December 2025

Inception Report

Inception Report of Comprehensive Study on Solutions for Forest Fire Management and Air Quality Improvement in the HKH Region

Submitted to
International Centre for Integrated Mountain Development
(ICIMOD)

The Energy and Resources Institute

...towards global
sustainable development

For more information

Dr J V Sharma, Senior Director
Land Resources Division
T E R I
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail jv.sharma@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delhi (0)11

Contents

List of Tables

List of Figures

Executive Summary

This inception report initiates the consultancy assignment on "Comprehensive Study on Solutions for Forest Fire Management and Air Quality Improvement in the Hindu Kush Himalaya (HKH) Region" covering Afghanistan, Bangladesh, Bhutan, China (HKH-relevant regions), India, Myanmar, Nepal, and Pakistan. The HKH is characterised by steep elevation gradients, complex meteorology, and high dependence of mountain and downstream communities on forest ecosystem services. Forest fires in the region increasingly reflect the combined effects of extended dry spells, seasonal wind patterns, land use pressures, and human ignitions. The resulting impacts are multi-dimensional, including forest degradation, biodiversity and watershed stress, reduced visibility, and disruption of livelihoods, and episodic but severe air pollution from smoke. These smoke events have cross-border relevance because pollutants can be transported along mountain valleys and into adjoining plains, creating a shared airshed challenge that cannot be addressed through suppression measures alone.

The overall objective of the assignment is to identify and assess practical forest fire management solutions for the HKH that address root causes and deliver air quality and climate co-benefits, and to map stakeholders and develop collaboration pathways that enable inclusive and effective implementation. In the inception phase, the focus is on consolidating existing evidence and operational practice, creating a consistent cross-country assessment template, and finalising the workplan and engagement plan for subsequent analytical components. The inception phase therefore serves as the organising platform for the consultancy, clarifying what is already in place across countries, where the main bottlenecks lie, and how the next deliverables will move from review findings to prioritised interventions, investment logic, and an implementation roadmap.

The methodological framework adopted for the inception phase is sequential, and it operates at two levels, a regional synthesis across the HKH and a country-wise assessment for each of the eight countries. The first methodological component is a systematic review of existing forest fire management practices, policies, and institutional arrangements, including prevention and preparedness measures, monitoring and detection systems, alert dissemination mechanisms, suppression and incident response protocols, and post-fire recovery approaches. The review draws on official documents, institutional reports, and credible regional syntheses and it also captures how forest biomass and fuel-load management are currently reflected within prevention planning, community programmes, or operational guidelines. The second methodological component is a technical assessment of fire monitoring, forecasting, and alert systems, focusing on the operational chain from satellite-based detection and meteorological inputs to validation, dissemination, and field action. Particular attention is given to whether alerts are linked to thresholds, standard operating procedures, and resource mobilisation, rather than remaining informational products. The third component synthesises the linkages between forest fires and air quality impacts, including smoke transport and transboundary dimensions, and reviews how far existing fire management systems connect with air quality, health, and disaster management advisories. The inception methodology also includes stakeholder and institutional mapping to identify roles, overlaps, and coordination gaps, and to structure engagement during validation and solution prioritisation.

Two practical synthesis instruments are included to support consistency and usability across the consultancy. First, a Country-wise Review and Assessment Matrix has been prepared as a desk-review output to summarise preliminary observations in a comparable structure across

all countries, covering fire monitoring, forecasting and alerts, suppression, biomass or fuel-load management, and air quality linkages, with an additional column identifying key gaps and immediate opportunities. This matrix is positioned in the findings chapter to provide a single reference point for country comparisons and to support the subsequent solution matrix and policy gap analysis. Second, a Stakeholder Mapping Matrix is included to document the principal stakeholder categories relevant to forest fire management and smoke response, including forestry agencies, disaster management authorities, air quality regulators, meteorological services, RS-GIS and space agencies, health institutions, local governments, community institutions, civil society organisations, research institutions, private sector biomass and clean energy actors, and financing partners. The stakeholder matrix clarifies expected roles, data inputs, and engagement modes, and it provides the basis for building a collaboration framework that is both technically grounded and institutionally workable.

Preliminary findings from the review and assessment indicate that forest fire management systems have evolved unevenly across the HKH. Satellite-based fire detections and near-real-time hotspot alerts have become a common backbone for situational awareness in many settings, but effectiveness depends on the downstream chain, including local validation, communication to field units, and clear decision triggers for preparedness and response. In several contexts, suppression remains the dominant focus, while prevention, preparedness planning, systematic fuel management, and post-fire recovery arrangements are less consistently embedded as routine practice. The review also highlights a recurring gap in connecting forest fire operations with air quality response and public health advisories. While the smoke impacts are widely recognised, especially during seasonal peak fire periods, coordination arrangements across forestry, disaster response, and air quality or health institutions remain variable across countries. In addition, cross-border cooperation on transboundary smoke events is an identified need, but operational mechanisms are constrained by differences in data access, institutional mandates, and harmonisation of alert thresholds and communication protocols.

The country-wise assessment suggests a shared set of constraints, combined with distinct national contexts. Remote and rugged terrain frequently limits rapid access, prolongs containment timelines, and increases the importance of prevention and community-linked early response. Differences in institutional structures also shape implementation feasibility, including where forest management is decentralised to provinces or states, where community forestry institutions are central to prevention, and where disaster management authorities play a strong coordination role during peak risk periods. In some countries, documentation access and data availability constraints create additional challenges for cross-country comparability, which is addressed in this inception phase through transparent documentation of evidence sources, explicit statements of uncertainty, and use of a consistent template that distinguishes confirmed institutional practice from inferred patterns based on secondary evidence.

The inception phase is directly linked to subsequent analytical components that will be undertaken during the remainder of the consultancy. Building on the review findings and the country-wise matrix, the next stage will develop a categorised inventory of solutions spanning technological options, ecological and restoration approaches, preventive and preparedness interventions, community and livelihood-linked measures, policy and institutional mechanisms, and post-fire rehabilitation strategies. These options will be evaluated using a solution matrix and a transparent scoring approach to compare practicality, cost, scalability, operational requirements, maintenance needs, and social acceptance under HKH conditions. The cost-benefit analysis workstream will then appraise selected intervention pathways across scenarios, including business-as-usual, improved sustainable management, and enhanced intervention packages, while integrating forest sustainability constraints and monetising relevant co-benefits such as avoided damages from reduced fire incidence, reduced emissions and smoke exposure, and improved ecosystem service outcomes. The policy gap analysis will benchmark existing legal and institutional arrangements against best practices, identify implementation barriers and coordination gaps, and propose reforms and regional cooperation mechanisms that strengthen prevention, monitoring, response, and productive utilisation of forest-floor fuel loads without undermining ecosystem integrity.

Across the overall project, the expected outcome is a set of prioritised and implementable intervention packages for HKH countries that link fire risk reduction with air quality improvement and climate co-benefits, supported by an evidence-informed evaluation framework and a practical collaboration architecture. The final outputs will provide decision-ready insights for agencies and stakeholders on what interventions are most suitable in which contexts, what enabling conditions are required, and how to sequence actions across short, medium, and longer time horizons. The assignment will also deliver a roadmap for integrating the proposed solutions into national and regional air quality management strategies, ensuring that fire management planning is connected with smoke advisories, exposure reduction measures, and cross-border coordination where relevant.

Way forward from this inception round focuses on completing validation of the review evidence base with targeted stakeholder inputs, confirming data access pathways and analytical tools for the next components, and finalising the implementation schedule and consultation plan aligned with the deliverable dates. The inception phase closes with agreement on the priority themes that require deeper analysis in the next stage, including gaps in alert-to-action chains, fuel and biomass management opportunities, institutional coordination mechanisms, and pathways for integrating satellite and ground monitoring into operational decision-making. This sets the transition from “current status and constraints” toward “solutions, evaluation, investment logic, and roadmap,” which will be delivered through the subsequent milestone outputs.

1. Introduction

The Hindu Kush Himalaya (HKH) region, encompassing Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan, is a mountain system of global environmental and socio-economic significance, hosting diverse ecosystems, critical water towers, and forest landscapes that support millions of livelihoods. Recent analyses indicate a rising trend in forest fires across the HKH, driven by climatic variability, extended dry seasons, and increasing anthropogenic pressures, which collectively contribute to elevated fire frequency and severity (Kumar et al., 2024). Evidence from spatiotemporal assessments shows that more than 65% of fires occur in forested areas, particularly during the pre-monsoon season of March–April, highlighting strong seasonal correlations between fire incidence, climatic conditions, and vegetation status (Zhou et al., 2025). Forest fire occurrences are not only ecological disturbances but also significant contributors to regional air pollution, releasing large quantities of aerosols and trace gases that degrade ambient air quality, influence visibility, and transport pollutants over long distances (Lee et al., 2018; Marvin et al., 2024). Biomass burning aerosols have been shown to obscure public health impacts due to uncertainties in air quality modeling, and they contribute to premature mortality from poor air quality across Southeast Asia, underscoring the complex linkages between fires, emissions, and human health (Marvin et al., 2024). In the Himalayan context, forest fire emissions have already been associated with measurable declines in air quality, and systematic analyses call for transboundary collaboration to manage forest fire-induced air pollution episodes effectively (Mahapatra & Dhital, 2025). Despite improvements in satellite-based early fire risk systems, such as the integration of Fire Weather Index (FWI) forecasts with high-resolution meteorological data, the operationalization of anticipatory fire management tools remains limited in many parts of the HKH, particularly under data scarcity and complex terrain conditions (Zhou et al., 2025). This study's inception phase establishes a unified understanding of existing forest fire and air quality management practices, early warning capabilities, and institutional contexts across the HKH, forming the analytical foundation for solution design, cost–benefit evaluation, entrepreneurship pathways, and policy gap analysis.

1.1 Background and Context of the HKH Region

The HKH region spans eight countries, Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan, and represents one of the world's most ecologically diverse and climatically sensitive mountain systems. Forest ecosystems across the HKH play a critical role in regulating regional hydrology, conserving biodiversity, storing carbon, and sustaining livelihoods of mountain communities as well as large downstream populations (ICIMOD, 2019; Wester et al., 2019). In recent decades, the region has experienced a marked increase in forest fire incidents, driven by rising temperatures, altered precipitation regimes, land-use change, and growing anthropogenic pressures. These fires have emerged as a major environmental concern, affecting ecosystem integrity, accelerating forest degradation, and contributing to regional air quality deterioration through biomass-burning emissions. Recent systematic reviews further highlight that climate-induced changes in fire regimes are intensifying ecological and socio-economic impacts of forest fires, underscoring the need for integrated and region-specific fire management approaches in mountain systems such as the HKH (Kumar et al., 2025).

1.2 Forest Fire Dynamics and Trends in the HKH Region

Forest fires in the HKH show a distinct seasonal concentration and a strong linkage with climate variability, fuel conditions, and human activity. Across much of the region, fire incidence typically rises during the late winter to pre-monsoon window (February/March to May), when vegetation moisture declines, forest-floor litter accumulates, and dry windy conditions increase ignition and spread potential. Satellite-derived fire datasets and burned-area products have enabled consistent tracking of these patterns over time, using standardized Earth observation sources such as MODIS active fire detections and MODIS burned area products (Giglio et al., 2018). Evidence from recent high-resolution risk assessment work in the HKH (with strong Nepal coverage) shows that pre-monsoon months dominate fire detections, reflecting the combined effect of seasonal dryness and fuel flammability, and also highlights that operational fire danger forecasting tools can capture a large share of observed fire events when calibrated with regional meteorology and satellite fire records (Zhou et al., 2025).

A key characteristic of HKH fire dynamics is the dominance of human-ignited, surface fires in many mid-elevation landscapes where forests interface with agriculture, grazing, and settlements. This is particularly evident in the Western Himalaya, where long-term MODIS-based analyses in Uttarakhand (India) demonstrate that fire incidence varies across forest divisions but is strongly influenced by pre-monsoon temperature and precipitation, and by the extent of chir pine (*Pinus roxburghii)* forests, which tend to accumulate flammable needle litter and support rapid fire spread under dry conditions. In a 19-year analysis (2002–2020), Singh et al. (2023) found that pre-monsoon warming, and lower precipitation were associated with high fire years, and that the proportional area under chir pine had a positive relationship with fire incidence density, while winter and pre-monsoon precipitation had negative relationships. Such findings are important for the HKH context because they underline how fire risk can increase even when ignitions are largely anthropogenic, if climatic conditions and fuel structure are shifting in ways that favour more frequent or intense fire seasons (Singh et al., 2023).

In the central and eastern HKH landscapes, including Nepal, MODIS burned-area-based studies similarly show strong climate sensitivity in fire outcomes. Early evidence using MODIS burned area in Nepal documented wildfire trends and highlighted the value of satellite products for mapping fire-affected areas in data-limited settings (Khanal, 2015). More recent analyses in Nepal's Churia–Siwalik region, using MODIS (MCD64A1) burned area data (2001-2024), further demonstrate measurable relationships between burned area, temperature, and precipitation, reinforcing the role of climatic controls alongside local ignition pressures (Poudel & Basnet, 2024). These studies collectively indicate that while fires may be initiated by people in many HKH settings, climate-driven fuel drying and rainfall deficits determine whether fires remain small and patchy or become widespread events.

Overall, the emerging trend across the HKH is not only a continuation of strong pre-monsoon seasonality, but also an increasing need to interpret fire risk as an outcome of (i) meteorology and drought conditions, (ii) fuel accumulation and forest composition, and (iii) human access and land-use practices. This combination has direct implications for forecasting and preparedness: strengthening short-range fire danger outlooks (such as, via Fire Weather Index–type systems), improving last-mile dissemination of alerts, and linking fuel-load management with community institutions become central to reducing the probability of high-impact fire seasons. The evidence base from satellite-driven fire assessments and region-specific studies therefore provides a solid foundation for the inception-phase review of existing practices, forecasting/alert systems, and forest biomass (fuel) management approaches across Afghanistan, Bangladesh, Bhutan, China (HKH-relevant areas), India, Myanmar, Nepal, and Pakistan.

1.3 Linkages Between Forest Fires and Air Quality in the HKH Region

Forest fires represent a major episodic source of air pollution in the HKH, emitting substantial amounts of fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_x), organic aerosols, and other reactive trace gases. These emissions frequently result in sharp and short-duration deterioration of air quality in mountain valleys and foothill regions, where complex topography, temperature inversions, and shallow boundary layers limit dispersion and prolong pollutant residence times. Across the HKH-influenced airshed, forest fires during the dry pre-monsoon season have been closely associated with elevated particulate concentrations and degraded ambient air quality, particularly when fire activity coincides with stagnant meteorological conditions (Mahapatra & Dhital, 2025; Lee et al., 2018).

A defining feature of forest fire–air quality interactions in the HKH is the transboundary transport of smoke and combustion aerosols. Pollutants generated by forest fires in Himalayan foothills and mid-elevation forests are frequently transported over long distances, influencing air quality well beyond the immediate fire locations. Atmospheric chemistry and transport modelling studies indicate that fire emissions interact with background anthropogenic sources and significantly alter regional $PM_{2.5}$ burdens across downwind areas, including the Indo-Gangetic Plain (Lee et al., 2018). These transport pathways contribute to widespread haze episodes, reduced visibility, and enhanced atmospheric absorption associated with carbonaceous aerosols, complicating source attribution and coordinated air quality management across national boundaries.

Beyond near-surface air quality impacts, forest fire emissions in the HKH also exert broader climatic and cryospheric influences. Recent Himalayan-focused assessments highlight that combustion aerosols from forest fires contribute to radiative perturbations in high-altitude environments, with implications for snow and glacier energy balance, seasonal melt dynamics, and longer-term water security. These interactions underline the coupled nature of forest fires, atmospheric composition, and climate sensitivity in mountain systems, reinforcing the need to address forest fire management within integrated climate and air quality frameworks for the HKH (Mahapatra & Dhital, 2025).

HKH-specific evidence further underscores the role of terrain-controlled transport pathways in linking forest fires to regional air quality impacts. Isotope-based source apportionment studies of black carbon across Himalayan transects have demonstrated that combustion aerosols originating from the Indo-Gangetic Plain and Himalayan foothills are transported northward into higher elevations through major valley systems, influencing aerosol concentrations and deposition along elevation gradients (Li et al., 2016). Complementary regional modelling studies using WRF-Chem show that South Asian combustion sources, including biomass burning, contribute substantially to aerosol loading and deposition across the Hindu Kush–Himalaya–Karakoram region, confirming the cross-regional nature of fire-related air pollution (Alvarado et al., 2018). These findings provide a strong basis for linking forest fire monitoring with regional air quality forecasting and advisory systems.

Country-level evidence across the HKH further reinforces these linkages. In Nepal, analyses of the March to April 2021 fire season documented marked increases in $PM_{2.5}$ concentrations in the Kathmandu Valley during periods of intense forest fire activity, supported by combined ground-based measurements and satellite-derived indicators such as aerosol optical depth and trace gas enhancements (Khadgi et al., 2024). Subsequent modelling studies integrating WRF-Chem simulations with Sentinel-5P observations showed that wildfire events during the 2020-2021 dry season substantially increased $PM_{2.5}$ levels across Nepal, with strong agreement between modelled concentrations and satellite-derived pollution signals (Shrestha et al., 2025). These findings highlight the vulnerability of densely populated Himalayan valleys to episodic fire smoke under stagnant meteorological conditions.

At the regional scale, products from the Copernicus Atmosphere Monitoring Service (CAMS) and the Global Fire Assimilation System (GFAS) provide additional evidence of widespread smoke influence across northern India, Nepal, Bangladesh, and adjoining regions during winter and early spring fire seasons. CAMS-based analyses indicate that biomass-burning emissions can dominate regional aerosol loads during peak fire periods, emphasising the importance of harmonised transboundary datasets for situational awareness and early warning in the HKH context (Copernicus Atmosphere Monitoring Service, 2025; ECMWF/CAMS GFAS, n.d.). In Bhutan, emerging high-resolution air quality simulations using WRF-CHIMERE at valley-scale resolution demonstrate how complex Himalayan topography can amplify pollution build-up in narrow valleys, reinforcing the need for terrain-sensitive modelling approaches when assessing fire-related exposure risks (Bessagnet et al., 2025). Despite the growing body of scientific evidence, monitoring and attribution of forest fire impacts on air quality remain challenging across much of the HKH due to sparse high-altitude ground monitoring networks and limited institutional integration between forest fire management and air quality agencies. Long-term observations at high-elevation sites such as the Nepal Climate Observatory–Pyramid show that aerosol variability reflects both long-range transport and regional episodic sources, underscoring the importance of coordinated measurements and harmonised datasets (Bonasoni et al., 2010). Addressing these gaps requires integrated approaches that connect fire forecasting and alert systems with air quality monitoring, improve characterisation of fire emissions, and strengthen regional coordination to manage transboundary smoke episodes and associated health risks.

1.4 Review of Existing Forest Fire Management Practices in the HKH Region

Forest fire management practices across the HKH region vary widely in terms of institutional capacity, technological adoption, and community engagement, reflecting differences in governance structures, forest tenure systems, and resource availability among Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan (ICIMOD, 2021; FAO, 2021; World Bank, 2021). In Bangladesh, forest fire management remains largely reactive, with the Forest Department relying on ground patrols, community reporting, and manual suppression in limited forested areas, while satellite-based fire detection using publicly available datasets is increasingly applied for situational awareness but remains weakly integrated into operational response, and systematic forest biomass or fuel load management is largely absent (FAO, 2021; ICIMOD, 2021). Bhutan has adopted more structured prevention-oriented approaches under the Department of Forests and Park Services, combining awareness programmes, fire lines, community forestry participation, and national fire information systems supported by satellite alerts; however, planned fuel load assessment, forest biomass utilisation as a risk reduction strategy, and explicit integration with air quality management frameworks remain limited (ICIMOD, 2021; FAO, 2021).

In the HKH-relevant regions of China, forest fire management is characterised by strong institutional control and advanced monitoring infrastructure, integrating satellite-based fire detection, aerial surveillance, ground sensors, and meteorological forecasting within centralised command systems, enabling rapid response and effective suppression, although publicly available documentation provides limited detail on post-fire ecological recovery practices and the role of forest biomass management in long-term fire risk reduction, and transboundary smoke coordination remains limited (World Bank, 2021; FAO, 2021). In India, forest fire management is implemented through State Forest Departments under national programmes such as the Forest Fire Prevention and Management Scheme, with increasing use of near-real-time satellite fire alerts and vulnerability mapping provided by the Forest Survey of India, supported by ground-based fire watchers, fire lines, and community engagement initiatives, particularly in Himalayan states such as Uttarakhand and Himachal Pradesh; however, suppression remains largely manual, fuel load management is not systematically addressed, and coordination with air quality planning is generally weak despite recurring smoke-related pollution episodes affecting hill towns and downstream urban centres (Forest Survey of India, 2023; ICIMOD, 2021; FAO, 2021).

In Myanmar, forest fire management capacity remains constrained, with practices relying heavily on traditional land-use burning, community reporting, and limited institutional resources, while satellite-based monitoring is used primarily for situational awareness rather than operational response, and formal systems for forest biomass management, post-fire recovery, and coordination with air quality or public health institutions are minimal (FAO, 2021; ICIMOD, 2021). Nepal presents a comparatively strong model of community-based fire management through Community Forest User Groups, which play a central role in prevention, early detection, and first response, supported by growing use of satellite fire alerts and meteorological information by government agencies and research institutions; nevertheless, suppression capacity in rugged terrain remains limited, systematic fuel load assessment and planned biomass utilisation are not widely implemented, and operational coordination between forest fire management and air quality authorities remains at an early stage (Ministry of Forests and Environment, Nepal, 2020; ICIMOD, 2021). In Pakistan, forest fire management is primarily the responsibility of provincial forest departments, with practices centred on ground-based measures such as fire lines, watch towers, and manual suppression, alongside increasing but inconsistent use of satellite fire data, limited institutionalised community participation, and minimal integration of forest biomass management or air quality considerations into fire management planning (FAO, 2021; World Bank, 2021).

Overall, across the HKH region, existing forest fire management practices remain heavily oriented towards detection and suppression, with comparatively limited emphasis on preventive fuel management, productive utilisation of forest floor biomass, post-fire ecological recovery, and systematic integration with air quality and climate planning, despite growing evidence of transboundary smoke impacts and climate-related fire risks, underscoring the need for coordinated regional approaches that strengthen prevention, improve the operational use of early warning systems, and align forest fire management with broader environmental and public health objectives (ICIMOD, 2021; FAO, 2021; World Bank, 2021).

1.5 Key Gaps and Challenges in Existing Forest Fire Management Systems in the HKH Region

Despite increasing recognition of forest fires as a recurrent and escalating risk across the HKH, existing forest fire management systems continue to face several structural, technical, and institutional gaps that limit their effectiveness. A primary challenge across most HKH countries is the continued emphasis on reactive fire suppression rather than proactive risk reduction. While near-real-time satellite-based fire detection systems are increasingly available, their use is often confined to situational awareness, with limited operational linkage to preparedness planning, fuel management, or pre-positioning of response resources (ICIMOD, 2021; FAO, 2021). Forecasting tools and fire danger rating systems are either absent or not consistently calibrated to local terrain, vegetation types, and meteorological conditions, reducing their utility for anticipatory action.

Another major gap relates to forest fuel load assessment and management. Across much of the HKH, systematic quantification of forest floor biomass and combustible fuel loads is limited, and planned interventions for fuel reduction or productive utilisation of biomass are rarely integrated into fire management strategies. In many landscapes, accumulated litter, pine needles, and dry understory vegetation increase fire intensity and spread potential, yet institutional mechanisms for linking fuel management with livelihood generation, local entrepreneurship, or circular bioeconomy approaches remain underdeveloped (FAO, 2021; World Bank, 2021). This gap is particularly pronounced in regions where community institutions exist but lack technical guidance or financial incentives to engage in sustained fuel management activities.

Institutional fragmentation further constrains effective fire management. Responsibilities for forest fire prevention, suppression, air quality management, disaster response, and public health advisories are often distributed across multiple agencies, with limited coordination mechanisms at national and sub-national levels. As a result, forest fire events that significantly degrade air quality are not consistently integrated into air pollution response frameworks, early warning systems, or health advisories, despite growing evidence of transboundary smoke impacts across the HKH (ICIMOD, 2021). This separation also limits the ability to address forest fires as a cross-sectoral risk spanning forestry, climate adaptation, disaster risk reduction, and public health.

Capacity constraints remain a persistent challenge, particularly in remote and high-altitude areas. Many forest departments continue to rely on manual firefighting methods, with limited access to specialised equipment, trained personnel, or rapid-response infrastructure suitable for rugged terrain. Although community-based models, such as Community Forest User Groups in Nepal, demonstrate the potential for localised prevention and early response, these approaches are not uniformly supported by technical training, safety protocols, or sustained financing across the region (Ministry of Forests and Environment, Nepal, 2020). Post-fire recovery and ecological restoration are also weakly addressed, with limited monitoring of fire impacts on forest structure, regeneration, and ecosystem services.

Finally, regional cooperation mechanisms for addressing transboundary fire and smoke risks remain limited. While regional platforms exist for data sharing and dialogue, operational coordination on fire forecasting, alert dissemination, and smoke impact management across borders is still at a nascent stage. Differences in data standards, institutional mandates, and access to monitoring infrastructure hinder the development of shared early warning and response systems. Addressing these gaps will require strengthened regional collaboration, harmonised datasets, and policy frameworks that recognise forest fires as a shared environmental and public health challenge in the HKH region (ICIMOD, 2021; World Bank, 2021).

1.6 Purpose and Scope of the Inception Phase

Building on the regional context, fire dynamics, air quality linkages, existing management practices, and identified gaps, the inception phase of this study is designed to establish a common analytical foundation for the comprehensive assessment of forest fire management and air quality improvement solutions in the Hindu Kush Himalaya. The focus of this phase is on consolidating existing evidence, reviewing operational practices and institutional arrangements, and refining the methodological approach for subsequent analytical components of the assignment.

The inception phase does not seek to introduce new fire modelling or generate primary datasets, but rather to synthesise available knowledge, assess current systems for fire monitoring, forecasting, alerts, suppression, and forest biomass management, and identify critical entry points for intervention. Particular attention is given to understanding cross-sectoral and transboundary dimensions, including linkages between forest fire management and air quality governance, and the role of community institutions and regional platforms in risk reduction and response.

Outputs from the inception phase provide the basis for subsequent tasks under the assignment, including detailed solution identification and evaluation, cost–benefit analysis of forest biomass management options, development of entrepreneurship and community-based models, policy gap analysis, and formulation of implementation roadmaps. The following section presents the methodological framework adopted for the inception phase, detailing the analytical steps, data sources, and assessment approaches used to address the objectives of this study.

2. Objectives and Scope of Work

2.1 Overall Objective

The overall objective of this assignment is to conduct a comprehensive assessment of solutions for forest fire management and air quality improvement in the HKH region, with the aim of identifying practical and context-appropriate approaches that address the underlying drivers of forest fires while considering their impacts on air quality, ecosystem sustainability, and transboundary environmental processes.

2.2 Specific Objectives

The specific objectives of the assignment are to review and assess existing forest fire management practices, including prevention, monitoring, forecasting, alert dissemination, suppression, and post-fire management across the HKH countries; to examine linkages between forest fire occurrence and air quality impacts, including seasonal pollution episodes and transboundary smoke transport; to identify and evaluate practical forest fire management solutions that can reduce fire risk and associated air pollution; to assess forest biomass and fuel load management options, including their costs, benefits, and sustainability implications; to explore entrepreneurship and community-based models that support forest fire risk reduction and productive utilisation of forest biomass; to analyse policy, institutional, and coordination gaps at local, national, and regional levels; and to develop a prioritised roadmap for integrating proposed solutions into national and regional forest fire management and air quality strategies.

2.3 Scope of Work

The scope of work covers the Hindu Kush Himalaya countries of Afghanistan, Bangladesh, Bhutan, China (HKH-relevant regions), India, Myanmar, Nepal, and Pakistan, and adopts a regional perspective complemented by country-specific assessments. The assignment focuses on synthesising existing knowledge, reviewing institutional frameworks and operational practices, and assessing technical systems related to forest fire management and air quality. Analytical work is based primarily on secondary data, geospatial information, policy and institutional documents, and stakeholder inputs.

The inception phase of the assignment is limited to review and assessment activities, stakeholder and institutional mapping, and refinement of the analytical approach and workplan. It does not involve primary field data collection, implementation of fire management interventions, or development of new operational forecasting systems. Outputs from this phase provide the foundation for subsequent components of the assignment, including solution evaluation, cost–benefit analysis, business model development, policy gap analysis, and formulation of final recommendations and implementation roadmaps.

3. Study Area and Geographic Coverage (HKH)

The Hindu Kush Himalaya (HKH) is a vast transboundary mountain system extending approximately 3,500 km from Afghanistan in the west to Myanmar in the east, spanning eight countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan (International Centre for Integrated Mountain Development [ICIMOD], n.d.). For regional-scale analyses, the HKH is commonly represented within an approximate geographic envelope of 16°–40° N latitude and 60°–105° E longitude, encompassing the main Himalayan arc, adjoining highland systems, and associated foothill belts that collectively influence fire regimes, smoke transport, and population exposure across the broader HKH airshed (You et al., 2017; Saha et al., 2024). As a major global headwater region, the HKH feeds ten major Asian river systems, including the Amu Darya, Indus, Ganges, Brahmaputra, Yarlung Tsangpo, Irrawaddy, Salween, Mekong, Yangtze, and Yellow rivers, thereby underpinning regional water security, ecosystem services, and downstream socio-economic systems across large parts of Asia (ICIMOD, 2013; ICIMOD, n.d.). Within the mountain and hill regions of the HKH, approximately 240 million people depend directly on its ecosystems and natural resources for their livelihoods, while downstream river basins support nearly 1.9 billion people, highlighting the scale at which environmental risks originating in the HKH can propagate far beyond national and ecological boundaries (ICIMOD, 2013; ICIMOD, n.d.).

A defining feature of the HKH is the strong cryospheric control on hydrology and seasonal water availability. Snow and glacier ice store a substantial fraction of the region's freshwater reserves, with seasonal snow cover reported to range from roughly 951,000 to 1,390,000 km² in winter and 388,000 to 481,000 km² in summer, and the maximum glacier-covered area estimated at about 87,340 km² (ICIMOD, n.d.). Along steep elevational gradients, ecosystems transition from subtropical and temperate forests in lower and mid elevations to conifer belts, alpine scrub, meadows, and cold-desert communities at higher elevations, creating pronounced heterogeneity in fuels, ignition conditions, and fire behaviour across short distances (Xu et al., 2019). In parallel, many HKH communities remain closely linked to agriculture, forests, and water resources, with livelihood systems often shaped by local access constraints, seasonal variability, and dependence on nature-based goods and services (Joshi et al., 2016). This combination of climatic sensitivity, topographic complexity, and resource dependence makes it important to define the HKH study area explicitly for consistent cross-country comparison and for integrating fire management solutions with air quality management strategies.

Table 1 and Figure 1 summarise the adopted HKH delineation for this study. Table 1 lists the country-wise areas included within the HKH definition used by ICIMOD for regional member countries, which provides a consistent basis for aggregating evidence and organising consultations across national, sub-national, and landscape scales (ICIMOD, n.d.). Figure 1 presents the corresponding map of HKH geographic coverage to support interpretation of fire patterns, monitoring system footprints, and transboundary smoke pathways in subsequent sections.

Table 1 Description of Countries in HKH Region

Countries	Areas included in the HKH region
Afghanistan	All provinces except the provinces of Kandahar, Helmand, Nimroz, Farah, and Herat
Bangladesh	Chittagong hills
Bhutan	Entire territory
China	Parts of the provinces of Yunnan (Diqing, Nujiang & Dali prefectures), Sichuan (Ganzi, Aba & Liangshan prefectures), & Gansu (Gannan, Wuwei & Zhangye prefectures); Xinjiang autonomous region (Kashigar, Kezilesu, Hetian & Altai prefectures); Tibet (entire territory), and Qinghai province (entire territory)
India	Entire territory of 11 mountain states (Assam, Uttarakhand, Himachal Pradesh, Manipur, Jammu & Kashmir (Indian administered area), Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Arunachal Pradesh), & Darjeeling district of West Bengal state
Myanmar	Chin, Shan, Rakhine & Kachin states
Nepal	Entire territory
Pakistan	Khyber Pakhtunkhwa province, 24 districts (out of 32) of Balochistan province (excluded districts are Kachhi, Gwadar, Jafarabad, Jhal Magsi, Lasbela & Sohbatpur), Federally administered Tribal Areas (FATA)

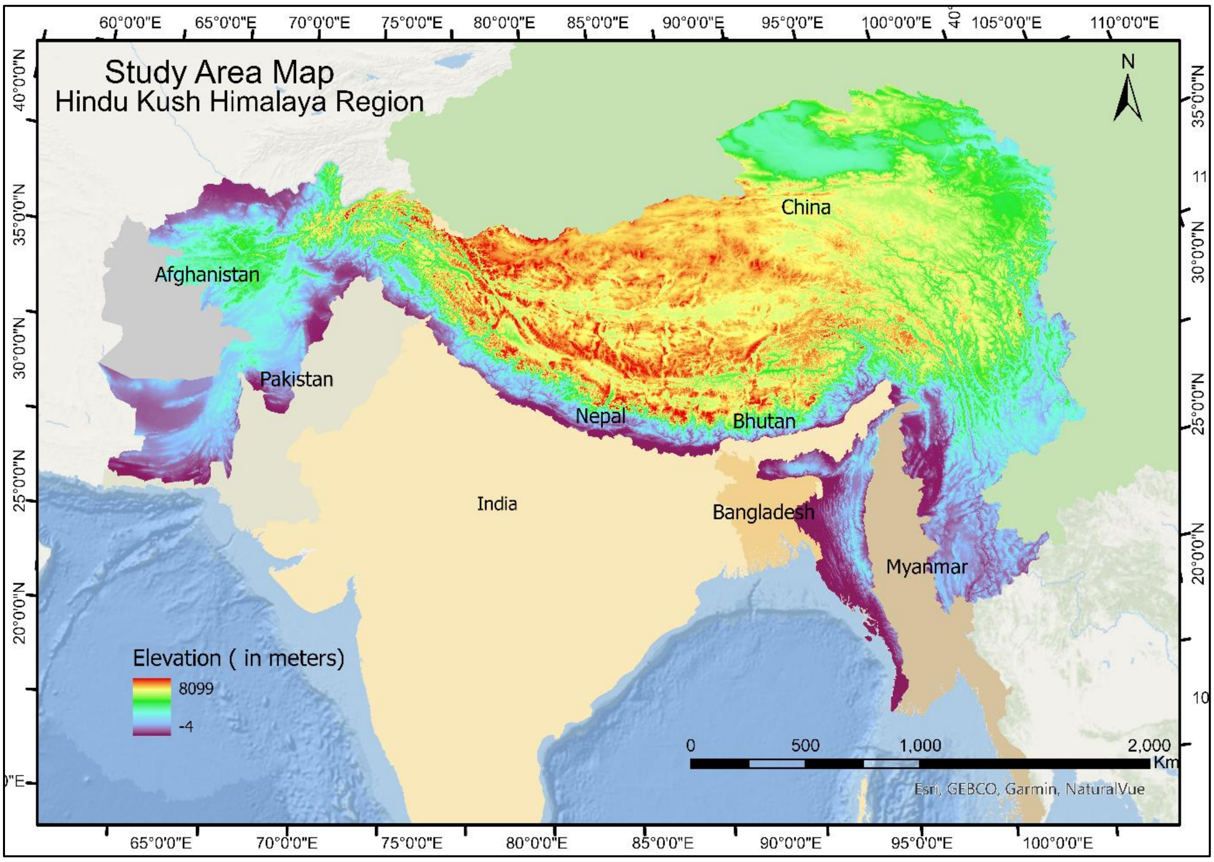


Figure 1 Map of Study Area

4. Methodological Framework for the Inception Phase

The inception phase adopts a structured and sequential methodological framework to review existing forest fire management practices, assess emerging risks and opportunities, and refine the analytical approach for subsequent project deliverables. The methodology is designed to operate at multiple scales, combining regional synthesis across the HKH with country-specific insights for Afghanistan, Bangladesh, Bhutan, China (HKH-relevant regions), India, Myanmar, Nepal, and Pakistan. Emphasis is placed on integrating institutional review, technical assessment, and stakeholder perspectives to ensure that findings are grounded in operational realities.

The first component of the methodology focuses on a systematic review of existing forest fire management practices, policies, and institutional arrangements across the HKH. This includes analysis of national forest fire management strategies, operational guidelines, early warning systems, and suppression mechanisms, drawing on official government documents, regional assessments, and institutional reports. Attention is given to identifying how forecasting, alert dissemination, preparedness planning, and response coordination are currently structured, as well as the extent to which forest biomass and fuel load management are incorporated into fire risk reduction strategies.

The second component involves a technical assessment of fire monitoring, forecasting, and alert systems currently used in the region. This assessment examines the role of satellite-based fire detection, meteorological inputs, and modelling tools in supporting early warning and decision-making, with attention to their spatial resolution, timeliness, accessibility, and operational use by national and sub-national agencies. The review also considers how fire information is communicated to frontline responders and communities, and whether alert systems are linked to actionable thresholds or preparedness measures.

A third component addresses the linkages between forest fires, air quality impacts, and transboundary considerations. This involves synthesising existing evidence on smoke transport, air pollution episodes, and health-relevant exposure pathways associated with forest fires in the HKH. The analysis assesses whether current fire management systems adequately consider air quality implications and whether institutional mechanisms exist for coordination between forest management, air quality agencies, and disaster response authorities at national and regional levels.

The methodology further incorporates a stakeholder and institutional mapping exercise, identifying key government agencies, research institutions, community-based organisations, and regional platforms involved in forest fire management and air quality governance. This mapping supports identification of coordination gaps, overlaps in mandates, and opportunities for collaboration, particularly in the context of transboundary fire and smoke management.

As part of the RS–GIS evidence base for the inception-phase assessment, country-wise fire and land-cover analytics for the HKH have been prepared (incorporated in the Annexure A) to complement the desk-based institutional and policy review. Spatial distribution maps of fire incidents have been generated using active-fire detections from MODIS and VIIRS (compiled over 2000-2025) accessed via NASA's Fire Information for Resource Management System (FIRMS) to identify persistent ignition belts, hotspot clustering, and transboundary fire-prone zones (NASA Earthdata, n.d.). Annual burned-area profiles and "burned area by land-use" summaries have been produced by combining the MODIS burned-area product with land-cover classes, enabling attribution of burned area to broad land-use categories (such as, forest, grassland, cropland mosaics) and supporting inference on likely drivers across HKH sub-regions (Giglio et al., 2018). In addition, country-level forest burned-area summaries have been compiled to quantify year-to-year variability in forested landscapes and support interpretation of temporal fire regimes using 30 m forest cover loss layers from the Global Forest Change dataset (Hansen et al., 2013).

Findings from these components are synthesised to identify priority gaps, challenges, and decision points that inform the subsequent analytical workstreams on solutions, evaluation, cost benefit analysis, policy gap assessment, and the final roadmap. In addition, a Country-wise Review and Assessment Matrix has been prepared as part of the inception outputs based on the desk-review. This country-wise assessment matrix has been included under Section 5.2 Summary of Country-wise Findings, providing a structured frame of current systems across monitoring, forecasting and alerts, suppression, biomass or fuel management, and air quality linkages, along with key gaps and immediate opportunities. A Stakeholder Mapping Matrix, HKH Forest Fire Management and Air Quality Improvement has also been included in Annexure B, detailing the key stakeholder categories, their roles across the fire management cycle and air quality response, relevant data inputs, and recommended engagement modes to support coordination and implementation planning in subsequent phases.

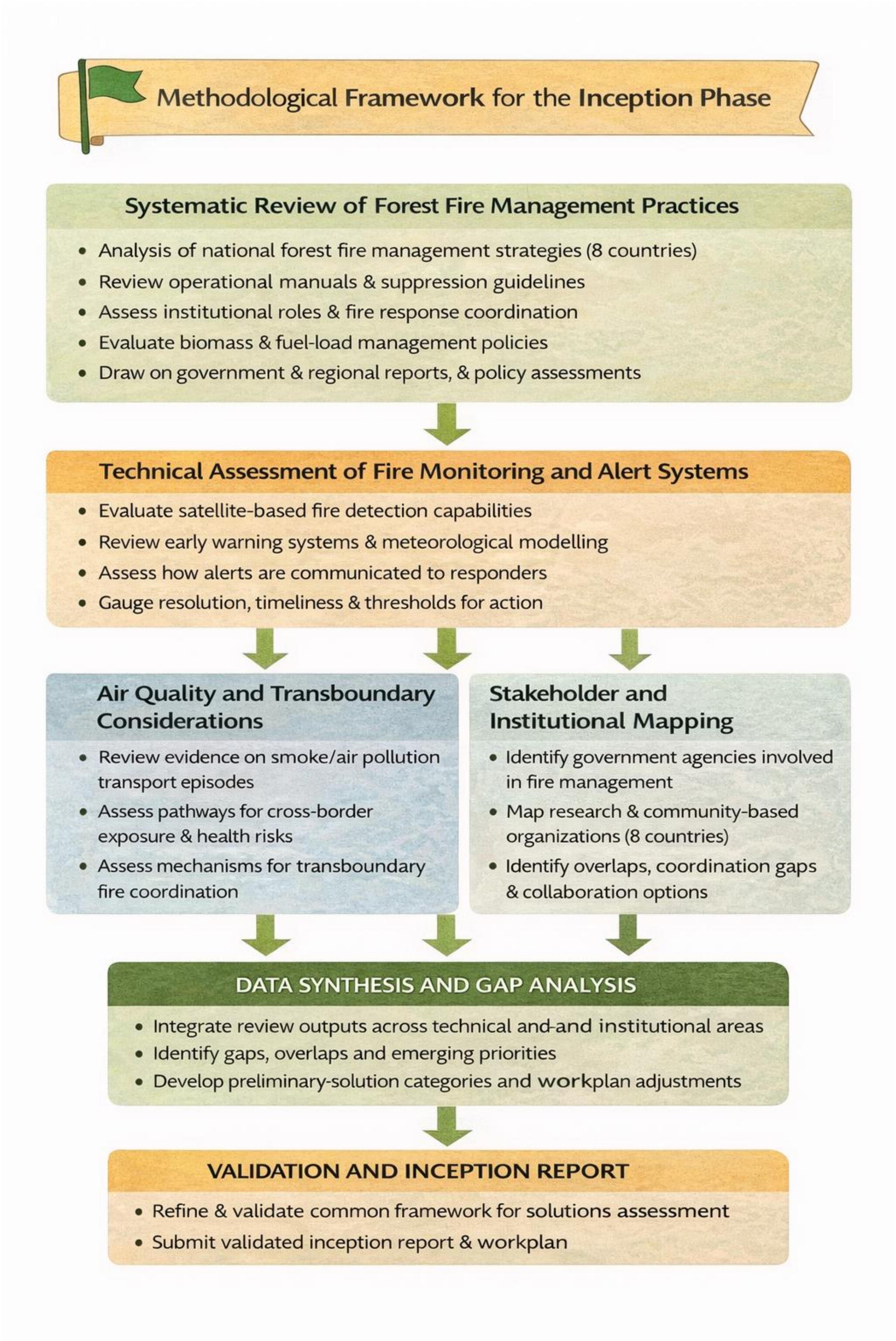


Figure 2 Methodological Framework for the Inception Phase

5. Preliminary Findings from Country-wise Review and Assessment

The preliminary country-wise review across the Hindu Kush Himalaya indicates that forest fire management systems have developed unevenly across countries, reflecting differences in institutional capacity, governance arrangements, and ecological contexts. Across most HKH countries, satellite-based fire detection systems are routinely used to identify active fire events during peak fire seasons, improving national-level situational awareness (Giglio et al., 2018). However, the operational use of these alerts for preparedness, coordinated response, and last-mile dissemination to sub-national authorities and local communities remains inconsistent. Fire management efforts continue to prioritise suppression-oriented responses, while preventive measures such as systematic forest fuel or biomass management are limited, despite international guidance advocating integrated fire management approaches that balance prevention, preparedness, response, and recovery (FAO, 2006). Regional evidence further indicates that forest fires in the HKH are increasingly influenced by climatic variability and human activities, with implications for ecosystem stability and transboundary environmental impacts (Bhattarai et al., 2022). Linkages between forest fire management and air quality response frameworks are emerging in some countries but are not yet uniformly institutionalised across the region. These preliminary observations highlight shared regional challenges alongside country-specific institutional and operational constraints that warrant deeper analysis in subsequent phases of the study.

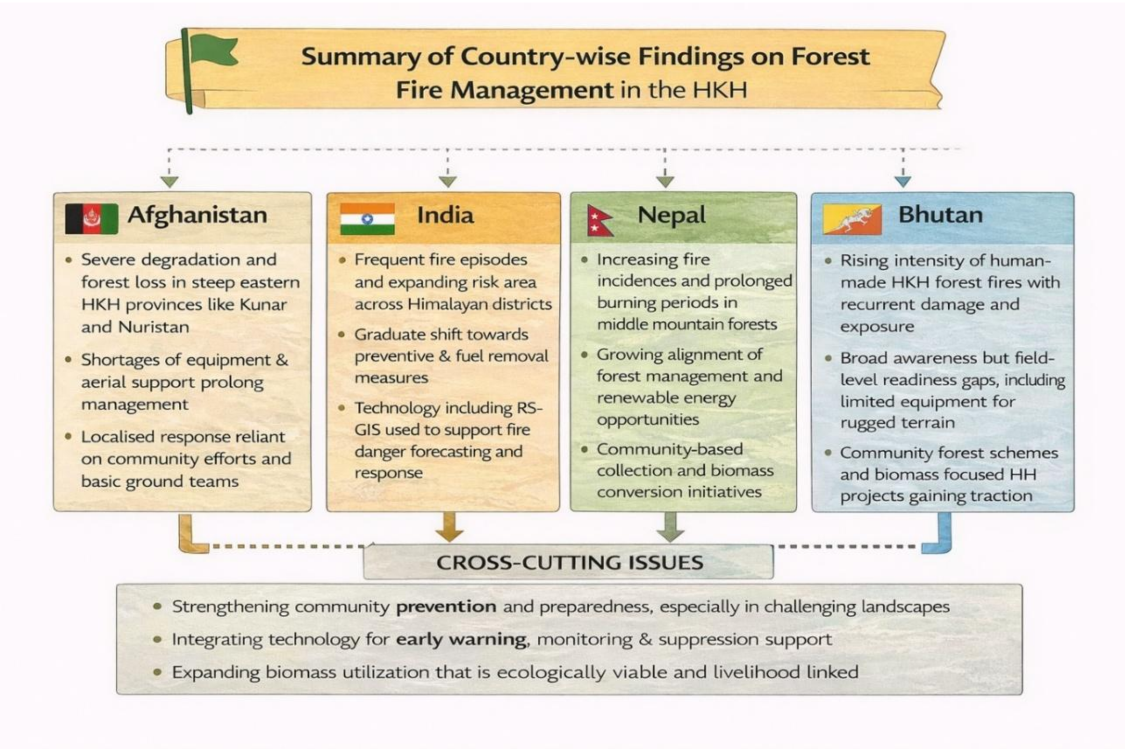


Figure 3 Country Comparison Framework for Forest Fire Management Practices in the HKH Region (Afghanistan, India, Nepal, and Bhutan)

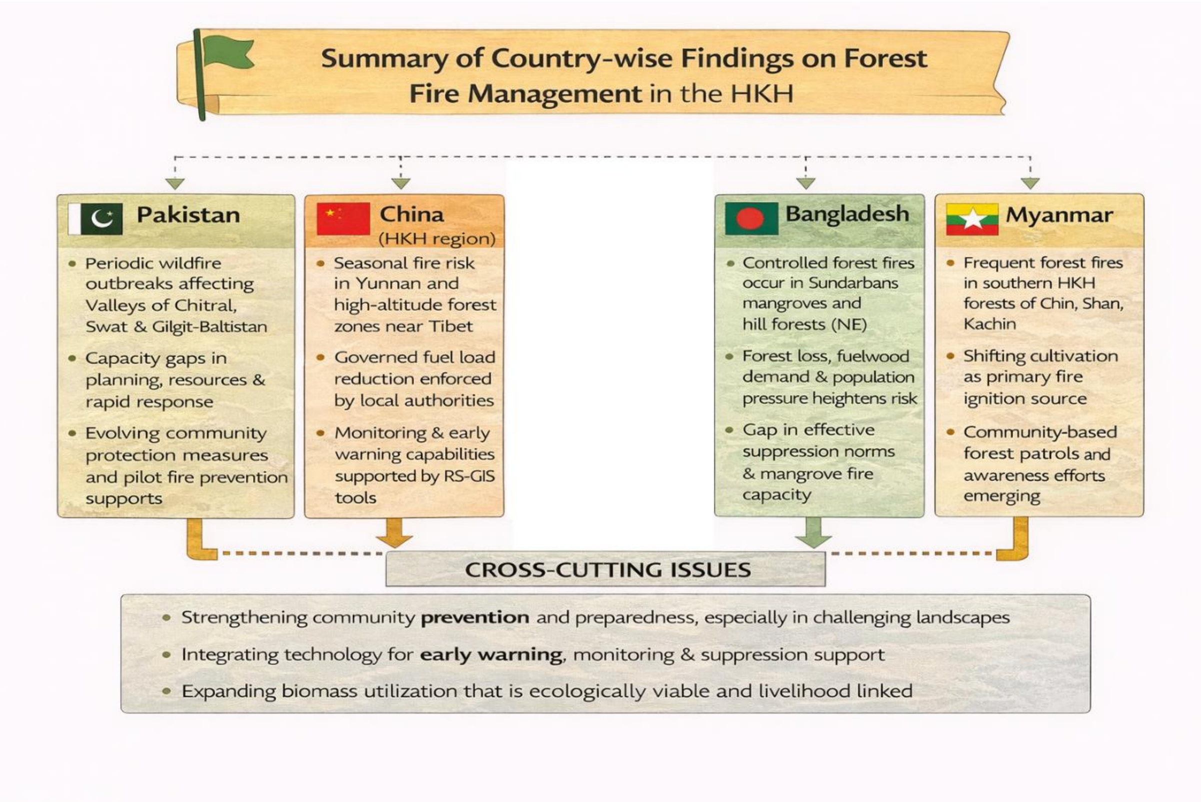


Figure 4 Country Comparison Framework for Forest Fire Management Practices in the HKH Region (Pakistan, China, Bangladesh, and Myanmar)

5.1 Cross-cutting Observations

Across the HKH countries, near-real-time satellite fire information has become a common backbone for situational awareness, with national teams increasingly drawing on global active-fire products and alert services for rapid identification of hotspots and fire locations (NASA Earthdata, n.d.). However, the review indicates that the operational value of these alerts is shaped less by detection capability and more by the strength of the downstream chain, namely how alerts are validated, communicated to field units, and linked to standard operating procedures for preparedness and response. A related cross-cutting observation is that fire-related emissions and smoke impacts are increasingly assessed using harmonised global datasets, particularly fire-emissions products that translate satellite observations into estimated pollutant fluxes and aerosol burdens. This includes emissions inventories such as GFED and CAMS GFAS, which are widely used for regional-scale smoke and air-quality analysis, especially where ground monitoring is limited (Randerson et al., 2017; ECMWF, n.d.).

The review also suggests a persistent imbalance in many contexts between suppression-oriented operations and preventive risk reduction, with limited systematic emphasis on fuel-load management, preparedness planning, and post-fire recovery arrangements, despite long-standing international guidance that promotes integrated fire management across prevention, preparedness, response, and rehabilitation (FAO, 2006). In parallel, institutional linkages between forest fire management and air quality or public health response remain uneven,

even though wildfire smoke is widely recognised as a significant driver of particulate pollution and public health risk during fire episodes and requires coordinated advisories and protective measures (California Air Resources Board & California Department of Public Health, 2021). Taken together, these cross-cutting observations reinforce the importance of strengthening decision pathways that connect satellite detection, emissions and smoke intelligence, and ground-based operations, while improving coordination between forestry agencies, disaster management authorities, and air quality and health institutions (FAO, 2006).

5.2 Summary of Country-wise Findings

5.2.1 Afghanistan

In Afghanistan, forest fire management operates under significant terrain, access, and capacity constraints, particularly in the HKH relevant eastern forest landscapes such as Kunar and Nuristan. National assessments highlight long term degradation and substantial forest loss in these provinces, including satellite-based estimates of severe declines in forest cover in parts of Nangarhar, Nuristan, and Kunar over past decades, which increases landscape vulnerability and complicates prevention and post fire recovery (National Environmental Protection Agency, 2019). Recent incident accounts from eastern provinces indicate that suppression remains heavily dependent on local responders and basic ground teams, while rugged mountainous locations, limited road access, and shortages of specialised equipment and aviation support can prolong containment timelines, as reported during extended forest fire episodes in Nuristan (TOLOnews, 2024). In parallel, Afghanistan's ongoing efforts to strengthen community and institutional capacity for sustainable land and forest management, including community-based approaches supported through international programmes, provide an entry point for improving prevention, preparedness, and fuel management in priority landscapes (Global Environment Facility, n.d.; Food and Agriculture Organization of the United Nations, n.d.). Overall, preliminary findings suggest that while response coordination mechanisms exist, strengthening prevention systems, field readiness, and community linked risk reduction measures in forest dependent provinces is central to improving fire outcomes and limiting smoke impacts, given the operational limits of suppression in steep HKH terrain (United Nations Environment Programme, 2022).

5.2.2 Bangladesh

In Bangladesh, forest fire occurrence is most frequently reported in fire-prone hill forest landscapes of the southeast, where slash-and-burn shifting cultivation, locally practised as jhum, is a recurrent driver of deliberate landscape burning, alongside localised fires linked to grass regeneration and plantation mosaics (Food and Agriculture Organization of the United Nations [FAO] & United Nations Environment Programme [UNEP], 1981; FAO, 2001). Recent incident-response practice in sensitive ecosystems such as the Sundarbans indicates a multi-agency suppression model led by the Forest Department, with support from emergency and security services, and the use of aerial monitoring such as drones during and after containment to track residual smoke and re-ignition risk (bdnews24.com, 2024). Operational constraints reported during these Sundarbans incidents include difficult access, limited space and logistics for water pumping, dependence on nearby channels for suppression water, and the need for extended post-fire surveillance, together highlighting the importance of preparedness logistics and coordinated response chains beyond detection alone (The Business Standard, 2024).

5.2.3 Bhutan

In Bhutan, forest fires are widely recognised as a recurrent dry-season risk, with national adaptation planning documents noting that fire incidence is commonly experienced below about 2,500 m, with higher intensity in dry zones, particularly within chir pine ecosystems, and with a seasonality extending broadly from November to May (United Nations Framework Convention on Climate Change [UNFCCC], 2006). The same national documentation indicates that most fire incidences are anthropogenic, linked to debris burning in orchards and cultivated fields, careless ignition sources, and deliberate burning for pasture improvement or resource extraction, underscoring the centrality of prevention and community-level engagement for risk reduction (UNFCCC, 2006). Bhutan’s regulatory framework also treats setting State Reserved Forest Land or State Land on fire as an offence and provides for penalties and restoration-related norms, reflecting a compliance-based pillar in forest fire governance alongside operational measures (Ministry of Energy and Natural Resources, Royal Government of Bhutan, 2023).

5.2.4 China (HKH-relevant regions)

In the HKH-relevant parts of China, including the Tibetan Plateau fringe and Hengduan mountain systems across Sichuan, Yunnan, and adjoining highland prefectures, wildfire risk is shaped by steep terrain, pronounced dry-season meteorology, and strong human influence near settlements and transport corridors. Evidence from Sichuan, which includes major mountain prefectures along the eastern and southeastern margins of the Tibetan Plateau, shows that wildfire occurrence is concentrated in the first half of the year, with high-incidence clusters in the southwest, and with key drivers spanning temperature, precipitation, elevation, population density, road proximity, and vegetation condition captured through NDVI (Peng et al., 2023). This pattern is consistent with the operational reality that fire-prone mountain landscapes often experience rapid fire spread and constrained access for suppression, making early detection, prioritisation, and pre-positioning of response capacity particularly important for high-risk counties and valleys.

In Yunnan, which contains several HKH-adjacent mountain systems and shares ecological and ignition similarities with the wider Indo-China fire-prone belt, ignition dynamics are strongly linked to fire weather and local land-use practices. A detailed ignition analysis based on confirmed wildfire records (2003-2015) found daily minimum relative humidity to be a dominant control, identifying an indicative threshold around which ignition probability rises markedly, while also showing that agriculture-related human activities account for a large share of ignitions and structure the spatial pattern of fire occurrence (Ying et al., 2021). For HKH-facing mountain districts, these findings reinforce the importance of aligning fire prevention with community-level risk behaviour and seasonal livelihood activities, alongside targeted readiness measures during the most critical windows of low humidity and high ignition likelihood.

Institutionally, China’s forest and grassland fire governance emphasises formal planning, daily prevention measures, and rapid emergency activation, with strengthening legal responsibility and compliance mechanisms. A State Council regulation on the prevention and control of forest and grassland fires, taking effect from 1 January 2026, requires competent departments to formulate fire prevention and emergency response plans, strengthen patrols and fire-prevention inspections, and improve firebreak and compartmentation infrastructure, while also mandating immediate activation of emergency response protocols upon receiving a fire alarm (State Council of the People's Republic of China, 2025). For the HKH context, this approach points to an operational model where risk reduction and enforcement measures are expected to work in tandem with monitoring and command systems, and where mountainous hotspots in Sichuan and Yunnan require locally adapted readiness and logistics that account for access constraints, rapid spread potential, and the need to coordinate prevention and response across administrative levels.

5.2.5 India

India's forest fire governance in the HKH is anchored in a tiered institutional set-up where State Forest Departments lead prevention, preparedness, suppression, and post-fire restoration at the field level, while national agencies provide policy direction, financing support, and decision-support services for early warning and situational awareness. The National Action Plan on Forest Fire, 2018 positions forest fire management as a continuum across prevention, preparedness, detection, response, and rehabilitation, and explicitly calls for strengthening institutional capacity, standard operating procedures, and community participation, which is particularly relevant for Himalayan states where ignition pressure is high during the dry pre-monsoon months (Ministry of Environment, Forest and Climate Change, 2018a). At the same time, diagnostic assessments have underlined that technology-enabled detection is necessary but not sufficient, and outcomes depend on last-mile validation, field readiness, inter-agency coordination, and sustained investment in prevention and risk reduction measures (Ministry of Environment, Forest and Climate Change, Government of India & World Bank, 2018b).

A defining feature of India's operational system is the national-scale remote-sensing backbone for active-fire detection and alert dissemination. The Forest Survey of India (FSI) operates a near-real-time forest fire alert system that shares hotspot locations with registered users and nodal officers, supporting faster awareness and field mobilisation across states including the Himalayan arc and the North Eastern Region (Ministry of Environment, Forest and Climate Change, Government of India & World Bank, 2018b). India has also moved toward anticipatory products through FSI's Pre-Fire Alert and Fire Danger Rating initiative, which uses daily weather inputs, fuel and terrain proxies, forest type layers, archival fire information, and forecast rainfall to generate gridded danger classes and publish them through the Van Agni geo-portal, with an operational pathway linked to the national alert architecture via CAP-based dissemination (Forest Survey of India, n.d.-b). This combination of near-real-time detection and forecast-oriented risk information is central to HKH contexts where fire windows are short, access is difficult, and response effectiveness depends on rapid decision cycles.

Evidence from peer-reviewed studies indicates that fire activity in the Indian HKH is strongly seasonal and topographically structured, with recurrent spring and early-summer fire peaks, especially across lower to mid elevations where human activity intersects with flammable fuel beds. In Uttarakhand, analysis of MODIS detections for 2002 to 2020 showed that human-ignited, patchy surface fires recur almost annually, with stronger fire seasons associated with warmer pre-monsoon temperatures and lower pre-monsoon and winter precipitation, and with fire incidence increasing in forest divisions with higher proportions of chir pine (*Pinus* *roxburghii*) (Singh et al., 2024). Complementary ecological evidence from chir pine forests in Uttarakhand indicates frequent burning during drought-prone pre-monsoon periods, reinforcing the role of coupled climate and fuel controls in shaping recurring fire regimes in parts of the western and central Himalaya (Fulé et al., 2021). At a broader western Himalaya scale, spatio-temporal hotspot and trend assessments for 2005 to 2022 point to clustering of fire events and burned area in specific landscape belts, highlighting persistent hotspots and the importance of using spatial statistics and climatic covariates to inform targeted prevention and response planning (Kumari et al., 2025).

Across other Indian HKH-relevant states and landscapes, peer-reviewed work also shows how risk varies sharply with terrain, vegetation, and human influence. In Jammu and Kashmir, vulnerability assessments at division scales have used GIS and MODIS-derived information alongside multi-criteria frameworks to delineate compartments and zones with elevated susceptibility, supporting prioritisation of prevention and preparedness investments (Kanga et al., 2021; Malik et al., 2025). In the eastern Himalaya, wildfire likelihood mapping in Sikkim using MODIS-FIRMS and ground-truthing has demonstrated that fire likelihood is spatially heterogeneous and can be linked to accessibility and landscape features, providing a template for state-level risk zonation and targeted interventions in Himalayan terrain where suppression logistics are constrained (Banerjee et al., 2021). For the wider Himalayan belt covering Indian, Nepal, and Bhutan sectors, long-term satellite-based emissions estimation for 2001 to 2020 indicates substantial inter-annual variability in burned area and emissions, with strong control by the pre-monsoon season and pronounced spatial gradients across western versus eastern Himalayan sectors, which is directly relevant for integrating fire management with smoke and air-quality response in the Indian HKH states (Bar et al., 2022).

In the North Eastern Region, fire dynamics interact strongly with land-use practices and dry-season meteorology, and impacts extend beyond burned area into air-quality degradation at regional scales. Satellite and modelling evidence increasingly links episodic fire activity to elevated aerosol and pollutant burdens over northeastern India, which can interact with terrain-driven ventilation limits and regional transport, adding to exposure risks in valleys and foothill settlements (Yarragunta et al., 2025). This has practical implications for the HKH objective of aligning forest fire solutions with air quality outcomes, since the same fire episode may require both suppression actions on the ground and advisories based on smoke intelligence for downwind populations.

A major India-specific direction emerging in recent years is the growing effort to link forest fire risk reduction with forest-floor fuel management and livelihood-linked biomass utilisation in fire-prone Himalayan landscapes, particularly in chir pine belts where needle litter increases ignitability during the dry season. Initiatives such as pine-needle collection and briquette or pellet units are increasingly framed not only as livelihood interventions but also as practical measures to reduce surface fuel loads and lower the probability of fire spread during the peak season (Forest Survey of India, n.d.-b; The New Indian Express, 2024). Taken together, India's HKH-relevant findings point to a mature national backbone for RS-enabled detection and expanding pre-fire risk products, while consistently highlighting that risk reduction depends on the full operational chain, including community-linked prevention, field logistics, inter-agency coordination, and pathways that translate early warning into timely action across Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Ladakh-adjacent landscapes, Sikkim, and the wider Himalayan and North Eastern arc (Ministry of

Environment, Forest and Climate Change, Government of India, 2018a; Ministry of Environment, Forest and Climate Change, Government of India & World Bank, 2018b).

5.2.6 Myanmar

In Myanmar, forest and vegetation fires are widely reported as a dry-season issue, with fires described predominantly as surface fires that become most frequent from around December through May, occurring across many States and Regions and noted as more common in upland areas including Bago, Chin, Kayah, Kachin, Mandalay, Rakhine and Shan, which are relevant to HKH-connected mountain and upland landscapes (Department of Meteorology and Hydrology, 2009). Fire occurrence is also closely linked to human land-use and ignition practices in dry months, including burning associated with shifting cultivation systems and land preparation in some upland contexts, underscoring the importance of prevention measures that address local drivers and reduce escape-fire risk (International Work Group for Indigenous Affairs, 2015; Forest Department, Government of the Union of Myanmar, 1995). From a governance standpoint, Myanmar has formal legal provisions that relate to forest fire risk and the use of fire in forest areas, including rules issued under the Forest Law (Forest Department, Government of the Union of Myanmar, 1995), while broader disaster governance arrangements are framed under the Natural Disaster Management Law (Republic of the Union of Myanmar, 2013), providing an enabling basis for multi-agency coordination when large fire episodes intersect with emergency response functions (Republic of the Union of Myanmar, 2013). From a regional monitoring and air-quality perspective, satellite-era analyses identify Myanmar among countries contributing substantially to observed fire activity across South and Southeast Asia, supporting the use of harmonised remote-sensing fire products for seasonal situational awareness when connected to validation and response chains (Vadrevu et al., 2019). In addition, modelling and remote-sensing studies show that biomass-burning plumes from mainland Southeast Asia, including areas within Myanmar's broader burning region, can be transported across borders and contribute to downwind $PM_{2.5}$ episodes, highlighting why forest-fire management and smoke-risk advisories benefit from coordination beyond administrative boundaries (Yang et al., 2022).

5.2.7 Nepal

In Nepal, forest fires are largely a dry pre-monsoon phenomenon, with multi-year evidence showing that the majority of incidents and burned area are concentrated between March and May, and decline rapidly with the onset of monsoon conditions (Poudel et al., 2022). Recent national-scale analyses using satellite-derived fire records and spatial modelling also confirm this strong seasonality and highlight increasing pressures in key physiographic belts, strengthening the case for fire-danger outlooks that combine weather information with historical fire occurrence (Poudel et al., 2022). A long-standing governance feature in Nepal is the prominent role of Community Forest User Groups (CFUGs) as first-line actors for prevention, early response, and local coordination in community forests, while capacity, equipment, and institutional coordination constraints persist across many non-community forest jurisdictions (Food and Agriculture Organization of the United Nations [FAO], 2001). Reflecting this, applied research and policy work in Nepal has increasingly focused on practical pathways to enable CFUG-led and local-government-led fire preparedness, including training and equipment provisioning, volunteer mobilisation, forest-fuel management priorities, and local coordination mechanisms that can escalate support quickly during peak fire periods (Parajuli et al., 2022; Shrestha et al., 2025).

Policy and planning instruments have also begun to place forest fire risk reduction within broader national adaptation and disaster-risk priorities, including actions such as revising forest fire strategies, establishing real-time early warning, mapping risk-prone districts, creating joint rapid response teams involving security forces and communities, and undertaking fuel management and fire-line maintenance in high-risk zones (Government of Nepal, 2021). Overall, the country-wise review indicates that Nepal's fire management trajectory is moving toward stronger anticipatory and community-centred preparedness, with growing emphasis on linking near-real-time detection and forecast products to operational decision chains at provincial and local levels (Government of Nepal, 2021; Parajuli et al., 2022; Shrestha et al., 2025).

5.2.8 Pakistan

In Pakistan's HKH-relevant geographies, wildfire risk and impacts are most frequently discussed in relation to the northern uplands and foothill systems, particularly in Khyber Pakhtunkhwa, Azad Jammu and Kashmir, and adjoining hill ranges where combustible seasonal fuels, dry windy conditions, and human ignition pressures combine to create recurrent fire episodes. Recent peer-reviewed work demonstrates a clear shift toward using RS/GIS and machine learning to identify fire-prone zones and drivers, for example, nationwide or regional assessments linking wildfire occurrence to environmental covariates derived from remote sensing and gridded datasets (Rafaqat et al., 2022), and northern Pakistan analyses that map vulnerability in subtropical chir pine landscapes using MODIS-based fire records together with vegetation, topographic, climatic, and anthropogenic variables (Muhammad et al., 2025). Complementary site-scale work in AJK has also applied spatial modelling to chir pine systems, underscoring how forest structure, needle-litter fuel accumulation, and topographic controls shape local vulnerability patterns and inform targeted prevention and preparedness (Naseem & Nurrochmat, 2024).

Institutionally, Pakistan's national disaster management system has issued guidance and advisories that explicitly frame forest fires as a prevention–preparedness–response–recovery challenge and highlight the operational value of satellite-based monitoring and early warning, community engagement, coordinated response protocols, and post-fire recovery measures (National Disaster Management Authority [NDMA], 2025a; NDMA, 2025b). In practice, country-wise findings point to a growing emphasis on strengthening early warning and surveillance, improving response readiness in fire-prone districts, and formalising inter-agency coordination for peak-risk months, alongside the continuing need to translate technical monitoring capacity into field-level logistics, rapid first response, and sustained prevention measures in remote mountainous terrains (NDMA, 2025a; NDMA, 2025b; Muhammad et al., 2025).

5.2.9 Country-wise Review and Assessment Matrix

To summarise the desk-review findings in a consistent and comparable format, a Country-wise Review and Assessment Matrix has been prepared for all HKH countries covered under this study. The matrix consolidates preliminary observations across key operational dimensions, fire monitoring, forecasting and alerts, suppression capacity, biomass or fuel-load management, and air quality linkages, and also highlights immediate gaps and practical opportunities for strengthening systems.

Table 2 Country-Wise Review and Assessment Matrix

Country	Fire monitoring	Forecast & alerts	Suppression	Biomass / fuel management	Air quality linkages	Key gaps and immediate opportunities
Afghanistan	Monitoring coverage is limited in HKH-relevant eastern forests, with dependence on local reporting and secondary datasets, and constraints from terrain and access.	Early warning and alert-to-action pathways are not standardised and are constrained by communications and preparedness capacity in remote valleys.	Response relies mainly on local ground teams; rugged terrain, limited access, and equipment shortages can prolong containment.	Structured fuel-load or biomass management as a prevention tool is limited; community-based land and forest programs provide an entry point for prevention and fuel management.	Fire - smoke - health coordination is not consistently institutionalized; smoke advisories and exposure protection are often ad hoc.	Gaps include limited SOP clarity and capacity and logistics constraints. Immediate opportunities include defining minimum SOPs for validation and response, strengthening community-linked prevention, and applying RS-based hotspot situational awareness and priority risk mapping.
Bangladesh	Increasing reliance on satellite hotspot information for situational awareness, but operational uptake and harmonised national practices vary by landscape.	Alerts exist, but systematic validation and dissemination chains linked to preparedness thresholds are limited.	Suppression is largely ground-based and agency-led, with capacity varying by ecosystem and accessibility.	Fuel and biomass management is not consistently integrated into fire-risk reduction at scale; tends to be site or project specific.	Air-quality linkage is recognized, but routine coupling of fire operations with air-quality and health response protocols remains limited.	Gaps include weak detection-to-action pathways and limited preventive fuel management. Immediate opportunities include strengthening the alert validation chain and integrating smoke advisories during peak risk periods.

Country	Fire monitoring	Forecast & alerts	Suppression	Biomass / fuel management	Air quality linkages	Key gaps and immediate opportunities
Bhutan	Use of satellite and national fire information tools supports situational awareness; institutional coordination mechanisms are established.	Warning and reporting systems exist and can be strengthened through clearer thresholds and last-mile dissemination.	Suppression is coordinated by responsible agencies with structured reporting, supported by volunteers and local coordination; gaps remain in equipment and training in remote areas.	Prevention measures are present including fire lines and community actions; pilots on fuel reduction and controlled approaches are emerging in select areas.	Air-quality integration is present in regional discourse but can be strengthened through defined triggers for advisories and cross-agency protocols.	Gaps include field capacity and sustained financing. Immediate opportunities include scaling burn mapping, strengthening brigades and drills, and formalizing smoke advisory triggers.
China (HKH-relevant regions)	Monitoring is comparatively strong, supported by multi-source surveillance systems and structured institutional capacity.	Forecasting and early warning are relatively mature in many jurisdictions, supported by meteorological integration.	Response and suppression capacity is organised and rapid under centralised systems.	Fuel and biomass management is addressed within broader forest management, but cross-country documentation and comparability can be limited.	Air-quality integration is stronger where smoke intersects with haze management, though public documentation access for synthesis can be uneven.	Gaps relate to access to comparable provincial operational details and documentation on biomass and post-fire practices. Immediate opportunities include structured evidence synthesis through literature and expert inputs and alignment of open datasets for regional comparability.
India (HKH states)	National and state systems provide near-real-time alerts and	Risk and alerts are improving, but validation and	Suppression is largely state-led and ground-based;	Fuel management and biomass utilization	Fire - air quality coordination is developing, yet	Gaps include bottlenecks between detection and field action, limited

Country	Fire monitoring	Forecast & alerts	Suppression	Biomass / fuel management	Air quality linkages	Key gaps and immediate opportunities
	vulnerability information; operational effectiveness varies by last-mile response capacity.	SOP-linked action pathways remain uneven across states and forest divisions.	outcomes depend on staffing, logistics, terrain access, and seasonal readiness.	initiatives exist in some Himalayan contexts, but continuity and scaling remain uneven.	linkage between forest response and air-quality advisories remains inconsistent.	systematic fuel management, and uneven air-quality linkage. Immediate opportunities include strengthening SOPs and pre-positioning, scaling livelihood-linked biomass utilization, and integrating smoke advisories and exposure reduction measures.
Myanmar	Satellite information is used for awareness, but institutional capacity varies and can be limited in remote uplands.	Early warning dissemination is less standardised, with limited evidence of SOP-driven alert-to-action pathways.	Response relies on forest agencies and local coordination; logistics constraints affect rapid containment in rugged areas	Biomass and fuel-load management is limited as a mainstream prevention approach; post-fire recovery arrangements vary.	Institutional coupling between fire operations and air-quality or health response is limited.	Gaps include low institutional capacity and weak alert-to-action chains. Immediate opportunities include low-cost early warning, community brigades, standardized reporting templates, and pilots on fuel reduction in priority landscapes.
Nepal	Satellite-based monitoring and partner platforms support national situational awareness, complemented by community forestry	Alerts exist but operational thresholds and last-mile preparedness triggers can be inconsistent across jurisdictions.	Suppression is shared across forest offices, local government, and community groups; terrain and resource	Biomass and fuel conditions are central to risk; scope exists to align utilization and fuel reduction with regeneration limits	Strong evidence exists for smoke-driven pollution episodes in valleys; operational fire -	Gaps include sparse mountain monitoring and limited fire - AQ - health institutional integration. Immediate opportunities include strengthening smoke forecasting and

Country	Fire monitoring	Forecast & alerts	Suppression	Biomass / fuel management	Air quality linkages	Key gaps and immediate opportunities
	networks for ground confirmation.		constraints persist during peak season.	and community enterprises.	AQ coordination is evolving.	health messaging and linking community response to RS-based risk zoning.
Pakistan (HKH-relevant regions)	RS and research-led risk mapping is increasing, but comprehensive geospatial planning and operational integration remain variable.	Disaster management guidance and advisories exist, with scope to strengthen geospatially enabled early warning and field-level triggers.	Suppression is largely provincial and ground-based; operational consistency varies in remote mountainous terrains.	Systematic fuel and biomass management is not yet scaled as a prevention lever in many contexts.	Smoke and particulate risks are acknowledged, but linkage to air-quality advisories and response protocols remains limited.	Gaps include incomplete operationalisation of RS/GIS risk zoning and last-mile readiness. Immediate opportunities include integrating geospatial risk mapping with SOPs, improving response logistics, and linking advisories with smoke-health messaging.

6. Subsequent Analytical Components and Proposed Approach

6.1 Solutions and Evaluations

The literature review and assessment will identify globally and regionally demonstrated solutions for forest fire management and forest biomass or fuel-load management that can be applied in HKH landscapes. The solution set will be organised into thematic domains that reflect both the fire cycle and implementation pathways, including technological, ecological, socio-economic, and policy and institutional approaches. Within each domain, solutions will be mapped to specific stages of the fire cycle, prevention and risk reduction, preparedness and early action, suppression and response support, and post-fire rehabilitation, so that options are comparable across countries and can be linked to operational responsibilities and enabling conditions.

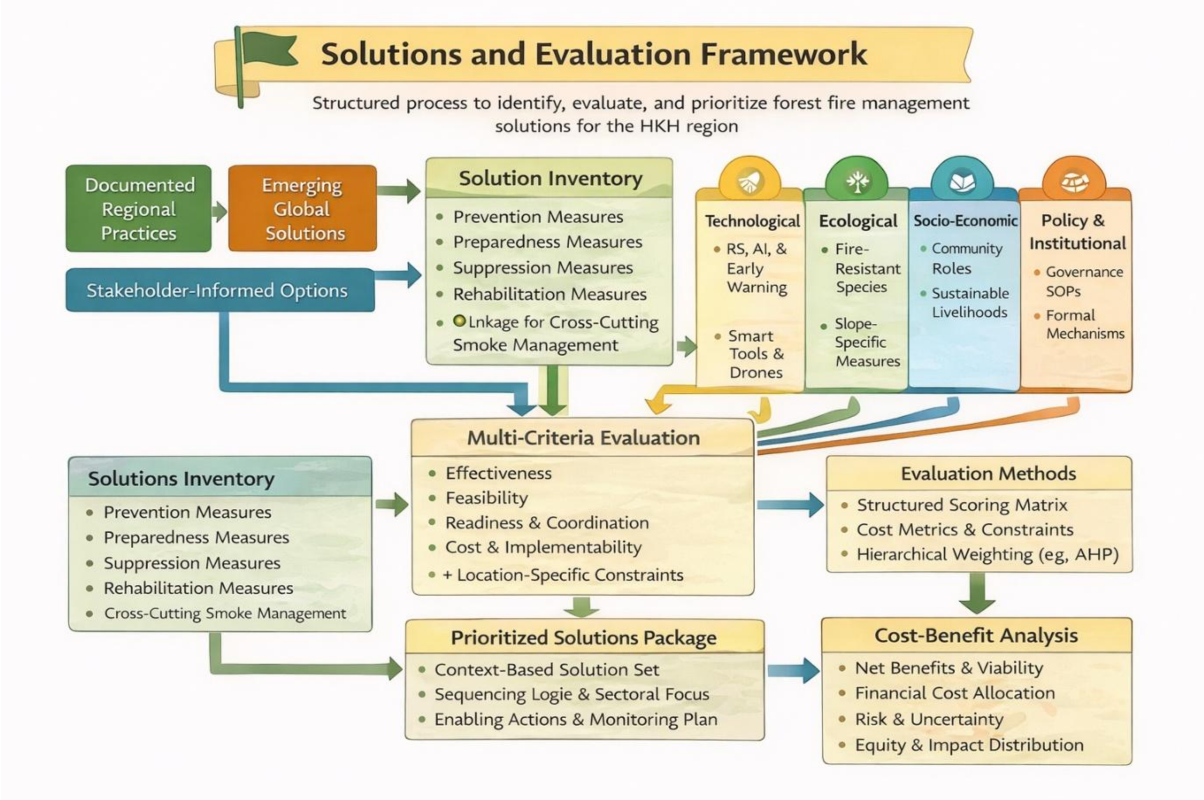


Figure 5 Framework for Screening and Prioritising Solutions for Forest Fire Management and Biomass Utilisation in the HKH Region

The technological stream will examine options such as automated early warning systems, integration of remote sensing with AI and machine learning for near-real-time fire detection and susceptibility prediction, and the use of drones for rapid reconnaissance, situational assessment, and support to containment planning. The ecological stream will focus on measures that improve landscape resilience and recovery, including restoration of fire-affected areas, regeneration planning using native and fire-tolerant species, slope and terrain-specific management practices, soil stabilisation measures to reduce erosion risk after burns, and continuous monitoring of vegetation recovery. The socio-economic stream will examine community-led and livelihood-linked approaches that reduce ignition risk and strengthen first response capacity, including awareness programmes, entrepreneurship and business development around sustainable biomass utilisation, strengthening Joint Forest Management mechanisms where applicable, incorporation of indigenous and traditional fire management knowledge, and development of community fire brigades that enable local rapid response. Preventive and preparedness solutions will include field-based risk reduction measures such as creating and maintaining fire lines, managing forest fuel loads, and developing fire risk zonation maps, supported by weather forecasts and drought indices to trigger preparedness actions. Options such as prescribed burning, controlled burning, and silvicultural thinning, along with emerging approaches such as community-run bio-briquette production using forest litter and residues, will be assessed for their suitability, safeguards, and practical constraints in mountain contexts. In parallel, a cross-country review of governance interventions and policy instruments will be undertaken to identify implementation bottlenecks and entry points to strengthen policy frameworks, formal coordination mechanisms, and dedicated financing arrangements that support sustained operational effectiveness.

The analysis will assess these solutions for the conditions under which they reduce fuel loads, support local livelihood benefits, and reduce the impacts of forest fires in ways that also improve air quality and contribute to climate-related co-benefits. A solution matrix will be developed across the identified domains and sub-categories, aligning each option with its primary focus, for example smart tools and innovation for resource allocation and modelling, ecosystem resilience for fire-resistant species and terrain-specific practices, community-centred actions for awareness and participation, framework and implementation for governance and SOPs, risk reduction for fuel management and fire lines, and landscape recovery for restoration and soil stabilisation. Each solution will then be evaluated using a structured scoring approach that considers criteria such as relative cost, scalability, maintenance and capacity needs, operational feasibility in steep terrain, implementation readiness, and social acceptance. Multi-criteria decision-making methods such as Analytic Hierarchy Process or Weighted Linear Combination will be used to generate transparent, comparable rankings, allowing trade-offs to be visualised across countries and contexts. The evaluation will also recognise that priority solutions may differ by location and risk profile, with low-cost, high-community-involvement measures ranking higher in socio-economically sensitive areas, while high-technology and capital-intensive options may be more appropriate for critical fire-prone corridors where rapid detection and coordinated response capacity are decisive.

The shortlisted solutions emerging from the matrix will be carried forward for further appraisal using cost benefit analysis to test their economic viability and practical applicability in the designated landscapes, including the distribution of costs and benefits across stakeholders and the implications for forest sustainability. The consolidated outputs will be presented as a prioritised package of solutions by domain and by fire-cycle stage, supported by an overall methodological flowchart that links solution identification, categorisation, multi-criteria evaluation, and economic appraisal into a single decision pathway for selecting and sequencing interventions.

6.2 Proposed Approach for Cost–Benefit Analysis

The Cost–Benefit Analysis under this study will provide an economic evaluation of forest biomass utilisation and management strategies in the HKH region, with the aim of quantifying the trade-offs between alternative management options such as fire prevention, controlled biomass extraction, sustainable fuelwood collection, and residue management, while ensuring that forest sustainability and ecosystem integrity are maintained. The assessment will compare intervention pathways on a common basis, so decision-makers can understand the cost of inaction, the value of prevention and sustainable utilisation, and the conditions under which community-linked biomass management can deliver net benefits without creating risks of long-term forest degradation.

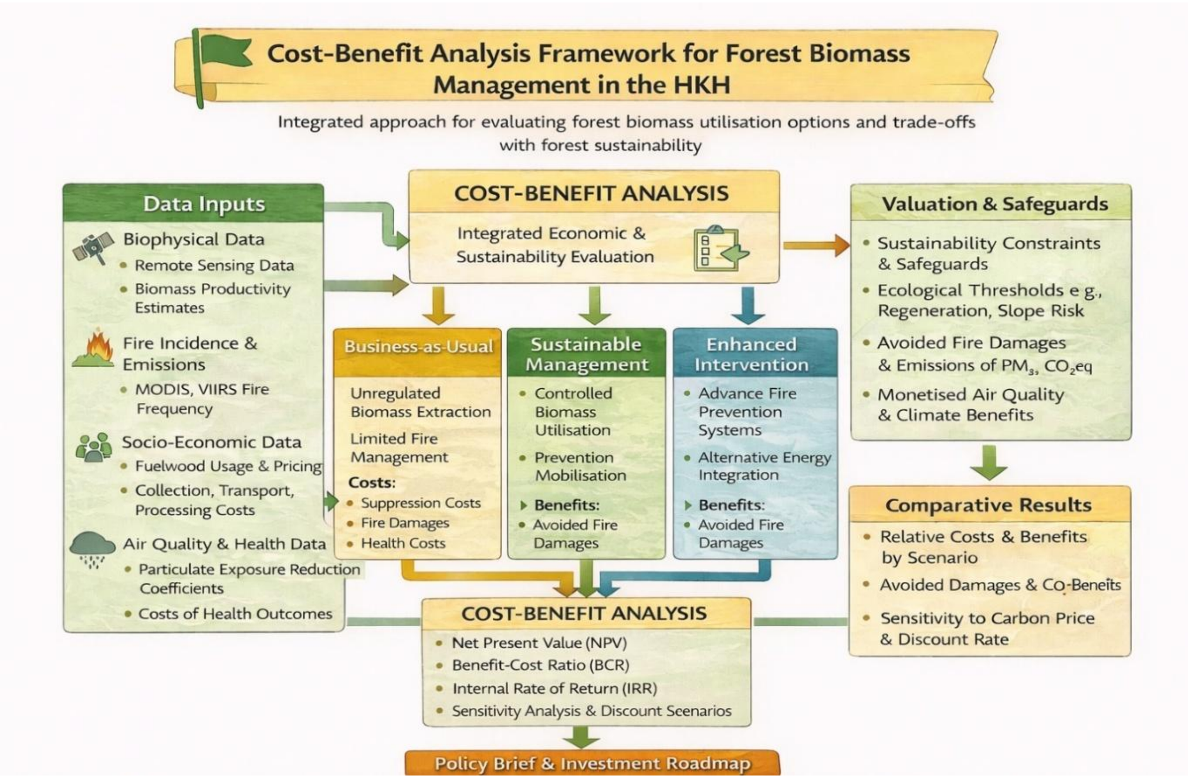


Figure 6 Cost Benefit Analysis incorporating Forest Sustainability

6.2.1 Conceptual Framework

The analysis will apply a Total Economic Value framework that captures both market and non-market values generated by forest ecosystems. Direct use values will include timber, fuelwood, and non-timber forest products, while indirect use values will include ecosystem services such as carbon sequestration, watershed protection, biodiversity maintenance, and regulation of air quality. The valuation will also incorporate avoided damages as economic gains, including reduced area burnt, avoided forest loss, avoided suppression and rehabilitation expenditure, and reduced particulate emissions during fire episodes. Sustainability will be treated as a binding condition through ecological thresholds and safeguards, so that intervention benefits are not overstated by assuming biomass removal levels that exceed regeneration capacity or undermine soil, slope stability, or habitat functions.

6.2.2 Data Inputs and Integration

The CBA will integrate multi-source biophysical and socio-economic datasets. Biomass availability and productivity will be assessed using remote sensing and geospatial approaches, including Sentinel-2 and Landsat data for vegetation condition and productivity proxies, and above-ground biomass information derived from sources such as ESA-CCI datasets and NASA GEDI products, supporting spatial estimation of biomass density and potential harvestable residues. Fire incidence and burn signals will be derived from MODIS and VIIRS active fire and related products, including FIRMS-based alerts and fire recurrence layers, to quantify likely biomass losses under unmanaged fire regimes and to identify where preventive actions yield the highest avoided-loss benefits. Socio-economic inputs will be compiled from secondary sources and validated through stakeholder interactions, covering household and community dependence on forest biomass, local market prices for fuelwood and biomass products, opportunity costs of restricted extraction, and cost structures for collection, transport, and processing. Air quality and health-related information will be incorporated to support monetisation of benefits from reduced emissions and smoke exposure where credible coefficients and accepted valuation parameters are available.

6.2.3 Analytical Methodology

Three scenario pathways will be evaluated. The Business-as-Usual scenario will represent current conditions with recurring fire incidence, limited systematic fuel-load management, and unregulated or weakly regulated biomass extraction. The Sustainable Management scenario will represent controlled biomass utilisation combined with preventive measures such as fuel-load reduction, fire-line maintenance, and community-based preparedness actions. The Enhanced Intervention scenario will represent strengthened prevention through improved early warning and decision-support systems, combined with sustainable harvest planning and complementary measures such as alternative energy integration or cleaner biomass conversion pathways, where relevant. For each scenario, costs and benefits will be computed over a two-decade horizon with clearly stated discount rates. Cost streams will include institutional and operational expenses for prevention and preparedness, equipment and monitoring, training and awareness programmes, community mobilisation, and any opportunity costs related to extraction restrictions. Benefit streams will include avoided fire damage and avoided suppression costs, retained carbon and avoided emissions, changes in ecosystem services, and health gains linked to reduced particulate exposure where quantification is defensible. Comparative assessment will be presented using NPV, BCR, and IRR metrics, supported by sensitivity analysis to test how results change under different discount rates, biomass prices, transport distances, and carbon values.

6.2.4 Valuation of Sustainability Components

Forest sustainability considerations will be explicitly incorporated through spatially defined ecological thresholds for biomass extraction and fuel-load removal. Remote sensing-derived biomass density, canopy cover, terrain slope, and regeneration proxies will be used to identify zones where extraction intensity may exceed sustainable limits. These sustainability constraints will be applied to adjust harvestable biomass volumes and expected revenues in a conservative manner where ecological risk is high, and to incorporate additional costs for safeguards such as monitoring, regulated extraction protocols, seasonal restrictions, and site-specific restoration measures where required. Ecosystem services linked to sustainable management, such as avoided soil erosion, improved water regulation, and biodiversity retention, will be valued using established methods such as avoided cost, replacement cost, or benefit transfer, with assumptions and limitations stated clearly to avoid over-interpretation.

6.2.5 Integration with Air Quality and Climate Co-Benefits

The CBA will include air quality and climate co-benefits associated with reduced fire emissions and improved biomass management. RS–GIS-based emission estimation will be used to approximate changes in pollutants and greenhouse gases, including $PM_{2.5}$ and CO_2, under alternative scenarios. Where credible coefficients are available, avoided emissions will be converted into monetary values using social cost parameters for carbon and accepted approaches for health-related exposure costs, with transparent sensitivity ranges. This will enable the combined benefit profile to reflect not only direct forest management outcomes, but also the wider implications for public health, agricultural productivity, and climate mitigation.

6.2.6 Outcome and Policy Implications

The final CBA outputs will present comparative results across scenarios with explicit reporting on sustainability outcomes, clarifying which intervention pathways yield the highest overall welfare gains without undermining forest resilience. The analysis will identify priority intervention types and enabling conditions, including how prevention-oriented financing, community-based biomass utilisation, and targeted early warning investments perform under different risk and accessibility contexts. The results will be summarised into decision-ready products that inform investment planning and policy direction, including an investment note and an implementation roadmap, and will highlight where carbon finance or results-based financing mechanisms could complement public funding without encouraging unsustainable extraction or perverse incentives. The overall intent is to use CBA as a structured decision tool that integrates economic returns, ecological thresholds, air quality improvements, and community welfare into one comparable framework for HKH forest biomass management.

6.3 Proposed Approach for Entrepreneurship and Business Model Development

The entrepreneurship and business model component will be designed to create self-sustaining community-based enterprises that link forest fire management, biomass utilisation, and livelihood enhancement under an integrated value-chain approach. The guiding principle is to transform fire-prone forest landscapes into bio-resource-based economic zones, where local communities, especially women and forest-dependent groups, become key stakeholders in prevention, utilisation, and monitoring processes.

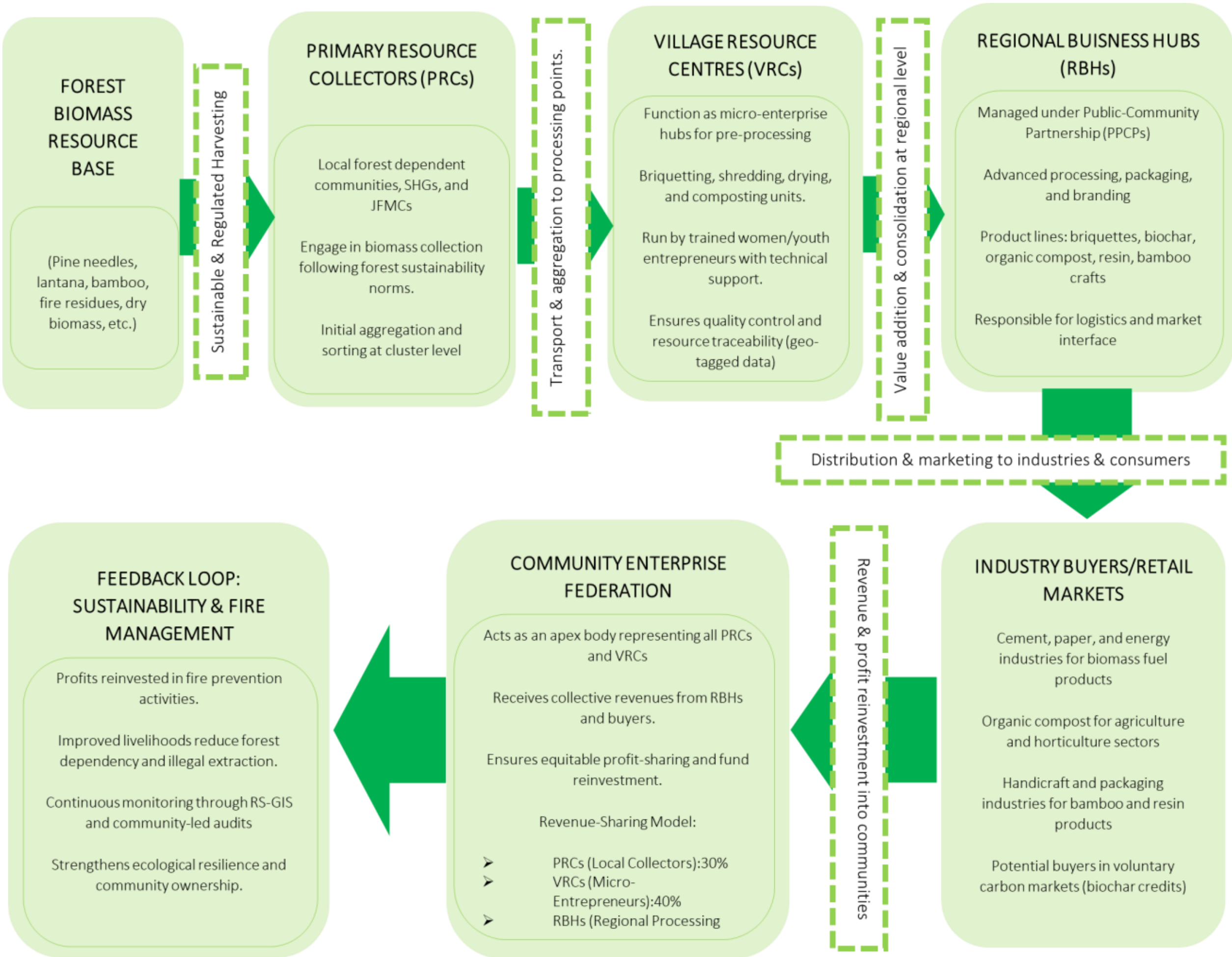


Figure 7 Supply Chain & Revenue-Sharing

6.3.1 Situation Assessment and Opportunity Mapping

The first stage will involve mapping existing community-based institutions, FPOs, JFMCs, eco-development committees, and self-help groups operating in the HKH region. Using RS-GIS-based fire hotspot data and biomass density maps, potential clusters with recurrent fire incidents and high biomass accumulation will be identified as entrepreneurial intervention zones. A livelihood and market assessment will evaluate available forest residues (pine needles, lantana, bamboo, dry biomass) and assess their potential for conversion into value-added products such as briquettes, pellets, compost, biochar, and resin-based materials. This stage establishes the business opportunity foundation, converting a fire hazard into a marketable bio-resource.

6.3.2 Business Model Design and Value Chain Integration

Based on the resource and market assessment, a circular bio-economy model will be designed. This model will connect biomass collection, value addition, and market linkages under a decentralized hub-and-spoke framework. Local community groups or cooperatives will act as Primary Resource Collectors (PRCs) responsible for aggregating forest residues using sustainable extraction norms. These PRCs will supply biomass to Village Resource Centres (VRCs), equipped with small-scale processing units (briquetting, pyrolysis, composting). Processed outputs will then move to Regional Business Hubs (RBHs) managed by public-private-community partnerships (PPCPs), which will ensure quality control, branding, and market facilitation. The revenue model will be built around a profit-sharing mechanism, ensuring at least 60-70% of the earnings return to community institutions, with the rest reinvested in fire prevention infrastructure, training, and capacity development.

6.3.3 Entrepreneurship Development and Capacity Building

This phase focuses on human capital development and enterprise incubation. A modular entrepreneurship training curriculum will be prepared covering business planning, financial literacy, product certification, marketing, and compliance with forest and environmental regulations. Special emphasis will be given to empowering women entrepreneurs and youth groups to manage processing units and engage in technology-driven monitoring (using drones or community GIS platforms). Partnerships with financial institutions, micro-credit agencies, and carbon finance investors will be explored to provide blended financing mechanisms, integrating community contributions, CSR investments, and carbon credit revenues from reduced fire emissions and avoided biomass burning.

6.3.4 Supply Chain Development and Market Linkages

A traceable supply chain will be proposed through digital monitoring and geo-tagging of resource flows. Each biomass collection site and processing unit will be mapped using GIS to maintain transparency and traceability. The study will explore market linkages with industries (cement, paper, energy) for biomass briquettes and with urban compost markets for organic fertilisers. Strategic partnerships will be sought with regional buyers and e-market platforms to establish a green value chain certification, ensuring sustainable sourcing and fair-trade compliance. The proposed business model will also incorporate a feedback loop where a portion of profits from biomass utilisation is reinvested into forest fire prevention measures, such as establishing fuel breaks, deploying community fire squads, and maintaining early warning systems.

6.3.5 Financial Modelling and Institutional Governance

The financial framework will use multi-tier cash flow modelling to evaluate economic viability at both community and enterprise levels. A Cost–Benefit Ratio (CBR) will be developed for each biomass value chain (briquettes, compost, resin, bamboo, etc.) incorporating capital investment, operating costs, and projected revenues. Institutional governance will be structured through a Community Enterprise Federation, linking local producers to district and regional business hubs. Each federation will operate under a tripartite governance model, Community–Private–Institutional (CPI), where ICIMOD or its partners act as technical anchors, private players as market facilitators, and communities as resource managers. This ensures transparency, scalability, and equitable benefit sharing.

6.3.6 Policy and Sustainability Integration

The proposed entrepreneurship model will be aligned with national forest policies, REDD+ frameworks, and SDG targets. Recommendations will be made for creating policy incentives such as green credits, tax exemptions for biomass-based products, and inclusion of community enterprises under green procurement schemes. A sustainability assurance mechanism will be embedded, ensuring that biomass extraction does not exceed regeneration thresholds. Periodic monitoring using RS-GIS data on canopy cover, fuel load, and regeneration will verify that the model remains ecologically balanced while generating socio-economic benefits.

6.3.7 Expected Outcomes: Community-Led Circular Bioeconomy for Fire-Resilient Landscapes

Implemented as designed, this entrepreneurship pathway is expected to convert recurrent fire risk into a structured, community-owned green value chain across HKH landscapes. It will operationalise RS–GIS-enabled identification of hotspot–biomass clusters and establish decentralised processing and market systems (PRCs-VRCs-RBHs) that create reliable local jobs, especially for women and youth, while improving traceability, quality control, and fair benefit sharing through federation-based governance. By diverting pine needles, lantana, bamboo and other dry residues away from open burning into products such as briquettes, biochar and compost, the model should reduce fuel loads, lower emissions, and generate a steady revenue stream that is partly reinvested into prevention infrastructure (fuel breaks, community fire squads, early warning upkeep). In parallel, the financial models and policy linkages are expected to deliver bankable enterprise cases and actionable incentive recommendations, resulting in a scalable, ecologically safe and socially inclusive template that can be replicated across Uttarakhand, Himachal Pradesh, J&K Ladakh-adjacent zones, Sikkim and the wider Himalayan-North Eastern arc.

6.4 Approach for Policy Gap Analysis

The policy gap analysis will apply a four-dimensional lens, governance and law, operations and technology, finance and incentives, and social and environmental safeguards, and will map this lens across the full forest fire management cycle, prevention, monitoring, suppression, and post-fire recovery. The evidence base will be drawn from statutory and regulatory instruments, institutional mandates, operational SOPs, and budgetary provisions relevant to each HKH country, so that both "rules on paper" and "rules in practice" are captured in the same analytical frame. To keep the analysis grounded in the actual risk geography, RS and GIS-derived layers on fire hotspots, recurrence, and exposure zones will be overlaid with the policy and institutional review outputs, allowing policy provisions to be interpreted against where fire burden concentrates and where smoke exposure is likely to be highest.

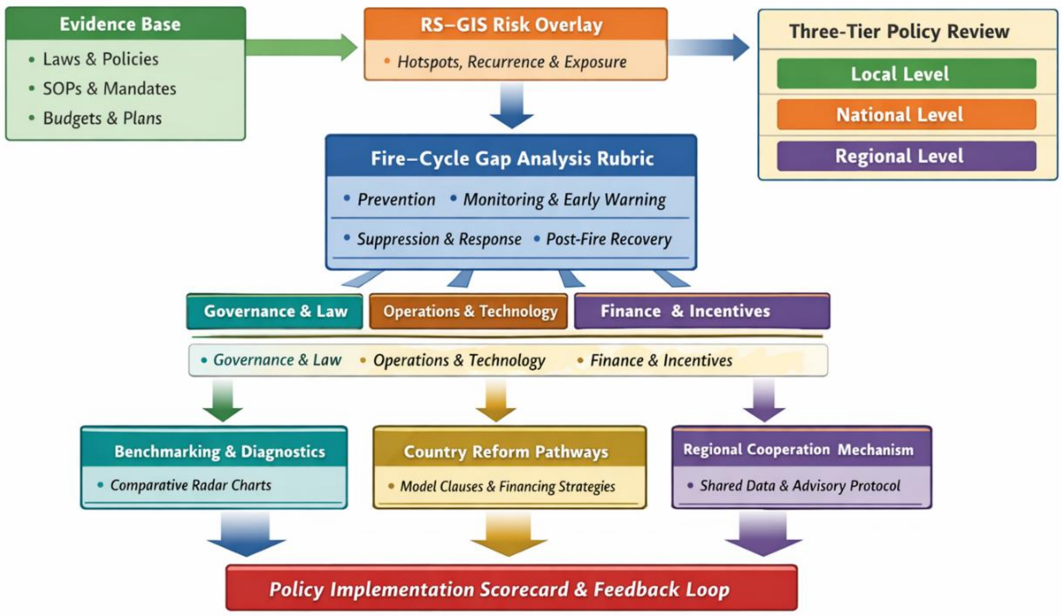


Figure 8 Policy-to-Implementation Pathway for Forest Fire Governance and Air Quality Coordination in the HKH

At the country level, the assessment will be organised across three governance tiers. At local level, the focus will be on community and district institutions and their functional roles in prevention, detection, and post-fire restoration, including how biomass removal and collection rights, benefit-sharing provisions, and local financing mechanisms shape the enabling environment for sustainable fuel-load utilisation. At national level, the review will cover forestry, environment, disaster management, and air quality policies and laws, with attention to coordination mechanisms, data-sharing provisions, and fiscal allocations that determine whether prevention and early action are supported or whether systems remain largely suppression-oriented. At regional level, the assessment will examine the presence and effectiveness of cross-border cooperation arrangements for shared monitoring, early warning, advisories, and coordinated response protocols, including the entry points that regional platforms can use to strengthen transboundary action on fire risk and smoke impacts.

Gap identification will then be undertaken through a structured rubric aligned to the fire-management cycle, so that gaps are not listed in isolation but tied to specific operational decision points. This includes identifying whether prevention is supported through legally permitted fuel management and incentives for community-based biomass utilisation, whether monitoring and early warning systems include agreed protocols for satellite detection, inter-agency data exchange, multilingual alerts, and linkage to air-quality advisories, whether suppression and response systems have defined inter-agency SOPs and incident coordination arrangements, and whether post-fire recovery is supported by restoration financing and recovery mechanisms (including carbon-accounting provisions where relevant). Each gap will be cross-referenced with the RS-GIS risk overlay so that institutional and legal shortcomings are explicitly connected to high-risk zones and recurrence clusters, and the outputs can be presented as country-specific policy gap sheets that clearly state the bottleneck and its operational implication.

Benchmarking will be carried out using a good-practice matrix adapted for the HKH context, comparing countries on practical criteria such as the preventive-to-suppression funding balance, the existence of multi-sensor monitoring and open data standards, inclusion of fire-emission metrics in air-quality and climate inventories, community participation mechanisms for prevention and early detection, legal provisions enabling biomass valorisation with sustainability controls, functional arrangements for regional cooperation, and adequacy of post-fire restoration and carbon recovery policies. Results will be synthesised using comparative policy radar charts to make cross-country contrasts legible for decision-makers.

Based on the identified gaps and benchmarking outcomes, targeted reform pathways will be drafted per country, including model clauses that recognise satellite-based fire alerts as official triggers for action and require real-time data sharing across forest, environment, and disaster management institutions, along with regulatory permissions, safety protocols, and benefit-sharing mechanisms for community fuel-load management. The reform package will also specify financing instruments such as prevention-oriented budget codes, eligibility pathways for community enterprises under green procurement or incentive schemes, and policy hooks that allow restoration and recovery options to be financed, including through carbon-related mechanisms where suitable.

At the regional scale, the cooperation component will be shaped as a light, functional "Regional Fire and Air Quality Cooperation Mechanism" with a shared dataset of indicators, agreed data latency and quality standards, and a defined protocol for transboundary advisory dissemination, anchored within existing institutions to avoid duplicating mandates. Finally, an evaluation layer will be proposed through a Policy Implementation Scorecard with measurable indicators across prevention, monitoring, response, and recovery, so progress can be tracked through periodic review and stakeholder feedback rather than remaining a one-time diagnostic.

6.5 Final recommendations & roadmap

The final recommendations and roadmap will be developed as an implementation-oriented package that translates the review findings, solution evaluation outputs, policy gap diagnostics, and cost benefit results into a sequenced set of actions that can be adopted by national and sub-national institutions across the HKH. The roadmap will begin by consolidating the intervention "menu" into a prioritised set of measures under prevention and fuel management, monitoring and early warning, suppression readiness, post-fire recovery, and smoke and air quality response, and will clearly identify which actions are feasible for immediate adoption using existing systems and which require policy, financing, or capacity changes. Recommendations will be framed to reflect country differences in governance and capability, while still retaining a common regional logic so that cross-country comparability and learning remain possible. Each recommendation will therefore be expressed with three elements, the operational intent, the enabling requirement in terms of policy or institutional responsibility, and the minimum data or monitoring requirement needed for tracking.

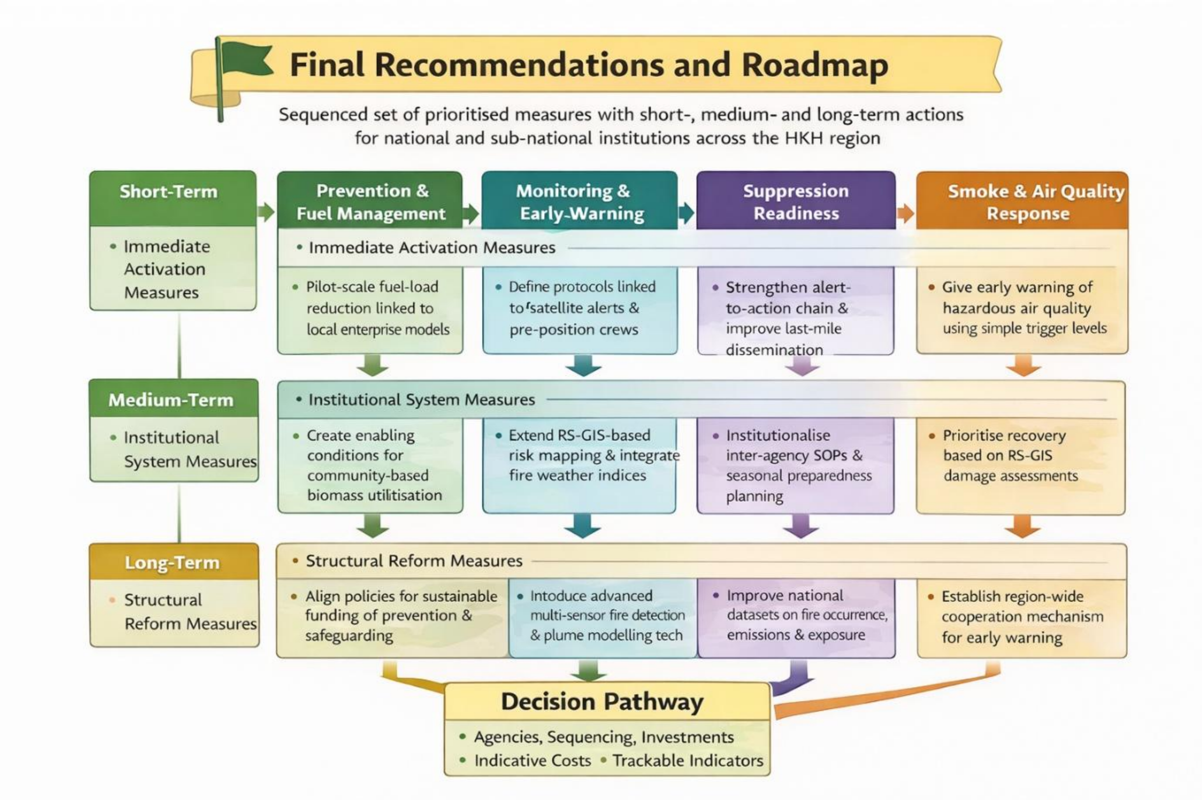


Figure 9 Roadmap for Final Recommendations and Phased Implementation in the HKH Region

Short-term priorities will focus on measures that can be activated quickly without major institutional restructuring. This includes strengthening the alert-to-action chain by defining response protocols linked to satellite alerts, improving last-mile dissemination to local authorities and communities through multilingual channels, and identifying priority districts and corridors for pre-positioning crews and equipment during peak fire periods. It will also include integrating fire monitoring outputs with air quality advisories through simple trigger thresholds, so public health messaging and protective actions are activated during smoke episodes. For prevention, the short-term roadmap will include pilot-scale fuel-load reduction measures in selected hotspots, aligned with local ecological context and safeguards, and linked to local enterprise models where biomass removal and utilisation are feasible. Where country systems already include community institutions, the roadmap will highlight steps for formal inclusion of these groups in preparedness planning, training, and reporting, so their role moves from informal response to structured prevention and early action.

Medium-term priorities will focus on institutionalising systems and scaling targeted interventions. This includes strengthening governance arrangements for inter-agency coordination across forestry, disaster management, and air quality institutions through formal SOPs, data-sharing agreements, and joint seasonal preparedness planning. It also includes expanding RS and GIS-based risk mapping into routinely updated decision layers that support budget allocation, deployment planning, and post-fire recovery prioritisation. On the technology side, the roadmap will include the adoption of fit-for-context early warning systems that integrate satellite detections with ground sensing, fire weather indices, and local reporting, alongside sustained capacity building so that these systems are used consistently across seasons. For biomass utilisation and entrepreneurship pathways, the medium-term plan will focus on creating enabling conditions, including safety and sustainability guidelines, permits and benefit-sharing provisions, and market linkages that allow community-led enterprises to operate without causing forest degradation or perverse incentives for burning.

Long-term priorities will address structural reforms and regional integration. This includes aligning national policies, so prevention and risk reduction receive stable budget allocations, improving the quality and interoperability of national datasets for fire occurrence, emissions, and exposure, and embedding forest fire and smoke risk into national and regional air quality management strategies. At the regional level, the roadmap will propose a cooperation mechanism for shared situational awareness and transboundary advisory dissemination, based on agreed indicator sets, data standards, and coordination protocols anchored in existing institutions. The long-term package will also include a forward pathway for adopting and localising global best technologies for early detection and warning, including multi-sensor satellite integration, automated smoke and plume tracking, and terrain-sensitive modelling where needed, supported by phased investments, regional training, and periodic joint simulation exercises. The final output will be structured as a decision pathway and investment note that identifies sequencing, responsible agencies, indicative costs, and measurable indicators for monitoring progress, ensuring that recommendations remain actionable and trackable rather than remaining as general guidance.

7. Detailed Workplan and Timeline

The assignment will be implemented during the contract period from 20 December 2025 to 20 March 2026, following a phased workplan sequenced across three principal deliverables. The sequencing starts with rapid mobilisation and inception reporting, followed by a structured country-wise review and assessment coupled with solutions identification, evaluation, and the cost–benefit analysis framework, and concludes with policy gap analysis, synthesis of findings, and final recommendations and roadmap. The workplan is designed so that early outputs establish common analytical templates and datasets, while later phases integrate evidence into decision-ready reports & spatial layers, including prioritised interventions and an investment-oriented pathway.

Table 3 Timeline and activity plan aligned to deliverables.

Period	Key activities	Output linkage
15-26 Dec 2025	Mobilisation and inception meeting, confirmation of reporting formats, finalisation of systematic review protocol, Stakeholder Mapping Matrix, rapid compilation of baseline literature and datasets, detailed workplan and timeline finalisation	Deliverable 1 (26 Dec 2025): Inception report detailing workplan and review plan on existing forest fire management practices, including forecasting, alerts, forest fire and forest biomass management across HKH
27 Dec 2025 - 20 Jan 2026	Country-wise evidence collection and structured review of existing forest fire management practices, monitoring, forecasting and alert systems, institutional arrangements, prevention and suppression practices, documentation of biomass or fuel-load management practices, preliminary RS–GIS compilation for fire occurrence and recurrence and exposure context, preparation of cross-country comparison templates	Inputs to Deliverable 2 (Task 1 foundation)
21 Jan - 07 Feb 2026	Consolidation of Review and Assessment outputs into a comparable analytical narrative, preparation of the Solutions and Evaluation framework and solution inventory aligned to technological, ecological, socio-economic, preventive and preparedness, policy and institutional, and post-fire rehabilitation domains, development of scoring criteria and evaluation rubric, finalisation of the CBA framework and scenario logic, conduct and documentation of the inception workshop	Inputs to Deliverable 2 (Tasks 1-3 + workshop report)
08 -13 Feb 2026	Final editing and submission, validation of internal consistency across country chapters, annexures on datasets and tools, workshop proceedings compilation	Deliverable 2 (13 Feb 2026): Consolidated report covering Task 1 (Review and Assessment), Task 2 (Solution and Evaluation), Task 3 (Cost–Benefit Analysis

Period	Key activities	Output linkage
		framework) + inception workshop report
14 Feb - 01 Mar 2026	Policy gap analysis and benchmarking against practices relevant to prevention, monitoring, suppression, and post-fire recovery, identification of coordination and financing gaps, drafting of country-specific reform pathways and regional cooperation options, integration of evaluation outputs with policy findings, preparation of prioritised short-, medium-, and long-term recommendations	Inputs to Deliverable 3 (Tasks 4-5 and synthesis)
02 - 06 Mar 2026	Final synthesis and packaging, roadmap and decision pathway, final presentation preparation, submission of final report	Deliverable 3 (06 Mar 2026): Comprehensive report on Task 4-5 and final report submission with presentation
07 - 20 Mar 2026	Incorporation of ICIMOD comments if received post-submission, dissemination support and handover of final datasets and figures, closure documentation and administrative wrap-up	Contract completion

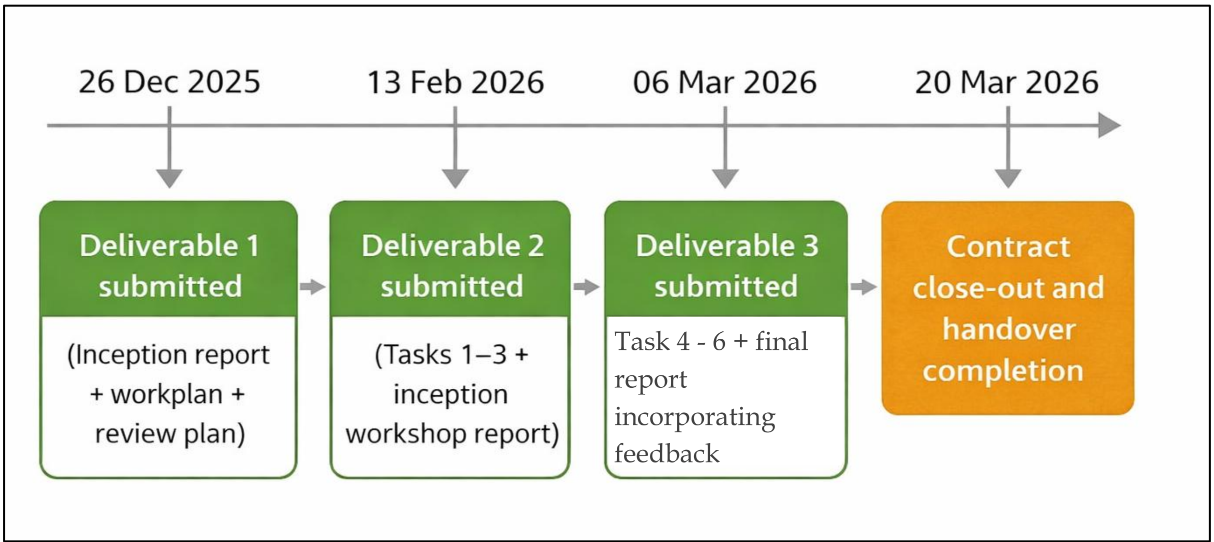


Figure 10 Project Milestone

8. Expected Outputs and Deliverables

8.1 Expected outputs

The inception phase will generate a set of outputs that establish a common evidence base across the HKH countries and provide clear direction for the subsequent analytical workstreams. These outputs include a consolidated account of existing forest fire management practices, including prevention, preparedness, suppression, and post-fire recovery arrangements, and an assessment of how forest biomass and fuel-load management is currently addressed within risk reduction approaches. The inception outputs will also include a structured assessment of fire monitoring, forecasting, and alert dissemination systems, focusing on how satellite and meteorological information is translated into operational decision-making and last-mile communication. In addition, the inception phase will produce an initial synthesis of the linkages between forest fires and air quality impacts, including transboundary smoke transport considerations, and will document the stakeholder and institutional landscape to clarify mandates, coordination pathways, and opportunities for collaboration. Collectively, these outputs will serve as the foundation for identifying and prioritising solutions, applying evaluation frameworks, and developing an implementation roadmap aligned to national and regional air quality management strategies.

8.2 Deliverables and submission schedule

8.2.1 Deliverable 1

This deliverable will provide the inception report setting out the agreed workplan, sequencing, and methodological framework for the assignment. It will include the systematic review approach, the country-wise review and assessment framework for Afghanistan, Bangladesh, Bhutan, China (HKH-relevant regions), India, Myanmar, Nepal, and Pakistan, and the initial review of existing forest fire management practices across the HKH, including forecasting, alert dissemination, and forest biomass and fuel-load management practices. It will also specify the data sources, analytical tools, and stakeholder engagement plan to be used during implementation.

8.2.2 Deliverable 2

This deliverable will present the complete outputs for Task 1, Task 2, and Task 3 as outlined in the TOR. It will include the consolidated review and assessment findings, including cross-cutting observations and country-wise summaries on prevention, preparedness, monitoring, suppression, and post-fire recovery. It will also include the categorised inventory of solutions for forest fire management and forest biomass management, the evaluation framework and scoring approach for prioritising interventions, and the cost-benefit analysis framework including scenarios, valuation approach, and integration of forest sustainability considerations and air quality and climate co-benefits. The deliverable will include an inception workshop report summarising participant engagement, key discussion points, and validated priorities and refinements to the analytical approach.

8.2.3 Deliverable 3

This deliverable will provide the consolidated final outputs for Task 4, Task 5, and Task 6, in line with the service contract deliverable structure. It will include the policy gap analysis and benchmarking (Task 4), the cost benefit analysis of forest biomass utilisation and management incorporating forest sustainability considerations (Task 5), and the final recommendations and roadmap, including prioritisation of interventions for short, medium, and long term implementation and the integration pathway into national and regional air quality management strategies (Task 6). The deliverable will also include an investment note and decision pathway describing priority interventions, enabling requirements, institutional roles, and monitoring indicators, along with a final presentation to support dissemination and discussion with ICIMOD and relevant stakeholders.

8.2.4 Contract completion

Following submission of Deliverable 3, the remaining contract period will be used to incorporate any formal comments from ICIMOD, complete dissemination support as requested, and hand over supporting materials developed during the assignment, including matrices, frameworks, figures, and reference datasets used for analysis, in agreed formats.

9. Risks, Assumptions, and Limitations

9.1 Key risks and mitigation measures

A primary delivery risk relates to uneven availability and accessibility of country-specific documents, operational SOPs, and datasets across the HKH, which may constrain the depth of comparable assessment in some contexts. This will be managed through early identification of minimum essential documents and data needs during the inception period, triangulation using regional and global datasets where national datasets are not accessible, and structured validation through stakeholder consultations to confirm operational realities. A second risk concerns scheduling and coordination across multiple institutions and countries within a short contract period, particularly for securing timely inputs from government agencies and technical partners. This will be managed through a stakeholder engagement calendar agreed early with ICIMOD, use of a standard consultation guide and documentation template, and prioritisation of key informants linked to monitoring systems, forest operations, and air quality response functions.

A further risk is that field consultations and travel may be affected by administrative approvals, weather, or logistic constraints, particularly in high-elevation or remote areas. This will be managed by keeping consultations modular, combining physical visits with virtual consultations where needed, and maintaining a clear upper-cap travel plan where actual costs are incurred only on an actual-cost basis within approved ceilings. There is also a technical risk that satellite-based fire alerts and emissions products may not fully represent small fires, understory burning, or terrain-induced detection gaps, and that uncertainties in biomass availability and emissions factors may influence downstream evaluation results. This will be managed by explicitly documenting data limitations, using multi-source comparisons, applying conservative assumptions in quantification, and using sensitivity analysis to show how results change under alternative parameter values.

9.2 Assumptions

The workplan assumes that timely access will be available to core reference materials and datasets needed for regional synthesis, including national strategies and guidelines where public, and commonly used global datasets for fire occurrence, emissions, and atmospheric indicators. It is assumed that key national and regional stakeholders will be available for targeted consultations within the contract period and that institutional focal points can support identification of relevant documents, operational protocols, and priority issues. For the cost–benefit analysis and solution evaluation, it is assumed that indicative cost and market information for biomass products and fuel substitution can be obtained from secondary sources and validated through expert consultations, and that relative comparisons across scenarios can be developed even where precise monetisation is not possible for all ecosystem service components.

9.3 Limitations

Data availability and accessibility are expected to vary across HKH countries and may constrain the depth of comparable assessment in specific contexts. In Afghanistan, constraints related to limited availability of recent operational documentation, sparse ground monitoring networks in remote areas, and restricted access to field-level information may require greater reliance on secondary sources and RS-GIS-based evidence and may limit the granularity of country-level conclusions. In China's HKH-relevant regions, access hurdles linked to language, institutional access pathways, and limited availability of certain operational datasets and documents in the public domain may similarly constrain detail in parts of the assessment, increasing reliance on peer-reviewed literature and RS-GIS products for interpreting patterns of fire occurrence, seasonality, and exposure. These limitations will be addressed through transparent documentation of evidence sources, explicit statements of uncertainty, and use of a consistent cross-country template that distinguishes between confirmed institutional practice and inferred patterns derived from secondary evidence and RS-GIS analysis.

10. Conclusion and Way Forward

The inception phase has established the foundation for the consultancy by confirming the study scope and geographic coverage, finalising the methodological framework, compiling the initial evidence base on existing forest fire management practices across the HKH, and setting up common templates and datasets for a consistent country-wise review. This phase has also clarified the linkage pathway between forest fire occurrence, fuel-load dynamics, and air quality impacts, including the relevance of transboundary smoke transport, and has mapped the stakeholder and institutional landscape that will shape coordination and implementation feasibility in subsequent work.

The next stage will complete the structured country-wise review and assessment, consolidating findings on prevention, preparedness, monitoring and early warning, suppression arrangements, and post-fire recovery, and documenting how forest biomass and fuel-load management is currently incorporated within risk reduction systems across Afghanistan, Bangladesh, Bhutan, China (HKH-relevant regions), India, Myanmar, Nepal, and Pakistan. In parallel, the solutions component will be developed into a categorised inventory of interventions spanning technological, ecological, socio-economic, preventive and preparedness, post-fire rehabilitation, and policy and institutional domains, supported by a scoring rubric to compare practicality and trade-offs across contexts. At the same time, the cost–benefit analysis will be operationalised by confirming baseline and intervention scenarios, data inputs, valuation assumptions, and sustainability constraints, and by defining how air quality and climate co-benefits will be reflected within comparative appraisal outputs. Following consolidation of the review, solutions evaluation, and cost–benefit framework outputs, the work will move into policy gap analysis and benchmarking to identify the most consequential barriers to implementation and the reforms needed at local, national, and regional levels. These findings will then be integrated with solution rankings and economic appraisal outputs to produce prioritised recommendations for short-, medium-, and long-term action, supported by a roadmap that specifies sequencing, responsible institutions, enabling requirements, and monitoring indicators. The assignment will close with submission of the final report and presentation and completion of handover of key matrices, figures, and reference datasets used in the assessment, enabling ICIMOD and national partners to translate the outputs into follow-on planning and implementation.

References

1. Alvarado, M. J., et al. (2018). Sources of black carbon deposition to the Himalayan glaciers in current and future climates. *Journal of Geophysical Research: Atmospheres, 123*(14), 7482–7505. https://doi.org/10.1029/2018JD029049
2. Banerjee, P., Kumari, S., & Roy, A. (2021). MODIS-FIRMS and ground-truthing based wildfire likelihood mapping of Sikkim Himalaya, India. *Natural Hazards*. https://doi.org/10.1007/s11069-021-04973-6
3. Bar, S., Parida, B. R., Pandey, A. C., & Kumar, N. (2022). Pixel-based long-term (2001–2020) estimations of forest fire emissions over the Himalaya. *Remote Sensing, 14*(21), 5302. https://doi.org/10.3390/rs14215302
4. Bessagnet, B., et al. (2025). High resolution air quality simulation in the Himalayan valleys: A case study in Bhutan. *EGUsphere* (preprint). https://doi.org/10.5194/egusphere-2025-3641
5. Bhattarai, N., Dahal, S., Thapa, S., Pradhananga, S., Karky, B. S., Rawat, R. S., & Avtar, R. (2022). Forest fire in the Hindu Kush Himalayas: A major challenge for climate action. *Journal of Forest and Livelihood, 21*(1), 14–31. https://www.nepjol.info/index.php/JFL/article/view/56576
6. Bonasoni, P., et al. (2010). Atmospheric Brown Clouds in the Himalayas: First two years of continuous observations at the Nepal Climate Observatory–Pyramid. *Atmospheric Chemistry and Physics, 10*, 7515–7531. https://doi.org/10.5194/acp-10-7515-2010
7. California Air Resources Board, & California Department of Public Health. (2021). *Wildfire smoke: A guide for public health officials* (hosted by AirNow). https://www.airnow.gov/publications/wildfire-smoke-guide/wildfire-smoke-a-guide-for-public-health-officials/
8. Copernicus Atmosphere Monitoring Service. (2025). *CAMS tracks intense global wildfire activity in first six months of 2025*. https://www.copernicus.eu/en/news/news/observer-cams-tracks-intense-global-wildfire-activity-first-six-months-2025
9. Department of Meteorology and Hydrology, Government of the Union of Myanmar. (2009). *Hazard profile of Myanmar*. PreventionWeb. https://www.preventionweb.net/files/14567_14567HazardReport25.8.091.pdf
10. European Centre for Medium-Range Weather Forecasts (ECMWF). (n.d.). *CAMS global biomass burning emissions based on fire radiative power (GFAS) v1.2: Data documentation* (Copernicus Knowledge Base). https://confluence.ecmwf.int/x/to1CBQ
11. Food and Agriculture Organization of the United Nations. (2001). *Global forest fire assessment 1990–2000* (Forest Resources Assessment Working Paper 55). https://www.fao.org/4/ad653e/ad653e00.htm
12. Food and Agriculture Organization of the United Nations. (2006). *Fire management voluntary guidelines: Principles and strategic actions* (Fire Management Working Paper 17/E). FAO. https://www.fao.org/3/j9255e/j9255e00.pdf
13. Food and Agriculture Organization of the United Nations. (2021). *Fire management: Voluntary guidelines*. FAO Forestry Paper. https://www.fao.org/3/i9519en/i9519en.pdf
14. Food and Agriculture Organization of the United Nations. (n.d.). *FAO-GEF Afghanistan project: Forest and landscape restoration in Asia, Afghanistan*. https://www.fao.org/in-

action/forest-landscape-restoration-asia/country-profiles/afghanistan/afg-gef-project/1/en

15. Food and Agriculture Organization of the United Nations, & United Nations Environment Programme. (1981). *Tropical forest resources assessment project: Forest resources of Tropical Asia* (section on shifting cultivation in South Asia). https://www.fao.org/4/ad908e/AD908E06.htm
16. Forest Department, Government of the Union of Myanmar. (1995). *Forest Rules (1995).* https://www.forestdepartment.gov.mm/sites/default/files/Law/Forest_Rules_1995_Englsih.pdf
17. Forest Survey of India. (2023). *Forest fire alert system and vulnerability assessment*. Ministry of Environment, Forest and Climate Change, Government of India. https://fsi.nic.in/forest-fire
18. Fulé, P. Z., Chhetri, S., Ghimire, B., & others. (2021). Frequent burning during pre-monsoon drought in a chir pine (*Pinus roxburghii*) forest, Uttarakhand, India. *Fire Ecology, 17*, 1–15. https://doi.org/10.1186/s42408-021-00106-3
19. Giglio, L., Boschetti, L., Roy, D. P., Humber, M. L., & Justice, C. O. (2018). The Collection 6 MODIS burned area mapping algorithm and product. *Remote Sensing of Environment, 217*, 72–85. https://doi.org/10.1016/j.rse.2018.08.005
20. Global Environment Facility. (n.d.). *Community-based sustainable land and forest management in Afghanistan* (GEF Project ID 9285). https://www.thegef.org/projects-operations/projects/9285
21. Government of Nepal. (2021). *National Adaptation Plan (NAP) 2021–2050*. https://doenv.gov.np/rules/NAP-2021-2050-1700841577.pdf
22. Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science, 342*(6160), 850–853. https://doi.org/10.1126/science.1244693
23. International Centre for Integrated Mountain Development. (2013). *Poverty and vulnerability in the river basins: A survey instrument for the Hindu Kush Himalayas (PVA-14).* https://lib.icimod.org/records/zya8h-x3304/files/PVA-14.pdf
24. International Centre for Integrated Mountain Development. (2021). *HKH2Glasgow: An urgent call for climate action for the Hindu Kush Himalaya.* https://lib.icimod.org/record/35503/files/HimalDoc2021_CollectiveHKH2Glasgow.pdf
25. International Centre for Integrated Mountain Development. (n.d.). *The Hindu Kush Himalaya.* https://www.icimod.org/who-we-are/the-hindu-kush-himalaya/
26. International Work Group for Indigenous Affairs. (2015). *Shifting cultivation in Myanmar: Case studies from Southern Chin State and Bago Division.* https://iwgia.org/en/documents-and-publications/documents/publications-pdfs/english-publications/335-point-iwgia-nicfi-book-shifting-cultivation-in-myanmar-2015-eng/file.html
27. Joshi, S. R., Rasul, G., & Shrestha, A. J. (2016). *Pro-poor and climate resilient value chain development: Operational guidelines for the Hindu Kush Himalayas* (ICIMOD Working Paper 2016/1). International Centre for Integrated Mountain Development. https://lib.icimod.org/record/32014/files/icimodWP16_1.pdf
28. Kanga, S., Rather, M. A., Farooq, M., & Singh, S. K. (2021). GIS based forest fire vulnerability assessment and its validation using field and MODIS data: A case study

of Bhaderwah Forest Division, Jammu and Kashmir (India). *The Indian Forester*. https://doi.org/10.36808/if/2021/v147i2/153779

29. Khadgi, J., Kafle, K., Thapa, G., Khaitu, S., Sarangi, C., Cohen, D., & Kafle, H. (2024). Concentration of particulate matter and atmospheric pollutants in the residential area of Kathmandu Valley: A case study of March–April 2021 forest fire events. *Environmental Pollution, 349*, 125280. https://doi.org/10.1016/j.envpol.2024.125280
30. Khanal, S. (2015). Wildfire trends in Nepal based on MODIS burnt-area data. *Banko Janakari, 25*(1), 76–79. https://doi.org/10.3126/banko.v25i1.13477
31. Kumar, R., Pippal, P. S., Kumar, R., et al. (2025). Forest fire consequences under the influence of changing climate: A systematic review with bibliometric analysis in the context of sustainable development goals. *Discover Sustainability, 6*, 541. https://doi.org/10.1007/s43621-025-00801-0
32. Kumari, A., Prakash, N., Reddy, C. S., et al. (2025). Hotspot and trend analysis of forest fires and its relation to climatic factors in the western Himalayas. *International Journal of Wildland Fire*. https://doi.org/10.1071/WF23163
33. Lee, H.-H., Iraqui, O., Gu, Y., Yim, S. H.-L., Chulakadabba, A., Tonks, A. Y.-M., Yang, Z., & Wang, C. (2018). Impacts of air pollutants from fire and non-fire emissions on the regional air quality in Southeast Asia. *Atmospheric Chemistry and Physics, 18*, 6141–6156. https://doi.org/10.5194/acp-18-6141-2018
34. Li, C., et al. (2016). Sources of black carbon to the Himalayan–Tibetan Plateau glaciers. *Nature Communications, 7*, 12574. https://doi.org/10.1038/ncomms12574
35. Mahapatra, P. S., & Dhital, N. B. (2025). Forest fire-induced air pollution events in the Himalayan region: Urgent need for regional collaboration and action. *BMC Environmental Science, 2*, Article 13. https://doi.org/10.1186/s44329-025-00027-5
36. Malik, F. A., Mushtaq, F., Farooq, M., et al. (2025). Assessing forest fire vulnerability with fuzzy-AHP: Insights from Poonch forest division, Jammu and Kashmir. *Discover Forests, 1*, 4. https://doi.org/10.1007/s44415-025-00004-5
37. Marvin, M. R., Palmer, P. I., Yao, F., Latif, M. T., & Khan, M. F. (2024). Uncertainties from biomass burning aerosols in air quality models obscure public health impacts in Southeast Asia. *Atmospheric Chemistry and Physics, 24*, 3699–3715. https://doi.org/10.5194/acp-24-3699-2024
38. Ministry of Energy and Natural Resources, Royal Government of Bhutan. (2023). *Forest and Nature Conservation Rules and Regulations, 2023*. https://www.moenr.gov.bt/wp-content/uploads/2017/07/FNCRR-2023.pdf
39. Ministry of Environment, Forest and Climate Change, Government of India. (2018a). *National action plan on forest fire.* https://www.moef.gov.in/uploads/pdf-uploads/pdf_68a4157b8b3d38.38401489.pdf
40. Ministry of Environment, Forest and Climate Change, Government of India, & World Bank. (2018b). *Strengthening forest fire management in India.* World Bank. https://hdl.handle.net/10986/30013
41. Ministry of Forests and Environment, Government of Nepal. (2020). *National forest fire management strategy.* Government of Nepal.
42. Muhammad, S., Nizami, S. M., Jiang, Q., et al. (2025). Machine learning-based forest fire vulnerability assessment in subtropical chir pine forests of Pakistan. *Fire Ecology, 21*, 72. https://doi.org/10.1186/s42408-025-00408-w

43. Murmu, M., Roy, A., Karnatak, H. C., & Chauhan, P. (2022). Impact of forest fire emissions on air quality over the Western Himalaya region. *ISPRS Archives, XLIII-B3*, 1153–1158. https://doi.org/10.5194/isprs-archives-XLIII-B3-2022-1153-2022
44. NASA Earthdata. (n.d.). *FIRMS: Fire Information for Resource Management System.* Retrieved December 22, 2025, from https://www.earthdata.nasa.gov/data/tools/firms
45. National Disaster Management Authority. (2025a). *Forest fires in Pakistan: A threat to nature* (guidelines document). https://www.ndma.gov.pk/storage/guidelines/April2025/fMOckP4LDDZSorahUhY3.pdf
46. National Disaster Management Authority. (2025b). *Forest fire advisory and preparedness measures* (Advisory dated 28 January 2025). https://ndma.gov.pk/storage/advisories/January2025/8SD9Hxc0SZL3yvRzDLeI.pdf
47. National Environmental Protection Agency. (2019). *Afghanistan's 6th national report to the United Nations Convention on Biological Diversity.* https://www.cbd.int/doc/nr/nr-06/af-nr-06-en.pdf
48. Naseem, M. A., & Nurrochmat, N. A. (2024). Assessment of forest fire vulnerability in chir pine forest of Pallandri, Azad Jammu and Kashmir (AJK) Pakistan. *Global Forests.* https://doi.org/10.54219/globalforests.03.01.2024.223
49. Parajuli, A., Gautam, A. P., Sharma, S., Lamichhane, P., Sharma, G., Bist, B. S., & Aryal, U. (2022). A strategy for involving community forest managers in effective forest fire management in Nepal. *Banko Janakari, 32*(1), 41–51. https://doi.org/10.3126/banko.v32i1.45476
50. Peng, W., Wei, Y., Chen, G., Lu, G., Ye, Q., Ding, R., Hu, P., & Cheng, Z. (2023). Analysis of wildfire danger level using logistic regression model in Sichuan Province, China. *Forests, 14*(12), 2352. https://doi.org/10.3390/f14122352
51. Poudel, K., & Basnet, R. (2024). Analyzing the relationship between temperature, precipitation and burned area: A case study from Churia–Siwalik, Nepal. *Forestry: Journal of Institute of Forestry, Nepal, 21*(1). https://doi.org/10.3126/forestry.v21i1.79729
52. Rafaqat, W., Iqbal, M., Kanwal, R., & Weiguo, S. (2022). Evaluation of wildfire occurrences in Pakistan with global gridded soil properties derived from remotely sensed data. *Remote Sensing, 14*(21), 5503. https://doi.org/10.3390/rs14215503
53. Randerson, J. T., van der Werf, G. R., Giglio, L., Collatz, G. J., & Kasibhatla, P. S. (2017). *Global Fire Emissions Database, Version 4.1 (GFEDv4.1)* (ORNL DAAC Dataset). ORNL Distributed Active Archive Center. https://doi.org/10.3334/ORNLDAAC/1293
54. Republic of the Union of Myanmar. (2013). *Natural Disaster Management Law (Pyidaungsu Hluttaw Law No. 21/2013).* Myanmar Information Management Unit (MIMU). https://www.themimu.info/sites/themimu.info/files/documents/Ref_Doc_Natural_Disaster_Management_Law_31Jul2013.pdf
55. Saha, S., Rahman, M. M., & Talukdar, S. (2024). Spatiotemporal variations in forest fire incidence and its relation with land surface characteristics in the Hindu Kush Himalaya (HKH). *Remote Sensing Applications: Society and Environment, 33*, 101217. https://www.sciencedirect.com/science/article/pii/S2352938524000480
56. Shrestha, K. L., Gyawali, A., Gyawali, S., Joshi, P., & Sharma, S. (2025). Modeling the impact of wildfire on air quality in Nepal using WRF-Chem and Sentinel-5P. *Environmental Pollution, 382*, 126545. https://doi.org/10.1016/j.envpol.2025.126545

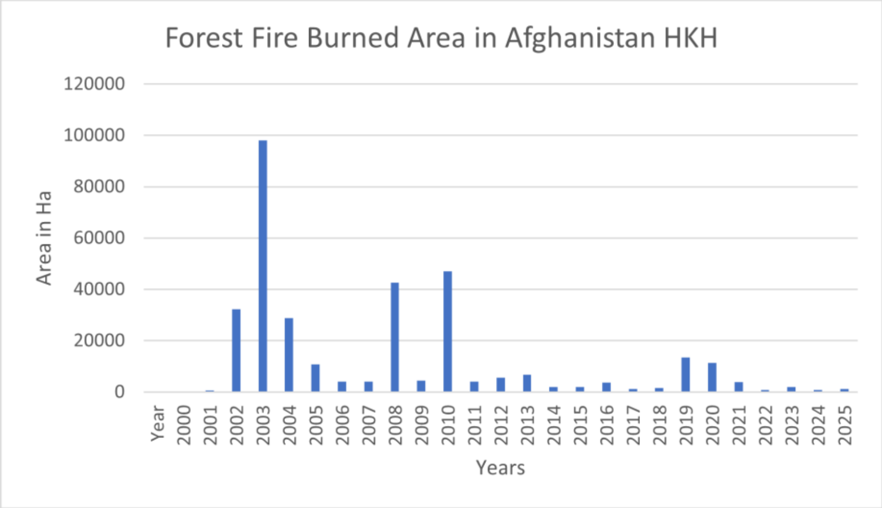
57. Shrestha, M., Bohara, M., Poudel, N. S., Karki, R., & Karna, B. (2025). *Strengthening forest fire management in Nepal* (Policy Brief No. 52). ForestAction. https://forestaction.org/wp-content/uploads/2025/06/Policy-Brief-52_Strengthening-Forest-Fire-Management-in-Nepal.pdf
58. Singh, R. D., Gumber, S., Sundriyal, R. C., Ram, J., & Singh, S. P. (2024). Chir pine forest and pre-monsoon drought determine spatial and temporal patterns of forest fires in Uttarakhand Himalaya. *Tropical Ecology, 65*(1), 32–42. https://doi.org/10.1007/s42965-023-00306-9
59. State Council of the People's Republic of China. (2025, November 21). China unveils regulation on forest, grassland fire management. https://english.www.gov.cn/policies/latestreleases/202511/21/content_WS6920398ac6d00ca5f9a07b8c.html
60. The New Indian Express. (2024, October 22). Uttarakhand to set up seven pine needle briquette units to prevent forest fires. https://www.newindianexpress.com/nation/2024/Oct/22/uttarakhand-to-set-up-seven-pine-needle-briquette-units-to-prevent-forest-fires
61. TOLOnews. (2024, November). Forest fire continues in Nuristan for tenth day, officials. https://tolonews.com/index.php/afghanistan-178275
62. United Nations Framework Convention on Climate Change. (2006). *Bhutan: NAPA project profile, promote community-based forest fire management and prevention.* https://unfccc.int/files/adaptation/napas/application/pdf/03_bhut_pp.pdf
63. United Nations Environment Programme. (2022). *Afghanistan: Building environmental resilience and sustainability in Afghanistan, 2002–2022.* https://wedocs.unep.org/handle/20.500.11822/40536
64. Vadrevu, K. P., Lasko, K., Giglio, L., Schroeder, W., Biswas, S., & Justice, C. O. (2019). Trends in vegetation fires in South and Southeast Asian countries. *Scientific Reports, 9*, 7422. https://doi.org/10.1038/s41598-019-43940-x
65. Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (Eds.). (2019). *The Hindu Kush Himalaya assessment.* Springer Nature. https://link.springer.com/book/10.1007/978-3-319-92288-1
66. World Bank. (2021). *Managing wildfire risks in a changing climate.* World Bank Group. https://openknowledge.worldbank.org/handle/10986/35252
67. Yang, Q., Zhao, T., Tian, Z., Kumar, K. R., Chang, J., Hu, W., Shu, Z., & Hu, J. (2022). The cross-border transport of $PM_{2.5}$ from the Southeast Asian biomass burning emissions and its impact on air pollution in Yunnan Plateau, Southwest China. *Remote Sensing, 14*(8), 1886. https://doi.org/10.3390/rs14081886
68. Yarragunta, Y., Satendra, et al. (2025). Assessing the impact of forest fires on air quality in Northeast India: Analysis of satellite observations and WRF-Chem simulations. *Environmental Science: Atmospheres.* https://doi.org/10.1039/D4EA00107A
69. Ying, L., Cheng, H., Shen, Z., Guan, P., Luo, C., & Peng, X. (2021). Relative humidity and agricultural activities dominate wildfire ignitions in Yunnan, Southwest China: Patterns, thresholds, and implications. *Agricultural and Forest Meteorology, 307*, 108540. https://doi.org/10.1016/j.agrformet.2021.108540
70. You, Q., et al. (2017). Projected changes in mean and extreme climates over the Hindu Kush Himalayan region by 21 CMIP5 models. *Advances in Climate Change Research, 8*(3), 176–184. https://doi.org/10.1016/j.accre.2017.03.001

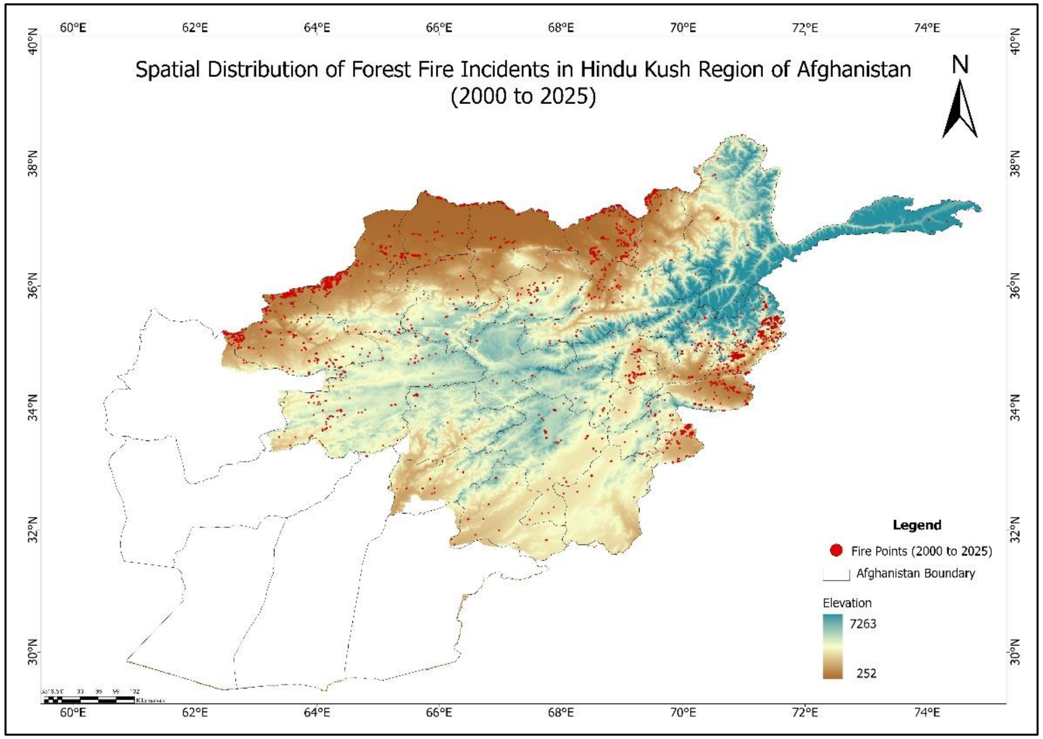
71. Zhou, Q., et al. (2025). Predictive assessment of forest fire risk in the Hindu Kush Himalaya (HKH) region using HIWAT data integration. *Remote Sensing, 17*(13), 2255. https://doi.org/10.3390/rs17132255

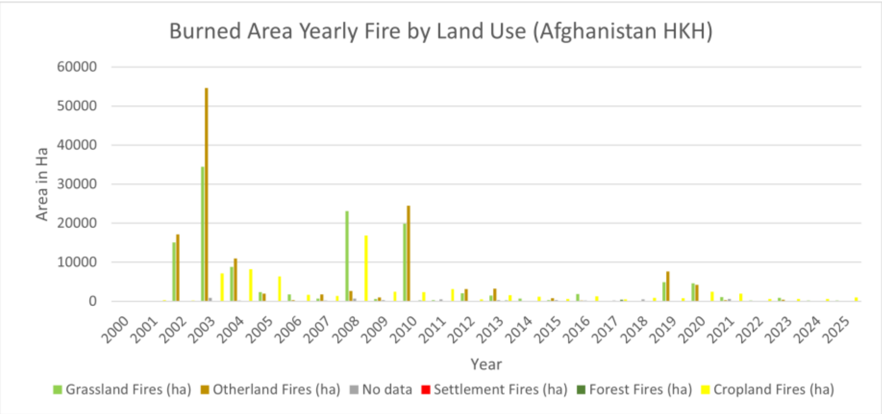
Annexures

Annexure A: Country-wise Fire Occurrence Scenario

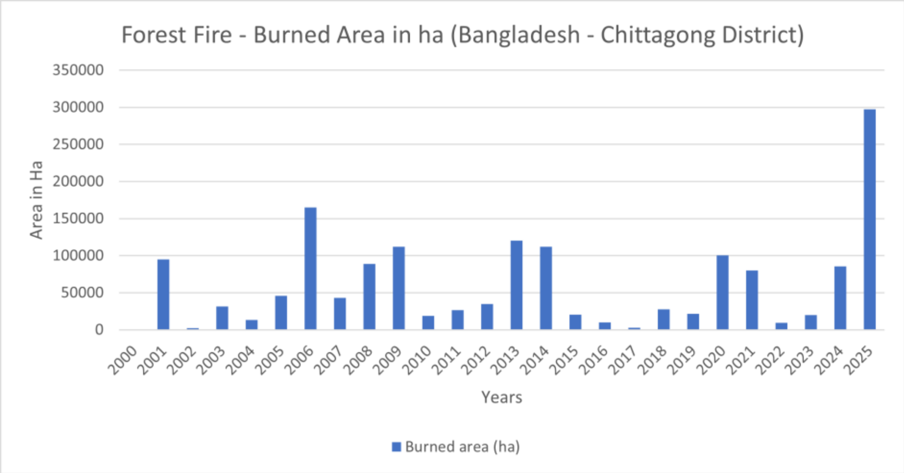
Afghanistan

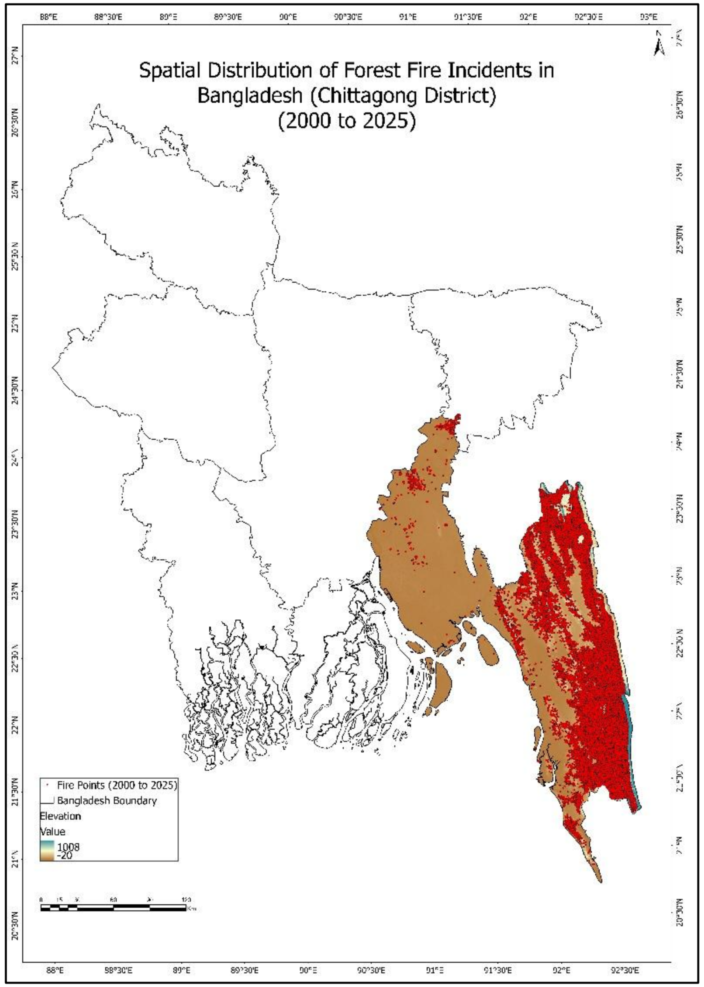


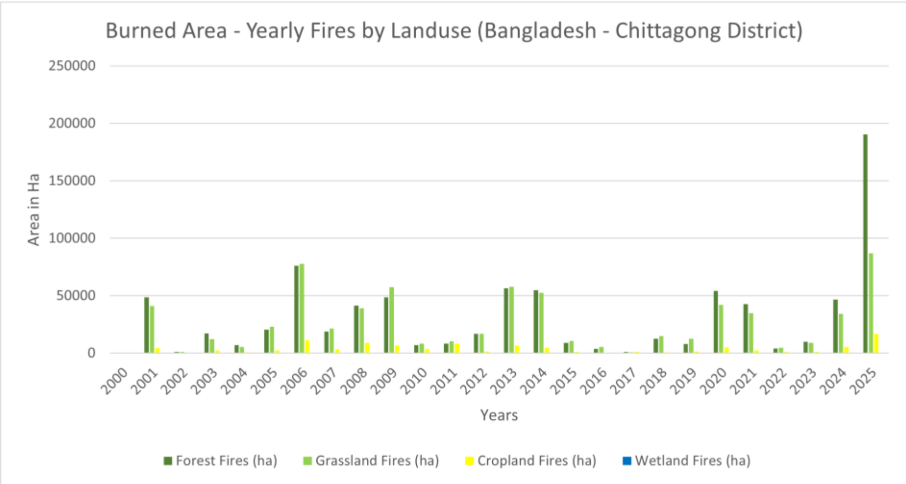




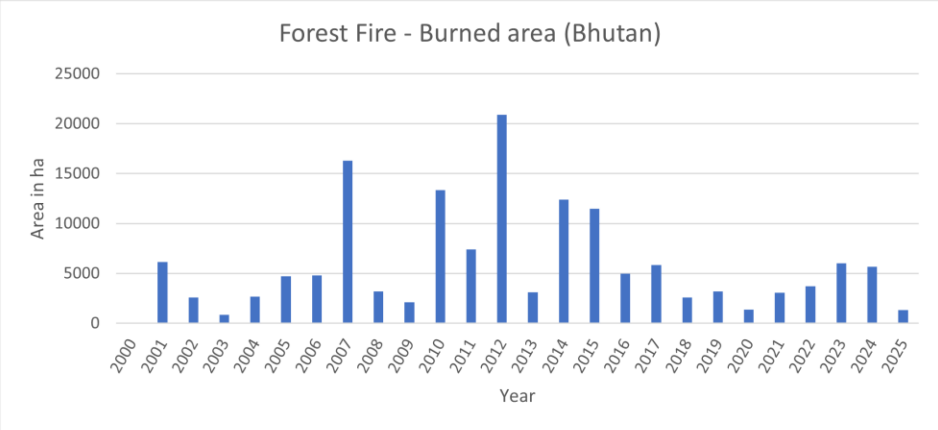
Bangladesh

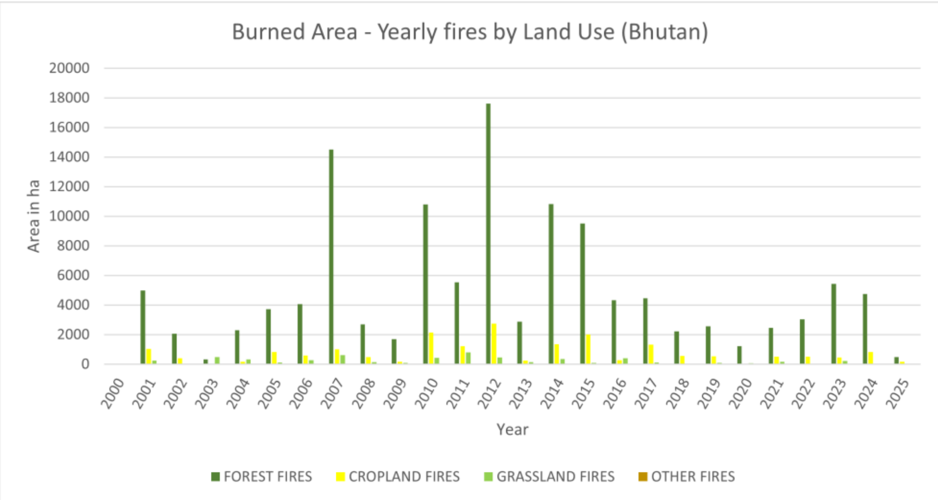

Forest Fire - Burned Area in ha (Bangladesh - Chittagong District)
Area in Ha
350000
300000
250000
200000
150000
100000
50000
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Years
Burned area (ha)

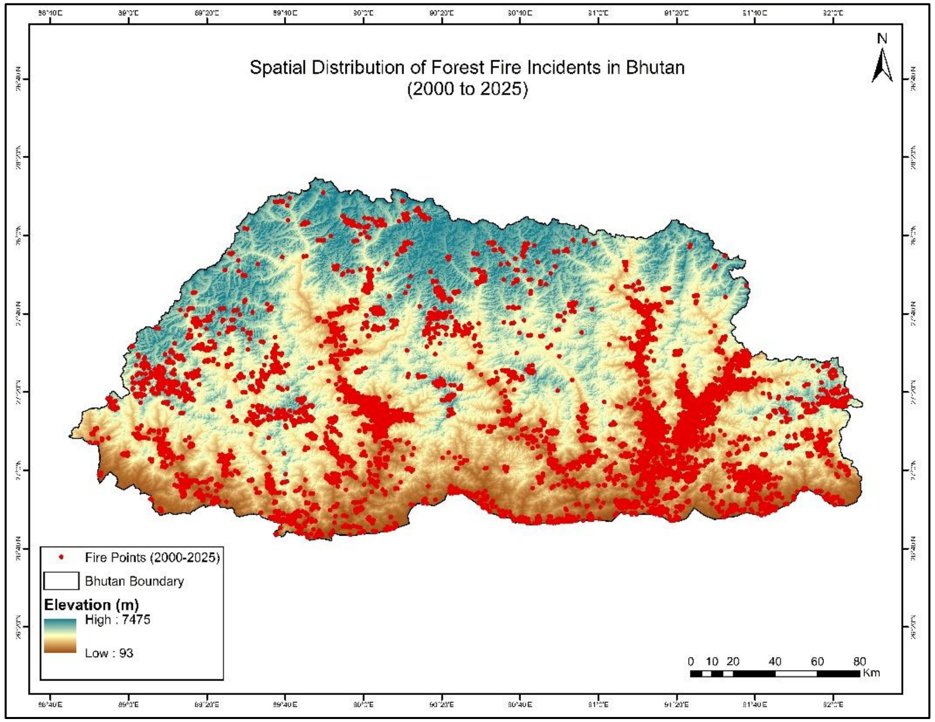

Spatial Distribution of Forest Fire Incidents in
Bangladesh (Chittagong District)
(2000 to 2025)
Fire Points (2000 to 2025)
Bangladesh Boundary
Elevation
Value
1008
-20


Burned Area - Yearly Fires by Landuse (Bangladesh - Chittagong District)
Area in Ha
250000
200000
150000
100000
50000
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Years
Forest Fires (ha)
Grassland Fires (ha)
Cropland Fires (ha)
Wetland Fires (ha)

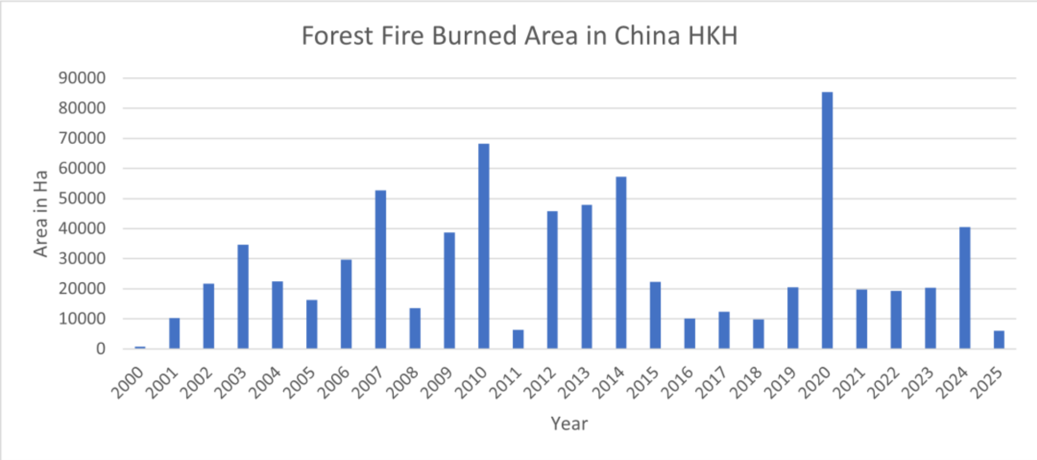
Bhutan

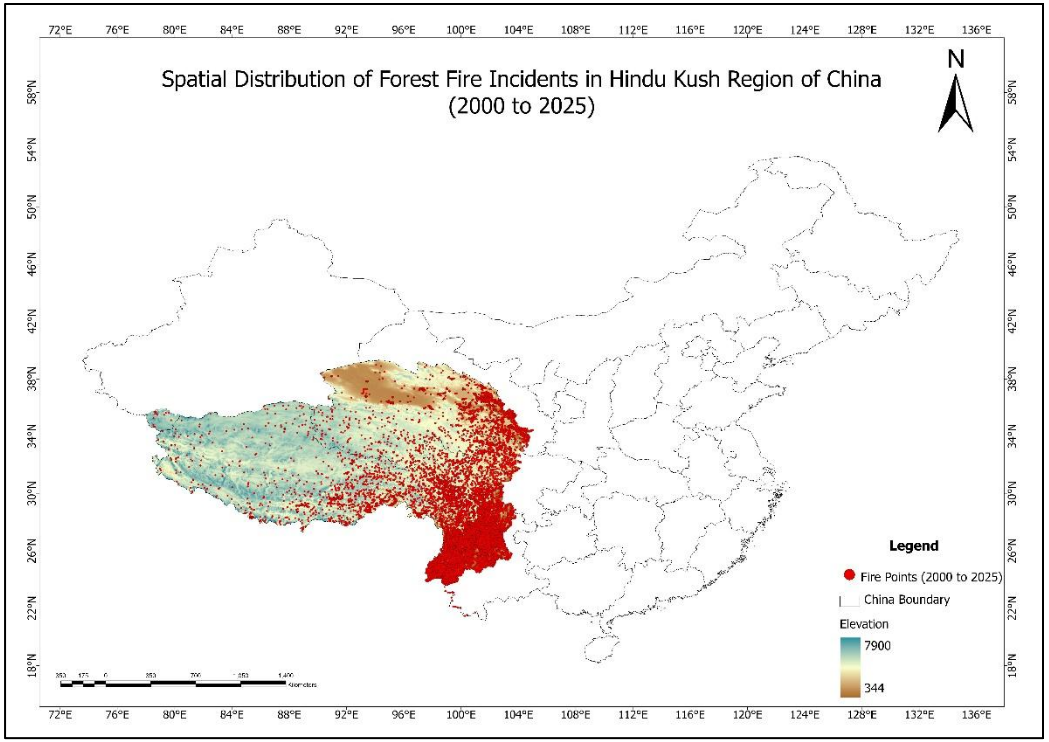

Forest Fire - Burned area (Bhutan)
25000
20000
15000
10000
5000
0
Area in ha
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year


Burned Area - Yearly fires by Land Use (Bhutan)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Area in ha
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year
FOREST FIRES
CROPLAND FIRES
GRASSLAND FIRES
OTHER FIRES

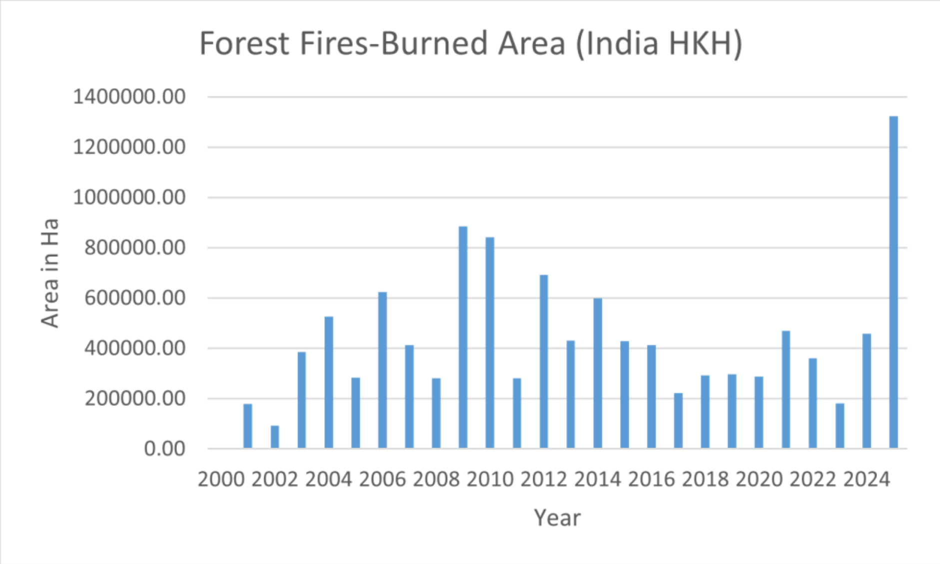

Spatial Distribution of Forest Fire Incidents in Bhutan
(2000 to 2025)
N
Fire Points (2000-2025)
Bhutan Boundary
Elevation (m)
High : 7475
Low : 93
0 10 20 40 60 80
Km

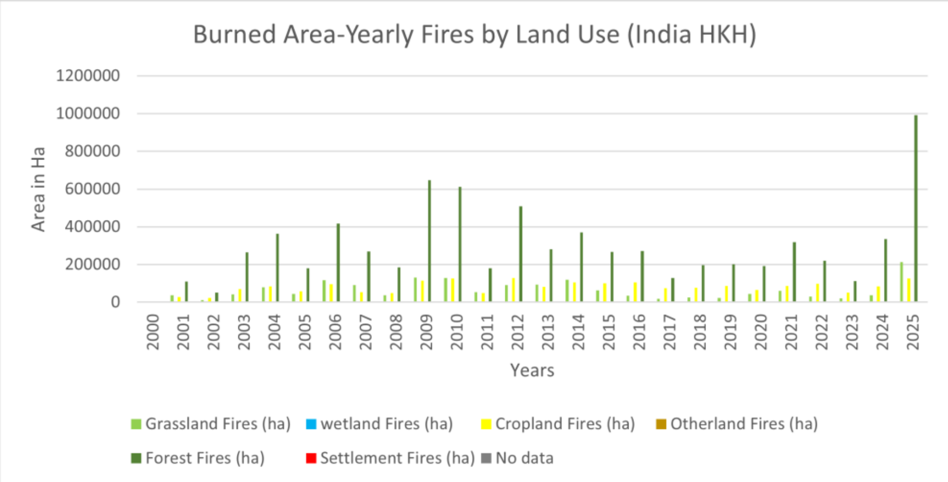
China

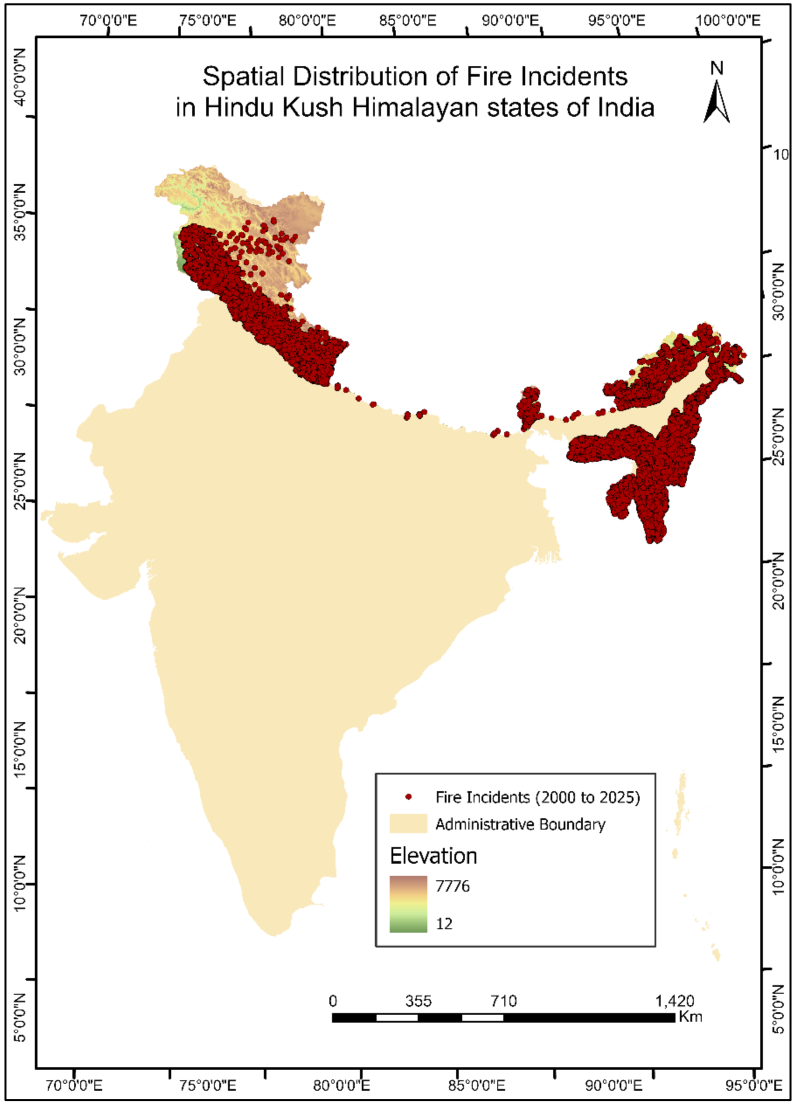

Forest Fire Burned Area in China HKH
Area in Ha
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Year


Spatial Distribution of Forest Fire Incidents in Hindu Kush Region of China
(2000 to 2025)
N
Legend
Fire Points (2000 to 2025)
China Boundary
Elevation
7900
344
72°E
76°E
80°E
84°E
88°E
92°E
96°E
100°E
104°E
108°E
112°E
116°E
120°E
124°E
128°E
132°E
136°E
58°N
54°N
50°N
46°N
42°N
38°N
34°N
30°N
26°N
22°N
18°N

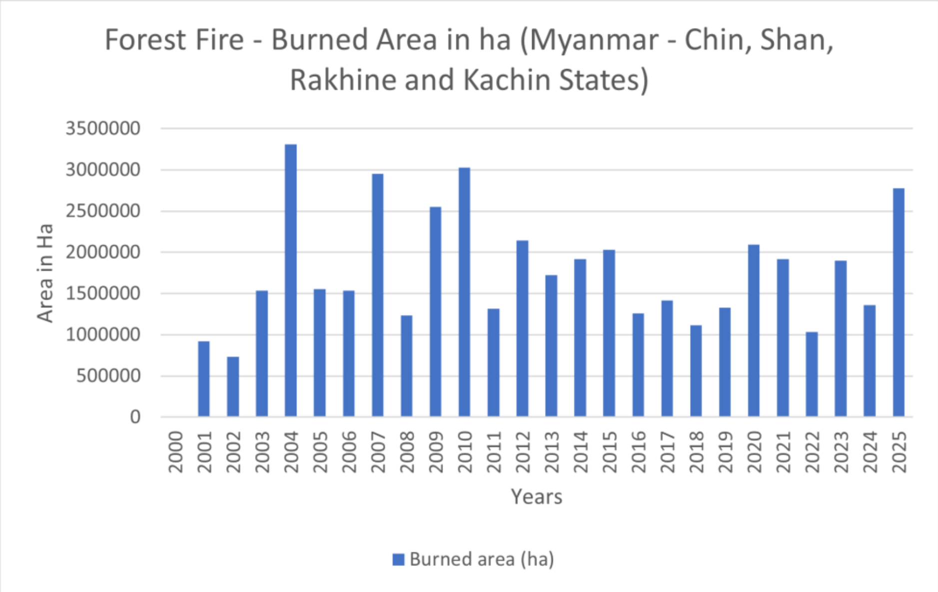
India

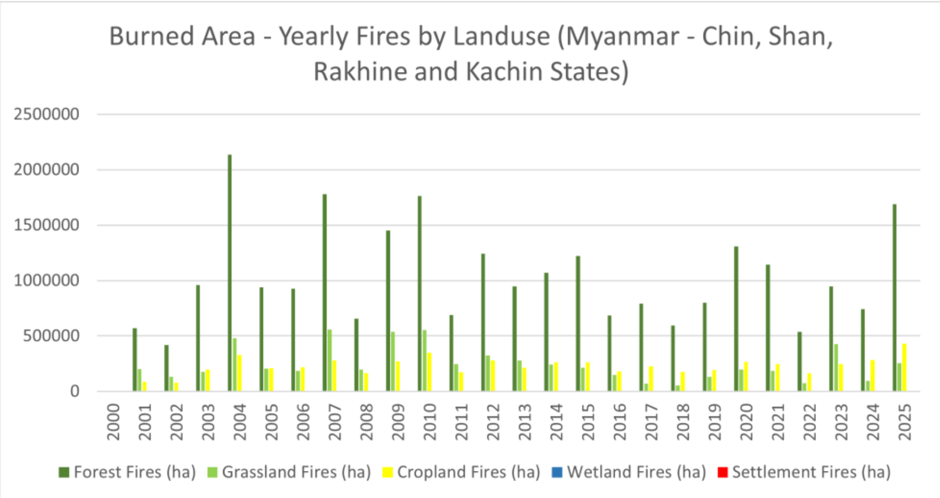

Forest Fires-Burned Area (India HKH)
Area in Ha
Year
1400000.00
1200000.00
1000000.00
800000.00
600000.00
400000.00
200000.00
0.00
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024

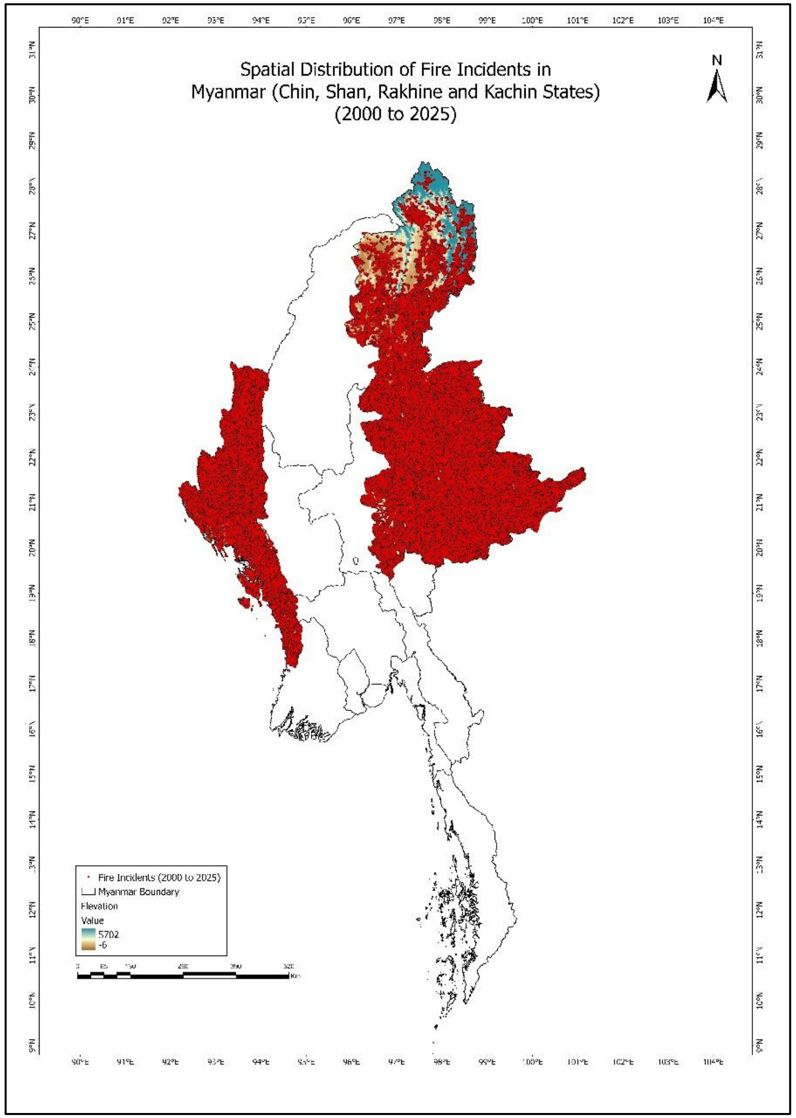

Burned Area-Yearly Fires by Land Use (India HKH)
Area in Ha
Years
Grassland Fires (ha)
wetland Fires (ha)
Cropland Fires (ha)
Otherland Fires (ha)
Forest Fires (ha)
Settlement Fires (ha)
No data


Spatial Distribution of Fire Incidents
in Hindu Kush Himalayan states of India
N
Fire Incidents (2000 to 2025)
Administrative Boundary
Elevation
7776
12
0 355 710 1,420
Km

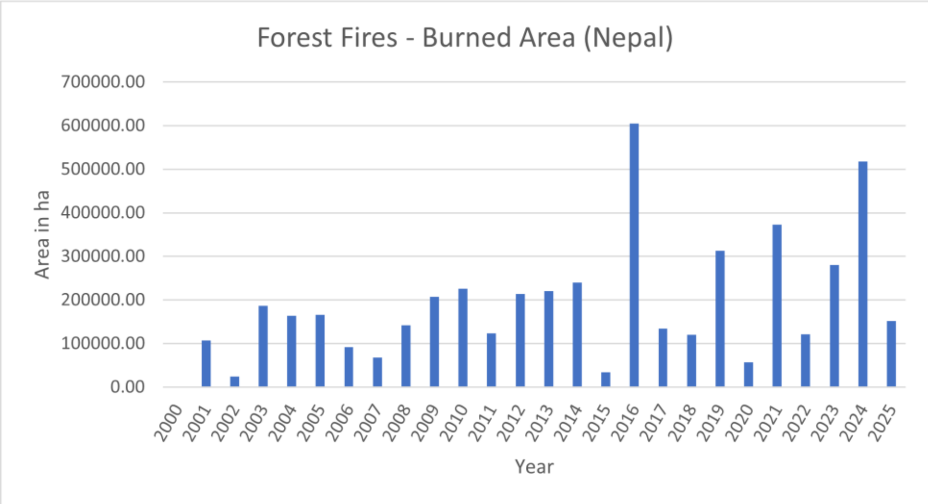
Myanmar

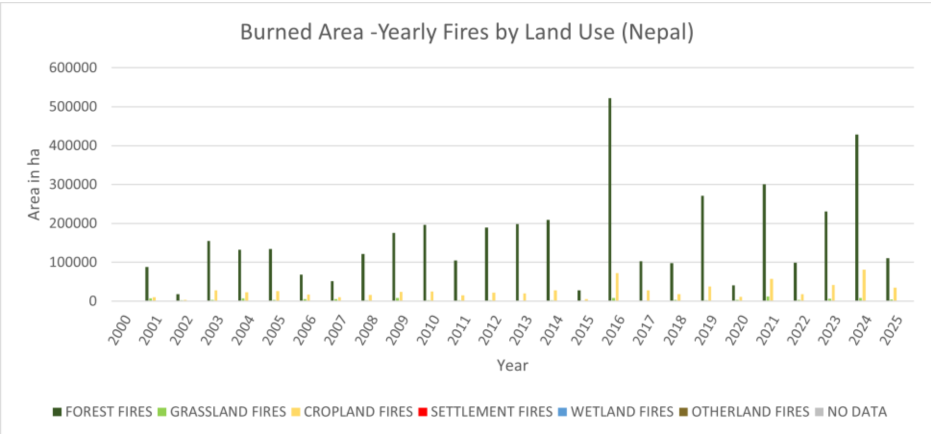

Forest Fire - Burned Area in ha (Myanmar - Chin, Shan, Rakhine and Kachin States)
Area in Ha
Years
Burned area (ha)

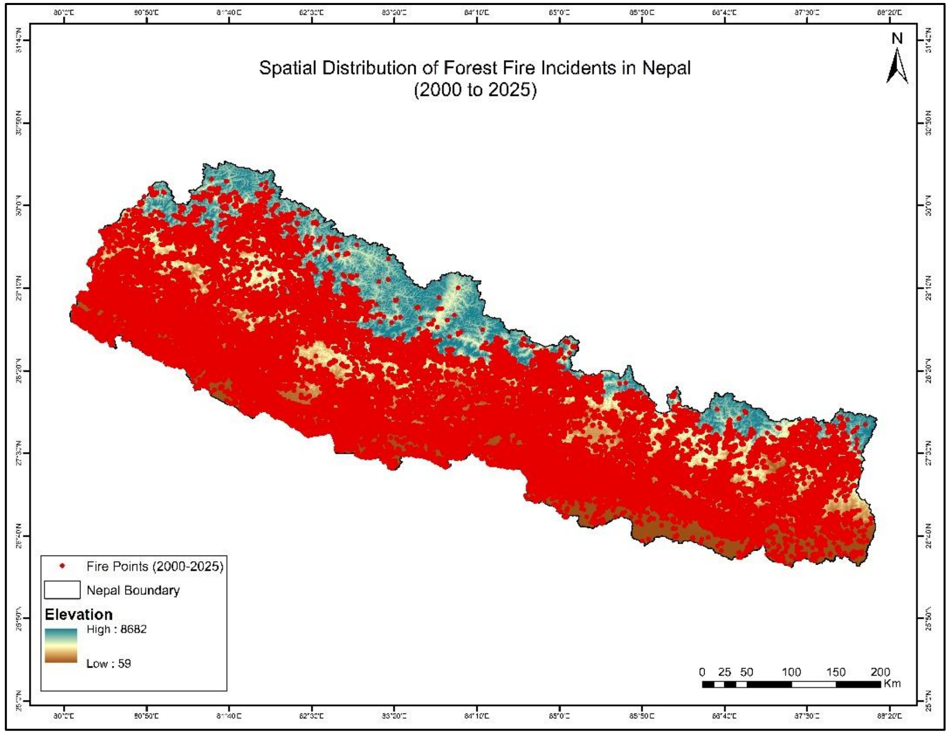

Burned Area - Yearly Fires by Landuse (Myanmar - Chin, Shan, Rakhine and Kachin States)
Forest Fires (ha)
Grassland Fires (ha)
Cropland Fires (ha)
Wetland Fires (ha)
Settlement Fires (ha)


Spatial Distribution of Fire Incidents in Myanmar (Chin, Shan, Rakhine and Kachin States) (2000 to 2025)
N
Fire Incidents (2000 to 2025)
Myanmar Boundary
Elevation
Value
5702
-6

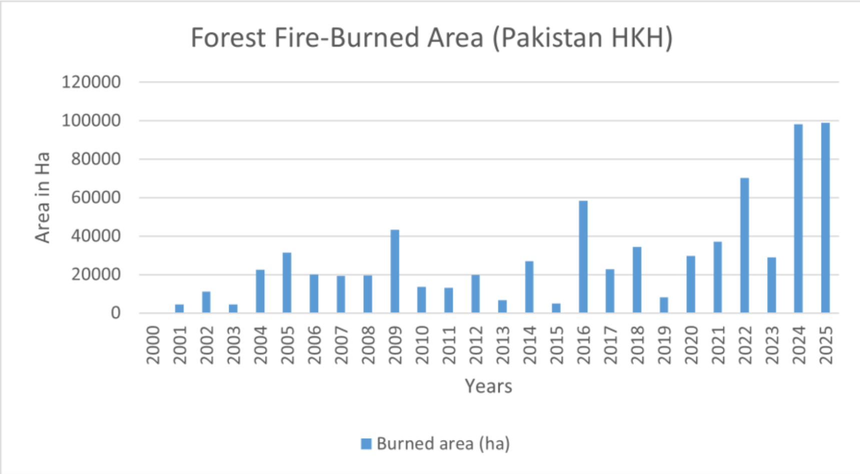
Nepal

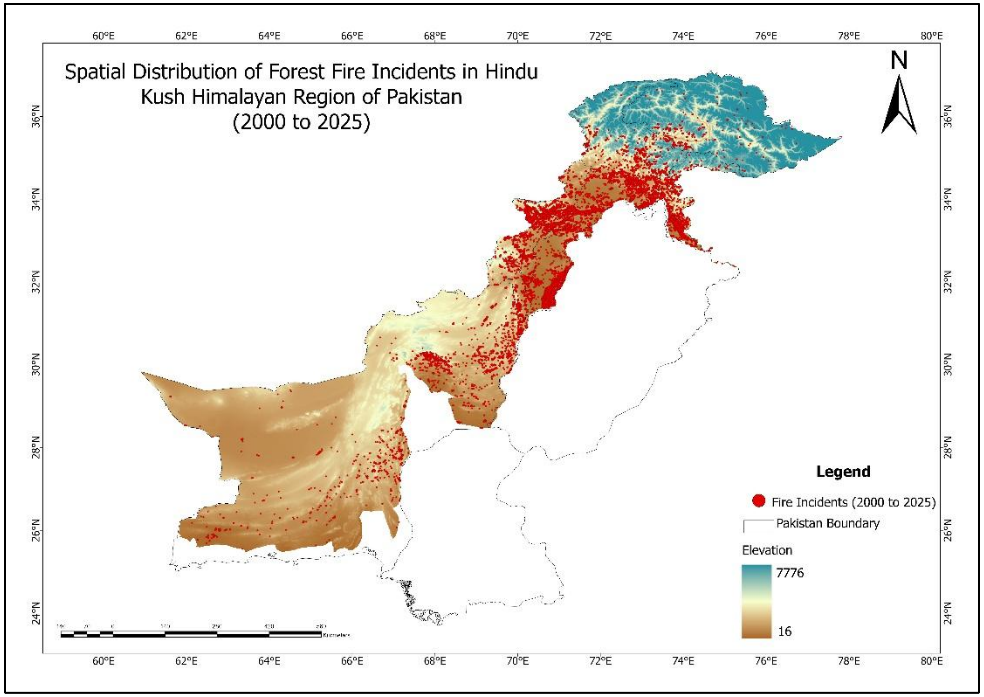

Forest Fires - Burned Area (Nepal)
Area in ha
700000.00
600000.00
500000.00
400000.00
300000.00
200000.00
100000.00
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Year

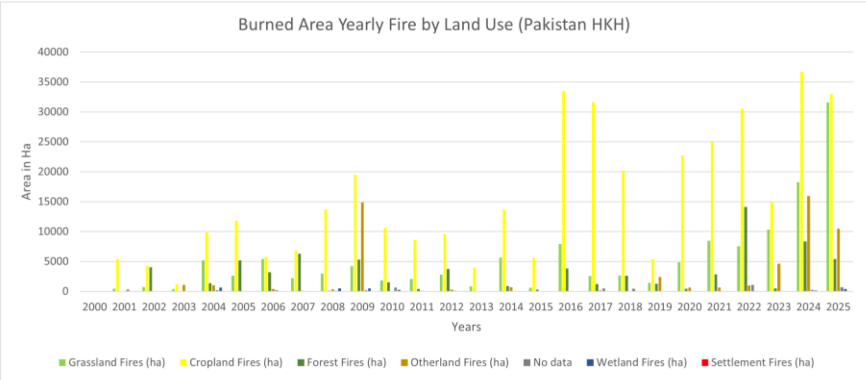

Burned Area -Yearly Fires by Land Use (Nepal)
Area in ha
600000
500000
400000
300000
200000
100000
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Year
FOREST FIRES
GRASSLAND FIRES
CROPLAND FIRES
SETTLEMENT FIRES
WETLAND FIRES
OTHERLAND FIRES
NO DATA


Spatial Distribution of Forest Fire Incidents in Nepal
(2000 to 2025)
N
Fire Points (2000-2025)
Nepal Boundary
Elevation
High : 8682
Low : 59
0 25 50 100 150 200
Km

Pakistan


Forest Fire-Burned Area (Pakistan HKH)
120000
100000
80000
60000
40000
20000
0
Area in Ha
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Years
Burned area (ha)


Spatial Distribution of Forest Fire Incidents in Hindu Kush Himalayan Region of Pakistan (2000 to 2025)
N
60°E 62°E 64°E 66°E 68°E 70°E 72°E 74°E 76°E 78°E 80°E
24°N 26°N 28°N 30°N 32°N 34°N 36°N
Legend
Fire Incidents (2000 to 2025)
Pakistan Boundary
Elevation
7776
16


Burned Area Yearly Fire by Land Use (Pakistan HKH)
40000
35000
30000
25000
20000
15000
10000
5000
0
Area in Ha
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Years
Grassland Fires (ha)
Cropland Fires (ha)
Forest Fires (ha)
Otherland Fires (ha)
No data
Wetland Fires (ha)
Settlement Fires (ha)

Annexure B: Stakeholder Mapping Matrix

Stakeholder category	Typical institutions and examples	Core roles in forest fire management (prevention, monitoring, response, recovery)	Roles in air quality and smoke response	Key data and inputs provided or required	Engagement mode and timing
Regional coordination platform	ICIMOD and regional networks	Regional synthesis, convening, cross-country learning, coordination on transboundary issues	Supports regional smoke awareness, coordination on advisories and evidence	Regional datasets, country inputs, consultation access	Continuous, inception, validation, final dissemination
National forest agencies	Forest Departments, Forest Ministries, protected area authorities	Fire prevention planning, fuel management, ground response, post-fire restoration	Inputs on smoke events from forest fires, joint advisories where practiced	SOPs, incident logs, crew deployment, fuel management plans	Primary technical consultations, country-wise review and validation
Disaster risk management authorities	NDMA or equivalents, provincial SDMAs, district administration	Incident command, emergency logistics, inter-agency coordination, rapid response escalation	Public advisories, emergency response during severe smoke episodes	CAP alerts, response protocols, resource mobilisation plans	Targeted consultations during review and solutions evaluation
Environment and air quality regulators	Environment Ministries, CPCB and SPCBs or equivalents, urban airshed bodies	Link fires to environmental compliance, coordination on emission control in sensitive periods	Air quality monitoring, health advisories, episode attribution	PM2.5, AQI data, episode reports, emission inventories	Consultations during air quality linkage analysis and roadmap design
Meteorological and hydrology services	National Met departments, hydrology agencies	Fire weather indices, drought indicators, seasonal outlooks	Supports smoke dispersion conditions and episode forecasting	Weather stations, gridded met data, drought indices	Early engagement for data pathways, continued coordination
Space, RS and GIS agencies	National space agencies, remote sensing centres, GIS units	Active fire alerts, burned area mapping, risk zoning, recurrence analytics	Fire emissions inputs, plume tracking support	FIRMS, MODIS/VIIRS, Sentinel, Landsat, risk maps, portals	Technical integration meetings, data validation, workflow alignment

Stakeholder category	Typical institutions and examples	Core roles in forest fire management (prevention, monitoring, response, recovery)	Roles in air quality and smoke response	Key data and inputs provided or required	Engagement mode and timing
Health agencies	Health Ministries, public health institutes, hospitals	Occupational health guidance for responders, exposure protocols	Health risk advisories, surveillance during smoke events	Respiratory morbidity trends, advisory protocols, vulnerability groups	Consultation during smoke and health impact framing, advisory design
Local governments	Municipalities, Panchayats, district councils	Local preparedness, community mobilisation, enforcement support	Local dissemination of advisories and protective actions	Local plans, staffing, communication channels	District-level consults, validation of feasibility and last-mile delivery
Community institutions	CFUGs (Nepal), JFMCs (India), Van Panchayats (Uttarakhand), SHGs, cooperatives	Early detection, prevention, patrolling, first response, fuel removal	Risk communication, local compliance, protective behaviour	Local knowledge, access rules, volunteer networks	Structured FGDs, feasibility checks for community-led measures
NGOs and civil society	Conservation NGOs, humanitarian NGOs, local CSOs	Awareness, training, community fire brigades, restoration support	Exposure awareness, behaviour change, support to vulnerable groups	Community mobilisation records, local monitoring	Consultations and pilot design support
Research and academic institutions	Universities, research labs, atmospheric and forestry institutes	Fire regime studies, fuel dynamics, evaluation of interventions	Modelling of smoke transport and exposure, policy inputs	Peer-reviewed evidence, models, validation studies	Expert interviews, peer review of methods, co-design of indicators
Private sector, biomass, and energy value chain	Aggregators, briquette or pellet units, transporters, clean cooking firms	Biomass collection, processing, logistics, enterprise operations	Indirect, supports cleaner alternatives and reduces open burning pressure	Cost structures, market prices, supply chain constraints	Market assessment interviews, business model design workshops
Finance and carbon ecosystem	Donors, CSR, development banks, carbon standards, local financiers	Funding for prevention, restoration, equipment, capacity building	Supports co-benefit framing for air quality and health	Cost benchmarks, financing terms, safeguards	Inputs during CBA and investment note preparation

Stakeholder category	Typical institutions and examples	Core roles in forest fire management (prevention, monitoring, response, recovery)	Roles in air quality and smoke response	Key data and inputs provided or required	Engagement mode and timing
Security and emergency services	Police, fire services, armed forces were engaged	Rapid response support, aerial support in select contexts, access control	Emergency logistics for high-smoke events	Incident reports, response capacity	As-needed, for response-chain mapping and feasibility
Media and communication partners	Print, radio, local digital platforms	Public awareness and prevention messaging	Dissemination of advisories and risk communication	Communication reach, local language channels	Strategy inputs during roadmap and dissemination planning

Annexure C: Travel Plan

Stakeholder consultations and any in-person engagements are proposed tentatively as five targeted visits, two international, Nepal and Bhutan, and three domestic, Uttarakhand, Himachal Pradesh, and Sikkim. Each visit is planned to support validation of desk-review findings, field-level sense-checking of RS GIS fire-risk and burned-area outputs, and structured discussions on early warning, monitoring, suppression readiness, biomass or fuel-load management, and air quality response linkages. All scheduling, routing, and meeting agendas will be finalised in coordination with ICIMOD and relevant national counterparts, and the plan is indicative and subject to access, permits, and seasonal fire conditions.

Tentative Travel Plan						
Visit No.	**Destination**	**Type**	**Tentative window, aligned to deliverables**	**Main purpose, in coordination with ICIMOD**	**Illustrative engagements**	**Expected outputs and linkage**
1	Uttarakhand	Domestic	Early January 2026, after Deliverable 1 submission and ahead of Deliverable 2	Field validation and operational reality checks for RS GIS derived hotspot patterns, burned-area and land-use intersections, plus consultations on fuel-load management and biomass utilisation models in coordination with ICIMOD.	State Forest Department, disaster management authorities, local institutions and community groups, biomass utilisation actors where relevant	State-level case inputs to solutions and evaluation matrix, field notes on feasibility constraints, examples of biomass utilisation pathways and safeguards needs
2	Himachal Pradesh	Domestic	Mid to Late January 2026	Consultations on prevention and preparedness practices in mid hill and conifer landscapes, validation of alert use and response chain, and review of fuel management and restoration practices, in coordination with ICIMOD	State Forest Department, line agencies involved in response, research partners and field units	State-level evidence on what converts alerts into action, operational gaps, and practical options for risk reduction and recovery

Tentative Travel Plan

3	Sikkim	Domestic	Early February 2026	Terrain-sensitive review of monitoring and first response challenges, validation of spatial outputs in representative landscapes, and consultations on community participation and preparedness measures, in coordination with ICIMOD	State Forest Department, local institutions, technical partners where available	Inputs on mountainous operational constraints, community interface options, and location-specific feasibility assumptions for solution ranking
4	Nepal, Kathmandu, and selected fire-prone landscapes as feasible	International	Mid to Late February 2026, after the submission of Deliverable 2	National consultations on forest fire governance, early warning, community forestry interfaces, and air quality episode response, plus alignment on data access and analytical priorities, in coordination with ICIMOD	ICIMOD technical team, national forestry authorities, air quality and meteorology institutions, community forestry representatives	Validated stakeholder mapping inputs, refined country-specific evidence on systems and gaps, agreement on data sources and coordination channels for subsequent tasks
5	Bhutan	International	Late February 2026, timed to inform Deliverable 2 and early Deliverable 3 drafting	Government consultations, selective field validation of hotspot and fuel-load mapping, community discussions, and alignment on early warning and air quality integration needs, in coordination with ICIMOD and national counterparts	Relevant ministries and forestry agencies, local authorities, technical counterparts	Country-level confirmation of institutional practice versus secondary inference, and targeted inputs for policy gap analysis and regional cooperation recommendations

Note for other HKH countries: For Afghanistan, Bangladesh, China (HKH-relevant regions), Myanmar, and Pakistan, stakeholder inputs during this phase can be planned primarily through virtual consultations facilitated in coordination with ICIMOD and relevant national counterparts, given access and cross-border constraints, while continuing the desk-review evidence consolidation in parallel.