarios is lacking which is crucial for sustainable forest fire management. We examine the existing disaster management policies relevant to forest fire, and analyse forest fire incidences and their impact on forest cover loss and eCO<sub>2</sub> (equivalent carbon dioxide) emissions using the data from Global Forest Watch (GFW) between 2001 to 2021. We also assessed public finance scenarios for forest fire management in Nepal and correlated and compared these data with each other. Our results find that the 'Forest Fire Management Strategy 2010' is the only comprehensive policy document that guides forest fire management in Nepal. Despite having low political and financial support (dedicated forest fire management budget is <0.5 per cent out of all forestry sector), awareness raising programme such as celebration of forest fire management week, broadcasting awareness raising messages and information, use of forest firefighting tools and equipments are some of the ground level interventions to prevent and control forest fire. GFW data shows that 29443 visual infrared imaging radiometer suite (VIIRS) fire alerts record (available only for 2012 to 2021), burns 207956.5 hectares (ha) area, 3.28 ha of forest cover loss, and 1132 Mg eCO<sub>2</sub> emissions every year on average. These figures are 0.07 per cent, 0.05 per cent, and 0.0176 per cent compared to total forest cover loss, total emission (eCO<sub>2</sub>) from the forest, and proportion of tree cover loss to burnt area, respectively. Results entail that the existing forest fire management policy requires a revisit considering the changed national and international context, forest fire should be considered as a high priority by all sectors and actors because of its widespread socio-economic, ecological, and environmental impacts. Ignorance of forest fire management could severely hinder the target for national and international commitments including performance-based carbon trading and maintaining forest cover. The findings would provide insights for policy decisions to manage forest fires sustainably.

**Keywords:** Forest degradation, public finance, policy envision, sustainable fire management

## INTRODUCTION

Climate change has become a prime discourse in the international and national forums and has been closely linked with the development agendas, sectors, and actors. Rising temperature, prolonged drought, sporadic rainfall, and seasonal change in the rainfall patterns are some of the evidences of climate change that triggers increase in forest fires' severity globally (Gavin *et al.* 2007; Wotton *et al.* 2010). Evidences on climatic change is apparent in Nepal as well (MoFE 2019) and the National

Climate Change Policy 2019 recognises forest fire as one of the climate-induced disasters (GoN 2019a). As climatic parameters like the mean annual temperature is likely to increase by 0.9- 1.1°C in the medium-term (2016-2045) and 1.3-2.8°C in the long-term (2036-2065) (GoN/MoFE 2021) in the country, the likely effect of changing climate on incidences of forest fires would further increase in the future. The risk of forest fire further increases with high accumulation of fuel load in the forests

(Saatchi *et al.* 2007), primarily due to poor forest management practices (Wijewardana 2008; Flannigan *et al.* 2013). Nepal is not an exception to this where lack of forest management practices has increased the risk of forest fire (Pandey *et al.* 2016; Pandey and Pokhrel 2021a). Therefore, Nepalese forest is likely to receive severe forest fire incidents vis-à-vis damage, as long as forest management practices are not carried out as per the forest management guidelines.

Globally, forest fires claim millions worth of properties and lives (Flannigan *et al.* 2013). Unprecedented forest fires in Australia (Borchers Arriagada *et al.* 2020) and in the United States of America (Abatzoglou *et al.* 2018; Keeley and Syphard 2019), are a few recent examples, that have resulted in damage to invaluable forests, loss of biodiversity, and claimed dozens of human lives. In South Asia, more than half of the forested areas have been lost to forest fire in past 15 years (2003–2017) and is regarded as the forest fire hotspots in the world (Reddy *et al.* 2020b). Fires in forests not only contributes to the global greenhouse gas (GHG) emission budget (Maraseni *et al.* 2016; Vizzuality 2021), but also results in the loss of floras and faunas that are considered important from biodiversity point of view (Pastro *et al.* 2011; Schmerbeck and Fiener 2015). Among South Asian countries, Bangladesh has the highest number of forest fire hotspots (34%) followed by India (32%) and Nepal, with 29.5 per cent of forest areas likely to catch forest fire every year (Reddy *et al.* 2020a). Not only do they cause serious environmental damage (Maraseni *et al.* 2016), studies show that forest fire triggers maternal health and pregnancy problems among women (Xue *et al.* 2021).

With diversity in the topography, Nepal is regarded as one of the disaster-prone countries in the world where incidents of natural disasters, including wildfire is experienced every year (NPC 2013). According to the records of the Ministry of Home Affairs, approximately an average of 500 disasters' events was recorded each year in the period of 1971 to 2016. During the same period, a total

of 8,721 forest fire events was recorded (MoHA 2017a; MoHA 2018). Likewise, about 590000 ha of forest was lost to forest fire in 2016, the highest for the period of 2001 to 2021 (Vizzuality 2021). The recent evidence from visible infrared imaging radiometer suite (VIIRS) (LAADS DAAC 2021) shows that there were 1048 VIIRS fire alerts reported between 31 August 2020 and 23 August 2021, considering high confidence alerts in Nepal (Vizzuality 2021). Developed countries have a well-established mechanism to tackle forest fires in a credible standard such as well-established and dedicated fire-fighting institutions, fire alert mechanisms, and early warning and awareness technologies. There have also been some efforts in developing countries like Nepal, where various provisions to combat against forest fires through policy instrumentation, institutional setup, and programmatic coverage exists. Yet, there are limitations in regards to the actual implementation in the ground due mainly to limited resources, technology, poor coordination among relevant institutions, low level of awareness, difficult terrains, and lack of human resources.

Fire is concerned with materials available for burning, required optimum temperature/heat as a source, and oxygen for burning support, and is associated with the shortage of moisture/water content in the burning material. The combination of these three components are called 'fire triangle'. The absence of any one would be an unfavorable condition for fire-ignition. Breaking that triangle of fire occurrence largely concentrates for forest fire management in and across the globe. In case of Nepal, it is often overlooked as fires mostly take place outside private properties, and there is always a limited resource and capacity of the concerned agencies to address the issue. A study shows that about 58 per cent of forest fire is a result of deliberate burning by grazers, poachers, hunters, and non-timber forest product (NTFP) collectors; 22 per cent due to negligence and 20 per cent by accident in Nepal. Likewise, more than 80 per cent of forest fire occurs in March and April whereas about 60 per cent forest fire occurs in April alone

(Mathema 2013). In addition, the changing climate has been believed to exacerbate the problem of forest fire (MoFE 2019).

Several institutional, legal, and policy frameworks are in place for disaster risk reduction, including forest fire in Nepal. Forest Fire Management Strategy 2010 is an explicit document on forest fire management in Nepal that largely guides the preparation of plans and prevention of wildfire on the ground. However, despite having the strategy (MoFSC/GoN 2010), continuous investment from the public finance, and tireless efforts from more than 22,000 community forest users' groups (Pandey and Pokhrel 2021a), the ever-rising trend of forest fire incidents (Vizzuality 2021), yet there are gaps on the existing mechanism and policy provision and practice to contain forest fires in Nepal. Moreover, in the context of federalism, it is quite relevant and timely to assess this strategy's relevance. It is also crucial to understand forest fire in order to meet the global targets including Sustainable Development Goals (SDGs) and Sendai Framework for Disaster Risk Reduction (MoHA 2017b), Paris Climatic Agreement (GoN 2020), road to net zero emissions, mainstreaming mitigation and adaptation options combating climate change and biodiversity conservation-related commitments concerning forests.

This paper critically assesses the existing policies concerning forest fire management, examines the current trend of forest fire occurrence, forest burns and its implication on forest cover, and public finance provisions to contain forest fires. In addition, it also suggests plausible way forward for sustainable forest fire management in Nepal and in the countries having similar political-social and environmental context.

## MATERIAL AND METHOD

This paper is prepared based on the review of existing policies pertinent to disaster management, primarily focusing on forest fire management provision. Similarly, historical forest loss, forest fires incidences, forest areas burn were examined

using the online data sources from Global Forest Watch (Vizzuality 2021). Comparison of total forest loss to the forest loss due to fire, and total GHG emissions from forest to the GHG emissions from forest fires, was carried out. Finally, the result is discussed with the government priority for forest fires management analysing public finance on forest fire management in Nepal.

We reviewed the following policies for disaster management in Nepal that addresses wildfire management directly and indirectly: Constitution of Nepal (GoN 2015); Natural Calamity Relief Act 1982 (HMG 1982); Local Self Governance Act, 2017 (GoN 2017); National Strategy on Disaster Risk Management, 2009 (GoN 2009); National Disaster Response Framework, 2013 (MoHA 2013); Guidance Note on Disaster Preparedness and Response Planning, 2011 (GoN 2011); National Guideline for Search and Rescue, 2014 (GoN 2014); District Disaster Preparedness and Response Plans for every district (sample plans from Rolpa and Darchula districts); National Policy for Disaster Risk Reduction, 2018 (GoN 2018a); Standard Operating Procedures of National Emergency Operation Center (NEOC); and District Emergency Operation Centre (DEOCs). As the Ministry of Forests and Environment is the focal ministry for dealing with forest fire management, the following policies concerning this ministry were critically analysed: Forest Fire Management Strategy 2010 (MoFSC/GoN 2010), National Climate Change Policy, 2019 (GoN 2019a); National Forest Policy, 2019 (GoN 2018b); National Environment Policy, 2019 (GoN 2019b); Forest Act, 2019 (GoN 2019c); National Parks and Wildlife Conservation Act and their regulations (HMG 1975) and Fiscal Acts for past 10 years, to weigh the emphasis of the government to contain the forest fires through public finance in the country.

The historic forest cover change, forest cover change due to fire, total eCO<sub>2</sub> emission from the forest, and eCO<sub>2</sub> emission from forest fire from 2001-2021 was obtained from the online portal of

the Global Forest Watch Organization (Vizzuality 2021). These observations were calculated using the moderated resolution imaging spectroradiometer (MODIS) data source for the forested area of Nepal. Similarly, the VIIRS fire alerts from 2012 to 2021 were obtained from the same portal with a spatial resolution of 750 m since VIIRS data were only available for 2012 and thereafter due to the commencement of such system only in 2011 (LAADS DAAC 2021).

The data on public finance were obtained from the Ministry of Forests and Environment and dedicated forest fire management budget from the Ministry of Finance (MoF), by reviewing the Fiscal Acts for past years. Likewise, GFW information and policy intervention on wildfire management were compared, correlated, and discussed. The variables such as total forest loss, total forest burn, total emission eCO<sub>2</sub> from forests, and emission from forest fires, and VIIRS alerts were tested against each other using correlation tests in R-programming (R Core Team 2019). Based on the findings and critical review of the existing policy documents on disasters management, plausible policy and practical insights for sustainable fire management are put forward.

## RESULTS

### Overview of Prevailing Forest Fire Management Strategy

Careful analysis of the above-mentioned disaster-related policy documents showed that the Forest Fire Management Strategy, 2010 is the only explicit document for wildfire management in Nepal. However, some provisions on forest fire management are also observed in the forestry sector policies such as, the Forest Policy, the Forest Act, and the National Parks and Wildlife Conservation Act and their regulations.

As statutory provisions are the guiding-frames, the policy document – Forest Fire Management Strategy, 2010 has been dealt in detail. The Forest Fire Management Strategy 2010, has covered a wider spectrum of strategic actions with four specified pillars. These pillars include policy, legal and institutional reform, ground-level awareness-raising, participatory research, and strengthening collaboration with national and international stakeholders working in forest fire management (Figure 1).

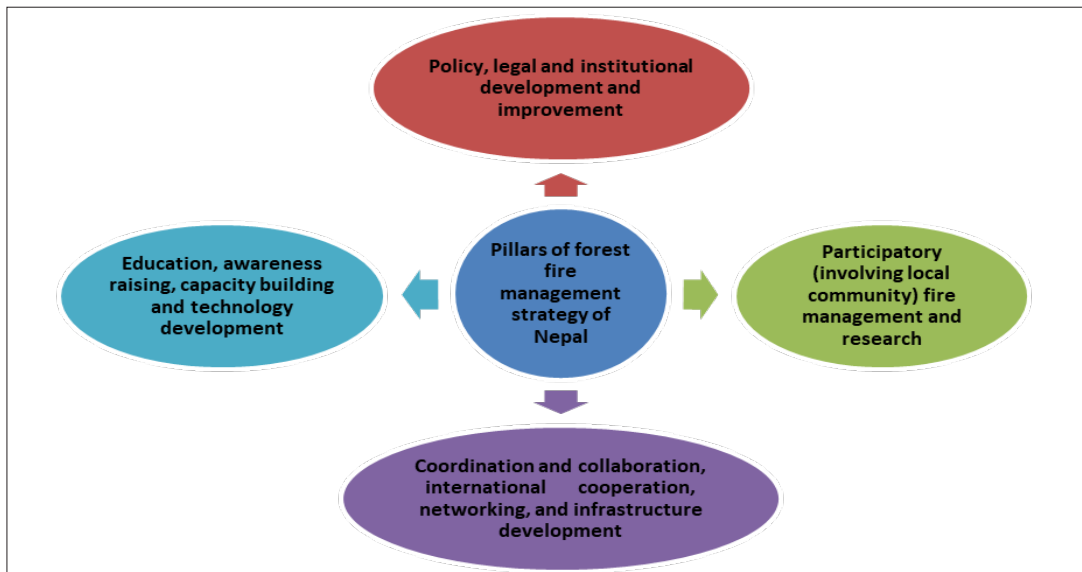


Figure 1: Strategic Pillars of Forest Fire Management Strategy, 2010 of Nepal (Adapted from MoFSC/GoN 2010).

The Strategy has a vision ‘to safeguard life and properties, protect the environment, and provide livelihood supports to the local communities. The goal of the strategy is to mitigate the loss of life, properties, biodiversity, and ecosystem

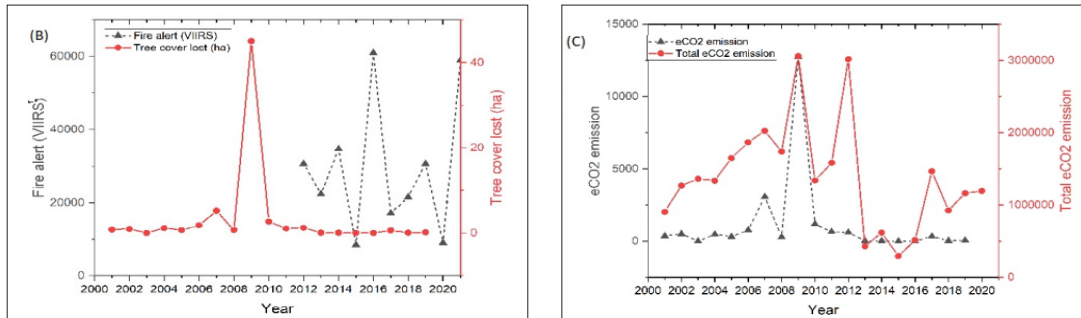
by managing forest fires properly to increase the productivity of forests. To meet the overall vision and the strategic goal, the strategy focuses on both preventive and remedial measures for forest fire management which are summarised in table 1.

**Table 1: Measures and Provisions of the Forest Fire Management Strategy 2010**

Measures	Major provisions	Remarks
Preventive	Policy, legal and institutional restructuring: participatory policy, law and strategy formulation linking forest fires management in all forestry sector policies; restructuring the ministry and its wings and strengthen the forest fire management mechanism through cooperation and coordination outside the forestry sector; motivate and encourage people and institutions to get involved in fire management, develop volunteer units for wildfire management; implement reward and punishment mechanism effectively	Achievements so far has not been satisfactory
	Education, awareness, capacity enhancement and technology development: integration of forest fire management to school level curriculum and training courses, and aware the public through various media; organising workshop, conferences and interaction to aware and capacitate the stakeholders; and promote/prioritise local-knowledge-based forest fire management technology	Achievements so far has not been satisfactory
	Forest fire related participatory research and development: carry out research on fires impact on forests, biodiversity, carbon emission, amenity and socio-economic aspect; communication and information management obtained from fire research through effective media; promoting technology development for forest fire management	Achievements so far has not been satisfactory
	Coordination, networking and infrastructure development: strengthen local, regional, national and international cooperation and networking; utilise prescribed burning, slash and burn; use of information and communication technology (ICT) for fire management and use fire as a management tool; facilitate fire management through sustainable forest management in all management models; incorporate livelihood supports to local people	Achievements so far has not been satisfactory
Remedial	Forest fire control: integration of all forestry sector plan to manage forest fire; managing all cycle of forest fire through local to central level coordination; establishing incident command system (ICS) and capacitate the forestry institutions; celebrating ‘Fire Management Week’ every year; provision of a declaration of ‘fire emergency’; rescue, relief, and rehabilitation. The focal agency is assigned to the Ministry of Forests and Environment (then the ministry of Forest and soil conservation).	Field gear purchase and fire management week celebration are prevalent

## Historic Forest Fire Incidences and Their Impacts on Forest and GHG Emission

The historic forest loss and total forest area burnt in Nepal is shown in figure 2A. Meanwhile, the VIIRS fire alert corresponds to the tree cover loss due to fire incidences (figure 2B) and overall forest emissions to forest fire emission (figure 2C).



**Figure 2: Forest Loss, Fire Alert, Forest Burn, and Emissions from Forest and Forest Fire in Nepal (Source: Vizzuality 2021)**

The trend indicates that there was hardly any relationship between forest burn and total forest loss observed until 2015, however there is a weak positive correlation (figure 2A). The peak of total forest loss was observed in 2009 and 2012, while forest area burns was at its peak – almost 600,000 ha, took place in 2016, the highest in two decades. The second peak of forest area burn was observed in 2019 (figure 2A). Similarly, there is no clear-cut correlation between fire alert (VIIRS) to tree cover loss due to fire. Though the VIIRS fire alert reached the highest – about 60000 in 2016 and almost equal for 2021, such fires are relatively

mild in terms of tree cover loss, compared to other years (figure 2B). However, as the total forest loss observed a peak in 2009 (figure 2A), the tree cover loss due to fire witnessed the highest in the same year (figure 2B). Meanwhile, the total emissions from forest and emission (eCO<sub>2</sub>) due to forest fire was positively correlated. Almost all emissions from the forests in 2009 can be attributed to forest fire alone (figure 2C). In 2012, though the fire incidences peaked (Fig. 2B), the proportional eCO<sub>2</sub> Mg emissions could not observe as peak as the fire incidences occurred and the corresponding forest area burned (ha) (Fig. 2A).

**Table 2: The Summary of Correlation between Forest Fire-Related Variables and the Annual Average Quantity of the Variables Under Consideration**

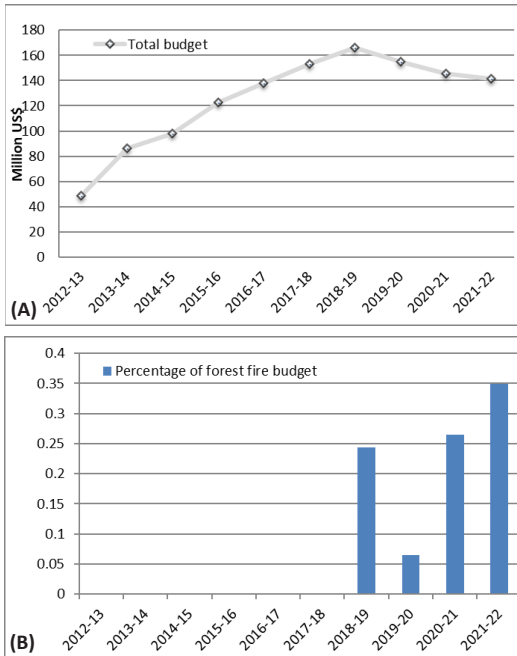
Variables	Correlation coefficient	Variables	Annual average quantity
VIIRS fire alert to forest burn area (ha)	0.763*	No. of VIIRS fire alert	29443
VIIRS fire alert to tree cover lost by fire (ha)	-0.242	Forest burn (ha)	207956.5
VIIRS fire alert to total forest cover loss (ha)	-0.325	Tree cover loss by fires (ha)	3.28
VIIRS fire alert to emission by fire (Mg eCO <sub>2</sub> )	-0.247	Fire emission (Mg eCO <sub>2</sub> )	1132.09
Burn area to total forest loss (ha)	-0.153	Total forest loss (ha)	2429.42
Total forest cover loss to forest covers loss by fire (ha)	0.627*	Total emission from forests (Mg eCO <sub>2</sub> )	1388797.82
Burn area (ha) to total emission from forest (Mg eCO <sub>2</sub> )	-0.163	Forest covers loss by fire (%)	0.07
Burn area (ha) to fire emission (Mg eCO <sub>2</sub> )	-0.007	Emission by fire (eCO <sub>2</sub> %)	0.05
Total emission from forests (Mg eCO <sub>2</sub> ) to emission from fire (Mg eCO <sub>2</sub> )	0.619*	The ratio of total forest loss to total area burns	0.0176

\*Significant at 5% significant level

The correlation test results reveal a significant positive correlation between VIIRS fire alert to forest burn area, total forest cover loss to forest cover loss by fire, and total emission from forest to emission from fires (Table 2). As the results show, having a higher number of VIIRS alerts does not necessarily mean that a higher quantity of total forest cover would lose by fire or total emission would increase from the forest, or fire emission would rise (Table 2). The annual average forest burn area is 207,000 ha, the tree cover loss is 3.28 ha (0.07%) and emission is 1332 Mg eCO<sub>2</sub> (0.05%) on average annually.

### Public Finance for Forest Fire Management

The MoFE has the sole responsibility to protect, manage, and utilise forest resources, including managing forest fires across the country. After a federal restructuring of Nepal, the federal government allocates the annual programmatic budget as conditional grant to the respective provincial ministries and then to the district-level forest authorities. In case of protected area, the federal government allocates budget for protected area management through its respective departments and division. Despite existing strategic emphasis (figure 1), the Government of Nepal (GoN) (including provincial governments and local units) has given low priority for forest fire management, as indicated by limited public finance (figure 3).



**Figure 3: (A) Budget Allocation Trend by GoN Under the Ministry of Forests and Environment, Nepal (Exchange Rate NRs. 100 = 1US\$). (B) The Percentage of the Dedicated Forest Fire Management Budget in the Forestry Sector for the Past Fiscal Years. The Proportion of such Budget is Well Below One-half Percentage but Rising the Trend Since Past Couple of Years.**

The forestry sector’s budget allocation soared up gradually until the fiscal year 2018-19 and reached the highest in 2021-22 (figure 3). Likewise, the GoN started allocating budgets in areas with forest fire management priorities, only from the fiscal year 2016-17. The budget seems nominal for two fiscal years and then rose in 2018-19 with an amount to 400,000 US\$. Again, the budget declined in 2019-20 before reaching to the highest allocation of 500000 US\$ in 2021-22 (figure 3). Though there are positive changes in the proportion and amount of budget on forest fire management, the proportionate figure is well below 0.5 per cent of the total budget allocated to the forestry sector.

## DISCUSSION

Our findings suggest that forest fire incidences in Nepal are increasing, burning more than 200,000 ha of forests annually. This has a significant contribution to tree cover change (3.28 ha per year), about 0.07 per cent of total forest cover changed on average per year solely due to burning. This has also been indicted by the latest country level statistics with increased forest degradation despite increased total forest area. For instance, in 1999, the mean tree volume per hectare was 178 m<sup>3</sup> (NFI/DFRS 1999) whereas that was maintained at 164.7 m<sup>3</sup> for 2000-2010 for Nepal’s forest (DFRS 2015). Increasing forest fire incidences, on one hand, and the declining quality of forest, on the other, illustrates that there has been some relations between two. This however needs to be verified by further research.

## Forest Fire Management Policies and Their Effectiveness

The fundamental challenge of effective implementation of forest fire control strategies and actions is the poor policy integration. There are several policy provisions on fire and disaster risk reduction under different sectoral agencies. However, no other sectoral policy including the one on disaster risk reduction explicitly spells out forest fire management provision (GoN 2014; GoN 2018a). Even the Forest Fire Management Strategy, 2010 has hardly seen any success in coordinating with other policies and strategies within the forestry sector. The National Forest Policy, 2019 hardly spells out the term forest fire management, and merely mentions the clause ‘reducing emission through sustainable forest management for upcoming carbon trade’ (GoN 2018b). Similarly, the National Climate Change Policy, 2019 only mentions about ‘saving the forests and biodiversity from forest fire’ but does not talk about the strategies to tackle the increasing



incidences and emissions from wildfires in the country (GoN 2019a). Likewise, dynamic and result-oriented actions/strategies are lacking. For instance, the Forest Fire Management Strategy, 2010 envisions educating, creating awareness, capacitating, and developing wildfire management technology. However, the majority of activities are limited to redundant public awareness actions including jingle production and media mobilisation, wall painting, and hoarding board installation, where the activities are seasonal.

Moreover, the Forest Fire Management Strategy envisions to facilitate integrating forest fire management contents in school-level curriculum and the government training courses (MoFSC/GoN 2010). However, these are rarely translated into action except few sessions for in-service training to mid-level forestry staff. Likewise, finger count awareness activities are being conducted at the ground level to the selected community members. In addition, the promotion of local knowledge-based forest fire management technology and incentives to such initiatives are still limited in the strategic document (figure 1). Therefore, a participatory and action-oriented approach is required to make a common understanding among stakeholders (government, public, private, and community) and incorporate all levels of capacities for effective management of wildfire.

The Strategy has emphasised promoting research on fires that has impacts on forest, biodiversity, carbon emission, amenity, and socio-economic aspect and expect to disseminate findings through effective media for all stakeholders (policy decision-makers to practitioners). However, very limited studies have been carried out so far in the case of forest fires in Nepal. Many of them are based on past incidences and burn area estimation using online or catalog sources (Mathema 2013; Bhujel et al. 2017) or using remotely sensed data for risk mapping or loss estimation (Parajuli et al. 2015; Parajuli et al. 2020) and forest cover analysis for carbon financing purposes under REDD+

(REDD/MOFE 2018). However, such research findings neither disseminate to the community level and public domain nor would they be part of the national policy discourse. So far, the Forest Research and Training Center (FRTC) has the sole responsibility to conduct forestry-related research including forest fires throughout the country where a regular budget is being allocated for them. But its tasks primarily focus on the estimation of forest cover change, biomass estimation, and analysis of deforestation and degradation, in addition to fire hazard zonation to a particular place. Yet, the root causes of forest fire in Nepal has hardly been explored. Very limited researches have examined the real ground about fuel load analysis, root cause and possible solutions for deliberate fires, and their practical alternatives.

There have been a couple of exercises to use fire as a management tool especially inside the protected areas for habitat management and in selected community-based forest management modalities that have adopted sustainable forest management (SFM) practices (MoFE 2020). Controlled burnings have several advantages such as controlling unwanted vines, habitat management, maintaining ecological successions getting support from public finance in Nepal (MoFE 2020). Such evidence is also reported in other studies across South Asia (Rodgers 1986) and Nepal (Poudyal et al. 2019). However, recent suspension of the SFM programme would further increase the uncertainty, thereby, support for uncontrolled forest fire management. Therefore, reintroduction of SFM could be one of the key strategies to address forest fire problems in Nepal.

The government has placed forestry sector in a low priority in terms of public finance (NPC 2019), while forest fire management lies way behind other priorities. This is evident as less than 0.35 per cent of sectorial public finance annually is allocated for wildfire management across the country. Also, non-budgetary or little resource-demanding provisions such as forestry sector policy

integration for wildfire management, managing all cycles of wildfire through local to central level coordination, establishing and operating ICS, and capacitating forestry institutions that could support wildfire containment should be established, as envisioned by the Strategy. Moreover, celebrating ‘fire management week’ every year, provision of a declaration of ‘fire emergency’, promoting rescue, relief, and rehabilitation, should be in priority as provisioned by the Forest Fire Management Strategy, 2010. So far, celebration of fire management week and purchasing and distributing firefighting gears are the two activities that are being implemented from the public finance so far. Moreover, a forest fire control room has been established in the Department of Forests and Soil Conservation to track forest fire incidences across the country (DoFSC 2021), though the effective functioning of such control room is questionable. Moreover, the government is distributing firefighting gears every year but in limited quantities to extinguish forest fire (MoFE 2020). Further, even the effectiveness of celebrating fire management week is unknown though it demands certain amount from public finance. In short, the effectiveness of the currently implementation of forest fire management programmes is poorly functioning. Despite the VIIRS fire alerts reached to more than 30,000 incident in a season and high confidence alert exceeding 1,000 (Vizzuality 2021), the government did not declare a ‘forest fire emergency’ despite having provision to do so. This evidence reflects the level of priority of the government on containing wildfires in Nepal. This may be due to the nominal contribution of the forestry sector on the gross domestic product (about 2%), despite the fact that the sector is recognised as an economic sector and covers about 44.74 per cent of the country’s land area (NPC 2019). In such instances, forests should not merely be judged from a monetary lens; however, other tangible and intangible value of the forest ecosystem are to be highlighted and considered while taking political decisions.

## Observed Forest Fire Incidences and Their Implication

Remote sensing data showed a gradual forest loss observed in the country from 2000 to 2020 and increasing forest fire incidences (figure 2). This observation correlates with the previous studies (Mathema 2013; Bhujel et al. 2017; Reddy et al. 2020b; Qadir et al. 2021). Such fires largely contributed to forest quality reduction as it occurs at the Earth’s surface – creeping fire, as a result, annual burning recurring in the same place consumes annual growth and/or leaf litter at the ground (Sibanda 2011). The ground-burning materials regrow in the following growing season and reabsorb the CO<sub>2</sub> emitted from such fires (Murray 2015; Maraseni et al. 2016). However, such burning hardly absorbs the additional CO<sub>2</sub> emitted from other sources such as industrial emission, emissions from solid waste, and emissions from transportation systems (IPCC 2014). Also, burning forests emit CH<sub>4</sub> (Methane) and N<sub>2</sub>O (Nitrous dioxide), that are non-reversible and have high global warming potential. Therefore, uncontrolled forest fires and their aftermath should be taken and treated seriously from policy to practice at any locality.

Preventing deliberate forest fires is a serious challenge for sustainable forest ecosystem management. As reported by previous studies, almost all forest fire incidents have anthropogenic connections intentionally or unintentionally (Mathema 2013; Pandey 2021), however, environmental factors that facilitate forest fire are being largely ignored (Pandey et al. 2020).

There are several legal and programmatic mechanisms to reduce deliberate fire incidences in Nepal. For example, the prevailing Forest Act considers forest fire as a serious offense and has provisioned to sentence the culprits for up to three years in jail, or slap a penalty of 600 US\$ or both on top of a fine equivalent to covering the

loss incurred by the fire in government forests outside protected areas (GoN 2019c). Similarly, the fine is double the amount of loss incurred by the fire as a penalty, or one-year jail sentence or both charges to the offenders or supporters who cause forest fires inside protected areas of Nepal (HMG 1975). Despite having such strict legal provisions, the continuity in such illegal activity can be attributed to weak law enforcement. Enhancing law enforcement mechanisms along with livelihood support strategy to the local people would be an option to reduce the wildfires in the country like Nepal.

Piles of dry biomass accumulate in and around the forest annually which is the prime reason for the occurrence of forest fires (Saatchi et al. 2007). The observations made by the authors during their visit to the fields at different periods showed that increased fuel load, lack of fire lines, less capacity among local communities, and weak surveillance are some of the underlying factors that contribute to the burning. In retrospect, people primarily relied on forest products and collected leaf litters for cattle beds and branches for fuel, while over 80 per cent people used fuelwood as a primary source of household energy (NPC 2019). However, with the availability of Liquefied Petroleum Gas (LPGs) and electricity for cooking, there has been a decline in the number of cattle and agriculture activities, and therefore resulted in passive forest management. Still, more than 10 per cent of the population in Nepal use cattle dung as a source of household energy (NPC 2019) due mainly to lack of fuelwood and unaffordable price of other sources of energy. Meanwhile, the Ministry of Forests has the ambition to reduce or mitigate GHG emissions from fire through SFM (GoN 2020; GoN/MoFE 2021). This is because forests under active SFM practice have been observed to have low fire incidences while at the same time, resulted in other socio-ecological and environmental benefits compared to unmanaged forests (Poudyal et al. 2019). Also, SFM is one of the government's key strategies to offset CO<sub>2</sub>

emission from other sources and recognises it as a major area for climate change adaptation and mitigation option (MoFE 2019; GoN 2020).

Nevertheless, community-based forest management regimes lack active management either due to lack of user' friendly management guidelines (Pandey and Pokhrel 2021b) or unavailability of updated data/information on forests that is crucial for implementing management options (DFRS 2015; Pandey and Pokhrel 2021a). This has resulted in piling of fuel load inside forests, which has increased the likelihood of forest fire. So, adoption of active forest management could be one of the ways to minimise the risk of forest fire. Moreover, Nepal has already embraced REDD+ mechanism and committed to conserving forest and control forest fire, one of the major drivers of deforestation and forest degradation. The increased fire incidences may directly impact the performance-based payment mechanism in relation to forests (REDD/MoFE 2018). For the logical conclusion of such ambitious plan of the country (for instance REDD+), forest conservation related policies - forest fire management being one of them, are required to harmonize and implemented.

## CONCLUSION

This paper explores the evidences of forest loss, forest loss due to forest fire and deleterious effect of the uncontrolled forest fires focusing in Nepal. It also highlights uncontrolled forest fire and its consequences, and policy and programmatic measures to be taken for the sustainable management of forests. Incidences of forest fire is in an increasing trend in Nepal and significantly contribute to forest degradation, forest loss, and greenhouse gas emission (eCO<sub>2</sub>). Nevertheless, it has remained in low priority from the lens of public finance, and lacks political commitment. Also, the existing Forest Fire Management Strategy has several areas to be contextualised and therefore demands a revisit. However, such strategy clearly envisions to execute preventive and remedial measures in equal footing, where the

forest fires management actions so far carried out are concentrated towards looking for technocratic solutions, but the policy envision to take the balance between technocratic to political-ecological and socio-economic aspects. Therefore, transactional analysis of root causes is needed for a sustainable forest fire management in Nepal. Moreover, breaking the fire triangle by promoting sustainable forest management, engaging local communities on active management of their forests, giving high priority from public to policy level for sustainable forest fire management would be some of the plausible ways forward.

## REFERENCES

- Abatzoglou, J. T., Balch, J. K., Bradley, B. A., Kolden, C. A., Abatzoglou, J. T., Balch, J. K., Bradley, B. A. and Kolden, C. A. 2018. Human-related Ignitions Concurrent with High Winds Promote Large Wildfires across the USA. *International Journal of Wildland Fire*, 27: 377–386.
- Bhujel, K. B., Maskey-Byanju, R. and Gautam, A. P. 2017. Wildfire Dynamics in Nepal from 2000–2016. *Nepal Journal of Environmental Science*, 5:1–8.
- Borchers Arriagada, N., Palmer, A. J., Bowman, D. M., Morgan, G. G., Jalaludin, B. B. and Johnston, F. H. 2020. Unprecedented Smoke-Related Health Burden Associated with the 2019–20 Bushfires in Eastern Australia. *Medical Journal of Australia*, 213:282–283.
- DFRS. 2015. State of Nepal's forests. Department of Forest Research and Survey, Government of Nepal, Kathmandu, Nepal.
- DoFSC. 2021. Species Conservation Plan. Department of Forests and Soil Conservation, Government of Nepal, Kathmandu, Nepal.
- Flannigan, M., Cantin, A. S., de Groot, W. J., Wotton, M., Newbery, A. and Gowman, L. M. 2013. Global Wildland Fire Season Severity in the 21st Century. *Forest Ecology and Management*, 294:54–61.
- Gavin, D. G., Hallett, D. J., Hu, F. S., Lertzman, K. P., Prichard, S. J., Brown, K. J., Lynch, J. A., Bartlein, P. and Peterson, D. L. 2007. Forest Fire and Climate Change in Western North America: Insights from Sediment Charcoal Records. *Frontiers in Ecology and the Environment*, 5:499–506.
- GoN. 2009. National Strategy on Disaster Risk Management, 2009. Government of Nepal, Ministry of Home Affairs, Government of Nepal, Kathmandu, Nepal.
- GoN. 2011. Guidance Note on Disaster Preparedness and Response Planning, 2011. Government of Nepal, Kathmandu, Nepal.
- GoN. 2014. National Guideline for Search and Rescue, 2014. Government of Nepal, Kathmandu, Nepal.
- GoN. 2015. Constitution of Nepal. Law Commission of Nepal, Government of Nepal, Kathmandu, Nepal.
- GoN. 2017. Local Self Governance Act, 2017. Government of Nepal, Kathmandu, Nepal.
- GoN. 2018a. National Policy for Disaster Risk Reduction 2018. Government of Nepal, Kathmandu, Nepal.
- GoN. 2018b. National Forest Policy 2018. Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- GoN. 2019a. National Climate Change Policy 2019. Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- GoN. 2019b. National Environment Policy 2019. Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- GoN. 2019c. Forests Act 2019, Nepal. Government of Nepal, Kathmandu, Nepal
- GoN. 2020. Second Nationally Determined Contribution (NDC). Government of Nepal, Kathmandu, Nepal.
- GoN/MoFE. 2021. Nepal's Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- HMG. 1975. National Parks and Wildlife Conservation Act, 1973. His Majesty's Government of Nepal, Kathmandu, Nepal.
- HMG. 1982. Natural Calamity Relief Act 1982. His Majesty's Government of Nepal, Kathmandu, Nepal.
- IPCC. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability - Contribution of

Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. <https://environmentalmigration.iom.int/climate-change-2014-impacts-adaptation-and-vulnerability-contribution-working-group-ii-fifth>.

- Keeley, J. E. and Syphard, A. D.** 2019. Twenty-first Century California, USA, Wildfires: Fuel-dominated Vs. Wind-dominated Fires. *Fire Ecology*, **15**:24.
- LAADS DAAC.** 2021. Visible Infrared Imaging Radiometer Suite (VIIRS) - LAADS DAAC. <https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/viirs/>.
- Maraseni, T. N., Reardon-Smith, K., Griffiths, G. and Apan, A.** 2016. Savanna burning Methodology for Fire Management and Emissions Reduction: A Critical Review of Influencing Factors. *Carbon Balance and Management*, **11**:25.
- Mathema, P.** 2013. Forest Fire and its Management Strategies in Nepal. *Banko Janakari*, **23**:1–2.
- MoFE.** 2019. Climate Change Scenarios for Nepal for National Adaptation Plan (NAP). Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- MoFE.** 2020. Annual Progress Report for Fiscal Year 2019-20. Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- MoFSC/GoN.** 2010. Forest Fire Management Strategy, 2010. Ministry of Forests and Soil Conservation, Government of Nepal, Kathmandu, Nepal.
- MoHA.** 2013. National Disaster Response Framework 2013 (first amendment 2019). Ministry of Home Affairs, Government of Nepal, Kathmandu, Nepal.
- MoHA.** 2017a. Disaster Risk Management in Nepal: Status, Achievements, Challenges and Ways Forward. National Position Paper for the Global Platform on Disaster Risk Reduction 22-26 May 2017, Cancun, Mexico. Ministry of Home Affairs, Government of Nepal, Kathmandu, Nepal.
- MoHA.** 2017b. Nepal Disaster Report 2017: The Road to Sendai. Ministry of Home Affairs, Government of Nepal, Kathmandu, Nepal.
- MoHA.** 2018. National Database of Disaster of Nepal. Ministry of Home Affairs, Disaster Management Unit, Government of Nepal, Kathmandu, Nepal.
- Murray, E.** 2015. Australia's Carbon Farming Initiative:2. In: A. Meybeck, J. Lankoski, S. Redfern, N. Azzu, V. Gitz (Eds.), Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Proceedings of a Joint FAO/OECD Workshop, Rome, Italy, 23-24 April 2012 2012 pp.343-344
- NFI/DFRS.** 1999. FRA 2000 - Forest resources of Nepal, Country Report. Department of Forest Research and Survey, Government of Nepal, Kathmandu, Nepal.
- NPC.** 2013. Environmental Causes of Displacement. National Planning Commission, Government of Nepal, Kathmandu, Nepal.
- NPC.** 2019. Fifteenth Periodic Plan of Nepal (2019/20-2023/24). National Planning Commission, Government of Nepal, Kathmandu, Nepal.
- Pandey, H. P.** 2021. Implications of Anthropogenic Disturbances for Species Diversity, Recruitment and Carbon Density in the Mid-Hills Forests of Nepal. *Journal of Resources and Ecology*, **12**:1–10.
- Pandey, H. P., Maaren, I. E., Shah, K. K. and Maraseni, T. N.** 2020. Response of Topographic and Biodiversity Variables on Biomass and Carbon Density in Community Forests of Himalayan Foot-hills. *Journal of Forest and Livelihood*, **19**(1): 51-65.
- Pandey, H. and Pokhrel, N.** 2021a. Formation Trend Analysis and Gender Inclusion in Community Forests of Nepal. *Trees, Forests and People*, **5**:100106.
- Pandey, H. and Pokhrel, S.** 2021b. Stocking Density and DBH Distribution of Community Forests in Nepal. *Small Scale Forestry*, **20**:145–159.
- Pandey, S., Cockfield, G. and Maraseni, T. N.** 2016. Assessing the Roles of Community Forestry in Climate Change Mitigation and Adaptation: A Case Study from Nepal. *Forest Ecology and Management*, **360**: 400–407.
- Parajuli, A., Chand, D., Rayamajhi, B., Khanal, R., Baral, S., Malla, Y. and Paudel, S.** 2015. Spatial and Temporal Distribution of Forest Fires in Nepal. Paper Presented in Conference on XIV World Forestry Congress, Durban, South Africa, 7-11 September 2015
- Parajuli, A., Gautam, A. P., Sharma, S. P., Bhujel, K. B., Sharma, G., Thapa, P. B., Bist, B. S. and Poudel, S.** 2020. Forest Fire Risk Mapping using GIS and Remote Sensing in Two Major Landscapes of Nepal. *Geomatics, Natural Hazards and Risk*, **11**:2569–2586.

- Pastro, L. A., Dickman, C. R. and Letnic, M. 2011. Burning for Biodiversity or Burning Biodiversity? Prescribed Burn Vs. Wildfire Impacts on Plants, Lizards, and Mammals. *Ecological Applications*, 21:3238–3253.
- Poudyal, B. H., Maraseni, T. and Cockfield, G. 2019. Impacts of Forest Management on Tree Species Richness and Composition: Assessment of Forest Management Regimes in Tarai Landscape Nepal. *Applied Geography*, 111:102078.
- Qadir, A., Talukdar, N. R., Uddin, M. M., Ahmad, F. and Goparaju, L. 2021. Predicting Forest Fire using Multispectral Satellite Measurements in Nepal. *Remote Sensing Applications: Society and Environment*, 23:100539.
- R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
- REDD/MOFE. 2018. Emission Reduction Program Document. REDD Implementation Centre/ Ministry of Forests and Environment, Government of Nepal, Kathmandu, Nepal.
- Reddy, C. S., Bird, N. G., Sreelakshmi, S., Manikandan, T. M., Asra, M., Krishna, P. H., Jha, C. S., Rao, P. V. N. and Diwakar, P. G. 2020a. Identification and Characterization of Spatio-Temporal Hotspots of Forest Fires in South Asia. *Environmental Monitoring and Assessment*, 191:791.
- Reddy, C. S., Unnikrishnan, A., Bird, N. G., Faseela, V. S., Asra, M., Manikandan, T. M. and Rao, P. V. N. 2020b. Characterizing Vegetation Fire Dynamics in Myanmar and South Asian Countries. *Journal of the Indian Society of Remote Sensing*, 48:1829–1843.
- Rodgers, W. A. 1986. The Role of Fire in the Management of Wildlife Habitats: A Review. *Indian Forester*, 112:845–857.
- Saatchi, S., Halligan, K., Despain, D. G. and Crabtree, R. L. 2007. Estimation of Forest Fuel Load from Radar Remote Sensing. *IEEE Transactions on Geoscience and Remote Sensing*, 45:1726–1740.
- Schmerbeck, J. and Fiener, P. 2015. Wildfires, Ecosystem Services, and Biodiversity in Tropical Dry Forest in India. *Environmental Management*, 56:355–372.
- Sibanda, C. 2011. Modelling Forest Fire Behaviour and Carbon Emission in Ludhikhola Watershed of Gorkha, Nepal. University of Twente, The Netherlands.
- Vizzuality. 2021. Nepal Deforestation Rates & Statistics | GFW. <https://www.globalforestwatch.org/country/NPL/?category=fires#firesAlerts>.
- Wijewardana, D. 2008. Criteria and Indicators for Sustainable Forest Management: The Road Travelled and the Way Ahead. *Ecological Indicators*, 8:115–122.
- Wotton, B. M., Nock, C. A., Flannigan, M. D., Wotton, B. M., Nock, C. A. and Flannigan, M. D. 2010. Forest Fire Occurrence and Climate Change in Canada. *International Journal of Wildland Fire*, 19:253–271.
- Xue, T., Geng, G., Han, Y., Wang, H., Li, J., Li, H., Zhou, Y. and Zhu, T. 2021. Open Fire Exposure Increases the Risk of Pregnancy Loss in South Asia. *Nature Communications*, 12:3205.