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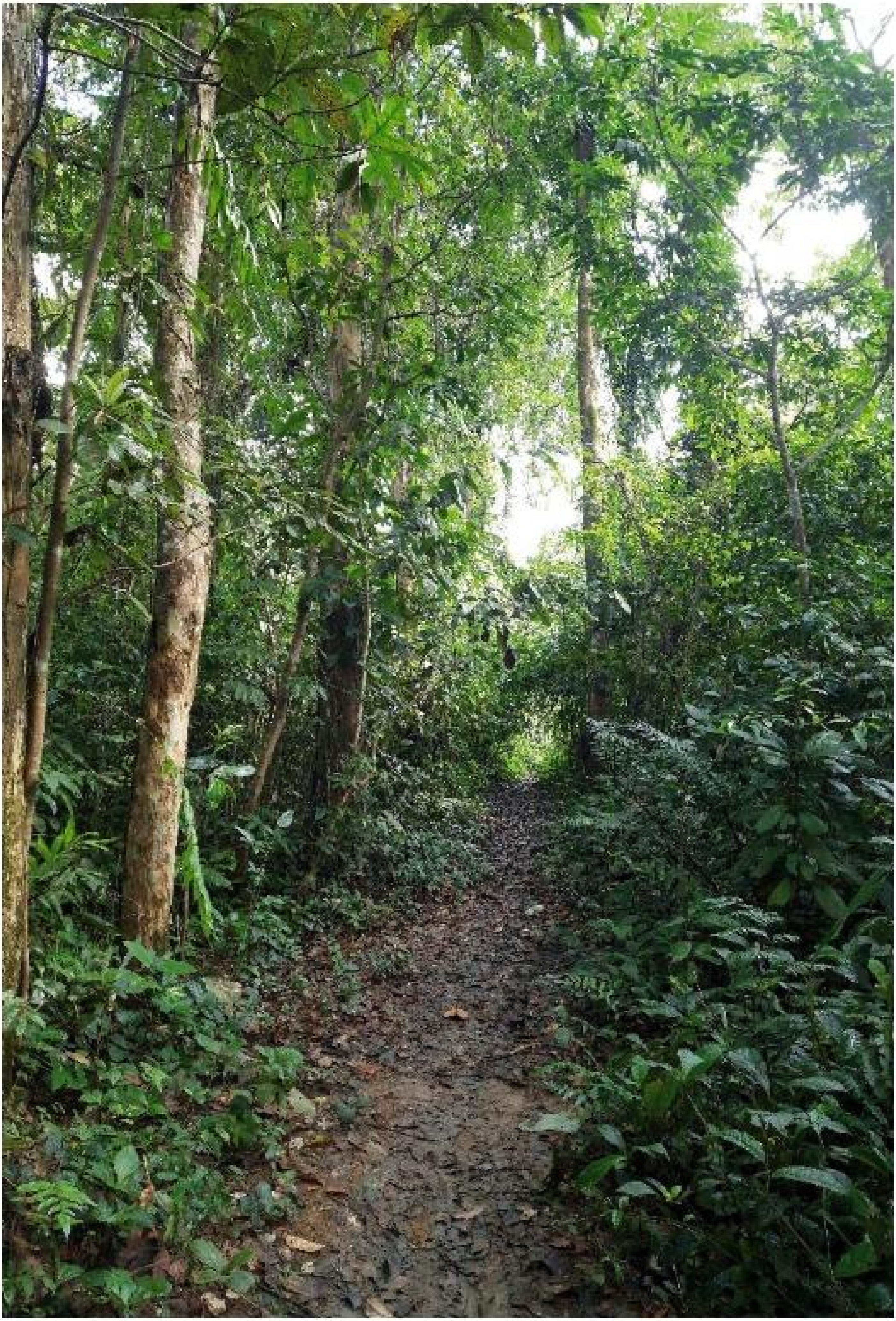
COMPENDIUM OF BEST PRACTICES: RESTORATION OF FOREST FIRE IMPACTED AREAS

JULY 2023

PRESIDENCY DOCUMENT



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The information included in this report is based on voluntary submissions from the G20 members.

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LIST OF ACRONYMS

ACSAD	Arab Centre for the Studies of Arid Zones and Dry Lands
AIDR	Australian Institute for Disaster Resilience
APN	National Parks Administration
BAER	Burned Area Emergency Response
BAM	Bundesanstalt für Materialforschung und –prüfung
BLM	Bureau of Land Management
CAMS	Copernicus Atmosphere Monitoring Service
CBS	Convention on Biological Diversity
CCRA	Climate Change Risk Assessment
CFFDRS	Canadian Forest Fire Danger Rating System
CFLRP	Collaborative Forest Landscape Restoration Program
CFS	Canadian Forest Service
CFSaT	Centre for Fire Science and Technology
Ch_4	Methane
CIEFAP	Centro de Investigación y Extensión Forestal Andino Patagónico
CIFFC	Canadian Interagency Forest Fire Centre
CNRS	Cational Centre for Scientific Research
CO_2	Carbon Dioxide
CONAFOR	Comisión Nacional Forestal
CONANP	Comisión Nacional de Áreas Naturales Protegidas
COP	Conference of parties
CP	Colegio de Postgraduados (CP)
CWFIS	The Canadian Wildland Fire Information System
DFFE	Department of Forestry, Fisheries, and the Environment
DEADP	Department of Environmental Affairs and Development Planning
DFE	Directorate of Forestry Education
DG ENV	Directorate General for Environment
DLUHC	Department for Levelling Up, Housing and Communities
DWD	Deutscher Wetterdienst

ECCC	Environment and Climate Change Canada
ECUFPA	Eastern Cape Umbrella fire protection association
EFFIS	European Forest Fire Information System
ERCC	Emergency Response Coordination Centre
EU	European Union
EWWF	England and Wales Wildfire Forum
FAO	Food and Agriculture Organization
FBP	Fire Behaviour Prediction
FDMA	Fire and Disaster Management Agency
FEMA	Federal Emergency Management Agency
FIRMS	Fire Information for Resource Management System
FRI	Forest Research Institute
FSI	Forest Survey of India
FUNAI	The National Indigenous Foundation (FUNAI
FWI	Fire Weather Index
GAMEP	General Authority of Meteorology and Environmental Protection
GBF	Global Forest Watch
GDF	General Directorate of Forestry
GDP	Gross Domestic Product
GeoMAC	Geospatial Multi-Agency Coordination (GeoMAC) Wildfire Mapping
GFAS	Global Fire Assimilation System
GFDL	Geophysical Fluid Dynamics Laboratory
GHG	Green House Gas
GFMC	Global Fire Monitoring Center
GPS	Global Positioning System
ICFRE	Indian Council for Forestry Research and Education
ICMBio	The Chico Mendes Institute for Conserving Biodiversity
ICS	Incident Command System
IGAC	International Global Atmospheric Chemistry
IGBP	International Geosphere-Biosphere Programme
IGNFA	Indira Gandhi National Forest Academy
IIFM	Indian Institute of Forest Management
INCRA	The National Institute of Colonization and Agrarian Reform
INIFAP	Instituto Nacional de Investigaciones Forestales Agrícolas
INPA	National Institute of Amazonian Research
INPE	National Institute for Space Research

INTA	The National Institute of Agricultural Technologies
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organizations
JFM	Joint Forest Management
JFSP	Joint Fire Science Program
JICA	Japan International Cooperation Agency
JRC	Joint Research Centre
KFS	Korea Forest Service
MDF	Moderately Dense Forest
MEAs	Multilateral Environmental Agreements
MHA	Million Hectare
MOEF & CC	Ministry of Environment Forest & Climate Change
MOST	Ministry of Science and Technology
MTG	Meteosat Third Generation
NCVC	National Center for Vegetation Cover
NCWCD	National Commission for Wildlife Conservation and Development
NDMA	National Disaster Management Authority
NDRF	National Disaster Reduction Force
NES	Nucleus Estate and Smallholder
NFCC	National Fire Chiefs Council
NFS	National Forest Service
NFSC	National Science Foundation of China
NGO	Non-Governmental organization
NIDM	National Institute of Disaster Management
NIFC	National Interagency Fire Center
NOx	Nitrogen Oxide
NPS	National Park Service
NRCAN	Natural Resources Canada
NWCG	National Wildfire Coordinating Group
OGM	Orman Genel Müdürlü ü
PFAS	Probabilistic Fire Analysis System
PNMF	National Fire Management System
PREVFOGO	The National Centre to Prevent and Combat Forest fires

PROARCO	Programme for Prevention and Control of Fires in the Brazilian Amazon Forest
RDP	Rural Development Program
RFF	Russian Forest Fund
RFM-Plan	Regional Fire Management Plan
ROK	Republic of Korea
SCI	Sites of Community Importance
SDGs	Sustainable Development Goals
SDMA	State Disaster management Authority
SDRF	State Disaster Reduction Force
SEMARNAT	Secretaria de Medio Ambiente
SFD	State Forest Department
SKLFC	State Key Laboratory of Fire Science
SO_2	Sulphur Dioxide
SPA	Special Protected Area
TFC	Total Forest Cover
TH HA	Thousand Hectare
TRC	Truth and Reconciliation Commission
UACh	Universidad Autónoma Chapingo
UFMT	Federal University of Mato Grosso
UFPAs	Umbrella fire protection Associations
UKFDRS	UK Fire Danger Rating System project
ULL	University of La Laguna
UN	United Nations
UNCCD	United Nations Convention on Combating Desertification
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNDRR	United Nations Disaster Risk Reduction
UNEA	United Nations Environment Assembly
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forest
UNICEF	United Nations International Children's Emergency Fund
UNISDR	United Nations International Strategy for Disaster Reduction
USA	United States of America
USAID	U.S. Agency for International Development

USDA	United States Development Agency
USFS	U.S. Forest Service
USFWS	United States Fish and Wildlife Service
USGCRP	U.S. Global Change Research Program
USP	University of San Paolo
VDF	Very Dense Forest
WB	World Bank
WFAS	Wildland Fire Assessment System (WFAS)
WFTCA	Wildfire Fire Training Center Africa
WII	Wildlife Institute of India
WoF	Working on Fire
WTA	Wildfire Tactical Advisors
WTRS	Wildfire Threat Rating System
WUI	Wildland-Urban Interfaces
WWF	World Wide Fund for Nature

Chapter 1

1.1 INTRODUCTION

Land is a finite resource that is the foundation of our economies and provides numerous benefits to society. Land use and management has continued to shape the world, having significant bearing on ecological functions, climate regulation, and the provisioning of essential ecosystem services. It is central to the varied and complex social relations of production and consumption - roughly USD 44 trillion of economic output, more than half of the global annual GDP, is moderately or highly reliant on land-based natural capital (UNCCD, 2022). Although, central to our well-being, land continues to be degraded with many processes accelerated by human activity. In 2019, an analysis of national reports submitted to the UNCCD conservatively estimated that, on average, 20% of global land is degraded to some extent – almost 30 million square kilometeres, an area the size of the African continent (UNCCD, 2022). Further, scientists have also warned that 24 billion tons of fertile soil is being lost every year, largely due to unsustainable agriculture practices. If this trend continues, 95 percent of the Earth's land areas could become degraded by 2050 (GEF, 2022).

Land degradation has been identified by the United Nations Convention to Combat Desertification (UNCCD) as one of the most challenging environmental concerns of present and future. IPBES warns that "unless urgent and concerted action is taken, land degradation will worsen in the face of population growth, unprecedented consumption, an increasingly globalized economy and climate change" and that the implementation of known, proven actions to combat land degradation will become more difficult and costly over time." It further advises that an "urgent step change in effort is needed to prevent irreversible land degradation and accelerate the implementation of restoration measures."

1.1.1 Global Context

The importance of restoration and improved land management as a means to achieve global sustainability objectives has gained significant attention over the recent years as landmark high-level reports have articulated the urgency with which climate change, land degradation and biodiversity loss need to be tackled (Van der Esch, Sewell, Bakkenes, Doelman et al. 2022). Various international and regional agreements, including Multilateral Environmental Agreements (MEAs) and the Sustainable Development Goals (SDGs), incorporate restoration objectives, including the three Rio Conventions (UNFCCC, CBD, UNCCD) on climate change, biodiversity loss, and desertification and land degradation, as well as the Ramsar Convention on Wetlands, the Sendai Framework for Disaster Risk Reduction, and the UN Forum on Forests (UNFF). Among the SDGs, SDG 2 (zero hunger), SDG 6 (clean water and sanitation), SDG 13 (climate action), and SDG 15 (life on land) are strongly linked to land restoration. The role of Ecosystem-based Approaches in tackling climate change and biodiversity loss has been discussed extensively in various high-level reports, with key messages being:

- Degradation is already affecting the well-being of an estimated 3.2 billion people –40 percent of the world's population. Every single year we lose ecosystem services worth more than 10 percent of our global economic output (UNEP, 2021).
- Restoration, if combined with stopping the further conversion of natural ecosystems, can help avoid 60 percent of expected biodiversity extinctions.
- The economic returns of restoring land and reducing degradation, greenhouse gas emissions and biodiversity loss could be as high as $140 trillion every year – up to 50% more than the $93 trillion global GDP in 2021.

Building on the momentum of several initiatives, including the Bonn Challenge (2011) and the New York Declaration on Forests (2014) and the urgent need to scale restoration efforts, the United Nations declared the decade 2021 to 2030 as the UN Decade on Ecosystem Restoration, jointly led by the UN Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO), and supported by collaborating agencies, including the three Rio Conventions, other international conventions, and regional partners including IUCN. The overarching aim of the UN Decade is to prevent, halt and reverse the degradation of ecosystems on every continent and in every ocean.

Ecosystem restoration under the UN Decade on Ecosystem Restoration has been defined as the "process of assisting in the recovery of ecosystems that have been degraded, damaged, or destroyed, and focuses on establishing the ecological processes necessary to make terrestrial and aquatic ecosystems sustainable, resilient, and healthy under current and future conditions while improving human well-being". Common principles are critical for a shared vision of ecosystem restoration. Towards this end, through extensive consultation process the Best Practices Task Force under the UN Decade identified nine principles that underpin ecosystem restoration (FAO, 2023). They include:

- **Principle 1:** Promote inclusive and participatory governance, social fairness, and equity from the start and throughout the process and outcomes.
- **Principle 2:** Include a continuum of restorative activities.
- **Principle 3:** Aim to achieve the highest level of recovery possible for ecosystem health and human well-being.
- **Principle 4:** Address drivers of ecosystem degradation.
- **Principle 5:** Incorporate all types of knowledge and promotes their exchange throughout the process.
- **Principle 6:** Tailored to the local context considering the larger landscape or seascape and social-ecological and cultural settings.
- **Principle 7:** Based on well-defined short- and long-term ecological and socioeconomic objectives and goals
- **Principle 8:** Plan and undertake monitoring, evaluation, and adaptive management throughout the lifetime of the project or program.
- **Principle 9:** Integrate policies and measures to ensure longevity, maintain funding and, where appropriate, enhance and scale up interventions.

to date more than 115 countries have made commitments to restore one billion hectares of degraded and deforested landscapes, which is equivalent to an area roughly the size of Canada (UNCCD, 2021).However, countries need to accelerate their delivery on their existing commitments to restore 1 billion hectares of degraded land to achieve the commitments.

1.1.2 G20 History and Context

Environment and sustainable development have been a focus area of interest within the G20 since 2015, with greater emphasis on addressing pressing global issues such as land degradation being prioritized for discussion under the Environment and Climate Sustainability G20 grouping for several years. Key developments on land degradation under the G20 include:

The Riyadh Summit of 2020, Saudi Arabia, held virtually due to COVID re-emphasised preventing environmental degradation, conserving, sustainably using and restoring biodiversity, preserving our oceans, promoting clean air and clean water, responding to natural disasters and extreme weather events, and tackling climate change are among the most pressing challenges of our time. The Summit pledged its commitment to safeguarding our planet and building a more environmentally sustainable and inclusive future for all people. The Summit also launched the Global Coral Reef R&D Accelerator Platform to conserve coral reefs and the 'Global Initiative on Reducing Land Degradation and Enhancing Conservation of Terrestrial

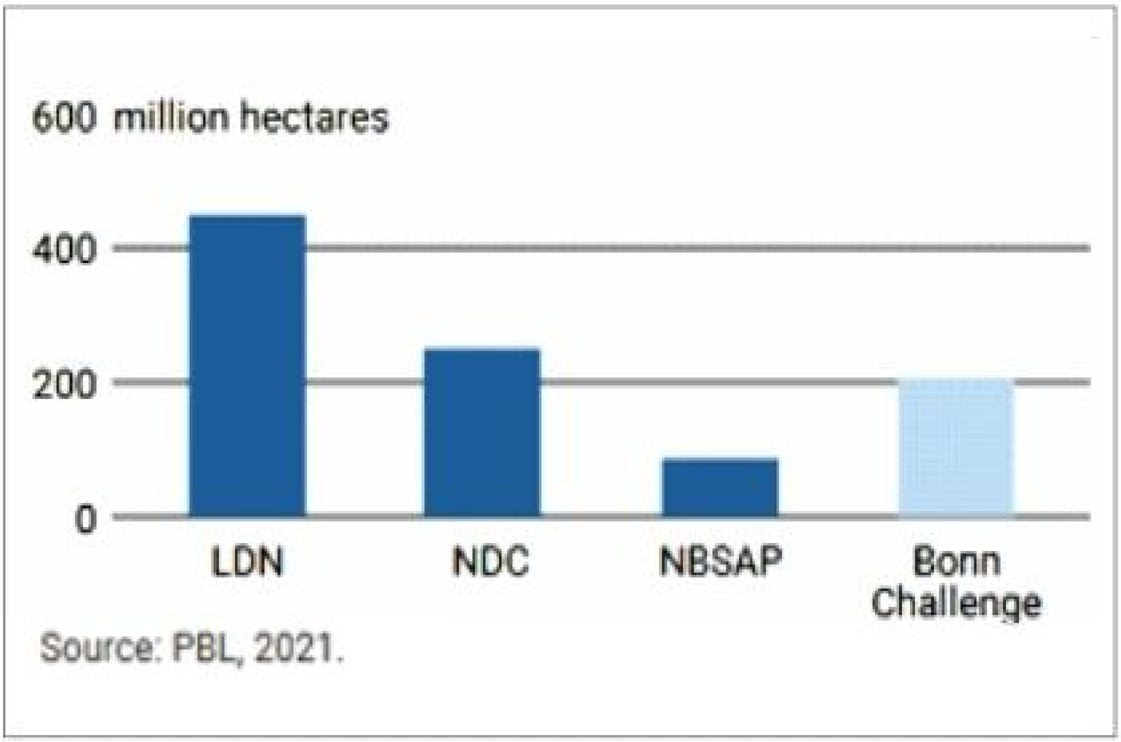


Figure 1.1.1

Commitments on land restoration globally

Habitats' to prevent, halt, and reverse land degradation. Building on existing initiatives, G20 countries share the ambition to achieve a 50% reduction of degraded land by 2040 on a voluntary basis.

In November 2020, the G20 launched the Global Initiative on Reducing Land Degradation and Enhancing Conservation of Terrestrial Habitats. This initiative aims to prevent, halt and reverse land degradation and reduce degraded land by 50% by 2040 (UNCCD, 2021). Further, the G20 also recognizes the urgent need for bold, coordinated, and collective initiatives on land protection and restoration and sustainable land management and use to strengthen existing efforts, such as the Bonn Challenge, the United Nations Decade on Ecosystem Restoration, post-2020 Global Biodiversity Framework and other multilateral initiatives. The aim is to preserve nature's life-support services and safeguard the productivity of land resources for generations to come, reduce the risks and impacts of disasters and pandemics, and boost ecosystem and community resilience in the face of impending environmental stresses and climate shocks.

The G20 Global Land Initiative brings at least three new elements to the table. First, it incentivizes the global community to tackle climate change, biodiversity losses and land degradation together. Second, it demands that while we think globally, we pursue inclusive solutions at the regional and national levels alongside indigenous and local communities, with their traditional knowledge at the heart of the action. Third, it demands the engagement of public and private actors (UNCCD, 2021)

The Rome Summit, 2021 in Italy, committed to strengthening actions to halt and reverse biodiversity loss by 2030 and called on CBD Parties to adopt an ambitious, balanced, practical, effective, robust and transformative post-2020 Global Biodiversity Framework at COP15 in Kunming. The Summit welcomed the launch of the UN Decade on Ecosystem Restoration 2021-2030 and reaffirmed the shared ambition to achieve a 50% reduction of degraded land by 2040 on a voluntary basis and will strive to achieve Land Degradation Neutrality by 2030.

The G20 leaders also formulated an ambitious goal of planting 1 trillion trees by 2030 to mitigate climate change and as a contribution to the UN Decade on Ecosystem Restoration in the G20 Rome Summit 2021. The G20 nations pledged to share the goal to collectively plant 1 trillion trees, focusing on the most degraded ecosystems on the planet, ideally as part of broader, inclusive ecosystem landscape restoration strategies - and in consultation and collaboration with local communities.

G20 also noted the think-piece by the International Resource Panel on 'Land Restoration for Achieving the Sustainable Development Goals, according to which land restoration and rehabilitation can have significant co-benefits for all the SDGs.

The Bali Summit, Indonesia, 2022 : The presidency of Indonesia took up the restoration of Peat-lands and Mangroves as two key ecosystems where the land degradation and restoration agenda within the G20 would be strengthened.

The Bengaluru Summit, India, 2023 : India assumed the Presidency of the G-20 in December 2022. India's Presidency intends to build upon the ongoing focus of the G20 countries on land restoration to drive meaningful action to arrest land degradation and accelerate ecosystem restoration. As landscapes which countries can take immediate and meaningful action with regards to land restoration, India's G20 Presidency has identified the restoration of forest-fire-affected areas and mining-affected areas as the priority focus areas on which G20 countries can cooperate in fast-tracking global commitments on land restoration. This report focuses on the restoration of forest fire-affected areas.

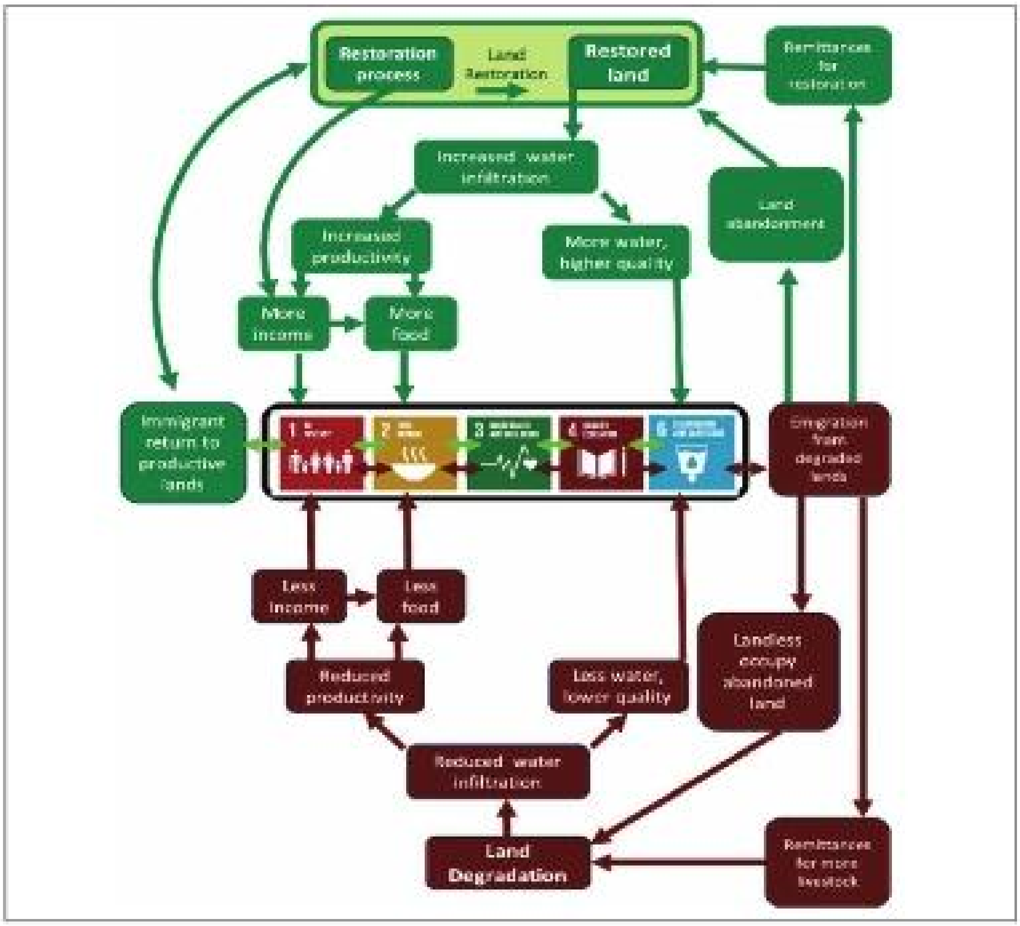


Figure 1.1.2

Impacts of land degradation (red, below, negative impacts) and restoration (green, above, positive impacts) on human migration through the synergistic effects of resulting changes in soil water infiltration on five of the SDGs (IRP (2019). Land Restoration for Achieving the Sustainable Development Goals: An International Resource Panel Think Piece)

1.2 CONTEXT: FOREST FIRES AND LAND DEGRADATION

1.2.1 Forest Fires and their Impact on Land Degradation

The past decade has seen a significant surge in the incidence of large and uncontrolled wildfires. For example, in April 2020, the number of fire alerts around the world rose by 13% compared to 2019, a record year for fires (WWF-BCG, 2020). This increase of wildfires in ecosystems has immense impacts on biodiversity, ecosystem services, human well-being, livelihoods and national economies dependent on them (IUFRO, 2018).

A global analysis of forest areas affected by fire between 2003 and 2012 identified approximately 67 million hectares burned annually (van Lierop et al., 2015). In 2015, around 98 million hectares of forest were affected by fires (FAO 2021). These fires occurred mainly in the tropics, where they affected about 4 percent of the forest area. Dramatic and high-profile wildfire events, such as those in Australia, Brazil, Greece, the Russian Federation and the United States of America in 2018, 2019, 2020 and 2021, have also caused significant losses to human and animal lives (UNEP, 2022). Table 1.2.1. provides summary statistics of tree cover loss due to forest fires in G20 countries and shows that, over 118 million hectares of tree cover have been lost due to fire incidences in the last two decades.

Table 1.2.1.

Tree Cover Loss of due to Forest Fires in G20 Countries (2001-2021)

S. No.	Country	Total Tree Cover Loss (ha)	Tree Cover Loss from fires (ha)
1	Argentina	6317526.33	534794.91
2	Australia	8727950.16	6262638.22
3	Brazil	62817600.58	9513978.35
4	Canada	46611577.94	26751110.11
5	China	10875236.46	893246.31
6	European Union	*data pending*	*data pending*
7	France	1333332.74	48209.01
8	Germany	1143170.60	6417.77
9	India	2066015.30	34836.44
10	Indonesia	28562386.82	2843361.80
11	Italy	415079.35	45809.63
12	Japan	810806.99	2558.25
13	Mexico	4481513.78	655931.35
14	Russia	76008405.95	52788981.99
15	Saudi Arabia	*data unavailable*	*data unavailable*
16	South Africa	1530042.50	115730.98
17	South Korea	288488.43	0.00
18	Turkey	624593.27	87748.30
19	United Kingdom	506737.20	23653.49
20	USA	44274580.82	11131936.29
	TOTAL	**297395045.22**	**111740943.20**
	Total (mha)	**297.40**	**111.74**

Source: www.globalforestwatch.org

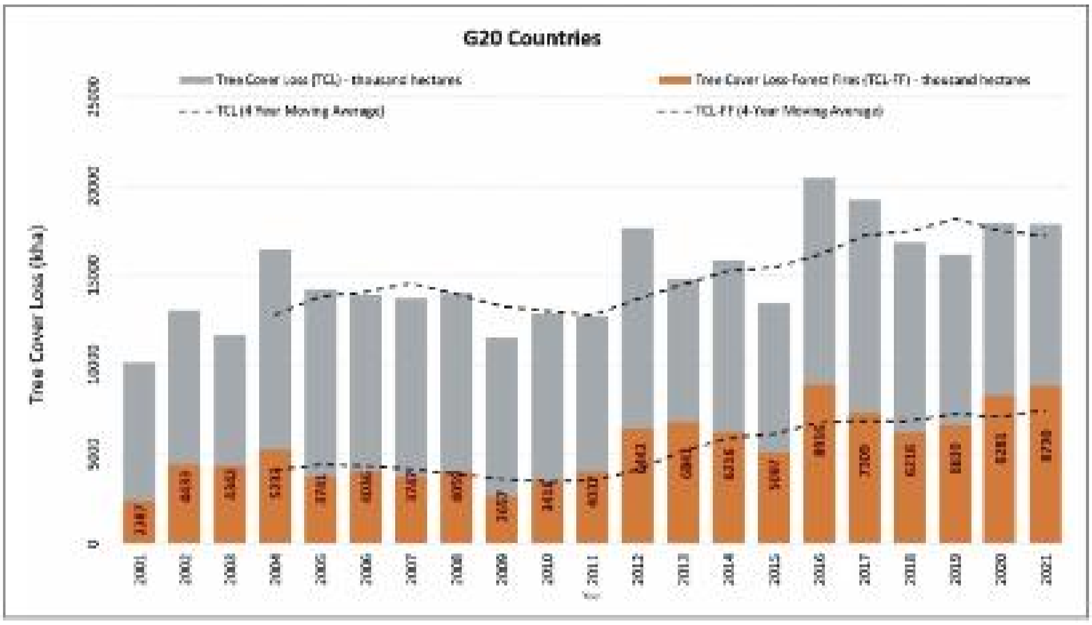


Figure 1.2.1.

Tree Cover Loss and Tree Cover Loss due to Forest Fires in G20 Countries (kha)

Data Source: *www.globalforestwatch.org*

Fires affect both physical and chemical properties of soils, particularly the productive soil layer. Changes in the soil's physical properties lead to loss of productive soil, increased runoff during wet periods, and lower underground water recharge, which increases water deficit over dry periods. Repeated fires deplete seed sources and can affect the regeneration and succession of forest ecosystems. Fire regime shifts in wild and semi natural ecosystems can become a degradation process impacting net carbon emissions.

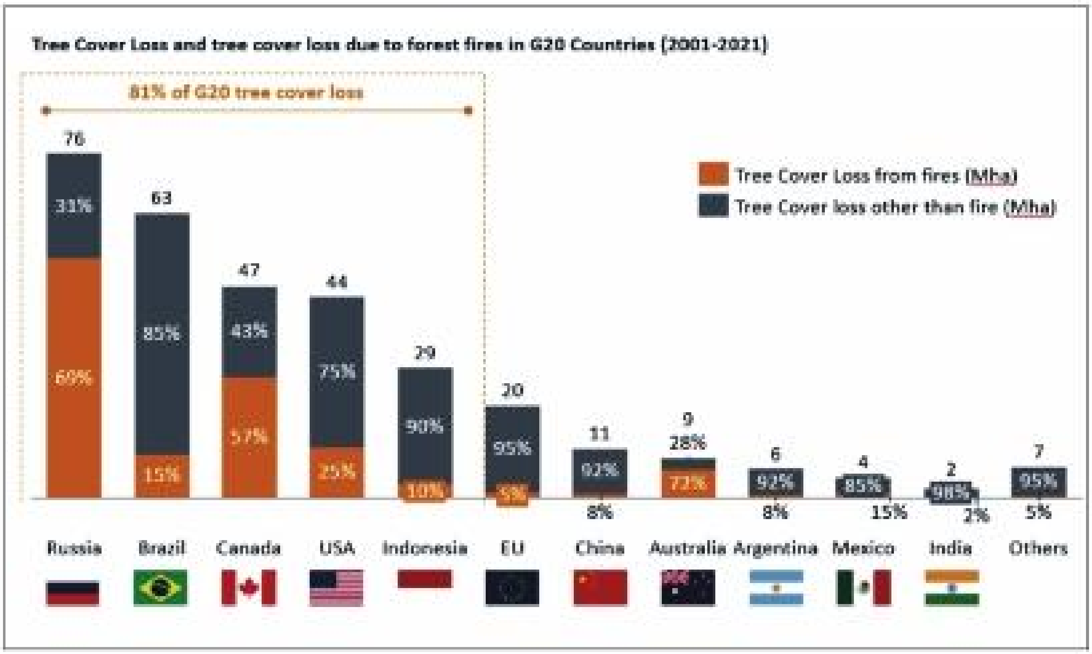


Figure 1.2.2.

Tree cover and tree cover loss due to forest fires in G20 Countries (2001-2021)

Data Source: *www.globalforestwatch.org*

Climate change and land-use changes are projected to make wildfires more frequent and intense, with a global increase of extreme fires of up to 14% by 2030, 30 % by the end of 2050 and 50% by the end of the century (UNEP, 2022). Forests are subject to increasing frequency and intensity of wildfires which is projected to increase substantially with continued climate change (Olsson et al., 2019). Furthermore, of the land degradation processes, deforestation, increasing wildfires, degradation of peat soils, and permafrost thawing contribute most to climate change through the release of GHG's and the reduction in land carbon sinks following deforestation (Olsson et al., 2019). It has also been acknowledged that wildfires disproportionately affect the world's poor, impede progress towards the UN Sustainable Development Goals and deepen social inequalities.

UNEP's 2022 report on wildfires released before the 5th session of the UN Environment Assembly (UNEA 5.2) finds an elevated risk for the Arctic and other regions previously unaffected by wildfires. It calls on governments to adopt a new 'Fire Ready Formula', with two-thirds of spending devoted to planning, prevention, preparedness, and recovery, with one-third left for response. Direct responses to wildfires typically receive over half of the related expenditures, while planning receives less than one per cent (UNEP, 2022).

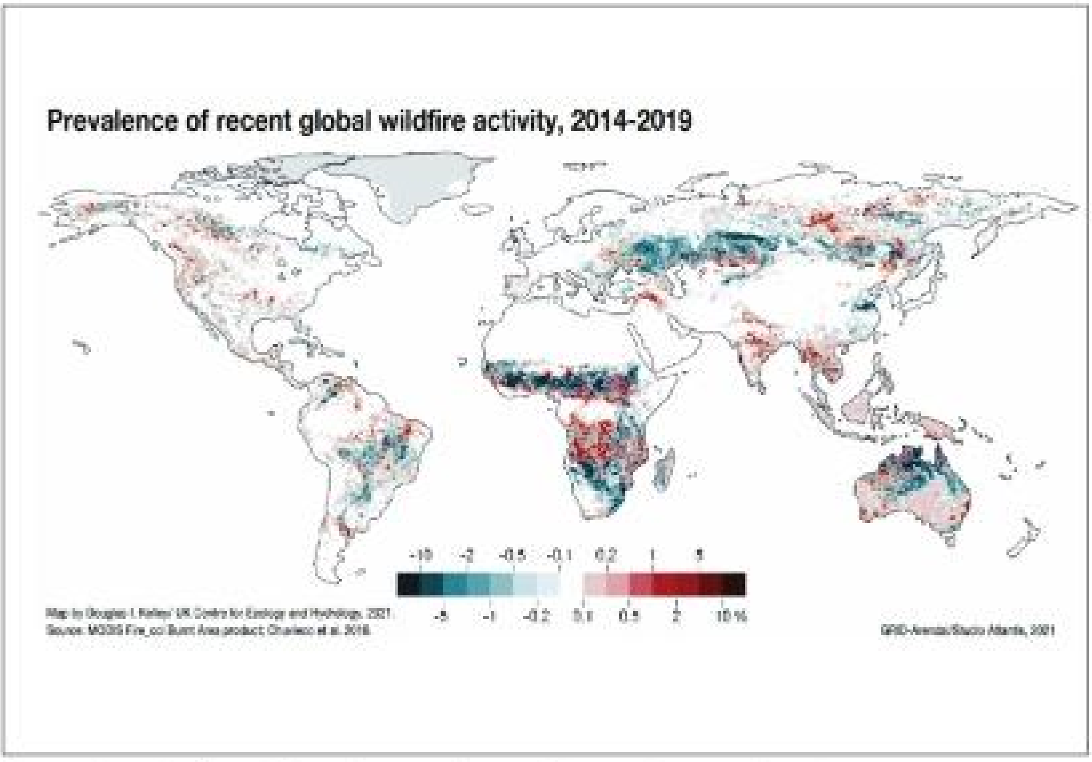


Figure 1.2.3.

Prevalence of recent global wildlife activity, 2014-2019

Source: *Spreading like Wildfire: The Rising Threat of Extraordinary Landscape Fires. UNEP-GRID-Arendal, 2022.*

The restoration of ecosystems is an important avenue to mitigate the risk of wildfires before they occur and to build back better in their aftermath. Achieving and sustaining adaptive land and fire management requires a combination of policies, a legal framework and incentives that encourage appropriate land and fire use.

1.2.2 Overall Landscape of Forest Fires

Forest landscapes have historically included fires as an integral part of their system. Fires have played a crucial part in succession and the churn of nutrients, aiding tree species in regrowth, getting rid of exotic weeds and maintaining some wildlife habitats. Forest fires are a regular phenomenon in G20 countries and are often observed during summer. As per UNEP between 2001 and 2021, about 111.74 mha (Excluding EU) tree cover loss was reported (UNEP, 2022). However, in recent years, wildfires in many G20 countries have claimed hundreds of lives, loss of property, and displaced large number of people.

Climate change, with an average increase in the temperature from 0.8°C to 1.5°C, has increased the forest fire frequency and intensity. America, EU, Australia, Indonesia, and Brazil have experienced mega-fires. In 2022, the Indonesian government declared a state of emergency in the Riau province due to forest fires, necessitating the implementation of urgent measures such as cloud seeding to stimulate rainfall. Similarly, Australia, suffered its worst fire season in history in 2019–2020, with an estimated 10.2 million ha burnt, including 8.19 million ha of native forest (FAO, 2022). As per a recent report, in India, there has been a ten-fold increase in forest fires in the past two decades, and more than 62% of Indian states are prone to high-intensity forest fires (FSI, 2021).

Grasslands occur on all continents and collectively constitute about 40.5% of the terrestrial area (Neary and Leonard, 2020). Any flora that is dominated by herbs, whether open woods or layers of savanna, falls under the category of grassland and grass fires are distinguished by a relatively narrow zone of flames advancing across finely divided and uniformly dispersed fuel (Daubenmire, 1968). However, fire has been and continues to be an important disturbance in grassland evolution and management (Neary and Leonard, 2020). It has been reported that grassland fires in recent years have increased, and in western US rangeland, large wildfires have increased over the last three decades (Li et al., 2022). Though the human ignites fires to improve animals and livestock habitat, but wildfires in grassland become an issue as drought persist in semiarid regions, because it affects the soils and water resources (Stavi, 2019).

Wildfires can be classified based on their nature and extent, and they are generally categorised as surface, ground, underground and canopy/ crown fire. Surface fire, i.e. spreading along the ground as the surface combustible materials on the forest floor in most of the tropical G20 nations. There are incidents of ground fire also reported in peat-land, organic soils and detritus under forest stands, which spread as a surface fire in the surrounding areas. There are reports of underground fires of low intensity and spread burn below the surface of a few meters. Canopy or crown fires reported from coniferous, eucalyptus, thorny forests, and Savannas often continual by a surface fire (Rein et al., 2008; Bond and Van Wilgen, 2012).

Nations are trying to place an effective prevention and mitigation mechanism to reduce damage due to wildfires. Most common prevention methods include reducing combustible material, laying fire lines, controlled burning, silvicultural practices (thinning and pruning) and planting fire-resistant species, etc. Forest fire zoning, early warning/ fire alert system, engaging fire reducing and firefighting techniques are used in most G20 countries as prevention and mitigation strategy. Prescribed burning is an essential part of wildfire mitigation across the Australian landscape to reduce risk to communities and maintain ecological health (AFAC, 2016). Further, fire agencies across Australia have developed programs, such as 'Community Fire Guard', which emphasize individual and shared responsibilities for the prevention of fires (Hesseln, 2018). In India, Forest Fire Prevention and Management Scheme (FFPM), is a centrally funded program to assist the States since

2017 to deal with forest fires effectively (MoEFCC & World Bank, 2018). In a few countries, a separate department is in place to prevent and manage forest fire, for example Forest Fire Prevention Department in South Korea. Providing education, knowledge and community participation is an effective measure to prevent forest fires.

1.2.3 Leading Causes of Forest Fire

Forest fire is recognized as a seasonal phenomenon, with most reported causes of forest fire being classified as accidental and anthropogenic. The changes in land cover, lightning activity and meteorology contribute to enhanced fire frequency and length of fire weather season (Huang et al., 2015; Jolly et al., 2015). Apart from anthropogenic pressures through land cover and land use change, global warming within the current context of global environmental change plays an exacerbating role in determining forest fire regimes. This is expected to enhance the recurrence and severity of wildfires in many biomes (Souza-Alonso, 2022). Distributions of temperature, vegetation coverage, distance to water bodies, distance to roads, and precipitation were found to be positively correlated with the occurrence of forest wildfires in Central Yunnan Province, China (Lan et al., 2022). High atmospheric temperatures and longer dry seasons (days) offer favorable conditions for a fire to start and sustain. As reported in the USA, 85% of wildfire are caused by human activities such as burning debris, unattended camp fires, negligence (e.g. discarded burning cigarettes), malfunctioning of equipment, fireworks, arson/ riots, etc. Accumulation of fuel load caused by current non-burn policies in fire-adapted ecologies and ecosystem type conversion (into agriculture, pasture lands, forestry practices and plantations) also is a major contributing factor (Kondrashov, 2006).

1.2.4 Global Experience on Losses and Damages

In recent years' forest fires have had a much wider impact than the previous decades, and as per the recent FAO report (2022), about 9.3 million hectares of global tree cover loss in the year 2021 alone is attributed to forest fires, which is of global concern. The land is vulnerable to forest fire, and frequent forest fire reduces the forest land productivity and ecosystem services. The physical and chemical properties of soil are altered due to the severity of forest fire, which further lead to loss of productive soil, increased runoff during wet periods, lower underground water recharge, and groundwater deficit (Olsson et al., 2019). More than 5.4 million ha of tree cover was lost due to a fire in Russia in2021, which is the highest in the past 20 years that has subsequently degraded the forest land (Mac Carthy et al., 2022). The seed resources declined due to frequent fires, which further affects the regeneration potential of forests. The successional process of the forest can also be altered due to the frequency and intensity of the forest fire (Olsson et al., 2019).

Forest fire danger and fire alert system based on satellite data and computer models, and Geographic Information Systems (GIS) has been one of the most practised approach for detecting and managing forest fire (Castro and Chuvieco, 1998; Lee et al.,2002; Roberto Barbosa, 2010). In G20 countries, the fire alarm system is used as a single system approach or in combination of multiple main systems, i.e. heat detectors, smoke detectors, carbon monoxide detectors and multi-sensors detectors (Chen et al., 2007). In India, MODIS sensors on-board Aqua and Terra Satellite, NASA and SNPP- VIIRS sensor data and GIS database are being used by the Forest Survey of India to alert the States on possible forest fire incidents. Reducing global wildfire risks is also a key component of the Agenda for sustainable development, 2030 and Sendai Framework for

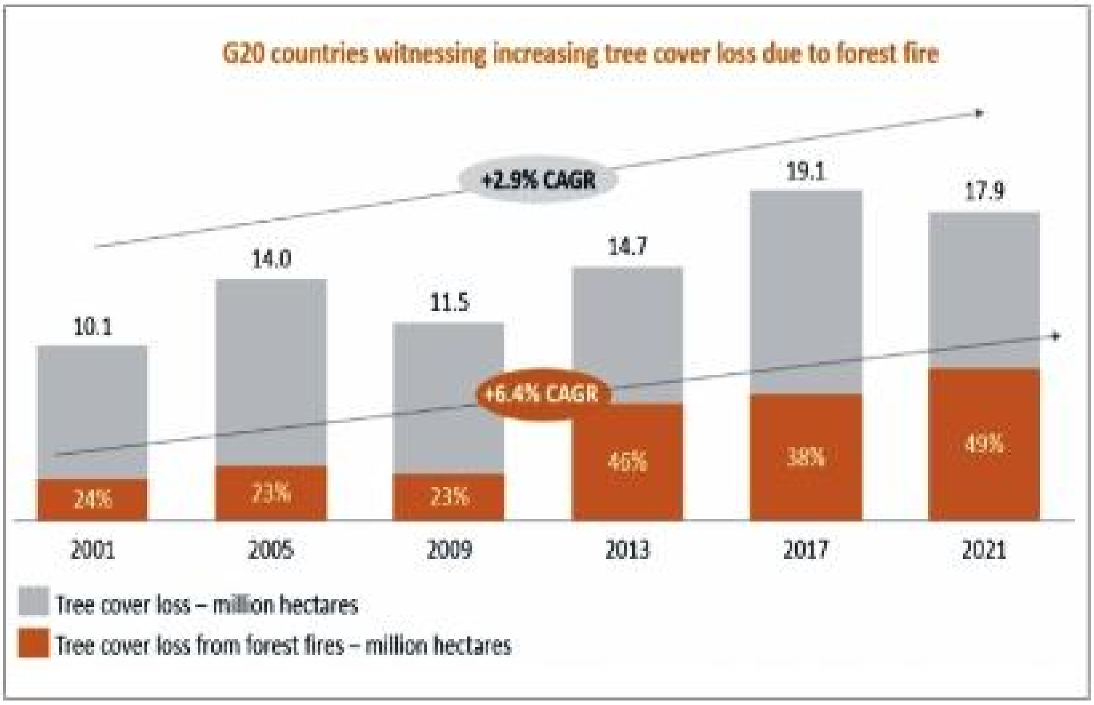


Figure 1.2.4.

G20 Countries witnessing increasing tree cover loss due to forest fire

Disaster Risk Reduction, 2030. Nature-based approach has been in practice to mitigate the forest fire. The nature-based includes silviculture, thinning and pruning in the dense forest, fire line creation and annual maintenance, watershed conservation, etc. (Miralles-Wilhelm, 2021). Science and technology can improve wildfire suppression effectiveness, and expertise and knowledge can improve capacity.

Globally, 118.8 million hectares of forest has been lost due to forest fires during 2001-2021 with 112.9 million hectares lost in G20 countries. 73% of tree cover loss (average for 20 years) occurred in G20 Countries during 2001-2021. 95% of tree cover loss due to forest fires (average for 20 years) has occurred in G20 countries during 2001-2021.

2019 was one of the worst years in terms of forest fires. Forest Fires engulfed large tracts of forest in the USA, Australia, Siberia, and the Amazon. The California wildfire season was overwhelming, with more than 2,59,823 acres burnt and costing about $80 billion in damage and economic losses. In 2018, fires burned through 1.8 million acres in the state compared to 1.3 million the previous year. Seven of California's ten most destructive fires have happened in the last four years (Goodman and Robinson, 2019).

1.2.5 Impacts of Forest Fires on Wildlife and Biodiversity

Wildfires can be disastrous to wildlife as they can cause extensive mortality Many scales of vegetation, from entire landscapes to specific plants, can be affected by wildfires. There is evidence that certain plant and animal species are threatened with extinction by wildfires. Forest fires have many implications for wildlife and biodiversity. The heat and emissions from the forest fire will contribute immensely to global warming, which can lead to changes in biodiversity structure and biomass stock, alter the hydrological cycle, impact the aquatic flora and fauna and also impact the wildlife functions (Davies and Unam, 1999; Nasi et al., 2002). The forest fire can further alter the migration pattern of wild animals leading to human-wildlife conflicts, including loss of crops, etc. In North Queensland, Australia, the aboriginal fire practices and fire regimes are historically controlled, where fire-prone tree-grass savannahs are replaced by the rain forest vegetation (Stocker, 1981). The forest fire invites invasive species to establish, subsequently altering the ecosystem properties and biodiversity. In Australia during 2019-20, the wildfire resulted in the loss and displacement of 3 billion animals.

Water catchments may be negatively impacted by wildfires. Contaminants, increased soil erosiveness, altered soil composition, and slope stability have long-term effects on production and quality. Careful fire management is necessary to sustain ecosystem function in sensitive habitats within water catchments without adversely affecting catchment performance.

1.2.6 Forest Fires and Climate Change

Forest fires greatly contribute to climate change by releasing greenhouse gases (GHG). A warmer climate causes woods to deteriorate and dry up, making them more fire-prone. A positive feedback loop is produced when the number and size of fires grow. Approximately 39 million t of methane (CH_4;1 t CH_4 = 21 t CO_2), 20.7 million tonnes of nitrogen oxides (NOx), and 3.5 million tonnes of sulphur dioxide (SO_2) are also released each year as a result of savannah and forest fires. These emissions total between 1.7 and 4.1 billion tonnes (t) of carbon dioxide each year. Forest fires are responsible for 15% of the world's GHG emissions, with the majority of these fires starting in tropical rainforests and converting the surrounding area. Almost 86% of soot and 32% of the world's carbon monoxide and methane emissions come from forest fires (Hirschberger, 2016).

The average global temperature has almost increased by 1°C against the pre-industrial period. A forest fire event is influenced by climatic conditions and is supported by the accumulation of fuel on the forest floor (Sharma and Rikhari, 1997). Climate change and land-use changes are projected to make wildfires more frequent and intense, with a global increase of extreme fires of up to 14% by 2030, 30 % by the end of 2050 and 50% by the end of the century (UNEP 2022). According to the IPCC, climate change increases the likelihood of drought, storms and weather anomalies and increases frequency of forest and grassland fires. Human-caused changes to climate, land management and demographics are fanning the flames, prompting a combination of dry lightning, droughts, lower humidity, stronger winds and warmer temperatures that can prolong natural fire seasons. Climate change enhances the drying of organic matter in forests (the material that burns and spreads wildfire), and has doubled the number of large fires between 1984 and 2015 in the western United States. Thus, forest fires could be viewed as an agent of change for forests as the fire regime will respond rapidly to climate warming. This change in the fire regime has the potential to overshadow the direct effects of climate change on species distribution and migration (Flannigan et al., 2016; Flannigan et al., 2000).

1.2.7 Significance of Ecosystem Restoration in Fire Impacted Areas

Ecosystem restoration in fire-impacted areas helps to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed (Souza-Alonso et al., 2022). In the case of fire-affected landscapes, experiences show that passive restoration may be as effective as active restoration, provided that soils are not severely affected. Restoration of fire burnt area helps to maintain the ecosystem services. The nations should incorporate the restorative principles in the fire-prone areas as the large-scale forest conservation and restoration can counter the forest fire. Restoration of forests within landscapes offers multiple social, economic, and environmental benefits that enhance the lives of local people, mitigate the effects of climate change, increase food security, and safeguard soil and water resources (Chazdon and Uriarte, 2016).

1.2.8 Role of Community Involvement in Forest Fire Management

Indigenous and local communities are known to play an important role in combating forest fires, restoring forest fire-affected areas and enhancing biodiversity. Several international platforms, including the Convention on Biological Diversity, the UN Declaration on the Rights of Indigenous Peoples, and the International Union for Conservation of Nature, have well recognized the role of these communities for the conservation and management of forests and biodiversity. Communities need to be better skilled and equipped to combat the adverse impacts of forest fires as they have to learn to live with fires. A significant effort is required to empower and provide adequate resources to indigenous people to restore ecosystems, biodiversity and cultural practices. Organizations such as the Pau Costa Foundation and Fire sticks (2022), an indigenous-led association based in Australia, prioritize education among young people and those living near or in fire-prone areas to reduce the potential of accidental ignitions.

1.3 FOREST FIRES AND CLIMATE CHANGE

1.3.1 Climate Change-Forest Vulnerability/Susceptibility and Risk

Paleoecological research indicates that fire regimes have evolved over time in response to climatic changes (Iglesias et al., 2015). Natural fires have influenced biological evolution and global biogeochemical cycles, making fire integral to the functioning of some biomes (Bowman et al., 2011). Every continent, except Antarctica experiences wildfires, and the majority of areas sometimes experience weather conditions that favour the start of a wildfire, and the risk they pose to the environment, and humans has been increasing due to various reasons, including climate change (UNEP, 2022). The risk of wildfire rises as a result of the intricate interactions of biological, climatic, physical, and social elements. For instance, due to favourable weather, the shift in climate increases the frequency and severity of wildfire outbreaks. According to UNEP (2022) it is highly probable that the arctic will experience a significant rise in burning by the end of centuary. This is according to the present projections. If greenhouse gas emissions continue at their current pace, tropical forest areas in Indonesia and the southern Amazon are likely to experience an upsurge in burning. The forest fire releases a massive amount of stored CO_2 into the atmosphere, and it will be irrecoverable in cases like Amazon's rainforest and Indonesia's peatlands, where massive amounts of carbon have been sequestered over the centuries (Verwer and Van der Meer, 2010; Jaenicke et al., 2011; Goodman, and Herold, 2014) and increase the global warming (Fearnside, 2008).

Fire regime, described based on fire intensity, frequency, size, seasonality, type and severity in a particular area or ecosystem (Flannigan et al., 2000), changes have been driven by climate and land use and, more recently, have also been influenced by fire suppression policies (Moreno et al., 2014), and likely vary in both temporal and spatial (Balshi et al., 2009).

Due to the interdependence of ecosystem components, a rise in windstorm frequency or fire frequency due to a changing climate will modify the forest species composition and physiognomy (structure). Scientific evidence indicates that climate change is causing changes in the global fire regimes (Noss, 2001; Krebs et al., 2010).

Compared to natural forests, plantations are frequently noticeably less resilient to disturbances like fire and more vulnerable to pest outbreaks (Schowalter, 1989; Perry, 1994).

In general, vegetation tends to shift toward more fire-tolerant species due to hotter, drier circumstances that tend to increase (Clark, 1990; Swetnam, 1993; Veblen et al., 1999; Veblan et al., 2000). Fire is essential for the persistence of many different types of forests and other plant groups (Mutch, 1970; Platt et al., 1988). Reviews of threatened ecosystems in North America reveal that fire suppression is substantially to blame for the collapse of many of the most threatened plant communities (Noss & Peters, 1995; Noss et al., 1995). However, human-caused fires threaten other forests, particularly in the tropics (Trapnell, 1959; Dudley, 1998). It has been shown that fire can cause long-term changes in flora, such as the Canadian boreal forest turning into tundra (Sirois & Payette 1991), and in Zambia, the arid tropical forest gives way (Trapnell, 1959).

Curiously, a 300-year fire history in the Quebecian boreal forest shows a significant decline in the number and size of fires without fire suppression, starting with a warming period 100 years ago (Bergeron & Flannigan 1995), indicating that the predicted increase in the fire with climate change is not necessarily widespread. In any case, efforts to prevent intense forest fires by regularly conducting controlled fires and/or understory thinning have been far more effective than those to put out extreme forest fires (Moore et al., 1999; Stephenson, 1999). a hybrid approach whereby managers let many natural fires burn, protect ancient growth from stand-replacing fires (to the greatest extent practicable), and manage other stands through controlled burning and understory reduction to lower the danger of high-intensity fire may be an optimal approach.

1.3.2 Relationship between fire emissions and global warming

Forest fires are a considerable contributor to aerosol and greenhouse gas emissions, water vapour modifying the radiative balance of the Earth as well as the devastation of thousands of acres of land each year. These emissions have been found to have a major impact on global warming (Singh, 2022). Based on studies of forests in Canada and America, most of the carbon emissions do not come directly from trees but also from other parts of them such as brush, forest floors, leaf litter and even from under the ground. Direct carbon emissions from fires release 2.0 Pg of carbon annually, or around 22% of all world emissions from fossil fuels, which has a significant impact on air quality, human health, and climate change (French et al., 2011). Aerosols block the ground surface from receiving solar energy, while greenhouse gases absorb it, and atmospheric transport of black carbon (soot) and its subsequent fallout in the cryosphere decrease the albedo and accelerate snow and ice melt. Extremely hot fires can also cause pyrocumulonimbus storms to form, injecting aerosols into the stratosphere where they can travel around the world and affect radiation budgets (Bowman et al., 2020). The expansion of vulnerable areas in high-elevation forests, earlier snow melt, longer fire seasons, and higher summer temperatures all together cause a rise in wildfire activity (Running, 2006). Global warming affects the shifts in carbon sequestration patterns and several aspects of fire (Van Bellen et al., 2010).

Climate is a key global indicator of fire patterns. Fire regimes are affected by weather, vegetation, and explicit human activity. In regions where global warming is a major problem leading to drought conditions, it is projected that fire frequency and intensity, two factors usually used to define fire regimes, would rise, at least in the medium term. New fire regimes will emerge from it (Marlon et al., 2008; Flannigan et al., 2009; Aponte et al., 2016). 9.3 million hectares of tree cover have been lost worldwide in 2021, one of the worst years for forest fires since the start of the century. This represents more than a third of the whole tree cover that year. Climate change is likely a key contributing factor to the rise in fire activity. Extreme heat waves are already five times more likely to occur now than they were 150 years ago due to the earth's continuing warming (Global Forest Watch, 2022).

Forest fires have become more frequent in recent years, primarily as a result of climate change and anthropogenic activities, causing significant socioeconomic and environmental losses. Therefore, post-fire restoration is essential to preserving the ecology of forests and the long-term viability of the impacted forest areas (Alyan et al., 2022). Severe weather events are directly affected by climate change since rising temperatures and less precipitation led to the severity of floods and forest fires (Angra and Sapountzaki, 2022). The main factor contributing to the increase in forest fires is climate change due to global warming (Singh, 2022).

Table 1.3.1

GHG Emissions from various fire categories based on the global fire emissions database (GFEDv4)

Forest Category	CO_2	CH_4	N_2O	All	Contribution %
Savanna	4.85	0.19	0.17	5.21	65
Boreal Forest	0.51	0.07	0.04	0.62	8
Temperate Forest	0.17	0.01	0.00	0.19	2
Tropical Forest	1.07	0.11	0.04	1.22	15
Tropical Peatland	0.23	0.10	0.01	0.33	4
Agricultural Waste Burning	0.44	0.06	0.01	0.50	6
Total	**7.27**	**0.53**	**0.27**	**8.08**	**100**

Source: *IUFRO 2018*

The climate mostly impact fires in two ways, the moisture content of both live and dead fuels is decreased during the months immediately before the fire season, which increases the chance of fire ignitions and spread. However, heavy rains a year or two earlier will increase the number of herbaceous fuels, which later raises the likelihood of ignitions and fire spread (Westerling et al., 2002). Even in tropical rainforests, where wildfires are common and particularly destructive, the fire season is growing more extreme and broader. This is true even for some forest ecosystems where wildfires are normal. Climate change related to hotter, drier weather as well as careless land management, lead to conditions that encourage frequent, massive and intense wildfires (Global Forest Watch). The vicious cycle worsens as more carbon from flames is released into the atmosphere, further accelerating global warming. This creates a positive feedback loop that magnifies how frequently strong fires are caused by extremely hot, dry weather, leading to higher forest carbon emissions. Continued deforestation and global warming are predicted to approach tipping points that will lead even the largest intact forest biomes to change from net sink to net source of billions of tonnes of stored forest carbon, as forecasted for the Amazon rainforest (WWF International, 2020).

Forest fire is an important driving force in regulating the flora and fauna of the ecosystem. It may be beneficial for particular species, and at the same time, it may be harmful to another species (Smith, 1995). Long before humans arrived on earth, fire as a natural force appears to have had a crucial role in shaping, placing, and growing the diverse plant groups in the Mediterranean. But as far as man was concerned, it became one of the most crucial tools for man-kind to clear forests in the simplest, quickest, and least expensive manner possible (Viegas, 1997). The overstory of coniferous composition is determined by fire frequency, creating a natural distance between the stands. To combat barren substrates and stop degradation, fire may also play a role in recycling nutrients from the ground-layer plants and litter to the overstory trees (Vogl, 1974). Greater densities of opportunistic species, higher tree seedling and shrub cover, and lower species richness are all present in areas under bigger burned patches than in smaller patches (Turner, et al., 1997).

1.3.3 Impacts due to Climate Induced Forest Fires

Fire influences forest structure and composition, creates landscape mosaics of different land-cover types, and directly impacts biogeochemical cycles. The present forests have been shaped in part by past fires (Heinselman, 1973, Wright and Bailey, 1982). Fires influence the forest in interaction with other processes. The fire regime results from interactions between fuel, topography and weather. The forest structure, moisture content and spatial continuity are also important. Ecosystem dynamics result from interactions between natural disturbances like fires, insect population fluctuations and weather patterns. These disturbances occur as discrete events with typical disturbance frequencies, sizes and severities over large spatial and temporal scales. For example, Mc Cullough et al., (1998) reviewed the interaction between fire and insects. The interactions between natural disturbances could be synergistic and change rapidly as the climate changes.

The climatic drivers of disturbances will vary strongly depending on the particular variable and the geographical area, though temperature-related variables have been the most prominent climatic drivers. More than half of the observations reported in the literature related to direct climate effects (Flanagan et al., 2000), which were the most prominent pathway. Abiotic disturbances, including forest fires, are often the direct consequence of climatic extremes and are thus highly sensitive to changes in their occurrence, intensity and duration. Climate change may already be causing increased fires, though current fire frequencies are within the expected range based on the historical past. Many models predict that current fire management will face difficulties by more frequent extreme fire-conducive weather conditions (Fried et al., 2004). The response of the fire regime to changes in climate will be both long-term and short term and may override the other effects of global warming on species distributions and population declines. Fire, exacerbated by climate change will catalyse global vegetation change. For example, Westerling et al. (2011) suggests that climate-driven fire frequency increases over the next century could transform the Yellowstone Ecosystem from conifer forests to more open vegetation types. Changes taking place include increased fire season length, frequency, and burned area (USGCRP, 2018; Westerling, 2016). Within forest stands, more frequent fires will likely decrease tree density in dry forests, and open savannas may increase in area. Forest understories may shift to shrub- or grass-dominated- factors, including warmer springs, longer summer dry seasons, and drier soils and vegetation will lead to this change (Halofsky et al., 2020). Halofsky et al., (2020) conclude that in the Pacific Northwest of USA, while the total area burned by fire may not be controllable, fuel treatments implemented spatially in a strategic manner may help to decrease fire intensity and severity and improve forest resilience to fire, insects, and drought. Parks et al., (2016) suggested that fire severity in a warming climate may not change significantly in the Northwest because of limitations in fuel availability. Because of climate change, the increased frequency and extent of fire will increase the likelihood of short-interval reburns- there is limited understanding of how earlier fires affect subsequent fires and how forests respond to multiple fires. Climate change may cause high severity canopy fires to become more common, replacing stands (Prichard et al., 2017). Repeated fires in the same area Multiple fires can interact as linked disturbances, with each other and pest attacks, for example (Simard et al., 2011), to produce compound disturbance effects (Paine et al., 1998), which are different from single fires.

1.3.4 Prediction and Trend

According to recent studies, climate change is dangerous to the southern Amazon's fire regimes. This could reduce the region's capacity to operate as a net carbon sink rather than a source by increasing the amount of land burned during drought. Both the post-2020 scenarios that include and exclude deforestation demonstrate this occurring regularly. In other words, the area would see its worst droughts ever, with a 10C warming trend above average between 2010-2015. These areas may have burned more than 3.6 million hectares during those years, an increase of nearly 110% compared to the extent of the 2007 fires. According to predictions, the burned forest area will increase from 17% to 41% by 2030 versus the period from 2002 to 2010 (Soares Filho et al., 2017; Brando et al., 2019). According to the GFDL and the CGCM, climate change-induced variation fire probability in the US ranged from 40% to over 275% (Guyette et al., 2014). Most climate models predict the greatest warming at higher latitudes and on land compared to over water. Precipitation, wind, cloudiness and the variability of extreme events are also predicted to be altered (Mearns et al., 1989, Solomon and Leemans, 1997). Overpeck et al., (1990) predict universal increases in fire frequency with global warming, though increasing temperature alone does not necessarily guarantee greater fire disturbance because of the interactions between disturbances. Evidence has been found for a substantial influence of climate on disturbances via direct, indirect and interaction effects. The climate would influence wildfire potential by modulating fuel abundance and aridity in fuel and aridity-limited environments (Little et al., 2009).

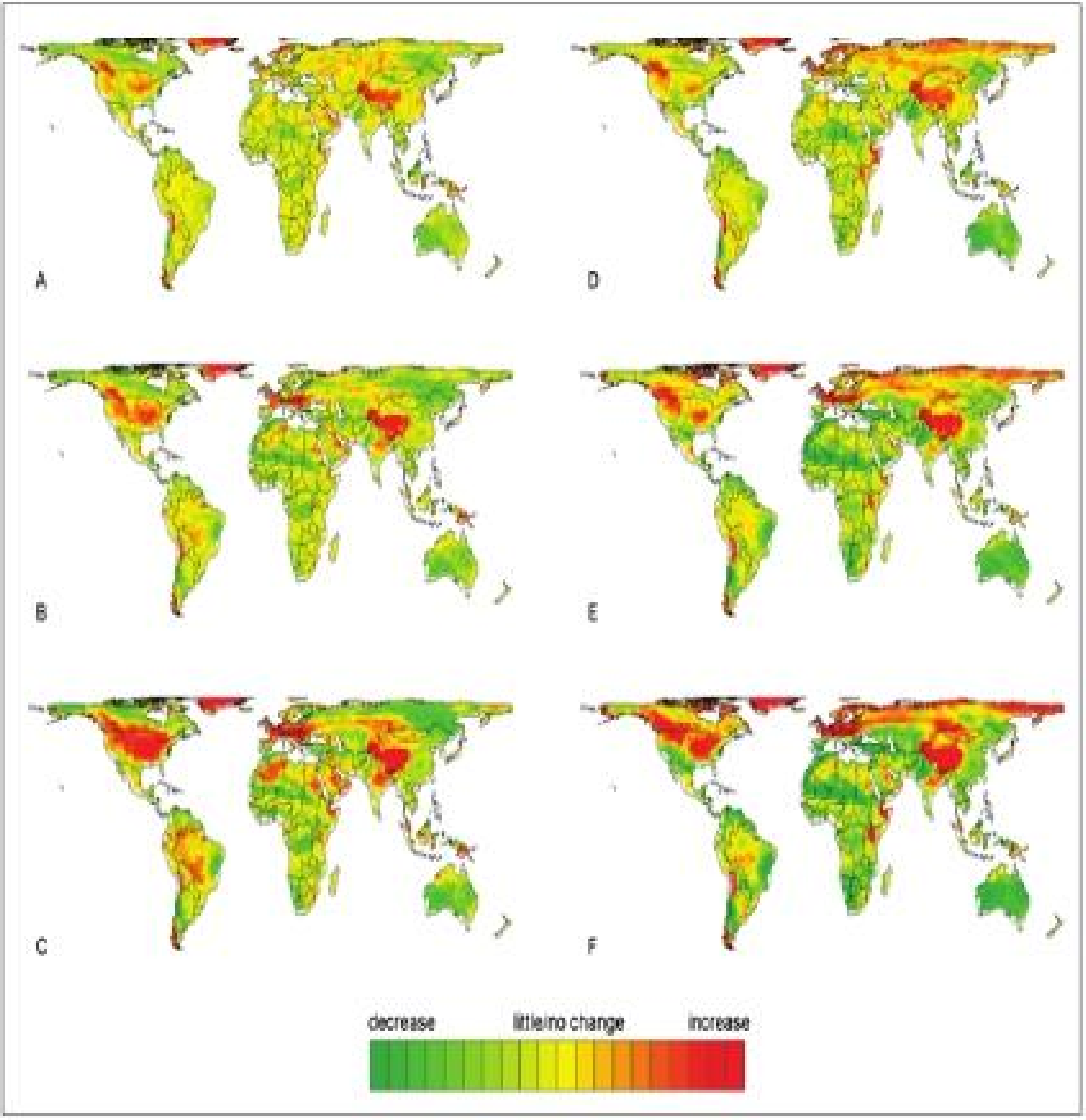


Figure 1.3.1

A2 (mid-high) emissions scenario has affected the global distribution of pixels that are prone to catching fire. (Krawchuk, et al., 2009)

1.3.5 Climate Mitigation to Manage Forest Fire

Resistance and resilience stand out as critical ideas when it comes to a pantheon of adaptation and mitigation concepts and approaches. (Holling, 1973; Waide, 1988; Millar and others 2007; Luce, Morgan, Dwire, Isaak, & Holden, 2012). To reduce risks associated with wildfire, the choices available to managers are somewhat limited in their general nature, although there may be many variations in details available for each to increase local suitability. Some of the general methods are 1. Fuel treatment 2. Hill-slope restoration 3. Fire suppression 4. Post-fire stabilization.

Fuel treatments include carefully managed mechanical removal of specific fuels that cause forest fires. (e.g. dry twigs, dry leaves and branches). Reducing fuel materials, altering the fire behaviour and intensity, and aiding fire suppression are some of the goals of fuel treatment processes (Graham and others, 2004; Luce, Morgan, Dwire, Isaak, & Holden, 2012). Managers may consider installing fuel breaks around valuable resources in regions with less effective fuel treatments (Halofsky et al., 2020).

In most forest ecosystems, hill-slope restoration refers to road repair, upgrade, or decommissioning with the goal of reducing erosion and mass wasting. In a broader sense, there are related activities applied to mined, over grazed, or logged sites. Reducing impacts from sediment over the longer term before a fire occurs helps to build populations and communities that are more diverse and productive and, thereby, more resilient to fire effects. (Luce, Morgan, Dwire, Isaak, & Holden, 2012).

Fire suppression becomes the default activity for reducing risks to forest and aquatic resources without strategic planning and implementation of other restoration actions. Fire suppression can be very successful, but caution should be taken for the few fires that escape initial attack can burn intensely and severely. Fire suppression should be only one tool in the "tool box" which is a broader plan for fire management for long-term ecosystem resilience.

Post-fire stabilization practices are done after fires to "suppress" post-fire erosion events. The nature of stabilization activities is diverse, but the most commonly applied measures focus on restoring strength to the soil to keep soil particles in place. In general, emergency stabilization is authorized for the protection of human life or property, although it can be applied for the protection of unique resources as well, including threatened or endangered aquatic fauna. (Luce, Morgan, Dwire, Isaak, & Holden, 2012). When post-fire planting is an option, using a different genetic stock may increase seedling survival (Halofsky et al., 2020).

1.3.6 Challenges and Opportunities in the Changing Climate

Availability of atmospheric CO_2 is positively associated with drought resilience of Amazonian forests by improving plant water use efficiency. On the other hand, a rise in forest productivity also increases the chance of fires by making the forest more flammable, particularly in years of severe drought (Swann et al., 2016; Faria et al., 2017). New problems arise from the need to understand the vulnerability and resilience of forest and forest fringe communities toward climate change. Forests offer a variety of economic and ecological services to communities linked with the adaptation of communities toward climate change(Locatelli et al., 2010). High fire suppression expenditures and a rise in hazardous emissions are two global concerns that have a harmful impact on human health (Goldammer et al., 2008; Flannigan et al., 2009).

Wildfire management organisations are required to make a conceptual shift to improve their capacity for prevention, strengthen values, and enable more managed wildfire on the landscape. Organisations need to align their capacity and capability to use a risk-based strategy that supports both wildfire suppression and use (Tymstra et al., 2020).

1.3.7 Climate Mitigation and Adaptation in Forest Fire Management

Several climate change mitigation management strategies, such as the use of flexible harvesting methods (like low-intensity logging), application of fire management, restoration of degraded forests, reduction of forest deforestation, and eradication of additional pressures to forests, will increase the resilience of tropical forest to forest fire. Low-intensity logging techniques result in less logging debris, more canopy cover, healthier trees, less risk of hazards, and greater fire resistance in forests. In addition to the ecological environment, effective fire control institutions and laws are crucial tools for adjusting to increased fire vulnerability due to climate change (FAO, 2003; Herawati and Santoso, 2011). Enrichment planting can give chances to establish a high genetic variation, especially in commercial areas vulnerable to extinction where post-logging silviculture operations are absent.

1.3.8 Forest Restoration and Biodiversity Recovery in the Changing Climate

Farimen et al., (2016), used the fire-tolerant and fire-sensitive eucalyptus forest of south-eastern Australia to evaluate the consequences of increased wildfire frequency on temperate forests. They examine historical and contemporary evidence, which suggests that if fire periods are shorter than the early stages of the species, recurrent wildfires can lead to a transition from a fire-sensitive forest to a non-forest condition. They highlight interesting issues and identify potential changes in forest structure brought on by higher tree mortality and poorer recruitment in their investigation of the consequence of increased fire frequency on fire-tolerant forests. But depending on the species present, some ecosystems might be more resilient to frequent fires.

In Indonesia, peat-land is crucial to mitigating climate change; its function extends to both economic and social dimensions. The study was carried out to determine how much CO_2 is preserved by community-based fire prevention and rewetting programmes. The result revealed that about 1 million Mg C, which is equal to 3.7 million CO_2, was preserved by these programs. The approach successfully prevented emissions from the sensitive areas, including plantations, dry land agriculture and swamp vegetation (Usup et al., 2021).

Ensuring restoration objectives are considered during the planning, decision-making, and implementation stages will assist in updating the outdated restoration methods and management strategies for post-forest fire restoration (Alayan et al., 2022). The prime objective of the forest fire prevention program is to minimize human-caused fires. Fire prevention experts often refer to the 3-E of prevention: engineering, education, and enforcement (Martell, 2015). To effectively manage and control forest fires, communities must be involved in the planning process, and their viewpoints must be taken into account. This terrible threat will be greatly diminished by an integrated strategy that considers ecological, economic, social, cultural, and religious concerns as well as the logical competence of the local people through consultation processes (Vasudeva, 2018).

1.4 METHODOLOGY FOR EVALUATION OF BEST PRACTICES

This review used an extensive literature review approach to identify scientific literature on the current state of forest fires in G20 member countries. The search included key terms synonymous with forest fires with particular focus on post-fire restoration globally and in the G20 member countries. Furthermore, the search scope was broadened to review National Action Plans and Strategies for trends in fire in G20 countries and post-fire restoration. Data extracted from various literature sources has also been utilized to provide an overview of the forest fires in member countries, its impacts on biodiversity, land degradation and climate change, the institutional mechanism for responding and recovering from incidences of megafires within the country. Further to a review of literature, examples of best practices, current state of play in G20 member countries on post-fire restoration has be compiled through information provided by G20 member countries and international organizations including UN Environment Programme (UNEP), Food and Agriculture Organization of the United Nations and the UN Convention to Combat Desertification (UNCCD)

Chapter 2

2

G20 MEMBER COUNTRY PROFILES ON FOREST FIRES

2.1 REGION : AMERICAS

ARGENTINA

Overview

- Of the total of 746,748.4 hectares affected in 2021 (through 6,251 fires), 7.50% were native forest, 78.19% rangeland, 10.98% shrub, and 1.20% cultivated forest. There is a small percentage (2.13%) of the area from which the vegetation type could not be determined.
- With respect to the Native Forests, the provinces of Córdoba (57.23%), La Pampa (15.86%) and La Rioja (12.50%) account for 85.59% of the burned area. The province of Formosa was the most disturbed, representing 45.60% of the total area burned in the country. The affected area in Entre Rios accounted for 18.58% of the total, placing it in the second most affected provinces in 2021.

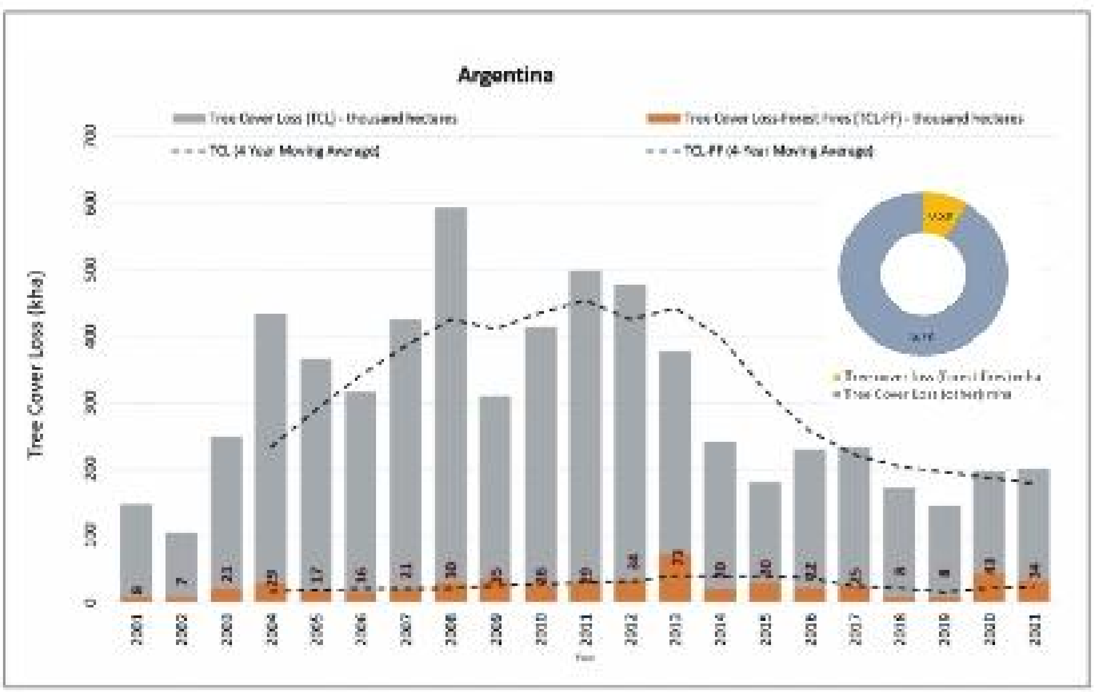


Figure 2.1.1.

Tree cover and tree cover loss due to forest fires in Argentina (2001-2021)

Source: *Global Forest Watch*

Tree Cover Loss Due To Fires:

From 2001 to 2021, Argentina lost 535kha of tree cover from fires and 5.78Mha from all other drivers of loss. The year with the most tree cover loss due to fires during this period was 2013 with 72.7kha lost to fires -19% of all tree cover loss for that year.

Regions with most Tree Cover Loss Due To Fires:

From 2001 to 2021, Santiago del Estero had the highest rate of tree cover loss due to fires with an average of 7.71kha lost per year.

Proportion of Tree Cover Loss Due To Fires:

Fires were responsible for 8.5% of tree cover loss in Argentina between 2001 and 2021.

Key Ecosystems Susceptible to Forest Fires

- Native forests in Argentina represent 19.2% of the country's surface (excluding Antarctica and the islands of the South Atlantic) and cover an area of 53.6 million hectares (ha) distributed in seven main forest regions: the Paranense Forest (o Misionera), the Yungas Argentinas (o selva tucumano-boliviana), the Chaqueño Park, the Andean Patagonian Jungle, the Espinal Argentino, the Mount and Delta Argentino and the Paraná River Islands. These regions have specific characteristics and dynamics, and are subject to different human and natural pressures.
- For the protection of these forests, Law No 26.331 has minimum budgets for the environmental protection of Native Forests that aims to promote their conservation, control the decrease in their surface and promote sustainable management, among others. This law has Strategic Technical Guidelines (LTE), agreed at the federal level among the 23 provincial jurisdictions that make up the Native Forest Land Management, through Resolution 360 of the Federal Environment Council (COFEMA), which serve as a guide to implement actions and ensure that the Law contributes effectively to development processes, achieving comprehensive land planning and promoting the rational use of forests. Among the guidelines mentioned are two dedicated to the problem of loss of forests due to unplanned fires; one for Forest Fire Prevention and another focused on Forest Management in Interface Areas. The first involves actions that reduce the likelihood of loss of native forest surface and/or functionality as a result of forest fires and/or interfaces and thereby promote resilient communities and landscapes. The second guideline focuses particularly on areas where urbanization processes advance over forested areas resulting in increased risks of starting and spreading fires that not only affect the forest, but also put life and housing at risk. On the other hand, these guidelines include the Restoration of Degraded Forests that includes those areas of native forests affected by; agricultural frontier advance, overgrazing, forestry without planning, urban growth or land occupation and forest fires.
- Through Resolution 497 COFEMA, in 2022 it was agreed among the provinces to carry out a planning of use of the National Fund for Enrichment and Conservation (FNECBN), created by Act No 26.331 to

strengthen national and provincial enforcement authorities and to promote the implementation of sustainable management and conservation plans with native forest holders and users, through the Provincial Strategic Plans for Native Forests (PEBN) based on the six strategic technical guidelines and thus mobilize resources based on these guidelines.

- Although since the adoption of the Forest Law, deforestation rates at the national level have decreased significantly, the loss of forests remains a concern, so political, technical and financial efforts, are mainly aimed at preventing deforestation through different measures to value native forests as a factor of local development, which promote restoration. Without detriment to this, the restoration of areas affected by fires, more than by other causes, is being addressed jointly between the National Forestry Directorate and provinces such as Chubut and Neuquén.
- Specifically, under the framework of the Strengthening of institutional capacities for the implementation of the National Native Forest Protection Program, the National Forest Authority has made agreements with several institutions to finance management, restoration and remediation activities for native forests affected by fires. One of them was with the Secretariat of Forests of Chubut to finance management and remediation activities in the areas of La Comarca Andina (El Hoyo, El Maitén, Lago Puelo and Cholila) affected by forest fires in 2015 and 2021 that affected 46 thousand hectares. The agreement concluded with the Pulmari Interstate Corporation is to finance activities included in the project "Restoration of the

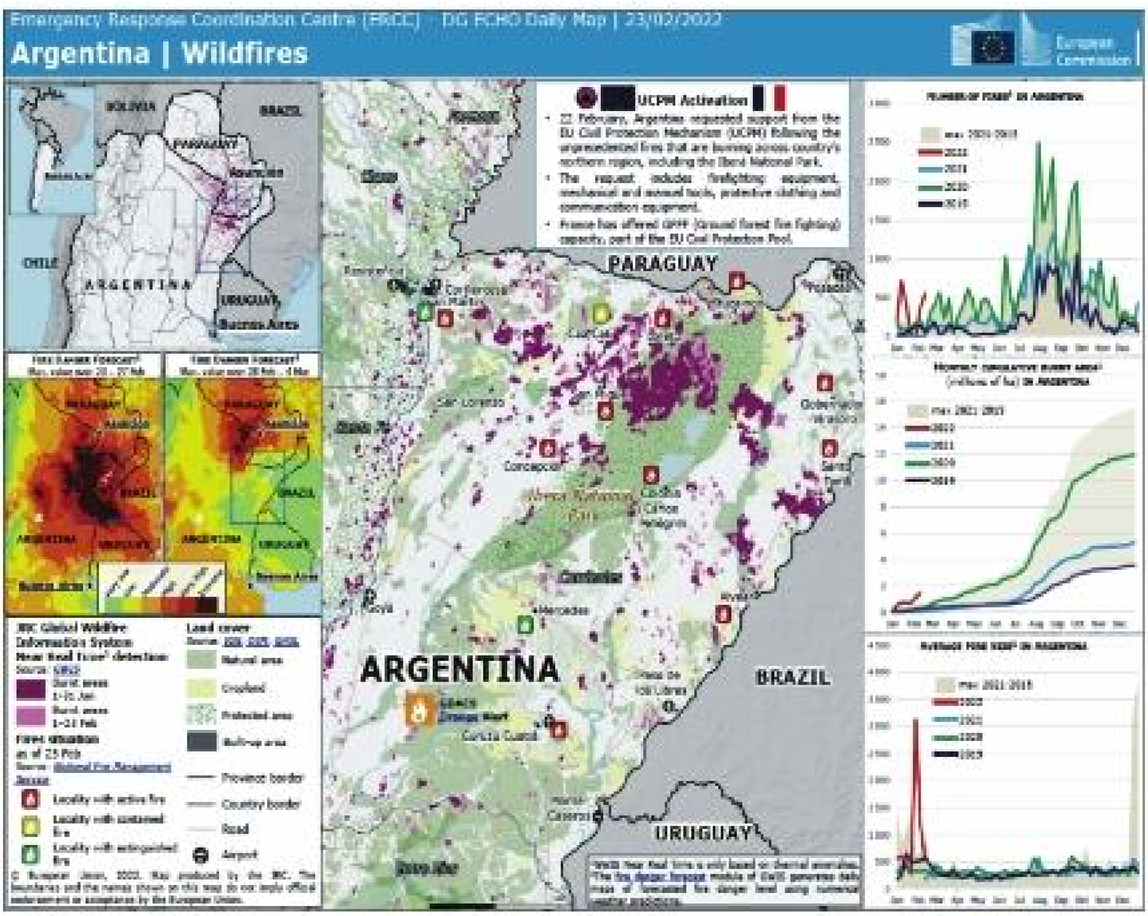


Figure 2.1.2.

Argentina Wildfires

Andean Patagonian Forest in the CIP". One of the goals stipulated is the restoration of the native forest of the Moquehue Basin (Dpto. de Aluminé, Neuquén) affected by fires in 2010, 2013 and 2017.

- In relation to native forests, restoration processes are costly and long-term, and to achieve them, certain social, institutional, technical and financial conditions must be in place to ensure viability and sustainability. In principle have a good diagnosis of damage, establish priority areas and define the best techniques to promote the recovery of ecosystem services (management of regeneration, enrichment, reforestation, closures, etc.). Achieve care commitments with the people of the lands on which the practices and the society that benefits from forest services under restoration processes will be carried out; ensure the provision of seedlings with local genetic material and nearby areas (when it comes to active restoration methods: enrichment/reforestation) and that these have adequate ground conditions to achieve their implantation (planting operations in summer period, irrigation possibilities, physical barriers for protection of browsing in early stages, etc). To all the above, the most important thing is to have a robust inter-institutional articulation that involves local forestry services, municipalities, rural development agencies, educational institutions, fire management services and civil society organizations, to achieve sustained and long-term commitments, in which having planning, mobilize human and financial resources to achieve the desired objectives with social involvement.

Causes of Forest Fires in Argentina

- The causes of forest fires in Argentina have been attributed predominantly to human activity. These are mainly caused by agricultural practices, such as using fire to clear land for crops or grazing livestock, as well as burning garbage and other waste.

Key Institutions Involved in Forest Fire Prevention and Management in Argentina:

The National Fire Management Plan provides a system of federal coordination and support to the provinces in activities related to fire management in Argentina through its administrative scheme 21 as described below.

National Coordination Centre: The National Coordination Centre is responsible for equipping the regional centres with equipment and technical support, developing and coordinating prevention plans, promoting research activities, training staff, coordinate the removal activities required by the regional authorities and organise air operations. It shares responsibility for producing fire statistics with the Native Forest Resources Authority, also under the Secretariat for Sustainable Development and Environmental Policies.

Regional Centers: The Fire Management Plan has grouped provinces with similar fire behavior and occurrence problems in six regions and installed a regional center in each. These centers are responsible for the development and implementation of a fire management program for the provinces under their jurisdiction. The provincial governments coordinate activities with the different local administrations and are responsible for the initial fire attack.

Figure 2.1.3.

Key Institutions involved in forest fire prevention and management in Argentina

Role of Research and Academic Institution in Generating Relevant Knowledge

- The National Institute of Agricultural Technologies (INTA) conducted the first courses on prescribed burns. Today, the National Fire Management System (PNMF) and provincial services are working together with international cooperation, which translates into significant progress in fire management throughout the country.
- Argentine institutions, INTA and CIEFAP (Centro de Investigación y Extensión Forestal Andino Patagónico) work on various fire-related projects as part of the European FIRE PARADOX program.

Community Involvement and Engagement in Forest Fire Management

Community Fire Management Training are administered in Argentina through:

- The National Fire Management System scheme for coordination where the government provides training to community members on how to prevent and manage forest fires through its Regional Centers. Training includes fire prevention, fire-fighting techniques and the use of equipment, and post-fire restoration of damaged or degraded forests. Communities are involved in reforestation efforts, including tree planting and protecting young trees from fires.
- Public awareness campaigns to educate communities about the risks of forest fires and how they can prevent them. These campaigns include radio and television spots, as well as educational materials such as brochures and posters.
- Volunteer fire brigades have been established to respond to forest fires, composed of community members who are trained to respond to fires and assist in fire-fighting efforts.

Capacity Building Initiatives

- National Fire Management Program (PNDF), a national program in Argentina that aims to strengthen the capacity of provinces and municipalities to prevent, control and mitigate forest fires. It includes research, training and education initiatives, as well as partnerships between different levels of government, communities and other stakeholders.
- Fire Management Brigades, which are community groups that provide fire management services to local communities. They are made up of trained volunteers who are responsible for responding to forest fires in their communities and neighboring areas.
- The National Institute of Agricultural Technology (INTA) provides research and development support for agriculture and natural resource management, including forest fire management. INTA supports research on fire behaviour, fuel management and fire ecology with the aim of improving forest fire management practices.
- The National Parks Administration (NPA) is a federal agency in Argentina that manages national parks and other protected areas, including forest fire management. APN coordinates resources, provides training and equipment, and supports research and development in forest fire management.
- Fire Education and Prevention Programs are conducted regularly by the government through its regional centers that provide education and training to communities on the causes and prevention of forest fires. They include programs for schools, community events, and public awareness campaigns.

BRAZIL

Overview

- Brazil has the largest primary rainforest in the world but also the highest amount of primary forest loss. In 2021, over 40% of tropical primary forest loss occurred in Brazil, equivalent to 1.5 million hectares.
- The loss is mostly due to changes in land use, deforestation and the use of fire to convert forests into agricultural and pasture areas.
- There was a significant increase in out-of-control forest fires in 2019 and 2020, particularly in the Amazon and the Pantanal, which led to record-breaking wildfires in the Pantanal that affected almost 30% of the biome's area.

Tree Cover Loss due to Fires:

- Fires were responsible for 15% of tree cover loss in Brazil between 2001 and 2021. With climate change effects expected to cause more extreme climatic events, the risk of severe fire events is likely to increase.

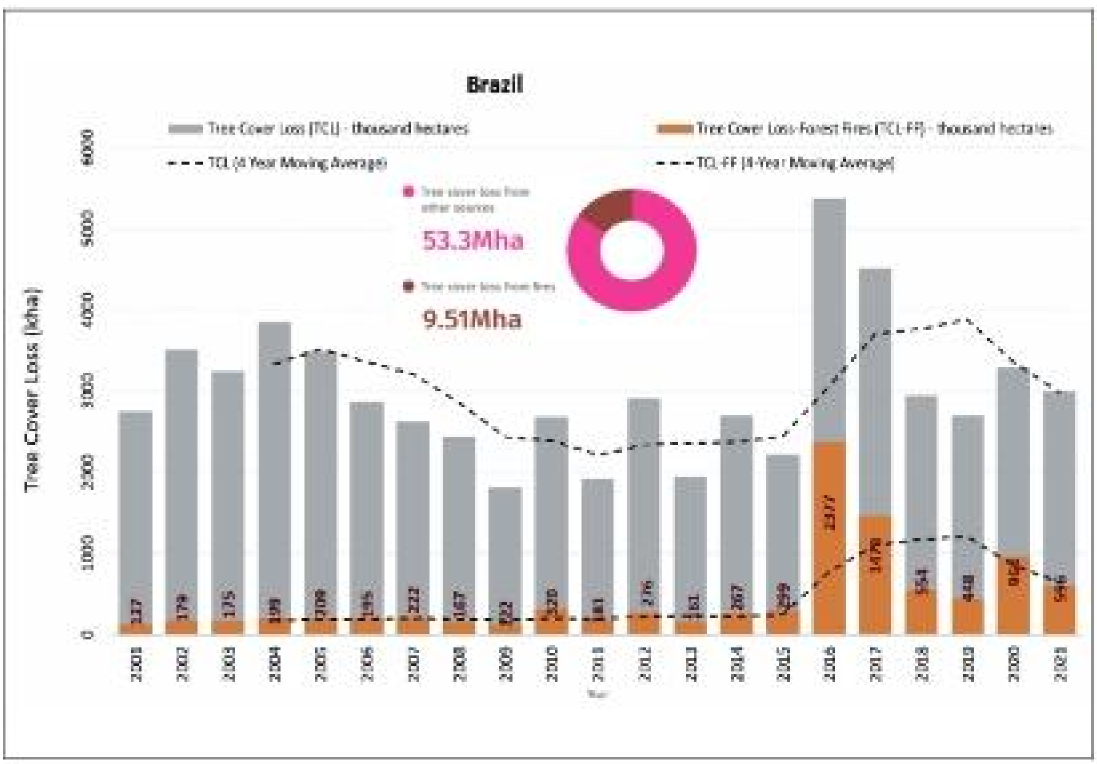
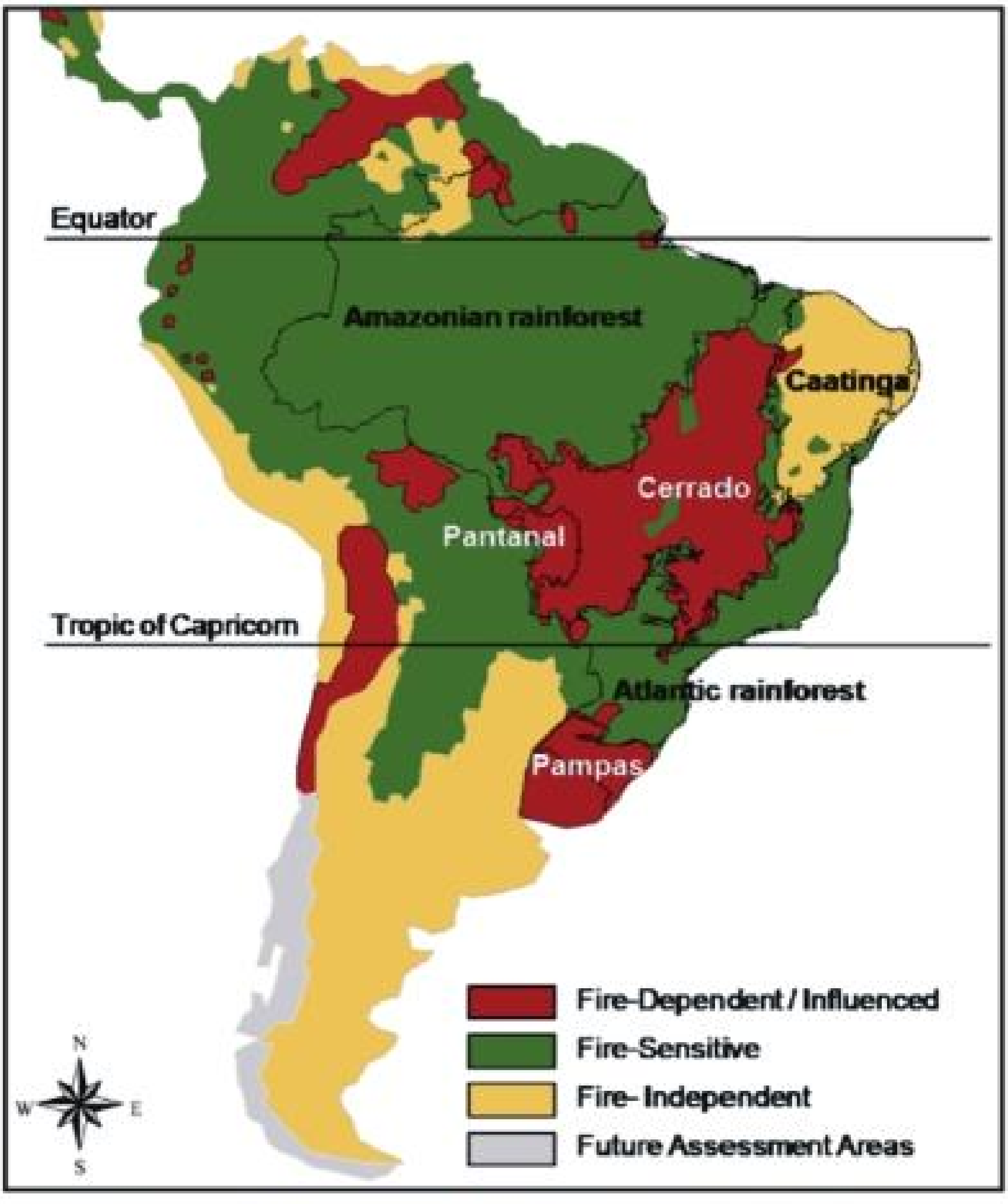


Figure 2.1.4.

Tree cover and tree cover loss due to forest fires in Brazil (2001-2021)

- From 2001 to 2021, Brazil lost 9.51 Mha of tree cover from fires and 53.3 Mha from all other drivers of forest loss. The year with the most tree cover loss due to fires during this period was 2016, with 2.38 Mha lost to fires — 44% of all tree cover loss for that year.
- **Cumulative Burned Area:** In Brazil, 730 kha of land burned in 2022. This total is normally compared to the total for previous years going back to 2001. The most fires recorded in a year was in 2007, with 36 Mha.

Regions with Most Tree Cover Loss Due To Fires: From 2001 to 2021, Mato Grosso had the highest rate of tree cover loss due to fires with an average of 129 kha lost per year.



Brazilian biomes and their relationship with fire (Hardesty *et al.*, 2005).

Figure 2.1.5.

Brazilian biomes and their relationship with fire

Causes for Forest Fires in Brazil

Key Institutions Involved in Forest fire Prevention and Management in Argentina:

The National Center to Prevent and Combat Forest fires (PREVFOGO) is the country's main federal structure making efforts to combat forest fires and unauthorized burn-offs directly. A series of new fire policies and management initiatives were introduced, including the Programme for Prevention and Control of Fires in the Brazilian Amazon Forest (PROARCO), with the main goal of controlling and preventing large-scale wildfires in the Brazilian Amazon.

One of the key objectives of PREVFOGO is to establish a systematic fire protection program through a network of organizations. This includes a National Center at the headquarters of IBAMA, a federal government agency responsible for environmental protection and conservation. PREVFOGO's strategy also involves collaborating with other institutions such as the National Institute for Space Research (INPE), the Chico Mendes Institute for Conserving Biodiversity (ICMBio), the National Institute of Colonization and Agrarian Reform (INCRA), and the National Indigenous Foundation (FUNAI), among other state entities.

Role of Research and Academic Institution in Generating relevant Knowledge

The National Institute for Space Research (INPE) aims to advance scientific research and technological applications in space and atmospheric sciences, as well as space engineering and technology, and to provide training for personnel in these areas. It also (INPE) researches forest fires using satellite images and remote sensing techniques.

The National Institute of Amazonian Research (INPA) researches the Amazon rainforest and its ecosystem services, including wildfire management. INPA support research on topics such as fire behaviour, fuels management, and fire ecology to improve wildfire management practices. Embrapa (Brazilian Agricultural Research Corporation) – Embrapa, UFMT (Federal University of Mato Grosso), USP (University of San Paolo), among others, also focus on researching fire management in Brazilian ecosystems with an aim to develop strategies to prevent, monitor, and manage fires, as well as restore areas affected by forest fires.

Community Involvement and Engagement in Forest Fire Management

Under the PREVFOGO and PROARCO programmes, the Brazilian government has trained community members to become firefighters and create local brigades trained to respond to fires, conduct controlled burns, and monitor the forest for potential fires. Local communities and organizations are invited to manage fires collaboratively, including resource sharing, development of fire management plans, and coordinating response efforts. Community-based training programmes for communities located in or near forested areas are trained to monitor forest fires and report them to authorities, aiding in the prevention and spread of forest fires. Further, the Brazilian government and various non-governmental organizations conduct educational and outreach programs to inform communities about the concerns associated with the spread of wildfires.

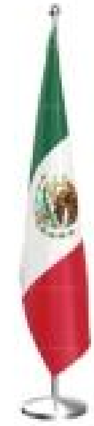
Capacity Building Initiatives

1. Floresta+ Program: is a payment for environmental services, including a component that refers to the voluntary carbon market, helping foster private sector investments for forest conservation in areas with native vegetation coverage.

2. The World Bank project on using Technology to Monitor Deforestation and Prevent Forest Fires in Brazil's Cerrado Biome (The World Bank, 2022) has provided innovative public and private sector instruments to address deforestation and forest fires, achieving a transformational impact on Brazil's Cerrado Biome to address deforestation and forest fires actively. The tools generated from this are currently in use by more than twenty (20) national agencies responsible for strategic aspects of law enforcement, first response and monitoring of deforestation, fire prevention, and biodiversity conservation in the Cerrado Biome.

The U.S. Agency for International Development (USAID), in partnership with the Government of Brazil and the U.S. Forest Service (USFS), is launching the Brazil Forest Management and Fire Prevention program. This incorporates fire prevention and management, governance and management of forests and natural resources, and the sustainable use of protected public lands. Program partners will work closely with stakeholders to strengthen technical capacity in those areas while promoting women and indigenous people's participation and leadership in forest and fire management.

MEXICO



Overview

- Forest fires have been devastating the country's natural resources and the vegetation on steep slopes, often inaccessible terrain during the extended dry seasons set for hundreds of wildfires each year. The wildfires cost a loss of government and private property every year and, occasionally, life of the firefighters (González and Sandberg, 1989).
- Over the past decade, Mexico has experienced a rise in the number of fires, with several years seeing more fires than usual, i.e. in 2011 (12,113 fires), 2013 (10,406), 2016 (8422), 2017 (8896), 2019 (7410), and 2021 (7337), except for a record high in 1998.
- The severity of these fires has also increased, with some areas now categorized as "very high" severity. This increase in fires and severity is likely due to global climate change, which has led to rising temperatures and increased the risk of wildfires, in addition to increased risk from human activity, particularly agricultural activities.
- The peak fire season in Mexico typically begins in late March and lasts around 14 weeks. There were 8,680 VIIRS fire alerts reported between the 31st of January 2022 and 23rd of January 2023 , considering high confidence alerts only. This is normal compared to previous years, going back to 2012.
- In Mexico, fires were responsible for 15% of tree cover loss in Mexico between 2001 and 2021, and 120 kha of land has burned so far in 2022. This total is normally compared to the total for previous years going back to 2001. The most fires recorded in a year were in 2011, with 3.8 Mha.
- From 2001 to 2020, Campeche had the highest rate of tree cover loss due to fires, with an average of 6.94 kha lost per year.

Key Ecosystems Susceptible to Forest Fires

Mexico has a vast forest area of approximately 64 million hectares, covering 34.5% of the country and are classified into different types based on the tree species and biome, including tropical, temperate, cloud, riparian, deciduous, evergreen, dry, and moist forests.

Rainforests are mainly located along the southeastern Atlantic coast, where the climate is warm and rainy throughout the year, with an average rainfall of more than 2,000 mm and temperatures between 23°C and

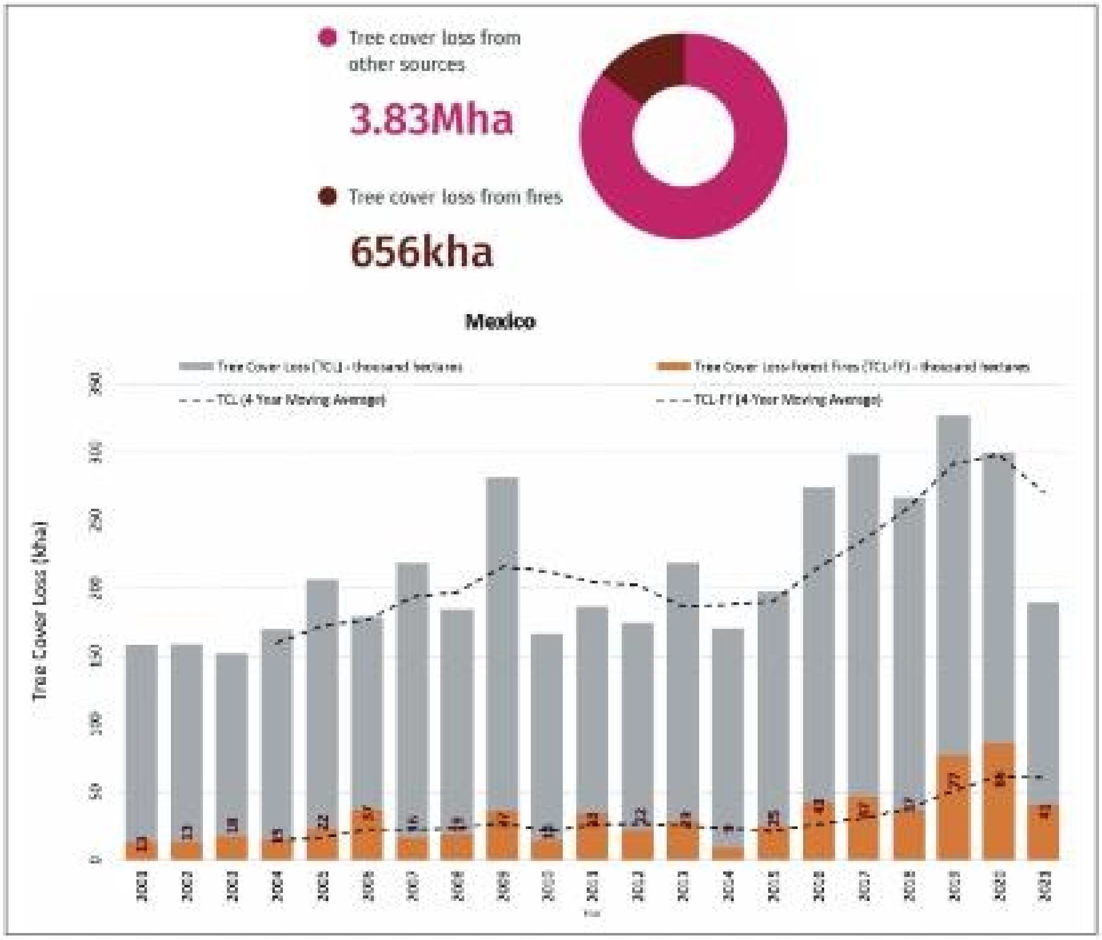


Figure 2.1.6.

Tree cover and tree cover loss due to forest fires in Mexico (2001-2021)

Source: *Global Forest watch*

25°C. Despite being partly or entirely destroyed outside of the protected areas, the Lacandon rainforest remains the largest montane rainforest in North America, providing habitat for jaguars, over 1,500 tree species, 33% of all Mexican bird species, 25% of all Mexican animal species, 44% of all Mexican diurnal butterflies, and 10% of all fish species in Mexico.

Mexico is home to about half of all pine species (50) and one-third of all oak species (around 200). Temperate forests in Mexico are estimated to have around 7,000 plant species. The southwestern Pacific Coast of Mexico has a series of diverse tropical dry forests adapted to seasonal droughts. This global ecoregion is made up of eight terrestrial ecoregions, including Jalisco, Balsas, Bajío, Chiapas Depression, Sonoran-Sinaloan, Southern Pacific, Sinaloan, and Sierra de la Laguna dry forests. The Jalisco dry forests are a diverse region in Mexico where trees lose their leaves for an extended period during the dry season, and the forest rarely burns.

Temperate forests in Mexico, especially pine and other coniferous forests have been most vulnerable to fires. These forests are important for their high diversity of pine and oak species, and fire plays a crucial role in their ecological dynamics. While fire can be destructive, it also serves a beneficial purpose in these ecosystems. For instance, certain species of pine, such as *P. douglasiana*, *P. durangensis*, *P. oocarpa*, and *P. devoniana*, depend on fire to survive, while others, like *P. greggii*, *P. attenuate*, and *P. patula*, rely on fire to promote the release of their seeds and support natural regeneration.

Causes For Forest Fires In Mexico

The frequency of forest fires in Mexico is influenced by both climate anomalies and human activities, such as the traditional practice of slash-and-burn agriculture, intentional burning for agriculture, and land-use change. Agricultural activities are estimated to cause at least 40% of forest fires in Mexico (CONAFORE 2001). The proximity of agricultural activities to forests and accessibility to forest ecosystems also affect their fire vulnerability. Invasive species, changes in land use, and illegal logging can also increase the likelihood of forest fires.

In Mexico, the number of forest fires shows a maximum during the spring months (April to May), i.e. during the period of minimum precipitation, when the highest maximum temperatures are observed (Magan˜a, 1999). After the onset of the rainy season, between June and July, few forest fires are detected. Therefore, most of the analysis focuses on forest fire activity during the first half of the year. The seasonality in forest fires also coincides with the beginning of the spring–summer rain-fed agricultural cycle, when slash and burn practices are common inmost of the country.

Key Institutions Involved In Forest Fire Prevention and Management In Mexico

The 1998 record high fire season changed Mexico's fire management policies and practices (Rodriguez-Trejo et al., 2011). Government agencies, universities, and institutes—such as the Comisión Nacional Forestal (CONAFOR), Secretaría de Medio Ambiente (SEMARNAT), Comisión Nacional de Áreas Naturales Protegidas (CONANP), Instituto Nacional de Investigaciones Forestales Agrícolas (INIFAP), Universidad Autónoma Chapingo (UACh), and Colegio de Postgraduados (CP) laid the foundations for fire ecology research and practice, integrated community management in rural areas, and fire prevention and combat (Domínguez & Rodríguez-Trejo, 2008) .

Until 2012, Mexico's national forest fire program focused on completely suppressing fires by contracting helicopters to douse the flames. State forest fire programs were weak and there was little institutional coordination. In 2013, the country recognized that the total suppression of fires was not enough, and the country's national forest fire program was restructured to consider the climate change concerns.

An agreement among institutions emerged regarding creating a public policy that recognizes the ecological and social importance of forest fires. This policy acknowledges that some fires can actually be beneficial, particularly in ecosystems like pine forests that are adapted to fire. Forest fires can promote regeneration by releasing seeds from cones, controlling pathogens and invasive species, maintaining natural pastures, and protecting wildlife habitat. By acknowledging these ecological and social functions of forest fires, the policy has shifted from one that entirely suppresses fires to one that manages them. This shift in policy emphasizes a more nuanced approach to fire management that considers the potential risk and benefits of employing varied fire management strategies.

Role of Research and Academic Institution in Generating Relevant Knowledge

Historical advances in fire management, particularly since the 1980s, include growth in the capacity to fight forest fires. During the 1980s, the US Department of Agriculture's Forest Service and the US Agency for

International Development (USAID), as well as the Spanish and Canadian governments, assisted the forest services of Mexico and other countries of the region in initiating a formal training plan, which currently continues to have an active training role. These organizations have also provided financial and technical support during periods of extreme fire activity in the region. Presently, the ideals of fire management in the region are to maintain appropriate fire regimes and to restore degraded areas, conserve biodiversity, reverse deforestation, maintain and promote the forms of subsistence and local economies, reduce catastrophic fires, and increase the use of prescribed fires with ecological and productive objectives.

Major reforms to fire management in Mexico occurred post the 1998 fire season, where institutions of research and learning ways have significantly contributed, including the Universidad Autónoma Chapingo, the Universidad de Guadalajara, the University of Washington, the Instituto Nacional de Investigaciones Forestales (INIFAP), and the Universidad Autónoma Agraria Antonio Narro. Instrumental non-government organizations (NGOs) include The Nature Conservancy and Fondo Mexicano para la Conservación de la Naturaleza. In addition, the Mexican government (Comisión Nacional Forestal and Comisión Nacional de Áreas Protegidas) has played a critical role in furthering research on post-fire management.

besides leading and generating policies, laws, and operations the federal government (fire protection organizations and biodiversity conservation organizations), has promoted analysis and direction. The institutions of teaching and research, along with investigating and including these topics in the universities, thus contributing to the formation of new generations with a new mentality with respect to fire, have also participated actively and operatively in fire management. Together, these organizations form a synergy of effort and policy determination that would be less effective if any of them were to not participate.

Community Involvement and Engagement in Forest Fire Management

The majority of forests in Mexico, around 80%, are communally owned and managed legally. The communal management of forests provides effective social and institutional mechanisms to ensure that local communities can be involved in fire prevention and control, post-fire management and restoration efforts.

- **Community-based fire prevention and control committees:** In Oaxaca, the government has worked with local communities to create community-based forest fire prevention and control committees. These committees comprise community members responsible for identifying potential fire hazards, developing fire prevention strategies, and coordinating the response to forest fires in their areas. The committees also work with government agencies to access resources and training to improve fire management skills.

- **Traditional ecological knowledge:** In Michoacán, the government has worked with indigenous communities to incorporate traditional ecological knowledge into forest fire management strategies. This knowledge includes practices such as controlled burning, which can help prevent the spread of wildfires.

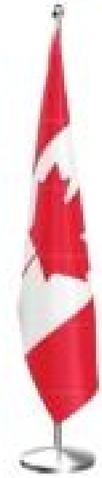
- **Education and awareness-raising campaigns:** The Mexican government has launched several education and awareness-raising campaigns to engage communities in forest fire management. For example, the National Forestry Commission (CONAFOR) has developed a program called "Fire Prevention and Control in Forests and Grasslands," which includes educational materials and training programs for communities. The program also works with community leaders to organize community events to raise awareness about the importance of forest conservation and fire prevention.

Capacity Building Initiatives

Although the fundamental pillars of fire management were not changed, the restructured National Forest Fire Program provides enhanced coordination between three tiers of government and increased participation by society in the management of forest fires. Particularly the range of measures implemented includes:

- Increased community-based fire management and training for rural teams.
- Agreements between CONAFOR with federal, state and local agencies.
- Establishment of Incident Command System (ICS) and incident management teams.
- Establishment of the National Center for Forest Fire Control, six regional centres and 32 state centres.
- Increasing the number of forest firefighters from 5,000 to 22,000.
- Upgradation of personal protective equipment and acquisition of tools, vehicles and tanker trucks.
- Improvement in the management of fuels.
- Capacity building of forest fighters and technical staff.
- Bolstering international cooperation with the United States, Canada, the Dominican Republic, Colombia and other Central and South American Countries.
- Promotion of public engagement.

CANADA



Overview

- Canada holds 9% of the world's forests, covering an area of 362 million hectares, with the forest sector contributing $34.8 billion to the country's nominal GDP in 2021.
- Since the 1970s, the average annual area burned has doubled, with wildfire experts predicting this number will double again by the end of the century(USEPA, 2021). Natural disturbance-related emissions have generally increased since the mid-2000s, with wildland fires alone emitting carbon equal to the annual total carbon emissions from burning fossil fuels across the country.
- Factors contributing to changes in the risk and behaviour of wildland fires include past practices of suppressing fires, expansion of the wildland-urban interface and climate change.
- Long-term solutions to limit the area burned and the severity of fires involve proactive forest and fire management strategies such as reducing fuel loads by thinning trees, conducting planned burns, removing deadwood, planting fire-tolerant tree species and creating additional fire breaks.

Tree cover loss due to fires: From 2001 to 2021, Canada lost 26.8Mha of tree cover from fires and 19.9Mha from all other drivers of forest loss. The year with the most tree cover loss due to fires during this period was 2013, with 1.98Mha lost to fires - 71% of all tree cover loss for that year.

Regions with Most Tree Cover Loss Due To Fires: From 2001 to 2021, Saskatchewan had the highest rate of tree cover loss due to fires, with an average of 292kha lost per year.

Key Ecosystems Susceptible to Forest Fires

The majority of the burned area occurs in the boreal and taiga forests. Lightning and people are the main ignition agents in Canada, accounting for roughly 50% of fires each. Forest regions of Canada include Boreal Forest, Great Lakes-St Lawrence Forest Region, Acadian Forest Region, Deciduous Forest Region, Coast Forest Region, Subalpine Forest Region and the Columbia Forest.

Causes for Forest Fires in Canada

Multiple factors contribute to changes in the risk and behaviour of wildland fires. These include past practices of suppressing fires, which have disrupted the natural role of wildfires in restoring ecosystems. Additionally, Indigenous cultural burning, which has been used for thousands of years to manage landscapes, has been excluded. Another factor is the expansion of the wildland-urban interface, which has led to more people, activities, and assets in forested areas. Climate change is also significant, with rising temperatures, irregular precipitation patterns, and drier forest conditions exacerbating fire risk.

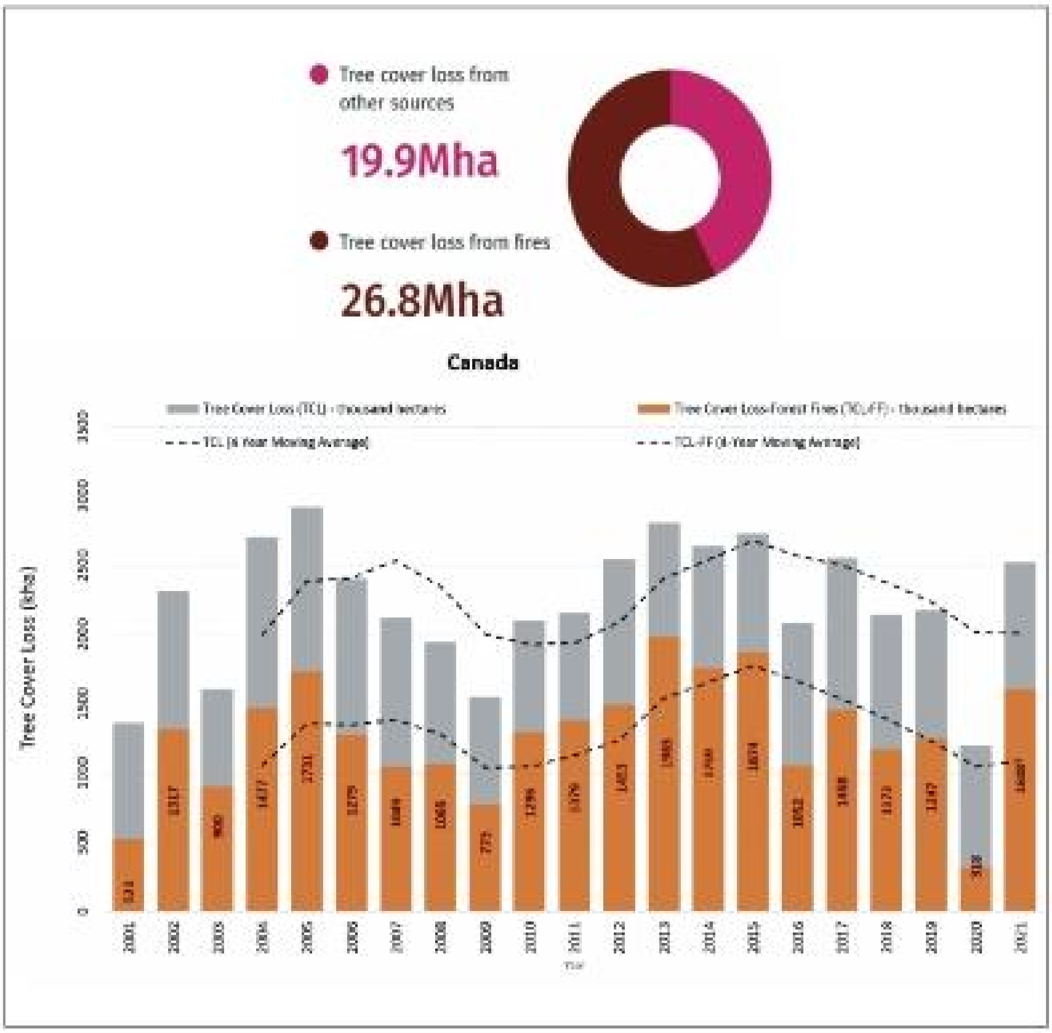


Figure 2.1.7.

Tree cover and tree cover loss due to forest fires in Canada (2001-2021)

Source: Global Forest watch

Key Institutions Involved in forest fire Prevention and Management in Canada

- Natural Resources Canada (NRCAN) is the department of the Government of Canada responsible for developing and implementing policies related to forest fire management, as well as providing scientific research and technical expertise.
- Parks Canada, the agency of the Government of Canada which manages the country's protected areas, is responsible for managing national parks and other protected areas. They play a key role in preventing and managing fires within these areas.
- Provincial and territorial agencies have their agency responsible for forest fire management. These agencies coordinate fire suppression efforts, provide public education, and monitor fire activity within their jurisdiction.
- The Canadian Interagency Forest Fire Centre (CIFFC) is the national organization that coordinates firefighting resources across Canada.

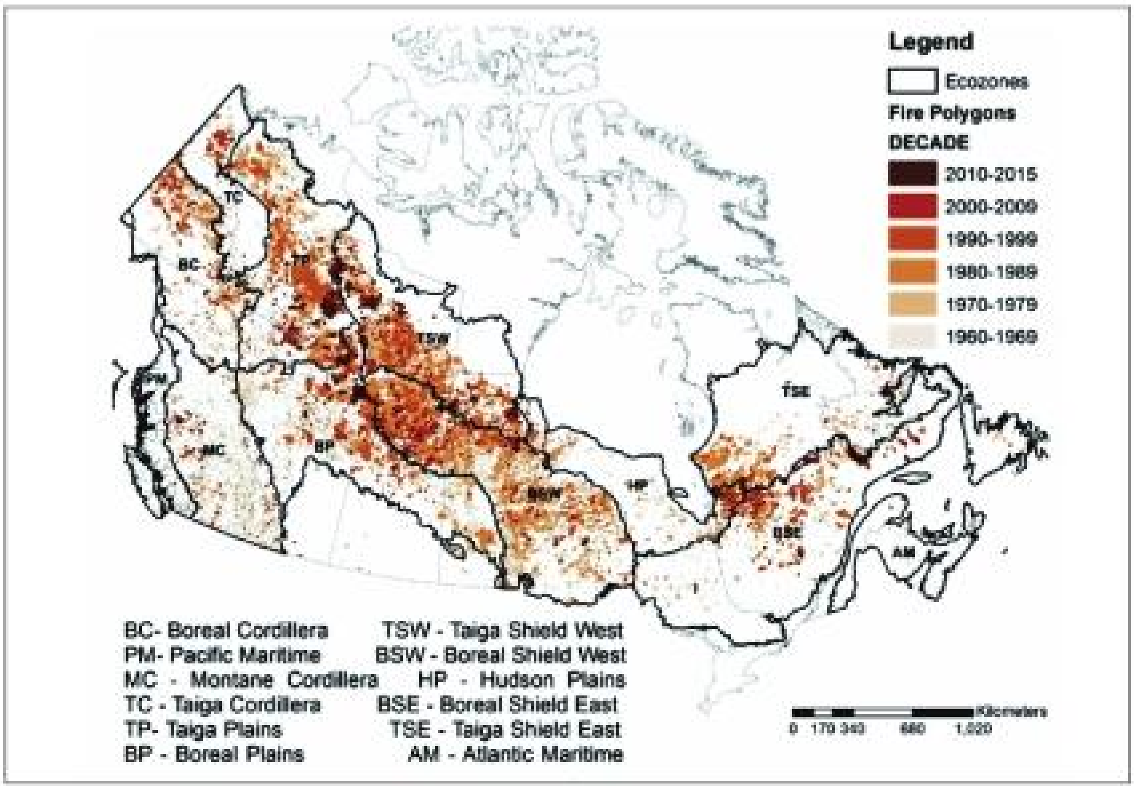


Figure 2.1.8.

National Distribution of large fire (>200 hs) polygons in Canadian ecozones

- Public Safety Canada coordinates and supports emergency management efforts in Canada, including forest fire management. They work to ensure that emergency responders have the resources they need to respond to natural disasters, including fires.

Role of Research and Academic Institution in Generating Relevant Knowledge

- Wildfire research in Canada achieved a significant accomplishment with the development of the Canadian Forest Fire Danger Rating System (CFFDRS), which includes the Fire Behaviour Prediction (FBP) System and the Fire Weather Index (FWI) System. The Canadian Wildland Fire Information System (CWFIS), provides data and maps of fire danger conditions across Canada.
- The Wildfire Threat Rating System (WTRS) assesses and maps four main components of fire risk - ignition, values at risk, suppression capability, and expected fire behaviour
- The Canadian Forest Service has developed extensive fire models and applications, ranging from hourly predictions of fire growth to long-term assessments of fire susceptibility over multiple years.
- The Probabilistic Fire Analysis System (PFAS) is a long-range fire growth model that combines the probability of a fire's spread with its survival.

Community Involvement and Engagement in Forest Fire Management

In recent years, Canada has made significant strides in recognizing and respecting the rights of Indigenous peoples, as outlined in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the establishment of the Truth and Reconciliation Commission (TRC). This has led to greater efforts to involve Indigenous communities in decision-making, particularly in the context of meeting international conservation targets such as those set out in the Convention on Biological Diversity (CBD).

The Government of Canada has created the Indigenous Guardians Program to support these conservation efforts. There is a unique opportunity to combine community-based knowledge and expertise with western science to protect and restore resilient ecosystems. The Canadian Forest Service (CFS), Environment and Climate Change Canada (ECCC) and Parks Canada, are working with Indigenous leaders and scholars to support community-led conservation efforts and achieve conservation and restoration goals.

Capacity Building Initiatives

The Canadian Interagency Forest Fire Centre (CIFFC) plays a key role in capacity building for post-fire management supporting federal, provincial, and local agencies involved in wildfire management and coordinating resources, providing training and equipment, and supporting research and development in wildfire management. The Fire Smart Program also provides education and resources to help communities develop and implement effective wildfire mitigation strategies with the objective to reduce the risk of wildfire damage to homes and other structures.

In addition, many provinces and territories in Canada have their capacity-building programs for post-fire management. For example, British Columbia's Strategic Wildfire Prevention Initiative provides funding and resources for community-based wildfire prevention projects. In contrast, Alberta's Fire Smart program provides education and resources to help communities reduce the risk of wildfire damage to homes and other structures.

UNITED STATES OF AMERICA

Country Overview of Forest Fires

- Over the past few decades, the National Interagency Fire Center (NIFC) has reported an average of around 70,000 wildfires per year in the US.
- The extent of land burned by wildfires has also been on the rise since the 1980s. In fact, of all 10 years with the most acreage burned have occurred since 2004, with the peak year being 2015 (Davis, 2022). These trends coincide with some of the warmest years on record nationwide.
- The proportion of land suffering severe damage from fires has ranged from 5 to 23% of the total burned area each year between 1984 and 2020. The Western US is particularly susceptible to large wildfires, and some regions in the West and Southwest have seen the largest increases in burned acreage.
- As per Global Forest Watch, the United States has lost 11.1 Mha of tree cover from forest fires during 2001-2021.

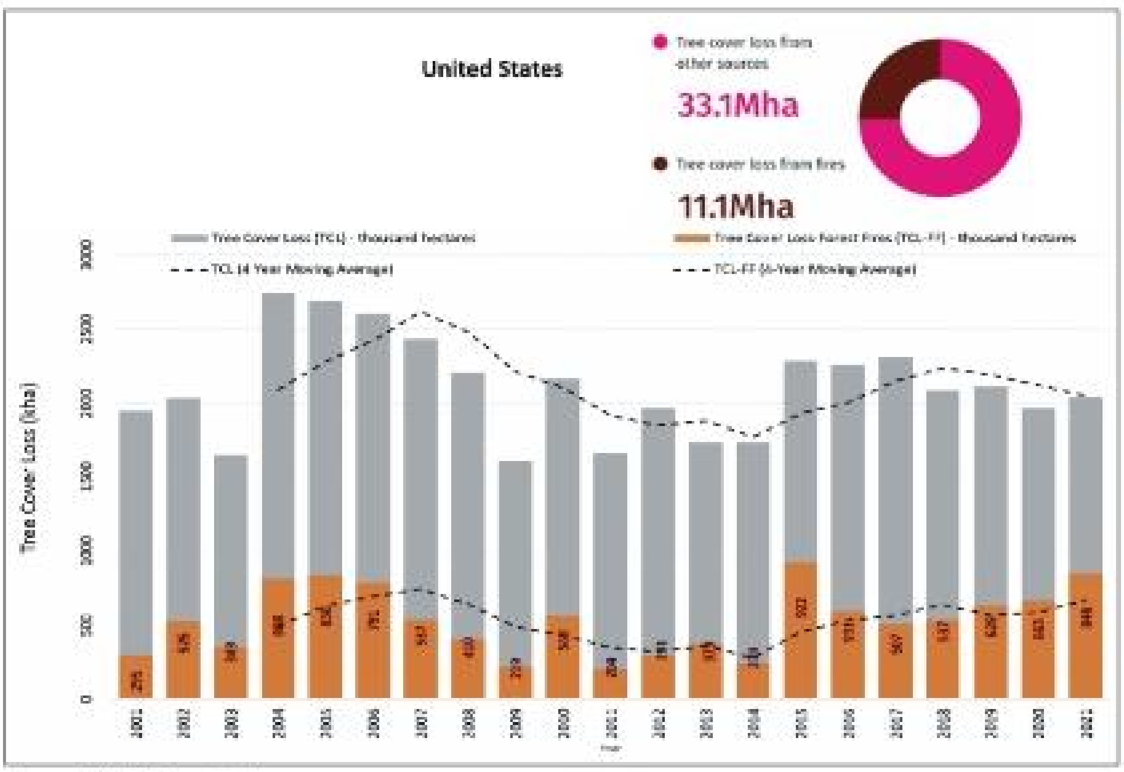


Figure 2.1.9.

Tree cover and tree cover loss due to forest fires in USA (2001-2021)

Source: *Global Forest watch*

Tree Cover Loss Due To Fires: From 2001 to 2021, United States lost 11.1Mha of tree cover from fires and 33.1Mha from all other drivers of loss. The year with the most tree cover loss due to fires during this period was 2015 with 922kha lost to fires - 40% of all tree cover loss for that year.

Regions with Most Tree Cover Loss Due To Fires: From 2001 to 2021, Alaska had the highest rate of tree cover loss due to fires with an average of 261kha lost per year.

Proportion of Tree Cover Loss Due To Fires: Fires were responsible for 25% of tree cover loss in United States between 2001 and 2021.

Key Ecosystems Susceptible to Forest Fires

Fire activity in North America is highly driven by fire exclusion, the increase in wildland urban interface (WUI) and a lengthening of the fire season. Over the past decade a marked increase in fire season length in parts of Alaska and the western United States has been experienced, largely impacting the State of California. Individual fire incidences are also observed to be getting larger, with prominent examples being the 2021 Dixie Fire, named the second-largest fire in California history, the Bay Area fire, one of the largest wildfires recorded in US history, the 2018 Butte County Fire and the 2017 Tubbs Fire (ucdavis.edu, 2020.). Although Forest fires can occur in any forest type, forest types that have been more susceptible than others due to factors such as vegetation density, climate, and topography include:

- **Northern Mixed Forest** is a transitional between the evergreen-dominated forests to the north and the broadleaf-dominated forests to the south.
- **Californian Chaparral** is a shrubland plant community and geographical feature found primarily in California, southern Oregon, and the northern portion of the Baja California Peninsula in Mexico. It is shaped by a Mediterranean climate (mild, wet winters and hot, dry summers) and infrequent, high-intensity crown fires.
- **Boreal Forests** of the United States can be found in Alaska and are characterized by dominant tree species such as fir, spruce, larch, aspen, and jack pine.
- **Pacific Coast Evergreen Forest** is one of the largest temperate rainforests in the world, native to the Northern and Southern California Coast Ranges and the Sierra Nevada of central and northern California; the Transverse Ranges and Peninsular Ranges of southern California; and the southwestern Oregon Coast Ranges.
- **Coastal Plain Mixed Evergreen Forest** can be found in the southern coastal plain region from southeastern Virginia to eastern Texas.
- **Great Plains Grasslands** span over 180 million acres, crossing five U.S. states and two Canadian provinces. This short- and mixed-grass prairie is one of only four remaining intact temperate grasslands worldwide.
- **Eastern Deciduous Forest** ecosystem stretches over 26 states from Florida to New England and southern Canada, extending as far west as Texas and Minnesota.
- **Montane Forests** are found at elevated plateaus and mountains of the Southwest.

- **Hawaiian Tropical Rainforests** are a tropical moist broadleaf forest ecoregion in the Hawaiian Islands that covers an area of 6,700 km^2 (2,600 sq mi) in the windward lowlands and montane regions of the islands.

Causes of Forest Fires in USA

Nearly 85 percent of wildland fires in the United States are caused by humans. Human-caused fires result from campfires left unattended, debris burning, equipment use and malfunctions, negligently discarded cigarettes, and intentional acts of arson.

Key Institutions Involved in Forest Fire Prevention and Management

The United States has five federal regulatory agencies responsible for managing forest fire response and planning across 676 million acres of land. These agencies are the Bureau of Land Management (BLM), the National Interagency Fire Center (NIFC), the National Park Service (NPS), the Federal Emergency Management Agency (FEMA), the United States Forest Service (USFS), and the United States Fish and Wildlife Service (USFWS). In addition to these federal agencies, wildfire management is also carried out by state, county, and local fire management organizations.

Role of Research and Academic Institution in Generating Relevant Knowledge

Forest and wildland fire management agencies in the United States were primarily established during the early 1900s in response to major fire incidents that caused significant loss of life and destruction of homes and natural resources.

Recent research on post-fire issues in the United States has included stabilization treatments (Burned Area Emergency Response), including post-fire treatment justifications, post-fire flooding and debris flows, fuel management, salvage, seeding and conifer regeneration.

The United States has also achieved significant achievements in the remote-sensing-based wildfire monitoring programs and including the National Interagency Fire Center (NIFC) Wildland Fire Assessment System (WFAS), Geospatial Multi-Agency Coordination (GeoMAC) Wildfire Mapping, and Fire Information for Resource Management System (FIRMS). In addition, the Firefly program developed by the University of Berkeley, California, also uses data from several sources to generate fire maps helping decision-making processes for fire managers and responders.

The USDA promotes research focused on understanding the mechanisms of soil recovery after wildfires through the USDA Forest Service Soil Severity Program.

Community Involvement and Engagement in Forest Fire Management

- The National Cohesive Wildland Fire Management Strategy, developed by the U.S. Forest Service, the Department of the Interior, and the National Association of State Foresters, aims to promote collaboration and coordination among federal, state, local, and tribal governments, as well as with communities and other stakeholders, to reduce the risk of wildfires and to manage the impacts of wildfires better.

- One of the key elements of this strategy is to incorporate traditional ecological knowledge into wildfire management and post-fire management planning.
- Community engagement has been implemented in the United States by creating Fire Safe Councils, which are community-led organizations that mobilize residents to protect their homes, communities, and environments from catastrophic wildfires.
- Community Wildfire Protection Plans (CWPPs) are also developed through collaboration between communities and government agencies to identify areas of high wildfire risk and to develop strategies to reduce that risk.
- Further, several programs, such as Firewise USA®, are oriented towards community preparedness for wildfires and provide resources and tools to become more fire-adapted.

Capacity Building Initiatives

- The National Fire Plan, established in response to the 2000 wildfire season, aimed to reduce the risk of wildfires by providing resources for preparedness, suppression, and restoration efforts. The plan included provisions for community education and outreach, firefighter training, and post-fire rehabilitation.
- The Fire Adapted Communities program, which is a partnership between the National Fire Protection Association and the USDA Forest Service aims to enhance capacities through the provision of resources and support for communities to become more resilient to wildfire by promoting effective land use planning, community engagement, and preparedness planning.
- The National Interagency Fire Centre provides support to federal, state, and local agencies involved in wildfire management and coordinates resources, provides training and equipment, and supports research and development in wildfire management.
- The Burned Area Emergency Response (BAER) program is a rapid assessment and response effort initiated after a wildfire to evaluate potential post-fire risks, such as flooding and erosion and provides technical and financial assistance to affected communities and organizations to support post-fire restoration efforts.
- The Joint Fire Science Program (JFSP), which is a collaboration between various government agencies, universities, and non-profit organizations, supports research and knowledge exchange related to wildland fire science. The JFSP provides funding and resources for research projects that aim to improve the understanding of wildfire behaviour, impacts, and management strategies.
- The USDA Forest Service also provides a variety of capacity-building programs, including the Collaborative Forest Landscape Restoration Program, which supports collaborative efforts between federal, state, and local entities to improve forest health and resilience, and the Hazardous Fuels Reduction Program, which provides funding and technical assistance to reduce the risk of wildfire through fuel reduction projects.

2.2 REGION : EUROPE

EUROPEAN UNION

The data and description provided under this section pertains to the remainder of the EU countries (numbering 23) as three countries, namely Italy, Germany and France, are considered individually in the G20 grouping.

Overview

- Despite a general decreasing trend in the area burned by fires in Europe since the 1980s, Portugal stands out as the only country with an increasing trend.
- While there has been some variability in fire activity due to favourable fire weather, the overall trend has been upward since the 1970s.
- However, fire frequency has decreased since its peak during 1990-2010, and the average size per fire has also reduced in southern Europe, from almost 20 hectares on average in 1980 to 7 hectares on average in 2019.
- However, climate change has begun to impact Europe's weather patterns, with 2019 recording the warmest temperature on record and recent temperatures exceeding normal temperatures by 0.5 to 1.5°C compared to 1981-2010.
- The length of the fire season is increasing in parts of Europe, including Spain and central Europe, while decreasing in other areas like parts of Scandinavia. Nevertheless, the frequency of long fire seasons is increasing in most of southern Europe, parts of Nordic countries, and European Russia.

Tree Cover Loss Due To Fires : From 2001 to 2021, EU lost 10.88kha of tree cover from fires and 2.02 Mha from all other drivers of loss.

Regions with most Tree Cover Loss Due To Fires : A northward expansion of moderate fire danger zones in western-central Europe is expected, but the countries with the highest absolute fire danger will remain Portugal, Spain and Turkey.

Proportion of Tree Cover Loss Due To Fires: Fires were responsible for 5.37% of tree cover loss in EU between 2001 and 2021.

Source: *Global Forest watch*

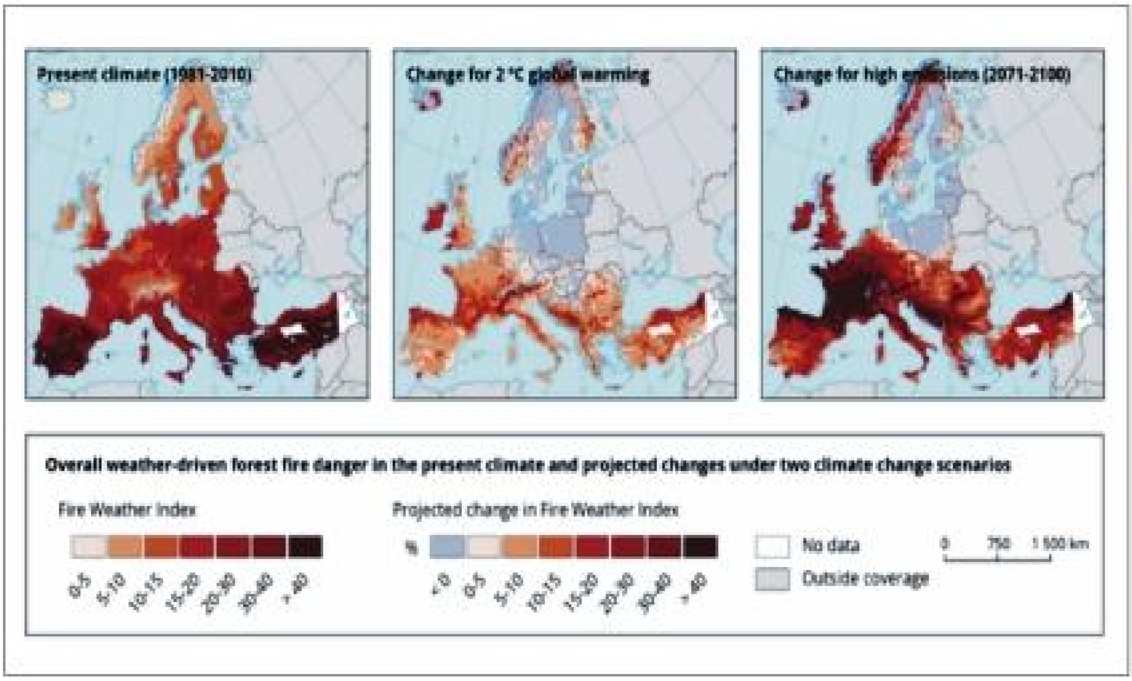


Figure 2.2.1.

Projected weather driven forest fire danger in present and projected climate change scenarios

Source: *https://www.eea.europa.eu/data-and-maps/figures/overall-weather-driven-forest-fire/overall-weather-driven-forest-fire*

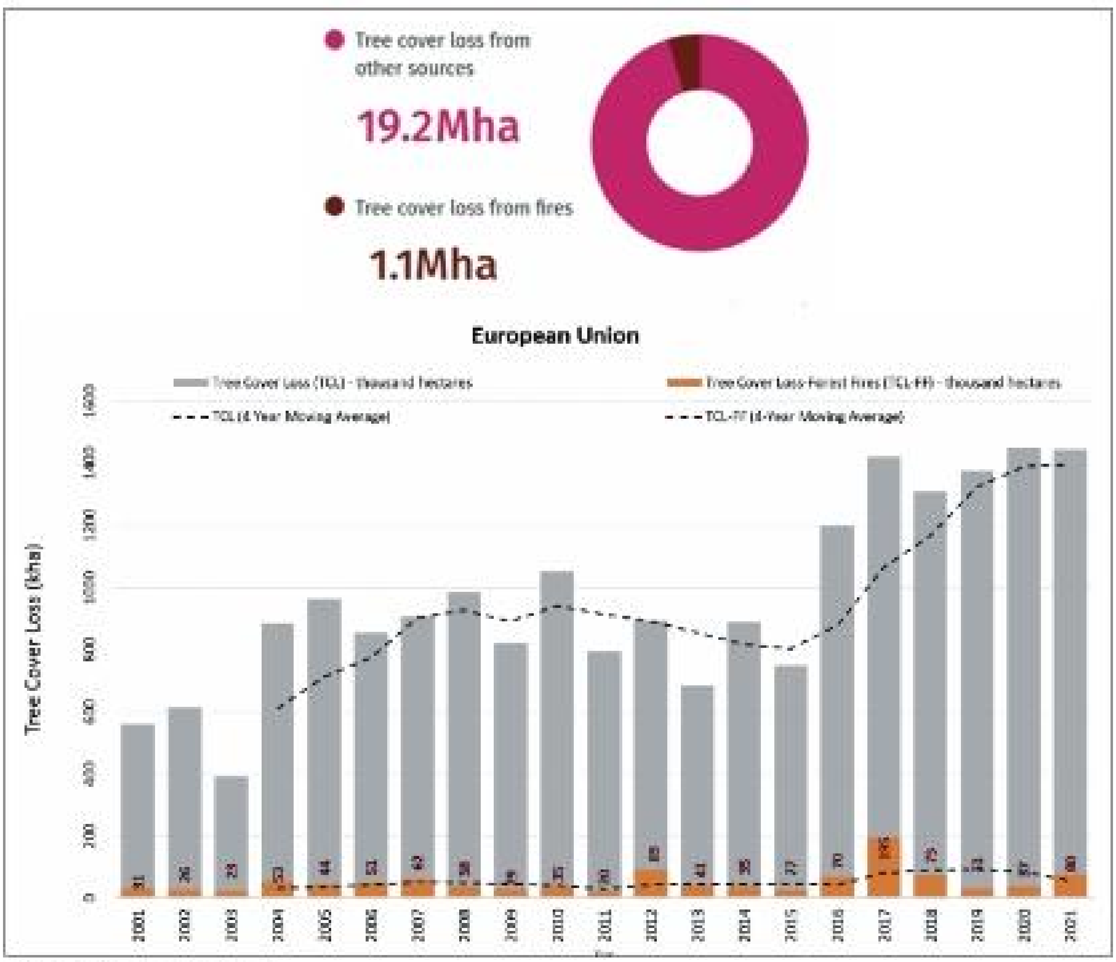


Figure 2.2.2.

Tree cover and tree cover loss due to forest fires in European Union (2001-2021)

Source: *Global Forest watch*

Key Ecosystems Susceptible to Forest Fires

The most significant events in Europe for the period 2015-2020 are as follow:

- In July 2018 in Greece, several fires started around Athens during high fire danger conditions (i.e., hot, dry, windy weather). With flames reaching 30 meters high, fires spread fast and reached settlements, taking the population by surprise. One hundred persons died, 1650 homes were destroyed, and nearly 1,500 hectares burned.
- In 2017, lightning-caused fires sparked in Portugal during severe fire danger conditions, burning over 500,000 hectares. One hundred twenty persons died, many trapped in their cars while trying to drive away from the fast-spreading fires.
- In 2018, unusually warm and dry conditions favoured fire spread across Scandinavia. Sweden was particularly impacted, with 25,000 hectares burned, mostly forests, in a country where timber is a major source of revenue, and between 300-500 people were evacuated.
- In 2020, wildfires in the exclusion zone of Chernobyl 2020, in Ukraine burned nearly 50,000 hectares.
- In Poland in 2020, during prolonged drought conditions, human-caused fires spread through the Biebrza National Park, the largest protected area in the country. Fires burned nearly 6,000 hectares, or 10% of the park, which is home to exceptional biodiversity.

Causes for Forest Fires in EU

- Over 95% of fires in Europe are human-caused and often linked to accidents, tourism, and arson.
- Besides the Mediterranean climate conditions (dry and warm summer) prone to fire ignition and propagation in very flammable vegetation, Mediterranean regions are also characterized by areas where wildland vegetation intermingles with human settlements, the so-called wildland-urban interfaces (WUI). The extension of the wildland-urban interface that concentrates both assets and fire ignitions combined with anthropogenic climate change has been exacerbating fire risk in southern Europe, as seen throughout the world.
- Development of extensive WUI in Mediterranean Europe has contributed to a worsening forest fire risk. The existence of diverse interface typologies (isolated housing, scattered housing, densely clustered housing, and very dense clustered housing) further complicates the situation.

Key Institutions Involved in Forest Fire Prevention and Management in EU:

The development of an EU Forest Policy began with the Council Decision 89/367/EEC and the Thomas Report on the European Union's forestry strategy in the early 1990s. While no EU Treaty provides for a comprehensive common policy, the EU has recognized forest fires as a common issue in all regions and has taken action to support forest conservation and management.

- The EU's approach to forest fire protection has shifted from concerns for protecting forests, people and property to the broader scenario of environment and climate change. The European Parliament has adopted various resolutions and reports to enhance the protection of EU forests, including the "European Parliament Resolution on Natural Disasters" in 2005 and the EU "Forest Action Plan" in 2006. These initiatives invite Member States to support forest fire prevention measures, restoration of forests damaged by natural disasters and fire, studies on the causes of forest fires, awareness-raising campaigns, training, and demonstration projects.

- The "Green Paper on forest protection and information" in 2010 was an opportunity to discuss options for ensuring that forests continue to perform all their productive, socioeconomic, and environmental functions in the future. The "Arsenis Report" in 2011 highlighted the importance of forest fire prevention through landscape planning and connectivity, infrastructure, and training.
- The EU's activity concerning forest fires has evolved from a sectorial activity in agriculture to a crucial environmental issue under the competence of the Directorate General for Environment (DG ENV) since 2003. The EU has implemented measures and provided funding to support forest fire prevention and protection as part of its broader efforts to address environmental and climate challenges.
- The new EU climate adaptation strategy aims to build a climate-resilient Europe by mitigating the negative consequences of climate change, such as the impacts of forest fires, by 2050.
- Modern satellite missions such as EUMETSAT's Meteosat geostationary satellites, Metop Polar-orbiting Satellites, and the Copernicus Sentinel series provide diverse data for various crucial fire-related products.
- The Copernicus Atmosphere Monitoring Service (CAMS) Global Fire Assimilation System (GFAS) brings together observations from different satellite sensors of fire radiative power from active wildfires the world over to estimate the emissions of pyrogenic pollutants in near-realtime. The estimated emissions are then used in the CAMS global and forecast systems to predict the smoke transport and potential air quality impacts up to 4-5 days ahead.
- Next-generation satellites and related products will support this endeavour. EUMETSAT's Meteosat Third Generation (MTG) geostationary satellites and Metop - Second Generation polar-orbiting satellites are potentially revolutionizing firefighting and recovery strategies.
- Emergency Response Coordination Centre (ERCC) is the emergency response hub of the European Commission. Upon an affected country's activation of the European Union's Civil Protection Mechanism, the ERCC coordinates assistance on the European level and ensures that the help provided is efficient and effective. When national capacities to respond to forest fires are surpassed, European countries often show solidarity by sending assistance in the form of water bombing aircraft, helicopters, fire-fighting equipment and personnel.

Role of Research and Academic Institution in Generating Relevant Knowledge

To monitor trends in forest fires, the European Forest Fire Information System (EFFIS), managed by the Joint Research Centre (JRC), reports on the number of fires and the burnt area. In recent decades, the EU has invested103 million Euros in 56 forest fire-relatedresearch projects in various fields (security, space, agriculture and forestry, environment, etc.)and with various instruments (large or smaller collaborative projects, fellowships, exchange schemes and networks). Future research under Horizon 2020 (2018-2020) will focus on innovative solutions, including ecosystem-based approaches, to reduce wildfire risk under new trends in climate, demographic and land use change. [reference: https://research-and-innovation.ec.europa.eu/system/files/2018-11/eu_research_and_innovation_to_support_forest_fire_management_.pdf]

Among the organizations involved at the EFFIS are several country-level forest and disaster management agencies. Among the Universities and research institutions involved in forest fire research are: University of Natural Resources and Life Sciences, University of Natural Resources and Life Sciences, Brandweer Nederland, Institute of Safety Department of Environmental Sciences, Wageningen University, Forest Research Institute, Poland, Instituto da Conservação da Natureza e das Florestas, Portugal, University of Belgrade- Faculty of Forestry, National Forest Centre; Forest Research Institute – Slovak Rep. and the Swiss Federal Research Institute WSL. [reference: https://effis.jrc.ec.europa.eu/partners].

Community Involvement and Engagement in Forest Fire Management

Involvement of the local communities in preparedness is vital for reducing and mitigating of fire hazards and loss of life and property. Research, Risk reduction, Readiness, Response and Recovery have been adopted as part of the integrated approaches to fire management. Indigenous fire management and community-based fire management are areas that have received attention. [reference: FAO, 2011, Community–Based fire management A review, FAO Forestry Paper 166, Rome Pp 99]

The island of Kythira in Greece suffered a major forest fire in 2017 that burned 8.91% of its total area and revealed many challenges regarding fire management. The Hellenic Society for the Protection of Nature, along with the Institute of Mediterranean and Forest Ecosystems, initiated Community involvement that included: Assessment of the risk of destruction of structures with community volunteers, Voluntary field activities by volunteers and students, including reforestation of selected sites, and understory fuel management in selected stands along roads and fuel treatment.

[reference: Xanthopoulos G, Athanasiou M, Nikiforaki A, Kaoukis K, Mantakas G, Xanthopoulos P, Papoutsakis C, Christopoulou A, Sofronas S, Gletsos M, Varela V. Innovative Action for Forest Fire Prevention in Kythira Island, Greece, through Mobilization and Cooperation of the Population: Methodology and Challenges. Sustainability. 2022; 14(2):594. https://doi.org/10.3390/su14020594].

Capacity Building Initiatives

eFIRECOM [https://efirecom.ctfc.cat/?lang=en] aims at enhancing the resilience of citizens to wildfires in interface areas from the Mediterranean region through effectively promoting and increasing awareness and participation in the culture of risk with updated knowledge and best practices. This is done through 1. Development of a communication toolkit for three target audiences: i) Communities and municipalities (inhabitants and managers of wildland-urban interface), ii) Scholars, youths and their teachers, iii) Journalists and media professionals. and 2. Edition and dissemination of operational and strategic recommendations for improving communication on risk and reducing social vulnerability to wildfires in Mediterranean areas, transferred to the relevant authorities.

[reference: European Commission, Directorate-General for Research and Innovation, Vallejo Calzada, V., Faivre, N., Cardoso Castro Rego, F., et al., Forest fires : sparking fire smart policies in the EU, Faivre, N. (editor), Publications Office, 2018, https://data.europa.eu/doi/10.2777/181450]

The EU Civil Protection Mechanism coordinates pan-European assistance. It ensures that all EU Member States and participating states to the Mechanism receive timely information in times of crises and emergencies. Upon its activation by any country worldwide, the Mechanism ensures the rapid deployment of resources and personnel that are tailor-made to fit the needs of each emergency.

[reference:https://civil-protection-humanitarian-aid.ec.europa.eu/system/files/2022-12/fst%20Forest%20fires%20EN.pdf].

UNITED KINGDOM

Country Overview of Forest Fires

- Between 2009 and 2017, over 258 thousand wildfires in England, were burning nearly 37 thousand hectares.
- The 2018 wildfire season in the UK was similar to or slightly worse than 2003 but possibly not as severe as 1995 and 1976.
- It is difficult to compare wildfire outbreaks in the past and draw conclusions about their relative severity due to differences in how fires have been reported over the years.
- Most of the land area burnt by wildfires across the UK is arable, grassland, or mountain and heath open habitats. Between 2009 and 2017, woodland and forest fires accounted for less than 5% of the land area burnt in England.

Tree Cover Loss due to fires in the United Kingdom : From 2001 to 2021, United Kingdom lost 23.7kha of tree cover from fires and 483kha from all other drivers of loss. The year with the most tree cover loss due to fires during this period was 2009 with 2.76kha lost to fires — 7.3% of all tree cover loss for that year.

Proportion of Tree Cover loss due to fires in the United Kingdom : Fires were responsible for 4.7% of tree cover loss in United Kingdom between 2001 and 2021.

Regions with most tree cover loss due to fires in the United Kingdom : From 2001 to 2021, Scotland had the highest rate of tree cover loss due to fires with an average of 605ha lost per year.

Key Ecosystems Susceptible to Forest Fires

- In the UK, fire activity is mostly limited by fuel moisture conditioning and fuel availability, i.e. the amount of dry vegetation or soil (i.e. peat) susceptible to burn, hence it does not have to be warm for fires to occur in the UK, in fact, fires often occur in dead and dry winter fuels. However, there are usually two fire seasons, the main one in spring and a secondary one in mid-late summer.
- The majority of wildfires occur in grasslands and broad leaved woodlands, although, in terms of the size of the area, heath lands, moorlands, and grasslands present the largest burnt areas. The intensity of most UK fires is usually low to moderate, with fire mostly affecting surface fuels, although crown fire behaviour has been known to occur in conifer forests (e.g., Swinley Forest, 2011) as well as smouldering fires in peat soils (see Case Study in section B of Saddleworth Moor).

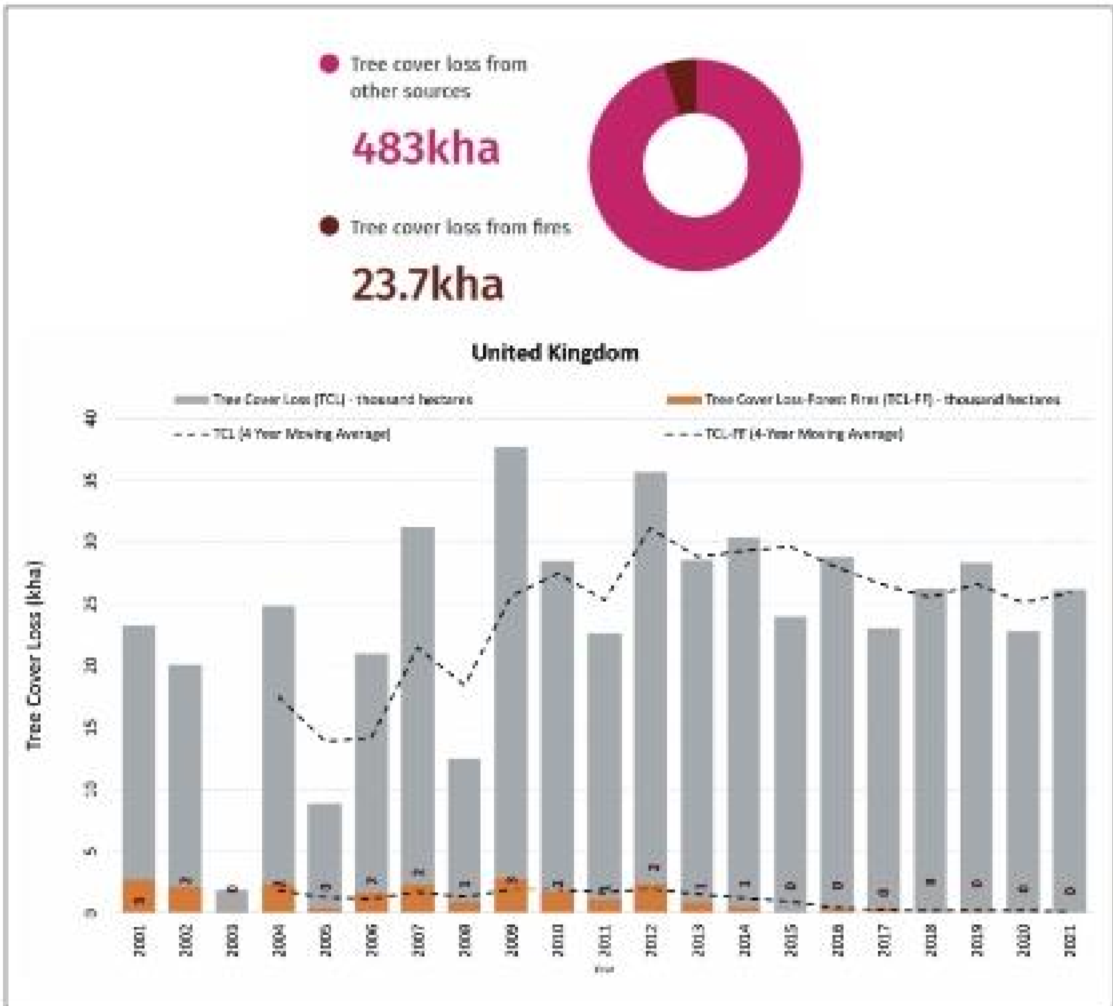


Figure 2.2.3.

Tree cover and tree cover loss due to forest fires in United Kingdom (2001-2021)

Source: *Global Forest watch*

- A great proportion of fires affect vegetated areas in close proximity to built-up areas, which is an important factor to consider in regards both the risk to human health and assets). This makes UK wildfires particularly challenging regarding to both their risk and threat(Belcher et al., 2021).

Causes of Forest Fires in UK

U.K. wildfires may be caused by arson, escaped prescribed burns, discarded cigarettes barbecues, and sparks from power lines, vehicles, or ordnance in military training areas.

Julia Mc Morrow School of Environment and Development, and Fire Research Centre The University of Manchester, U.KWILDFIRE IN THE UNITED KINGDOM: STATUS AND KEY ISSUES: Proceedings of the Second Conference on the Human Dimensions of Wildland Fire GTR-NRS-P-84.

Key Institutions Involved in Forest Fire Prevention and Management

- The National Fire Chiefs Council (NFCC) is the professional voice of the UK fire and rescue service. This is advised by its specialist wildfire tactical advisors (WTAs).

- UK National Resilience has taken on a greater role in coordinating the management and deployment of the WTAs.
- The England and Wales Wildfire Forum (EWWF) is a multi-agency stakeholder group of public, private and third-sector parties which works to address wildfire issues. The forum shares updates amongst members about relevant policy, guidance, research, opportunities and wildfire news. During 2021, EWWF and the Scottish Wildfire Forum provided an evidence submission to The House of Lords Select Committee on Risk Assessment and Risk Planning, which considered assessment and risk planning in the context of disruptive national hazards.
- The Home Office has produced a Wildfire Framework with support from the EWWF and government departments, principally The Department for Environment, Food and Rural Affairs, Defra, the Cabinet Office and the Department for Levelling Up, Housing and Communities (DLUHC). This is a significant and very welcome document as it "identifies responsibilities, clarifies relationships and facilitates coordination at government level and between key wildfire stakeholders, in England." Therefore, guiding how the EWWF and other partners liaise with government in a coordinated approach to wildfire mitigation is of fundamental importance.

Role of Research and Academic Institution in Generating Relevant Knowledge

- **UK Wildfires and their Climate Challenges:** This report assesses the magnitude of present and future UK wildfire risk in the context of climate change, together with a review of the response to that risk in terms of adaptive risk management. The report offers a more comprehensive assessment of wildfire risk for the third CCRA, bringing together new evidence that has emerged over the past five years.
- An analysis using a version of the Met Office wildfire model and the latest UKCP18 climate projections (Arnell et al., 2021) showed how climate change substantially increases fire danger across the whole UK. The greatest absolute fire danger is in the south and east, although the danger is projected to increase everywhere. Results are available at uk- cri.org. The projected amount of change varies to a certain extent across different indicators of fire danger, supporting the need to develop a fire danger rating system tailored to UK conditions.
- In January 2021, the UK Wildfire Research Group met virtually for a second time to bring together researchers and practitioners to develop proposals for the research recommendations defined in Natural England's "The causes and prevention of wildfire on heath-lands and peat-lands in England (NEER014)". This followed up the series of focused breakout room discussions, and participants explored the topics to identify potential collaborations and funding sources to progress the topic within the research community.
- "Toward a UK fire danger rating system: Understanding fuels, fire behaviour and impacts" - At the start of 2021, the NERC-funded UK Fire Danger Rating System project (UKFDRS) was still working through the disruption due to the Covid-19 pandemic. Through 2021 we were able to restart our field monitoring and laboratory work, and in spring 2021, several full-time postdoctoral research associates and technician roles joined the project. In September 2021, the project team met in person for the first time at Wareham Forest to explore recent fire activity and to further develop research activities across the different work packages.
- A collaboration between four UK universities (Imperial College London, King's College London, University of Reading and Royal Holloway, University of London), it is a ten-year, £10 million activity addressing the

many challenges of wildfire, integrating approaches from the social and natural sciences. It aims to develop theory and advance prediction capability for wildfire; quantify its impacts on societies and economies; and initiate a process leading to better ways for people, ecosystems and wildfire to coexist. For more information, please visit the project website: wildfire@imperial.ac.uk. (Source: Forestry Commission, UK).

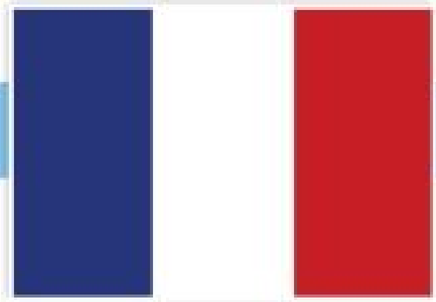
Community Involvement and Engagement

- Community-based solutions first appeared at local, regional, and then national levels during the 1990s, long before formal awareness and government policy began to deal with the issue.
- These local wildfire groups and later regional and national forums evolved in response to crisis events. A patchwork of local solutions developed in Scotland, across England and in Wales from this bottom-up process. Knowledge of wildfire management has grown within these informal networks and diffused upwards from local and regional to national.
- Local and regional fire groups: Local stakeholders have taken ownership of the wildfire problem, forming wildfire groups in collaboration with local FRS and working across conventional institutional boundaries. The Peak District Fire Operations Group was founded in 1997. It became a model for other local wildfire groups, as has its Scottish equivalent, the South Grampians wildfire group.
- These self-assembling local groups have co-produced knowledge of the management of wildfires. Examples include local fire plans with inventories of fire fighting equipment, emergency contacts, vehicle rendezvous and access points, and water sources for fire fighting.
- National Forums are cross-sector, multi-agency groups of public, private, and third-sector stakeholders established to address wildfire issues, but they are non-statutory. Their roles include coordination, lobbying for change, serving as centres for knowledge exchange, and a point of consultation for government bodies.
- Local Resilience Forums and Community Risk Registers: The Civil Contingencies Act in England also required Local Resilience Forums to undertake contingency planning. Local Resilience Forums are multi-agency, consisting of Category 1 responders in a Police Area (emergency services, including Fire Authorities), Category 2 responders, including Local Authorities, the Health and Safety Executive, Environment Agency, and invited groups.

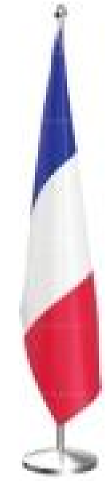
Capacity Building Initiatives

University-based knowledge exchange projects have also helped build a cross-disciplinary and cross-sector national wildfire community.

Initiatives have included: Fire Beaters (2006–2008), the Fire Interdisciplinary Research on Ecosystem Services (FIRES) 2007–2009 seminars and the resulting influential policy brief whose recommendations directly influenced the Chief Fire Officers Association Wildfire Group's action plan; collaborative heather burns with Northumberland FRS and five universities, etc.



FRANCE



Overview

- With respect to large wildfires, France has been divided into six environmental units. The northern region, which is less fire-prone corresponds to a temperate climate in which average summer temperatures are relatively low. This region covers more than half of France but contributed only 1.9% to the national burned area from2001 to 2016.
- The Alpine region, dominated by conifer forests at high elevation and broadleaf forest at low elevation, contributed 2.3% to the national burned area during 2001 to 2016.
- The western region, corresponding to the southern Atlantic climate characterized by warm and dry summers coupled with mild and humid winters, contributed 5.4% to the national burned area during 2001 to 2016.
- The Mediterranean mountains, combine the influence of both Mediterranean and mountain climates, and contribute 34.8% to national burned area during 2001 to 2016.
- The Mediterranean north contained holm-oak and cork-oak-dominated vegetation contributed 25.7% to the national burned area during 2001 to 2016.
- The Mediterranean south, a low-elevation area spanning the Rhône delta contributed 7.1% to the national burned area during 2001 to 2016. The high percentage for the Mediterranean north illustrates that large wildfires occur when multiple conditions are gathered, namely high winds, dry fuel and low soil moisture levels. Long-term drought is a significant predictor of large wildfires in flammability-limited systems such as the Alpine and southwestern regions.

Key Ecosystem Susceptible to Forest Fires

- So far, forest fires do not constitute a significant hazard in the central and northern parts of the Alps. At the same time, on the southern side, they are more common even if the fire number and the burned area are low compared to the neighbouring Mediterranean area, where the climate favours the development of frequent and large wildfires.
- Due to their high potential impact in terms of human lives, commodities and natural heritage, the Alpine forest fires require a relatively large amount of resources for fire-fighting and prevention: the mountainous environment makes firefighting very difficult, and rapid intervention is required because the fires readily endanger human activities and infrastructures. Furthermore, secondary damages via other consecutive natural hazards, such as an enhancement of debris flows, erosion and avalanche danger, may occur, too.

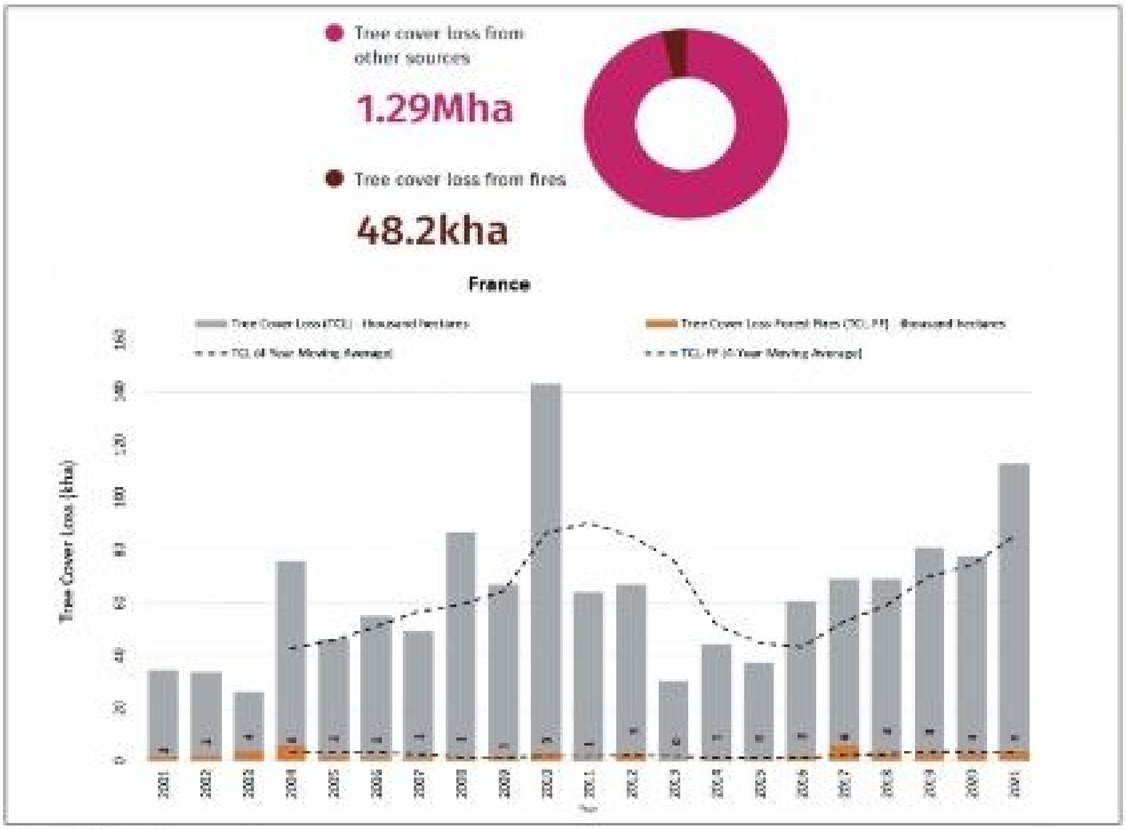


Figure 2.2.4.

Tree cover and tree cover loss due to forest fires in France (2001-2021)

Source: Global Forest watch

- In southeastern France, most of the large fires (>120ha) occur within the coastal Mediterranean areas, whereas the mountains (the Pyrenees, Southern Massif Central and Southern Alps) are less affected. In 1973–2013, on average, 66% of the annual burnt area in southeastern France burnt during July and August. Corsica is by far the most fire-prone region of southeastern France.
- Trends of fire activity and climate across the Mediterranean and mountain ecosystems of south-eastern France over the period 1973–2009 show a general decrease. However, extreme conditions in fire weather (fire danger indices) have greatly increased in south-eastern France over the past four decades: the flammability of ecosystems in south-eastern France has probably increased in these recent decades.

Causes of Fire

- Regarding the causes of large fires in France, the proportion of unknown causes was high till 2003. Large fires caused by lightning were rare in Southern France. Arson was the main known cause in Southern France, especially in 2000, 2003 and 2005, during which fire weather conditions were the most severe. Increased fuel accumulation and connectivity and more frequent extreme weather events, were thought to have promoted an increase in large fires.
- With respect to climate effects, the situation is even more complicated because climate affects wildfires in two opposing ways. In dry ecosystems, wet conditions may be so rare that insufficient fuel accumulates to start large fires, and fire activity is limited. These areas have a fuel-limited fire regime. In moist ecosystems, on the other hand, dry conditions may be so rare that fuel doesn't get sufficiently dry to sustain

fire spread. These areas have a drought-driven fire regime. However, the alternation of wet and dry conditions, favours fires by increasing the amount of fine fuel in the litter, grass and shrub layers during wet periods, which burn more intensely in subsequent dry periods. In Mediterranean ecosystems, both fuel-limited and drought-driven fire regimes are present.

Key Institutions Involved in Forest Fire Prevention and Management

- In fire protection, the French state services take three types of actions: (a) fire prevention education for the public, (b) surveillance of forested areas for early fire detection, and (c) vegetation management to reduce fuels.
- INRA (Institute National de la Recherche Agronomique). This institution is very much involved in studying forest fires via its laboratory. Located in the south of France in the city of Avignon. It conducts research in the spreading of forest fires.
- IUSTI (Institut Universitaire des Systkmes Thermiques Industriels) Marseille- A group of this laboratory located in Marseille is a partner of the INRA. It executes experiments and simulations for the improvement and validation of behaviour models of forest fires.
- Universitb tie Corte (SDEM)- This team located in Corsica have been studying forest fires for several years, most of the time in collaboration with INRA Avignon.

Role of Research and Academic Institution in Generating Relevant Knowledge

- Mediterranean forests are characterized by complexity and fragility. Their management with the objectives of protection, production and biodiversity necessitates mastering, especially adapted techniques. The French research programmes aim to define the different vulnerable zones of the Mediterranean forest corresponding to soil characteristics, vegetation and relief. Different research projects funded by the European Union and international contracts show that scientific cooperation is essential (https://gfmc.online/iffn/country/fr/fr_2.html).
- The Mediterranean forest research division at I.N.R.A. with its forest fire prevention unit (prévention des incendies de forêt) in Avignon concentrates its research on (a) modelling of flammability and fire propagation, (b) traditional and new hazard reduction methods for fuel breaks, including modelling of vegetation dynamics on fuel breaks, and (c) effect on trees of surface fires and convective activities in prescribed fires.
- The École Nationale des Mines is investigating digitized cartography of fire-prone zones. The National Centre for Scientific Research (C.N.R.S.) and various universities are working on the different aspects of fire ecology, e.g. plant succession after fire. Remote sensing of savanna fires and determination of gaseous and aerosol emissions is one of the major research activities conducted under the umbrella of IGBP/IGAC.
- The National Centre for Agricultural Machines, Rural Engineering, Water and Forestry (Centre National du Machinisme Agricole, du Génie Rural, des Eaux et des Forêt) provides access to an important documentation on forestry and forest fires in the Mediterranean basin.
- A study was conducted by the National Forestry Office, the National Forest Inventory and Meteo-France

on the evolution of the areas concerned by the risk of fire throughout the metropolitan territory. This study is being updated to aim to resolve a number of points for improvement identified at the time. The first step, carried out in 2021, consisted of producing a homogeneous vegetation sensitivity map over the whole of France. *(Source: Ministere de l'Interieur – DGSCGC/SPGC/BAGER; Ministere de l'Agriculture et de l'Alimentation: DGPE / SDFE / SDFCB / BGED, France).*

Community Involvement and Engagement

- To support firefighters funded by local authorities (37 000 in the Mediterranean departments, 7700 in the Landes massif), the Ministry of the Interior deployed reinforcements that included; 660 military Civil Protection Training and Response Units (UIISC), 17 water bombers (12 Canadair, 5 Dash); 2 heavy water bomber helicopters (Super-Puma); 3 reconnaissance and coordination planes as well as about thirty rescue and command helicopters.
- French local actors are very involved and regularly carry out preventive measures, but certain types of behaviour are even more worthy of publicization. This is why the Ministry for an Ecological and Inclusive Transition, in conjunction with the Ministry of the Interior and the Ministry of Agriculture and Food, launched 2019 a national forest fire awareness and prevention campaign. The campaign's purpose is to publicize advice and recommendations to follow in the event of a forest or vegetation fire, as much as to ensure that people don't start a fire themselves and to advise on how to protect themselves should a fire break out.
- At a national level, major stakeholders' broad participation helps shape long-term forest management policies. Regional plans are produced by the regional commissions on Forests and Forest Products and involve a wide range of organised stakeholder groups, such as private owners, hunters, youth groups, unions, consumers, environmental NGOs, and professional agencies and ministries.

Capacity Building Initiatives

- France is fully committed within Europe and internationally to protecting the biodiversity of forests, the fight against deforestation and the sustainable management of these ecosystems. To achieve this, it advocates better coordination between international forestry-related forums and instruments while maintaining a high level of political commitment.

The National Mountain Law for France (1996) also addresses special problems of mountain communities in natural resource management. It recognizes that mountains constitute unique geographic, economic and social phenomena that require specific policies for development and protection.

GERMANY

Overview

The country profile for Germany will focus on forests and forest fires. However, since non-forest lands are also affected by fire, including fire-sensitive and fire-dependent ecosystems of high conservation value, examples of non-forest ecosystems are included.

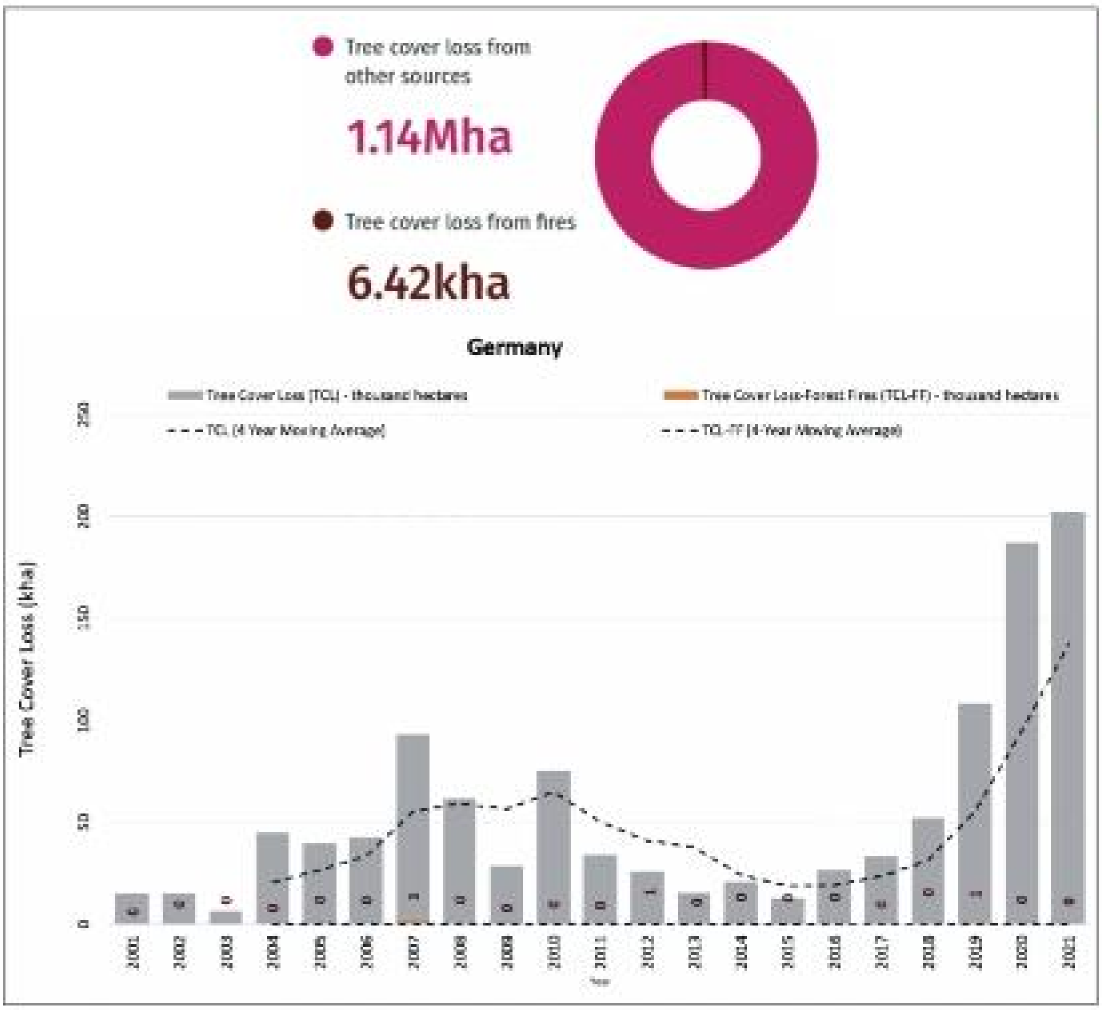


Figure 2.2.5.

Tree cover and tree cover loss due to forest fires in Germany (2001-2021)

Source: *Global Forest watch*

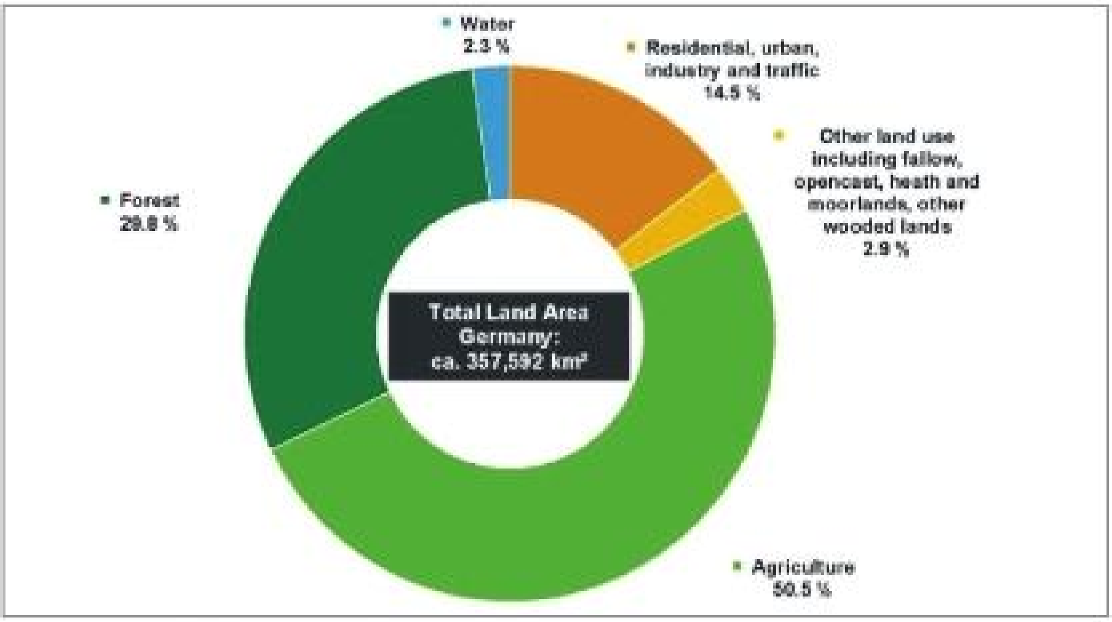


Figure 2.2.6.

Land use in Germany 2022.

Source: *German Federal Environment Office (Umweltbundesamt, n.d)*

Figure 5.15 shows the share of land-use and land cover categories, including water bodies, in Germany. The forest cover of 29.8% of the total land area corresponds to 11.4 million hectares (ha). Since 2016, other wooded lands and high-value conservation areas, which bear significant biodiversity outside of forests, including heath-lands and moorlands, are included in the category "other land use". Agricultural lands cover 16.7 million ha. The total area of heath-lands and moorlands is 148,700 ha. Out of the 8,878 protected areas on land and sea, a total of 1.42 million ha of terrestrial conservation sites are established, corresponding to 4% of the land cover of Germany (bfn, n.d).

Half of the German forest lands are privately owned (48%). One-fifth is owned by municipalities, cities and other public bodies (19%). One-third belongs to the federal states (29%) and the federal government (4%). The total forest area comprises 54.2% conifers and 43.2% deciduous trees; the remaining area constitutes open spaces. About 47% of the forest lands are protected landscape areas (bmel, n.d).

The federal government's current "National Strategy on Biological Diversity" aims at establishing wilderness areas. Wilderness areas are sufficiently large, (largely) undivided, unused areas that ensure that natural processes can run unaffected by humans over the long term. Natural processes are particularly important for many species and habitats, and their protection or reintroduction is a key goal of nature conservation. This is reflected by the Federal Nature Conservation Act, in which the protection of natural developments in National Parks is expressively stated as the central goal for this type of protected area. In this way, nature should develop according to its laws on at least 2% of Germany's land area. This goal is to be achieved primarily through large-scale wilderness areas. The wilderness areas are also to be integrated into the transnational biotope network. In addition, forests should be able to develop naturally on 5% of the forest area (bfn, n.d)

More than 1.1 million people are employed in the forestry and timber industry (1.7% of the German workforce). The annual turnover of forestry and forest industries is €132 billion, representing 1.2% of the gross national value added (bmel, n.d).

Area Under Forest Fire

Wildfire statistics are available for forest areas. Statistical data on fires affecting agricultural lands and other open landscapes are not collected. Fire statistics of protected areas are available if the area burned is classified as forest.

Forest fire statistics are collected by the 16 Federal States and evaluated and published annually by the German Federal Agency for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung). After the reunification of Germany in 1990, coherent and consistent statistical data have been available since 1991 (bmel, n.d)

In the following, extracts of statistical evaluation are provided for the 30 years 1991 to 2021. The evaluation of forest fire statistics for2022 cannot yet be included as they will be available only by mid-2023. Figure 5.16 shows the annual area burned and the number of fires between 1991 and 2021. Figure 5.17 shows the average forest area burned per fire (green columns) and damages (purple line) in Germany from 1991 to 2021. Figure 5.18 shows the share of burned area classified as coniferous forests and deciduous stands in the same 30-years period. Figure 5.19 displays the causes of forest fires in Germany in 2021 – representative of long-term averages.

Since 2018 Germany is experiencing increasing occurrence and severity of dry spells/droughts, some associated with heat waves, which have significant impacts on the forest ecosystem, i.e. lowered water tables, reduced soil moisture, increased dryness of forest microclimate and forest fuels (combustible materials), forest dieback with consequences on secondary stresses such as pests and diseases, notably bark beetle infestations, and thus an overall increased flammability and susceptibility to fire.

Thus, long-term average statistical data such as from 1991 to 2021 reflect the environmental conditions and forest health under historical climate. The climate crisis poses unprecedented wildfire risks to Central Europe's natural and cultural landscapes, including Germany.

The following assessments and deliberations intend to reflect the status quo ante and uncertainties of future development of and the role of fire in forest and non-forest landscapes in light of the climate crisis.

Figure 2.2.7.

Forest area burned (ha) (green columns) and number of fires (purple line) in Germany 1991 to 2021. The total forest area affected in 2022 is currently estimated to exceed 4300 ha.

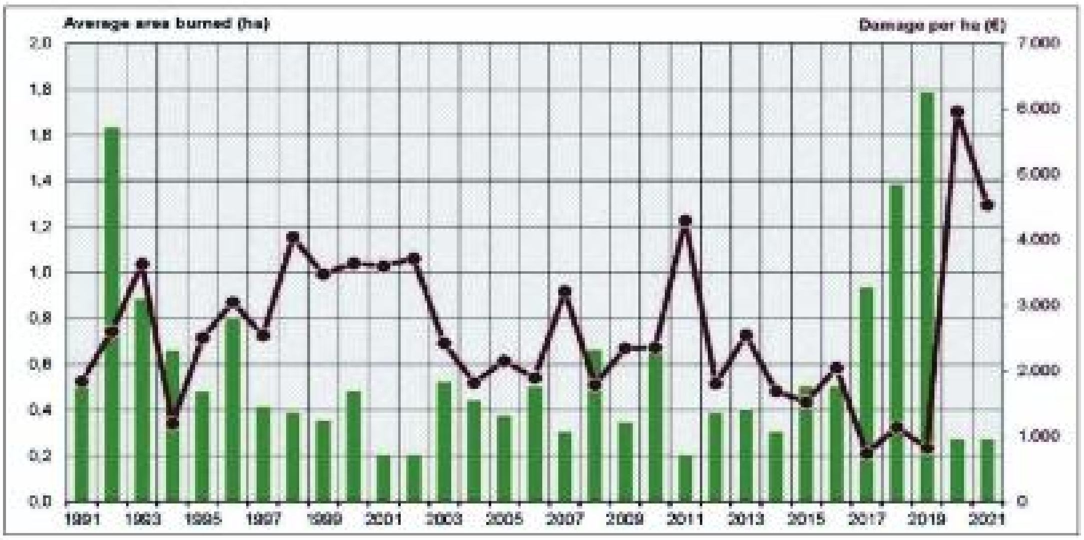


Figure 2.2.8.

Average forest area burned per fire (ha) (green columns) and damages per ha (purple line) in Germany 1991 to 2021. The average area burned per fire in the 30-years period is 0.6 ha.

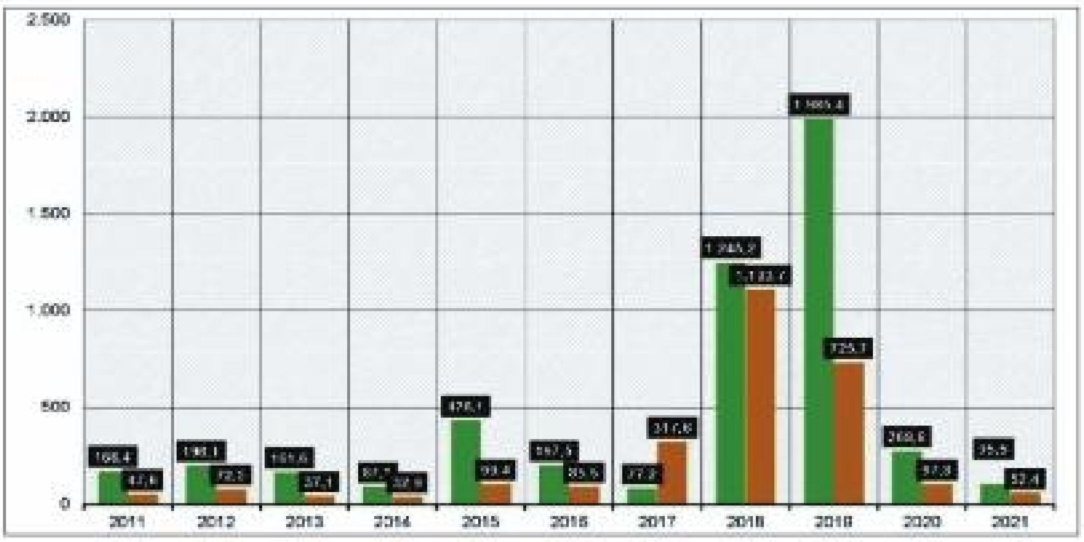


Figure 2.2.9.

Share of area burned classified as coniferous forests (green columns) and deciduous stands (ochre columns) in Germany 1991 to 2021.

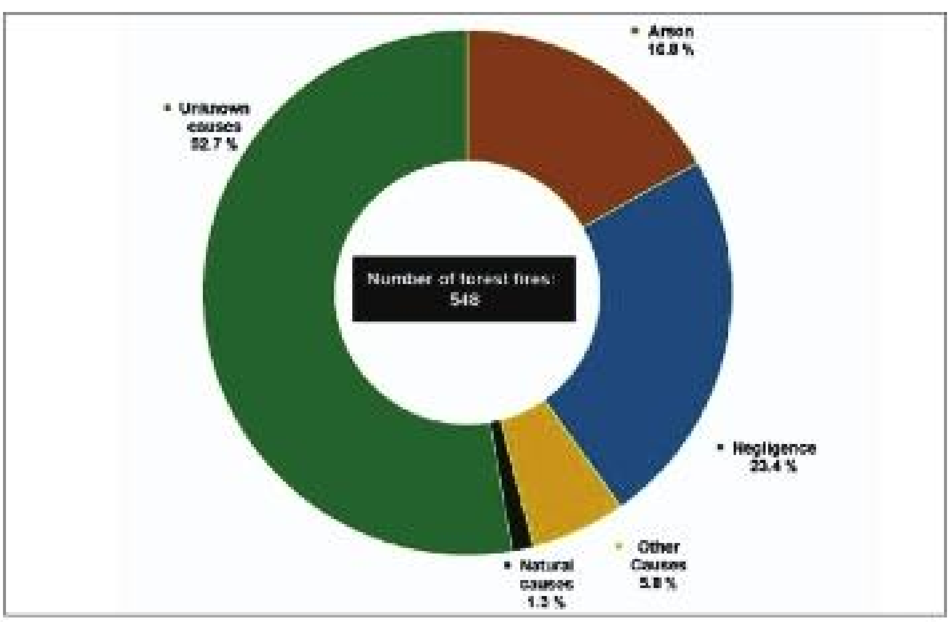


Figure 2.2.10.

Causes of forest fires in Germany – example 2021. Unknown causes represent human-caused fire of which the origin or intent could not be identified. Natural causes refer to thunderstorm / lightning-caused fires. The 30-years averages (1991-2021) show that around 4% of fires are of natural origin and 96% of fire starts are human caused – thereof 20 % arson, 24% negligence, 9% other causes, 43% unknown causes.

Key Ecosystems Susceptible to Forest Fires

Plantation forests of Scotch pine (*Pinus sylvestris*), many of them stemming from reforestation after World War II, bear the highest risk and susceptibility to wildfires. However, in 2022 it became evident that, in principle, all forests of the country are susceptible/vulnerable to wildfires as they become increasingly subjected to drought. The drought and heat stress of recent years have resulted in crown defoliation of coniferous and deciduous forest stands. Opening of the canopy layer, associated with lack of precipitation, lowered upper soil moisture and groundwater level.

For the first time in 2022, protected areas like Saxon Switzerland National Park (National Park Sächsische Schweiz) (Wikipedia, n.d) and Harz National Park (Wikipedia, n.d) have been affected by wildfires. Wildfires in these and other protected forests, managed by "close-to-nature principles", have resulted in fire behaviour, which was not observed before. The developing wilderness areas and "close-to nature" forest management aims, among other, at increasing biodiversity and terrestrial carbon storage. However, there are a few controversial implications: Protected or non-managed forests are becoming less accessible for firefighting and the burning of larger amounts of deadwood results in fires of higher intensity and severity. This led to a controversial public debate during and after the 2022 fire season.

In this scientific discourse about the future forest and fire management concepts, the Global Fire Monitoring Center (GFMC) / Fire Ecology Research Group attempted to clarify the role and consequences of deadwood on fire behaviour and fire impacts, which will also have implications on post-fire restoration/rehabilitation of fire-affected forests (Gfmc, 2022)

Among the non-forested ecosystems, organic terrain (peat-lands) are vulnerable to fire. In 2018 a major wildfire affected a moor near Meppen, State of Lower Saxony, on the terrain of a military site and the Tinner Dose-Sprakeler Heide Nature Reserve. Caused by missile tests of the German Army, the fire affected an area of ca. 1200 ha with considerably impacted the flora, fauna, air quality and carbon storage (Wikipedia,2018).

Peat soils make up about eight percent of the agriculturally used area in Germany. Most recently, around 53 million tons of CO_2 emissions and thus around 6.7 percent of German greenhouse gas emissions were emitted from the decomposition of peat soils through drainage measures and peat use. With the target agreement, the federal and state governments are creating the basis for area-effective moorland protection. By 2030, greenhouse gas emissions from moorland will be reduced annually by five million tons of CO_2 equivalent. The most important measure for saving emissions is the rewetting of previously drained peat soil. Together with the federal states, we ensure enormous savings in emissions because intact moors are considered carbon sinks. On 9 November 2022, the National Peat-land Conservation Strategy was adopted in the cabinet. The federal government will implement effective incentive programs for peat-land protection on peat-lands used for agriculture based on the federal-state target agreement (bmel, n.d).

Key Institutions Involved in Forest Fire Prevention and Management

Fire Danger Rating

The German Weather Service (Deutscher Wetterdienst – DWD) provides forest fire danger forecasts for Germany and a 60-years archive of forest fire danger ratings, which allow to identify long-term trends of changes.

Forest Fire Prevention

Owners and managers of forests, protected areas and agricultural lands are responsible for fire prevention. National federal laws and laws of the federal states regulate the use of fire and prohibitions, respectively. In general, the use of fire inside forests, along the interface of forests and surrounding lands, is regulated and widely restricted by state laws on forestry, conservation, waste disposal and emissions (gfmc, n.d).

Federal State Level Regulations

Mecklenburg-Vorpommern State is an example of federal state-level regulations. The State provides similar subsidies and supports the construction of forest roads for accessing water supply points (wald-mv, n.d). In 2021, a total of €6 million has been invested in forest fire prevention measures in Germany (cf, n.d).

A new financial support instrument, "Climate-adapted Forest Management", provides financial subsidies for forest owners to adjust forests to changing climate conditions. Financial subsidies of up to €900 million will be available until 2026 (infobrief, n.d).

Forest Fire Suppression

The responsibility for fire protection in Germany is with the 16 Federal States, out of which the three city States, Berlin, Bremen and Hamburg, have a rather limited wildfire risk.

In the 13 Federal States, which cover large areas of rural space, including forests and protected areas, the responsibility of firefighting lies with the local communities in 294 counties and 107 independent cities. In the independent cities, 110 professional fire and rescue services provide the backbone for fire protection and disaster management.

The rural communities and counties are protected by 22,000 voluntary fire services. The voluntary firefighting workforce comprises more than one million volunteers. The total workforce of voluntary, professional and youth fire service personnel amounts to 1.3 million persons (feuerwehrverband, 2020).

In addition to the professional and voluntary fire services, specialized volunteer teams are available, e.g. the non-profit organization **@fire**, which has a history of more than 20 years, from the founding idea to a recognized and internationally active aid organization with several hundred members, most of them professionally working in forestry and fire services (at-fire, n.d).

Role of Research and Academic Institutions in Generating Relevant Knowledge

In Germany, fire research projects and publications are documented since around a century. In 1979 the Fire Ecology Research Group was established at the Faculty of Forest Sciences of Freiburg University. Since then, fundamental research on fire ecology and its impacts on forest and non-forest ecosystems in Germany has provided the necessary scientific evidence for fire management planning and decision-making. Since the early 1980s the research group expanded its international work to the tropics (Latin America, Asia and Africa) and to the boreal zone , focusing on Central and Eastern Eurasia. In 1990 the research group transited to the Max Planck Institute for Chemistry and remained at Freiburg University, Faculty for Environment and Natural Resources (gfmc, n.d).

With the support of the German Foreign Office, the Global Fire Monitoring Center (GFMC) was established as an additional function of the Fire Ecology Research Group, aimed at providing an interactive science-policy interface with countries and international organizations worldwide.

In 2004, the GFMC established the UNISDR Wildland Fire Advisory Group and the Global Wildland Fire Network and has been serving since as coordinator and facilitator (unisdr, 2005). This global voluntary network provides advisory services for the development of national fire management policies and science and technology transfer to enable nations to:

- Reduce the negative impacts of landscape fires on the environment and humanity.
- Advance the knowledge and application of the ecologically and environmentally benign role of natural fire in fire-dependent ecosystems and sustainable application of fire in land-use systems.

In 2019, the Federal Ministries for Food and Agriculture (BMEL) and for the Environment, Nature Conservation and Nuclear Safety (BMU) reacted to the increased risk of forest fires. Starting in May 2020, 22 research and pilot projects are funded with a volume of €11.3 million funded by the jointly financed forest climate fund (Waldklimafonds – WKF). Most of these projects are in the final phase (waldwissen, n.d).

Information for the public is displayed on a dedicated website of the information and communication platform waldwissen.net, which is currently operated jointly by four research institutes in Austria, Germany and Switzerland and provides a special section of easy-to-read information on forest fires (waldwissen, n.d).

Community Involvement and Engagement

The total of 22,000 voluntary fire services are organized at local community level and comprise more than one million volunteers. The members of the local volunteer fire services are recruited from local inhabitants of towns and villages and dispersed farm-steads. The volunteers provide the best knowledge of local conditions of infrastructures, private communal assets, critical infrastructures at risk, and road networks and communication means.

The tasks for the prevention and control of forest fires traditionally lie with the forest owners and managers on the one hand and the fire brigades on the other. However, it has been recognized that sharing of joint responsibilities will facilitate firefighting's effectiveness, efficiency and safety. In 2012, the city of Freiburg (Baden-Württemberg State) initiated a model of sharing of personnel and resources of the forest department and the local fire and rescue service with a professional fire brigade and ten voluntary fire brigades. Two voluntary teams are forming the "Task Force Landscape Fire" (gfmc, n.d).

Training, exercises and initial wildfire response are shared with forestry personnel. Forestry personnel provides in-depth knowledge of the terrain and characteristics of burnable vegetation resources, forest road access, and natural and technical infrastructure. In addition, skilled by joint field training with fire service personnel, the forestry personnel is equipped with hand tools, allowing them to confine a starting fire until the fire service will intervene on site.

The interface between rural villages individual houses and the adjoining forest bears a risk to private and public assets and human health and security. In Beelitz, a town located in Brandenburg State, the application of a new model of wildfire prevention is underway to analyze and map wildfire risk and to establish wildfire protection corridors along the forest-residential interface (beelitz, n.d). This will include intensive thinning of corridor forests, removal of debris (removal or mechanical treatment of downed fuels and understory) and prescribed grazing (brandherde, n.d).

Capacity Building Initiatives

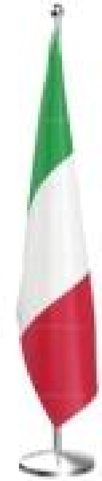
Besides the aforementioned, institutions and groups several initiatives have been launched since 2018. Most initiatives focus on wildfire suppression. Local initiatives for landscape management and restoration include the involvement of volunteers.

At the international level, Germany actively contributes to the UN Decade for Ecosystem Restoration – "Preventing, Halting and Reversing Loss of Nature" (decadeonrestoration, n.d.). The agenda of the German contribution to the Decade includes a broad suite of projects (undekade, n.d). The project "Restoration of near-natural forests in the Berchtesgaden National Park through natural disturbance dynamics" addresses Germany's only national park in the Alps, in which only remnants of the mixed mountain forests with beech and fir, which originally covered extensive parts of the landscape, have been preserved due to centuries of cultivation. Instead, poorly structured stands of spruce dominate today over a large area. While the forest development in the core zone is completely left to natural development, the national park in the buffer zone implements innovative forest conversion measures to restore near-natural mixed mountain forests. In the frame of the project, restoration measures follow the natural forest dynamics by using naturally occurring disturbances in the canopy (e.g., caused by wind and bark beetles) as starting points for forest conversion (undead, n.d).

Similarly, the GFMC has been building capacity using prescribed fire as a substitution tool for restoring historic cultural activities disturbances. , The capacity building, included personnel of the Federal German Forest Service, which is responsible for managing forests and other lands under the auspices of the Federal government, including active and abandoned military training areas (gfmc, n.d)

In March 2023, a coalition of voluntary groups, academic institutions, and private entrepreneurs founded the "Fire Management Advisory and Support Group", offering capacity building for advanced fire management and support of public bodies in responding to wildfire emergencies (bundestag,n.d).

ITALY



Overview

- In 2021, the mean fire danger in Italy during the fire season (July to September) was markedly above the average (period 1988-2020), corresponding to 96% of the highest FWI in 2007.
- A significant proportion of the inter-annual change in total burnt area in Italy is explained by changes in fire weather.
- A change in FWI from one year to the next is correlated with the corresponding change in burnt area, with 2021 showing above-average changes for both FWI and burnt area.

Key Ecosystems Susceptible to Forest Fires

Forest fires are more common on the southern side, and they do not constitute a significant hazard in the central and northern parts of the Alps. However, the alpine forest fires require a relatively large amount of resources for fire-fighting and prevention as the mountainous environment makes fire fighting very difficult (www.climatechangepost.com/italy/forest-fires/).

Causes for Forest Fires in Italy

About 2% of forest fires are due to natural causes (lighting). The analysis highlights that for man-made and intentional fires, the most frequent motivations are the renewal of pastures. At the same time, further reasons

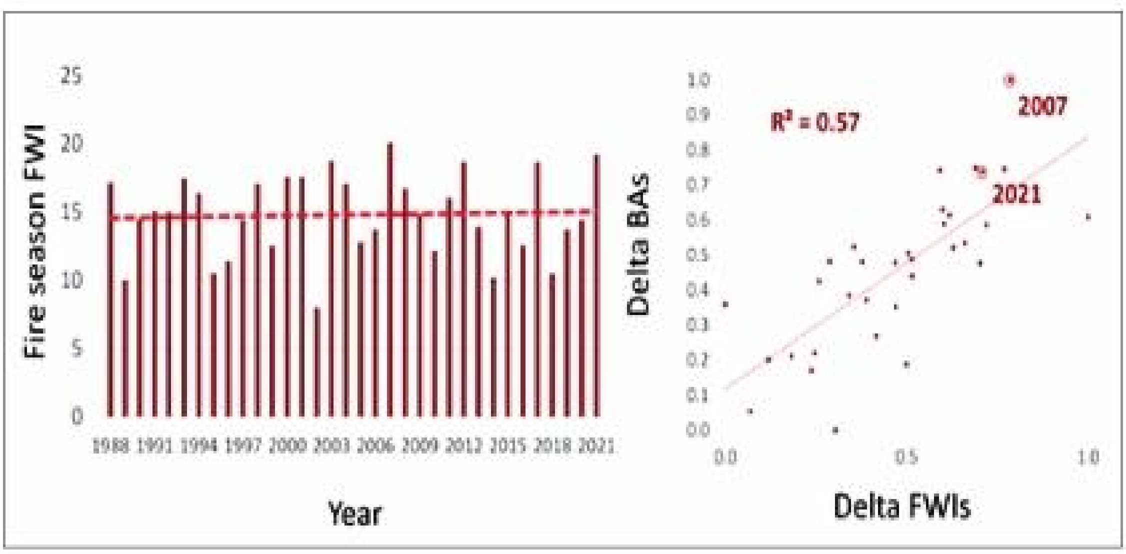


Figure 2.2.11. Average changes for FWI and burnt areas (1998-2021)

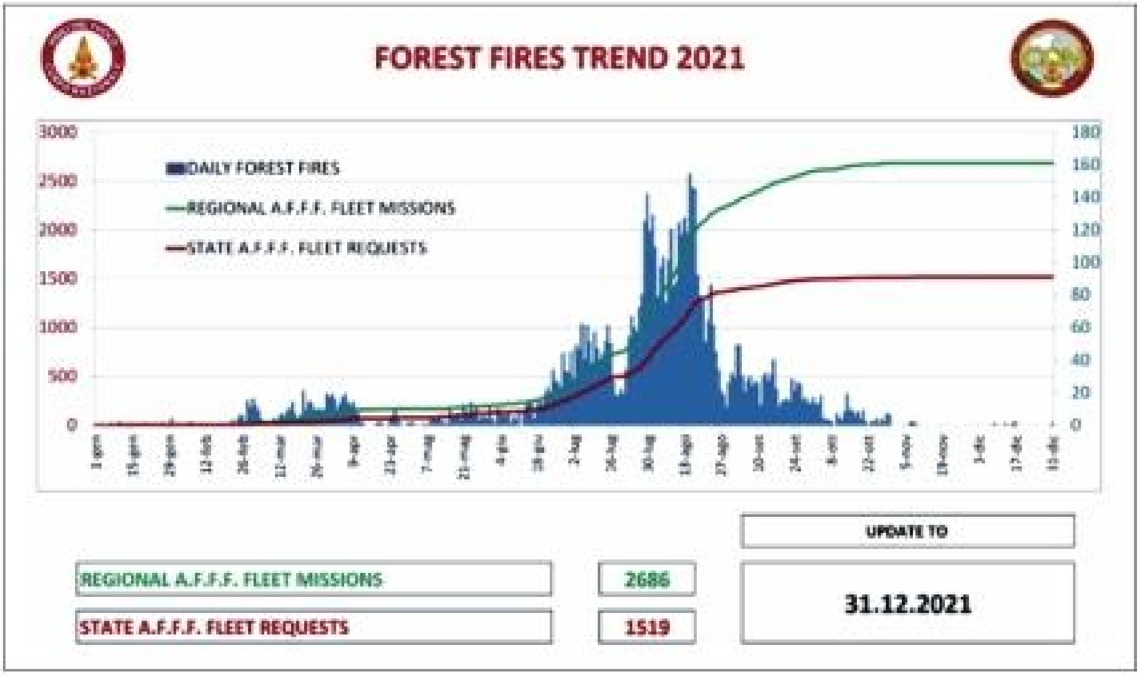


Figure 2.2.12.

Forest fire trends in Italy in 2021

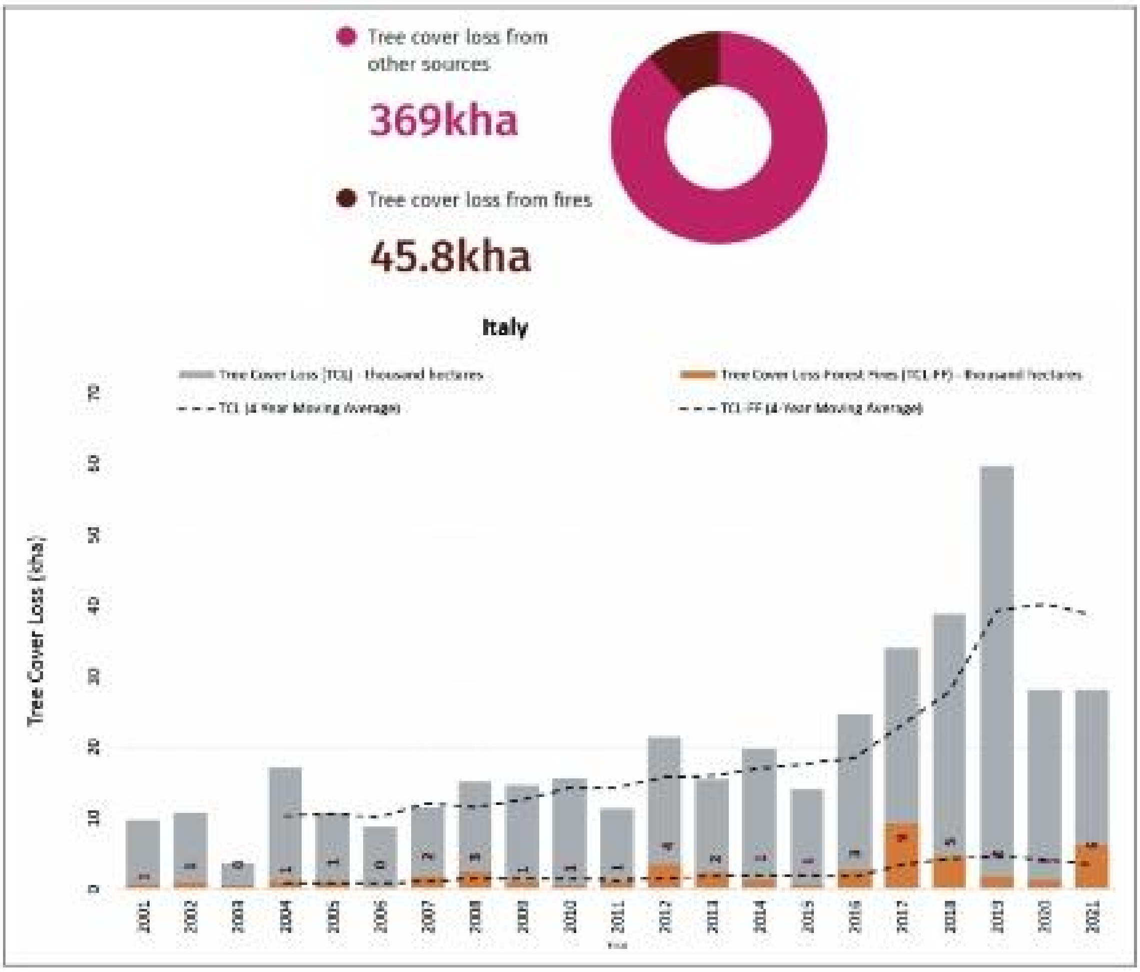


Figure 2.2.13.

Tree cover and tree cover loss due to forest fires in Italy (2001-2021)

Source: *Global Forest watch*

are linked to hunting activity, social unrest, and pyromania. Unintentional causes are mainly due to activities related to burning plant debris generated by agriculture activities. In this case, the perpetrators are mainly elderly people who are not able to keep the fire under control and sometimes become victims of those fires.

Key Institutions Involved in Forest Fire Prevention and Management

Fire prevention in Italy involves several actors at both regional and national levels. The Italian Civil Protection Department, National Fire and Rescue Corps, and The Regional Emergency Agency are key institutions involved in forest fire prevention. Regional forest agencies are responsible for setting the Regional Fire Management Plan (RFM-plan) where fire prevention activities are programmed (Art. 3, Law 353/2000), usually for the following 5 years. Planned activities include:

- Maintenance of the road and fuel-break network to support firefighting;
- Realization of pyro-silviculture interventions in blocks (i.e., variable retention harvest, prescribed burning) to increase forest ecosystem services resistance and resilience;
- Information campaigns targeted citizens with short-term (e.g., fire danger rating) and long-term goals (e.g., increasing risk awareness). These plans complement the RFM-plan in high-fire risk territories defining the spatiotemporal distribution and resources for fuel management activities for 10 years, including extraordinary interventions to improve the forest vegetation structures and their resistance and resilience to fire disturbance.

The main funding scheme to finance prevention interventions in Italy, as defined by both RFM-plans and Specific Fire Prevention Plans, remains the measures and interventions of the Rural Development Program (RDP) of the European Commission (https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural -policy/rural-development_en).

Role of Research and Academic Institution in Generating Relevant Knowledge

Several studies and research programs to improve fire management in Italy were carried out and published in 2021. Ascoli et al., (2021) tested the hypothesis that in Italy, large wildfires and repeated fires (series 2007-2017) selectively burn areas characterized by a more intense land abandonment (series 1980-2006). They found that large fires (>500 ha) affected areas with higher rates of forest expansion, and recurrent fires tended to occur in areas with higher transitions from abandoned pastures and grasslands toward shrublands. Interestingly, buffer areas of 200 m along large fire perimeters experienced lower levels of land abandonment and higher increases in orchards and vineyards, suggesting that continuous management of agroforestry territories limits large fires by increasing the accessibility and effectiveness of firefighting.

D'Este et al., (2021a) developed a set of models combining multi-source remote sensing data (SAR, Sentinel 1, 2, and LIDAR), field data, and machine learning techniques to quantitatively estimate fine dead fuel load (1-h time lag) and understand its determining factors in Mediterranean vegetation types. The results showed that Random Forest had more predictive power than the other models, while LIDAR variables were more important in fuel estimation than optical and radar variables.

Several studies addressed wildfire exposure, risk, and adaptation (e.g., Bacciu et al., 2021, Salis et al., 2021) with a particular focus on the wildland-urban interface (WUI). A WUI raster map was created for the Italian peninsula with a resolution of 30 m per pixel (D'Este et al., 2021b). The map creation process consisted of three fundamental steps: (1) selection of buildings within the wildland-urban interface areas and subsequent classification of these into isolated, scattered, and clustered buildings; (2) creation of the tree canopy cover layer (low, medium, high); (3) generation of WUI map by the intersection of 3x3 previous products to obtain 9 categories of WUIs.

Spano et al., (2021) explored differences between citizens with and without previous wildfire experience in terms of 1) knowledge, 2) perceptions, 3) information, 4) self-protection, and 5) community involvement. Additionally, they investigated differences in the same variables focusing more deeply on individuals with previous wildfire experience, classifying them according to fire-related employment and WUI proximity. Results partially confirmed the hypothesis that direct experience leads individuals to have a greater preparedness on wildfires.

Several studies addressed fire effects on air quality, soil, vegetation, and fauna (Ancillotto et al., 2021, Castagna et al., 2021, Maringer et al., 2021, Memoli et al., 2021). Argentiero et al., (2021) adopted a combination of methods to easily assess post-fire erosion and prevent potential risks in subsequent rain events. The model they presented is structured into three modules implemented in a GIS environment. The first module estimates fire severity with the Monitoring Trends in Burn Severity method; the second estimates runoff with rainfall depth–duration curves and the Soil Conservation Service Curve Number method; and the third estimates pre and post-fire soil erosion.

Community Involvement and Engagement

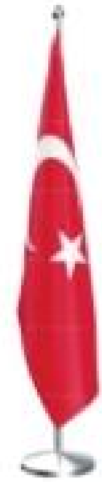
Local landowners, community groups, municipalities, and volunteers collaborate with the Civil Protection, the Vigili del Fuoco (fire service), the Carabinieri Forestali (investigation after fire events), and the National Civil Protection Department to deal with forest fire management activities including fire forecasting, prevention, and suppression. Acknowledging the high risk of forest fires in the Monte Pisano area, constituted by the mountain slopes, fire-prone vegetation, limited evacuation routes, building materials of houses, and continuous usage of fire to burn agricultural remains despite regulations, several communities agreed to become fire-wise communities. A trusting relationship has been established between fire technicians, administrators, researchers, and residents (Uyttewaal et al., 2023).

Capacity Building Initiatives

The competence for forest fire management in Italy falls on the regional level as defined by the national framework law 353/2000. Villano is the first fire-wise community in Italy. Zones of high fire risk are identified to target management interventions. The Comuna di Calci takes responsibility for fire breaks and management of forested areas, while local landowners conduct fuel reduction in the olive orchards surrounding their houses. Similar initiatives take place in Peretto and Via Crucis. La Pineta (Municipality of Monticiano – Siena) is a regional training centre, which imparts training to forest fire operators, fire analysts, ground staff, and volunteers (www.dream-italia.it/en/).

Uyttewaal, K., Prat-Guitart, N., Ludwig, F. et al., 2023. Territories in Transition: how social contexts influence wildland fire adaptive capacity in rural Northwestern European Mediterranean Areas. Fire Ecology, 19, 13. https://doi.org/10.1186/s42408-023-00168-5.

TÜRKIYE



Country Overview of Forest Fires

- In Türkiye, the coastline, which starts from Hatay and extends through the Mediterranean and Aegean up to Istanbul, has the highest fire risk. Approximately 57% (12.5 million ha) of Türkiye's forest area is located in fire-sensitive areas.
- According to data derived from the General Directorate of Forestry, Department of Forest Fire Combating, 2021, the total burnt area was 139 503 hectares. The number of fires was 2 793 in the same year.
- Forest fires mostly occurred during March-December, particularly in June, July, August, and September. When we look at the number of forest fires, July is the highest month, with 503 fires and 104 665 ha.

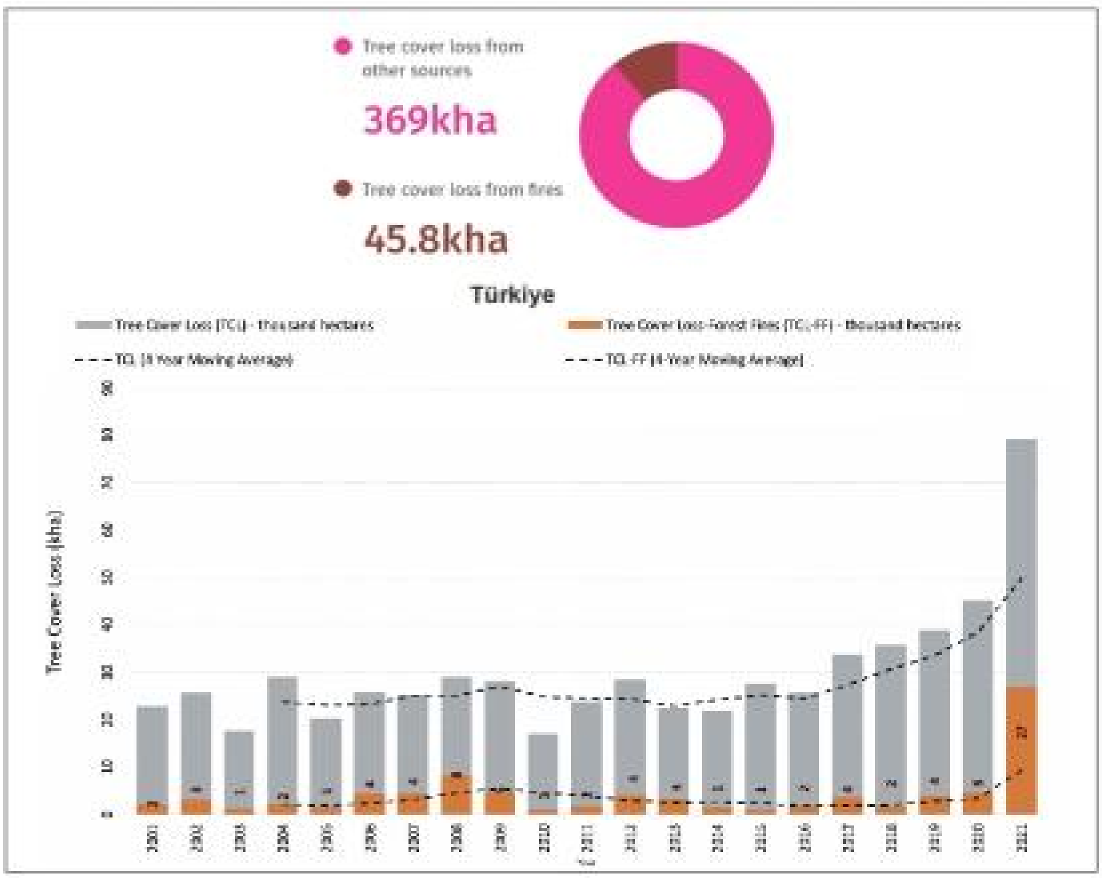


Figure 2.2.14.

Tree cover and tree cover loss due to forest fires in Türkiye (2001-2021)

Source: *Global Forest watch*

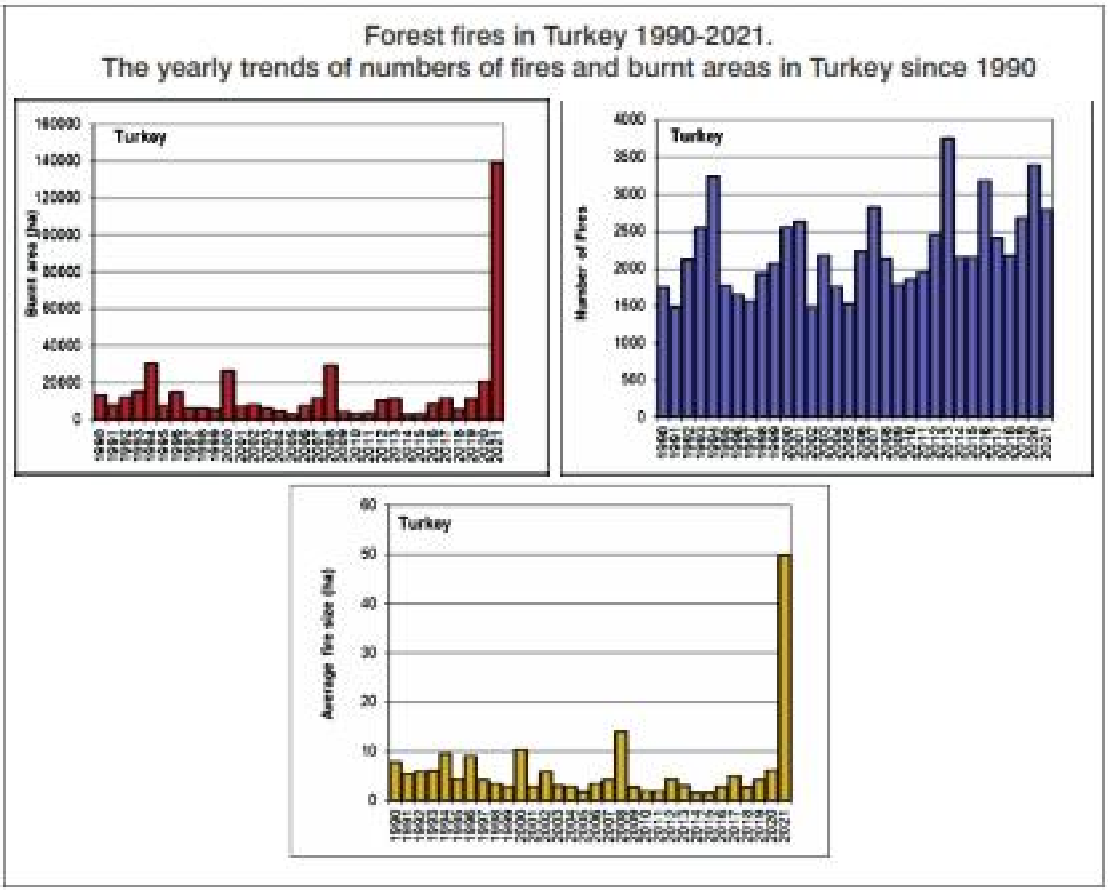


Figure 2.2.15.

Burnt areas (a), number of fires (b) and average fire size © in Türkiye from 1990 to 2021.

Key Institutions Involved in Forest Fire Prevention and Management

Fire management in Türkiye is carried out under the responsibility of the General Directorate of Forestry (GDF). Duties are carried out by state forest enterprises functioning under regional directorates.

So far, 776 fire towers have been built to detect fire and report to firefighting teams. With 324 cameras at 162 points, the fires detected in our forests in the fire-sensitive zone are reported to the fire management centers and the teams are sent.

Regardless of the high costs, all required activities are planned and implemented immediately. Fire management deals mainly with early detection, prevention, and control activities. The system enables rapid forest fire detection to visible range optical cameras (Fire management centers can also monitor the progress through these cameras). Unmanned aircraft were used for the first time in 2021. Fire detection can be done easily with thermal cameras. Thermal cameras are very useful for managers in the ongoing fires at the decision stage.

Restoration Practices for Biodiversity Recovery in Fire Affected Areas

- Planting fire-resistant species when rehabilitating burning areas.
- Converting existing forests to fire-resistant forests. (YARDOP Project: Rehabilitation of Burned Areas and the Establishment of Forest with Fire Resistant Species Project).

- Creating differential elements (roads etc.) to stop probable fires starting in settlements and agricultural lands from going towards the forest.
- Planting fire-resistant species along roadsides hinders forest fire from turning into crown fire.

Role of Research and Academic Institution in Generating Relevant Knowledge

An International Forestry Training Center, developed and directed by Orman Genel Müdürlüü, OGM, in Antalya, is a state-of-the-art training facility complete with living quarters where fire managers use computer-based training modules to teach job-based skills for personnel assigned different tasks in forest fire management. Trainees take formal course work and use realistic fire simulators to develop operational, tactical, strategic, and leadership skills. Over 4,000 Türkish firefighters have trained at the centre since it opened in 2013.

Türkiye's Life: Fire Management Grant Program, launched to reduce the risk of wildfires causing great damage to nature and people, and to be better prepared for possible fires, will support local organizations in preventive and remedial actions before, during and after wildfires. Türkiye's Life: Fire Management Grant Program: https://www.turkiyenincani.org/"

Community Involvement and Engagement

In the Bergama district, the Stone Pine farming in the region is a good example of agro-silvipastoral systems. Of 16 villages, 13 are involved in pine seed production in the Kozak subdistrict. Because the distances between trees are wide enough to allow plant growth, grazing is practiced under the trees. As a result of cone collection, pruning, and grazing, there is very little fuel accumulation in stone pine stands, and the height to live crown has increased significantly.

In Cal district, the people are alerted to forest fires through a municipality siren and intervene immediately, with their hand tools, before the Forestry Department requests assistance. Local people are well organized for managing the forestry plantation and have their local leaders. They have very good relations with the local forestry administration.

Capacity Building Initiatives

Training has been given to Forest Fire Workers about fire-fighting methods, first-aid and other technical subjects.

Public awareness and information campaigns can be aggregated into 2 groups:

Awareness-raising activities for target groups.

Activities for children and young people:

- During 2021, brochures, books, and magazines on forests were distributed to schools and other places to raise awareness about environmental, social, and economic issues, fire causes, and how they can be avoided.
- Education, Public awareness and information campaigns.

Several education/training and awareness raising campaigns have been carried out.

Training of Technical Staff: A Fire Expert Training Program has been implemented for personnel who will take charge of forest fires. Subjects such as fire-fighting methods, application of fire-use, first aid, etc., have been given to technical staff in this training program. In 2012 the International Forest Fire Fighting School was opened in Antalya. The facilities provided training to forest fighting teams at national and international levels with a forest fire simulator.

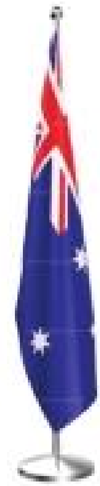
Training of Technicians: Information has been given to technicians about the use and maintenance of tools used to combat forest fires, such as GPS, meteorological equipment, electronic hand tools, and communication devices.

Awareness-raising activities at national level:

- Activities for specific days and weeks. (e.g., World Forestry Day).
- Coordination meetings with local authorities.
- Cooperation with radio and television channels.
- Cooperation with media and voluntary organizations. Training of personnel working in travel agencies and tourist facilities in fire risk areas about forest fires and the preventative measures needed to be taken.
- Training of soldiers and local fire departments.

2.3 REGION : ASIA-PACIFIC

AUSTRALIA



Overview

- Australia's forest area totals 125 million hectares, which accounts for 16% of the country's total land area.
- The largest proportion of forest area is in Queensland (41%; 15,219,000 ha), followed by New South Wales (18%; 22,679,000 ha) and Western Australia (15%; 19,201,000 ha). The forests cover the northern tropical regions of Australia, the subtropical regions on the east coast, and the warm and cold temperate zones in the southeast.
- Weather systems operate differently in temperate and tropical regions of Australia. Severe bushfires are influenced in most cases by hot, dry winds blowing from central Australia.

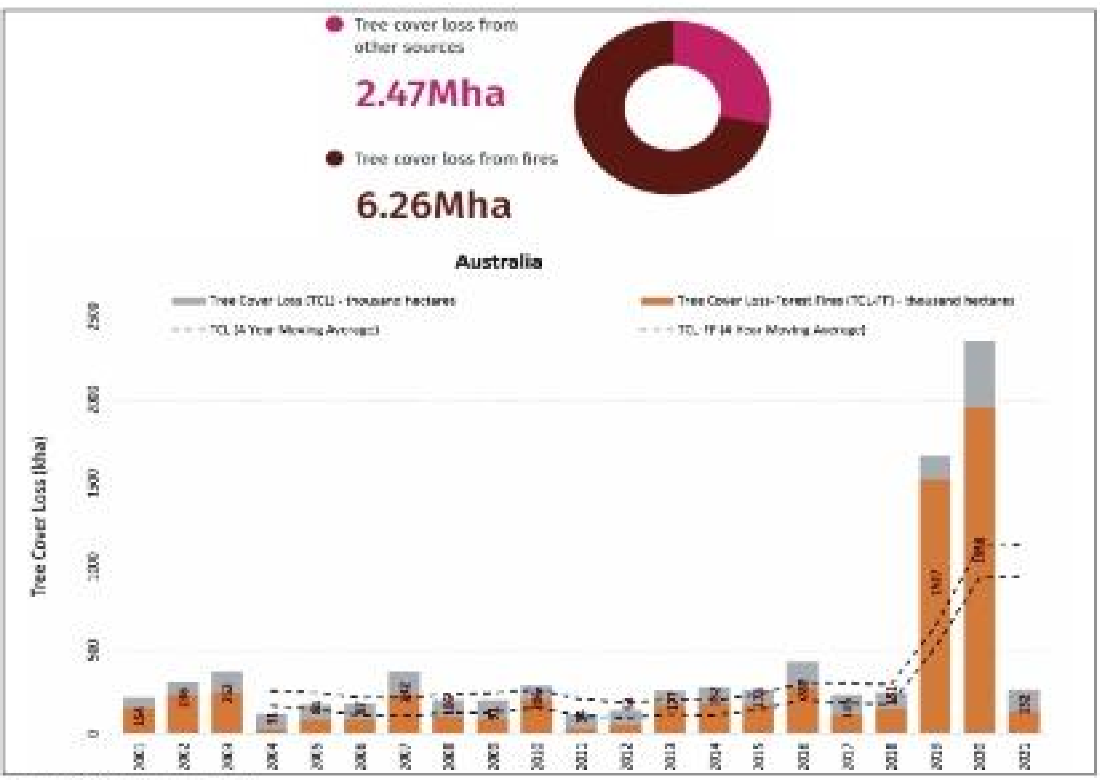


Figure 2.3.1.

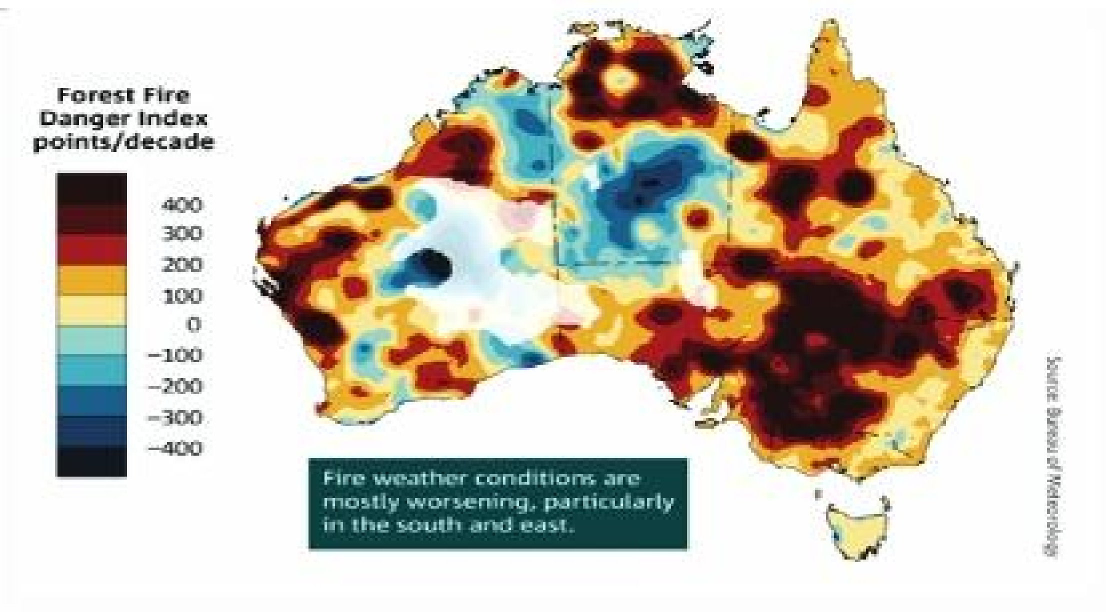
Tree cover and tree cover loss due to forest fires in Australia (2001-2021)

Source: *Global Forest watch*

- The dry summer months are the most dangerous time for South Australia, while North Australia is more vulnerable in winter.

Key Ecosystems Susceptible to Forest Fires

Australia's forests are recognized and valued for their diverse ecosystems and unique biodiversity Wildfires are the greatest threat to these ecosystems, depriving them of their vegetation diversity. The severity of fires is a good indicator of the impact that fire has on ecosystems; however, in the case of Australian wildfires, it is difficult to tell which major ecosystems are vulnerable to wildfire, as more than three billion animals died and 19 million hectares were burned in the 2019-2020 fires. For instance bushfires burned approximately 1,500,000 hectares in Victoria, affecting threatened species and their unique habitats, including about 78% of Victoria's remaining warm temperate rainforest.



(Source: Australian Government Bureau of Meteorology, no date)

Figure 2.3.2.

Forest fire danger Index points/decade

Causes for Forest Fires in Australia

The frequency and severity of bushfires in Australia are worsened by climate change, as it influences temperatures, the moisture of the environment, weather patterns, and fuel conditions. In recent decades, forest fires in Australia have become more dangerous as the weather conditions worsened. Especially in southern and eastern Australia, weather conditions were more extreme in summer, and the bushfire season started much earlier in spring. The changes are directly linked to human-made climate change and increasing temperatures.

Key Institutions involved in forest fire prevention and management in Australia:

- **Australian Institute for Disaster Resilience:** The Australian Institute for Disaster Resilience (AIDR) cooperates with different sectors to enhance the resilience of Australian communities to disasters.
- **The Bushfire Foundation:** Support families, individuals, and communities across Australia before and after bushfires to advance the security and safety of the public, advance the natural environment and prevent or relieve the suffering of animals.

- **Country Fire Association:** T represents the Fire Associations of the different states and territories. They respond to hazards, support the local communities to be fire ready, and use their expertise in fire prevention in one of the world's most bushfire-prone environments.
- **National Emergency Management Agency:** Improves the response to emergencies, help communities with recovery and prepare the Australian public for future disasters, fund programs and initiatives on the topic, work with communities, companies, and NGO and provide 24/7 all-hazards monitoring.

Role of Research and Academic Institution in Generating Relevant Knowledge

Australian Bushfire Research, University of Adelaide: Conducts research on Australia's bushfire response focusing on the consequences of forest fires on the population of Koalas.

Bushfire Research Group, University of New South Wales: enhance the understanding of forest fire, their processes, and their relation to the safety of communities and firefighters. The research includes climate change and fire extremes, fire behavior modeling, and extreme fire development.

Flare Wildfire Research: The institute has developed their own software to predict fire regimes and their impacts. They collaborate with National and international research partners, including agencies, institutions, and research centres.

Community Involvement and Engagement in Forest Fire Management

Safer Together: Safer Together is a program by the State Government of Victoria designed to reduce the forest fire risk through stronger community partnerships with land and fire agencies and the latest science and technology.

Girls On Fire: Girls On Fire is a fire and resilience program for girls and young women to create a sustainable movement of empowered women, diverse allies, and indigenous communities in fire and emergency services.

Northern Territory Fire and Rescue Service: The community engagement unit of the Northern Territory Fire and Rescue Service is focused on educating communities about the dangers of fire and the preparedness for disasters.

Capacity Building Initiatives

Fire Centre Research Hub: The Fire Centre Research Hub offers an online course called Bushfire and your Health, covering topics like the physical and mental health impacts of bushfires and bushfire smoke, and what one can do to reduce your risk. It is conducted in cooperation with the Institute of Medical Research of the University of Tasmania.

Fire Protection Association Australia (FPA Australia): has developed two courses to implement building and planning requirements for development in forest fire-prone areas in Australia. The BAL Assessor Short Course is customised to each jurisdiction's relevant regulations and provisions. It supports the development of skills, knowledge, and ability to determine bushfire attack levels and provide advice on the required construction provisions.

National Council for Fire and Emergency Services: offers a course on Basic Wildfire Awareness to build up knowledge about the key risks associated with bushfires and precautions to stay safe. The course is open to professionals like ambulance officers, police officers, emergency service personnel, first aid officers, and contractors.

INDIA

Overview

- According to the Forest Survey of India's most recent report, the country's total forest cover covers 7,13,789 square kilometrs, or 21.7% of its total land area. According to the current assessment, VDF and MDF combined comprise 57% of the nation's total forest cover. (FSI,2022) India has also been ranked third among the top 10 countries that have gained in forest areas in the last decade, as per the latest Global Forest Resources Assessment (Down to Earth, 2020).
- Forest fires are a regular phenomenon in India, and they frequently occur in the summer. It has a major negative impact on forest ecosystems, landscapes, and the atmosphere, which results in biodiversity loss, deforestation, and densification. In the early 2000s, one of the major forest management problems was the absence of an effective system for monitoring and alerting forest fires (Malakar and Verma, 2019).
- Forest fires based on their origin, are classified into 1. Natural or controlled fires 2. Fires that occur due to heat generated by littler and also due to carelessness 3. Fires ignited by the residents. The other type of classification describes fires as 1. Surface Fire: Spreads from dry leaves etc., at the surface. 2. Ground Fire: burns the organic matter found beneath the waste surface. 3. Crown fire: also known as canopy fire, burns the canopy of trees and is the most difficult type of forest fire. (ICFRE, 2019).
- Punjab had the highest number of fire incidences, with 1,77,000 - a majority of these were caused by man-made stubble burning during the winter season. Madhya Pradesh had 1,43,923 fire incidences, and Odisha had 1,03,919 fire incidences.
- There has been a 10-fold increase in forest fire incidences in the last two decades. While the total forest cover (TFC) has increased by 1.12%, the frequency of forest fire incidents has increased by 52 percent.

Key Ecosystems susceptible to Forest Fires in India

- Fires are particularly frequent in tropical deciduous forests where summertime water stress is higher. Additionally, it is predicted that 3.73 million ha of forests are damaged annually, with the proportion of forest areas prone to fire ranging from 33% in some Indian States to over 90% in others. (Chandra et. al,)
- The biodiversity of Himalayas has also suffered greatly due to forest fires, which negatively impacts the regeneration of forest species (Binjola, et al., 2022). According to the National Action Plan on Forest Fire, fires-both natural and man-made have played a significant role in reshaping forests since ancient times. The majority of forest fires in India are caused by human activity. It is used by people to prepare land for

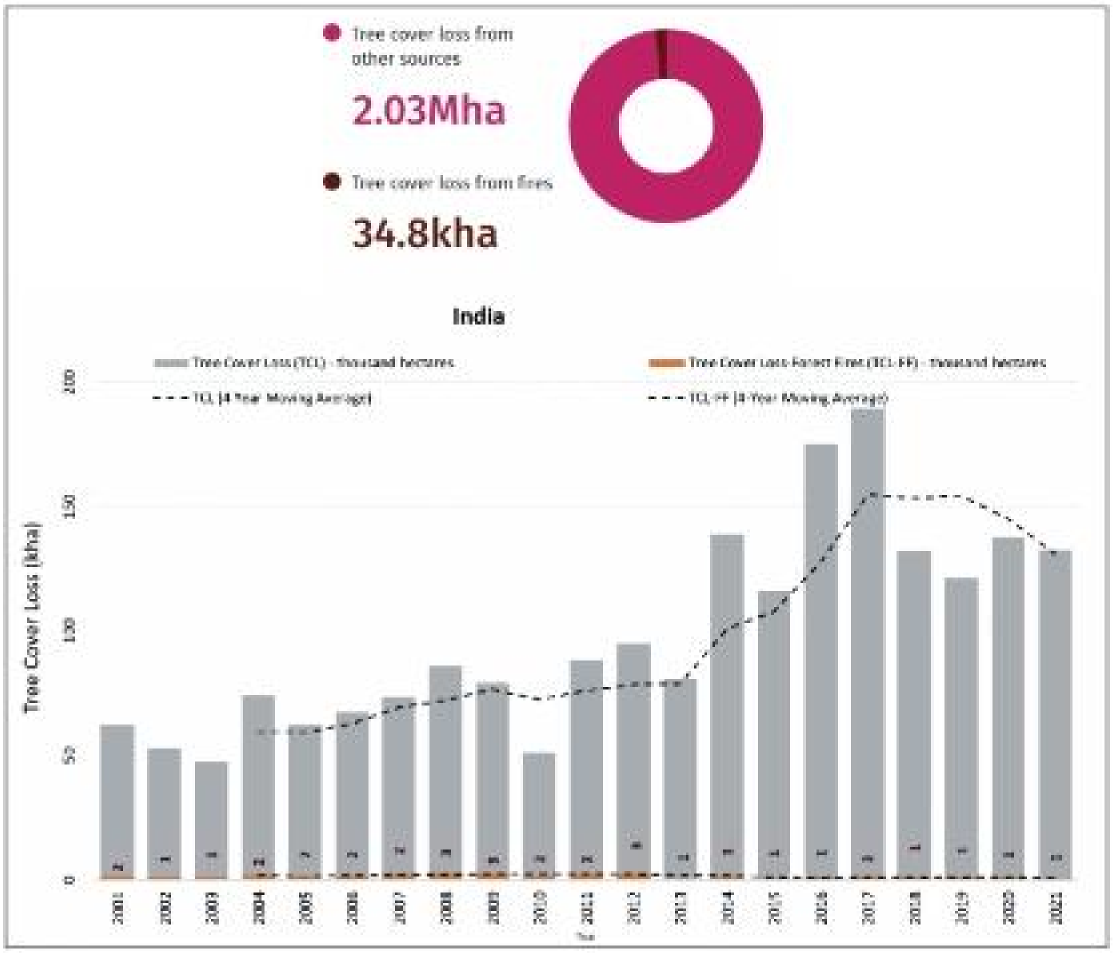


Figure 2.3.3.

Tree cover and tree cover loss due to forest fires in India (2001-2021)

Source: *Global Forest watch*

shifting cultivation, clear the forest floor for the gathering of NTFP, and boost pasture for livestock grazing. Poachers use it to force wild animals out of their hiding places, and many fires are started by careless matchstick throwers and cooking fires that escape from makeshift road worker shelters.

- More than 62 percent of Indian states are prone to high-intensity forest fire events. Andhra Pradesh, Assam, Chhattisgarh, Odisha, Maharashtra, Madhya Pradesh, Manipur, Mizoram, Nagaland, and Uttarakhand were extreme forest fire-prone states across the last two decades (2000-19).
- The most devastating forest fires ever recorded in India occurred in the northwestern Himalayan regions of Uttaranchal and Himachal Pradesh in the summer of 1995. Fires spread over a 677,700-hectare area.

Causes of Forest Fires in India

- Anthropogenic causes (90% of all wildfires) are the major ones in India, including Smoking, Campfires, as during camping or outdoor activities, people normally leave lit fires or combusting materials unattended, which ignite wildfires, Burning Debris, and Fireworks. Natural causes, such as Heat patterns, Lightning etc., are also responsible for forest fires in India.

Key Institutions Involved in Forest Fire Prevention and Management

- A seamless contact with a variety of organizations and social groups becomes crucial for optimal functioning in the multifaceted activity of managing forest fires. MoEF&CC is the prime authority for managing forest fires, and State Forest Departments take charge at a sub-national level. MOEF&CC provides overall policy guidance and standard setting for FFPM.
- FSI (under MOEF&CC) issues pre-warning alerts for high fire danger to state forest departments nationwide. Nationwide monitoring and alerts for active fires are provided to state forest departments and the public. It also provides data on the nationwide estimation of burnt forest areas.
- Besides ICFRE, DFE, NDMA, NDRF, SDRF, SDMA, Fire services, Police, Armed Forces, Eco-Task Force, and State Forest Departments (SFD) along with Military and paramilitary forces plays a crucial role in the prevention and management of forest fire.

Role of Research and Academic Institutions in Generating Relevant Knowledge

- Even though State Forest Departments (SFDs) have taken up direct responsibilities of managing the forests under their geographical jurisdiction (UNDRR), the Government of India established the Indian Council of Forestry Research and Education (ICFRE) under the Ministry of Forest, Ecology and Climate Change to pay greater attention to the task of forestry research and forestry education in the country.
- Academic and research institutes like FRI, IGNFA, FSI, WII, IIFM, NIDM work on diverse fire-related research and capacity development projects to generate relevant knowledge in forest fire prevention and management.

Community Involvement and Engagement in Forest Fire Management

- Joint Forest Management has been used as a tool to involve the local communities in the prevention and management of forest fires. In India, Joint Forest Management (JFM) Committees have been established at the village level to involve people in forest protection and conservation. Currently, there are 36 165 JFM committees throughout the country, covering an area of more than 10.24 million hectares.
- Evidence from most forest-dense districts of Orissa (an Indian state) suggest that the initiatives that these local communities take to prevent or manage the incidences of forest fires are closely related to how much the dependency is if a scarcity of resources occurs, they are more likely to take quick steps for the control. There were activities carried out by locals which had the potential to cause damage but the provisions taken up showed that the community had potential to keep fire in control, which serves as an example of capacity building among the locals themselves.
- Community-based fire management techniques were employed in Uttar Kannada district of Karnataka state of India. The measures taken were a mixture of community involvement and capacity-building approaches such as awareness programmes, street plays, door to door campaigns, fire control rooms, and building of watch towers. The forest department started receiving more than 5% less alerts within a year of the programme, the burnt area as a result of forest fires over one year, drastically decreased by more

than 58%. This served as an evidence for how dramatically better reporting, putting out, and managing forest fires have been made possible by community-based techniques. (Prashanth et. al, 2020).

Capacity Building Initiatives

The principal need for forest fire suppression is to have an adequate competent, trained, and equipped workforce on the ground, ready to respond and take immediate action. The spread of forest fires can be effectively contained by training on high-tech tools (like drones) and nature-based modules, such as making efficient fire lines in the forest. The action suggested for SFD and DFE are;

- The SFDs should develop a modern and standardized training curriculum with the guidance of the Directorate of Forest Education (DFE) of the MoEFCC. Other agencies involved in fire response, including National Disaster Management Authority (NDMA), NDRF, and the State Disaster Management Authorities, may be involved in a consultative role.
- Mock drills should be organized before fire season at various fire-prone areas involving all the stakeholders, such as District Administration, Police, Fire Department, NDRF, SDRF personnel, community organizations etc. to identify gaps in the existing mechanism and better preparedness during crisis time.

The provision of training, equipment, and coordination should extend beyond state-managed forests to community institutions in regions such as the Northeast, where communities are responsible for managing most of the forest estate.

INDONESIA

Overview

Indonesia has total land area of 1,904,569 sq km, of which 1,811,569.00 sq km is land areas and 93,000 sq km is inland seas (e.g., straits, bays, and other bodies of water; World Atlas, 2021).Indonesia's forest land is divided into conservation, protection, and production forests. The production forest is further divided into limited and permanent production forests. The area under forest is 49%. As of 2020, the total land area of permanent production forest in Indonesia was around 292,200 sq km (FAO, 2022). Production forests are a mix of primary forests, secondary forests, plantations, non-forested land, and unclassified areas (World Resources Institute, 2021). Forest and peat-land fires are common in Indonesia during the dry season however, in 2019, it was escalated due to a combination of factors, including extended droughts and global warming,

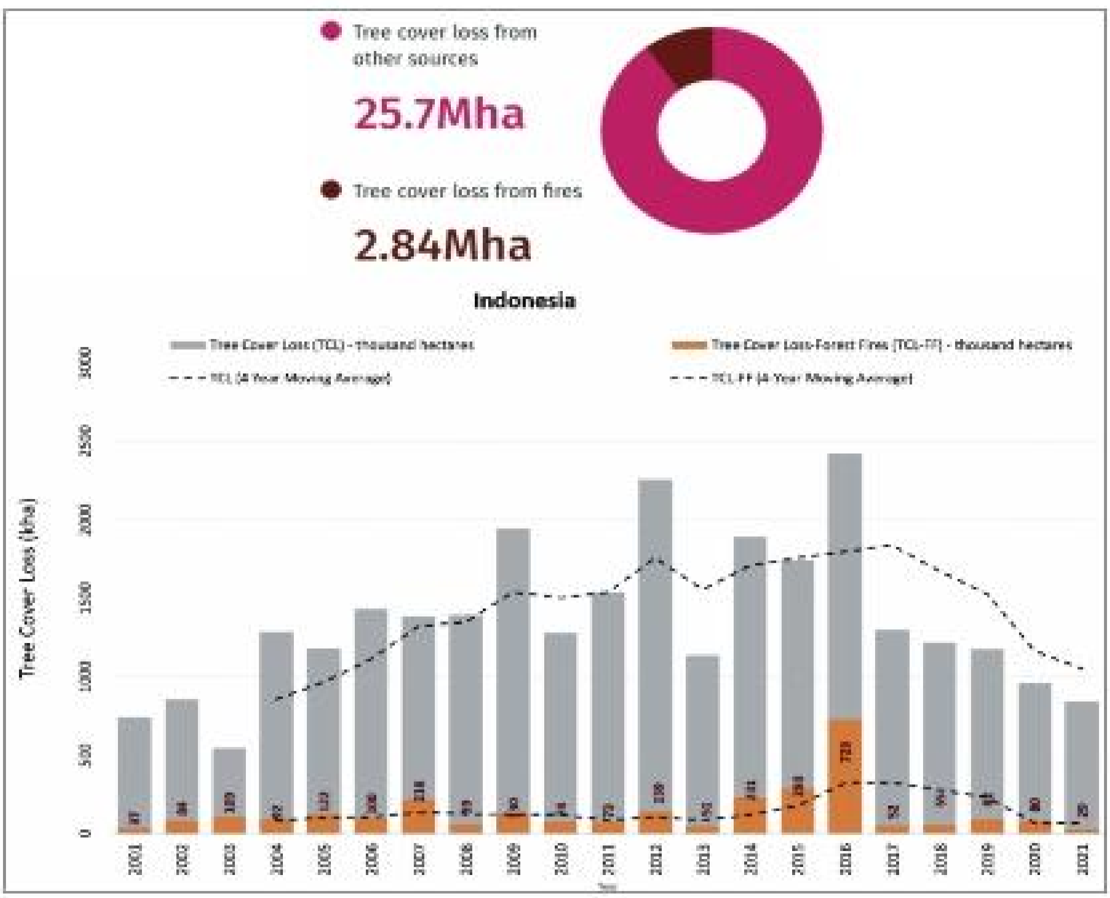


Figure 2.3.4.

Tree cover and tree cover loss due to forest fires in Indonesia (2001-2021)

Source: *Global Forest watch*

which subsequently dragged nearly 10 million children at risk from air pollution across Kalimantan and Sumatra (UNICEF 2019). The forest and peat-land fires resulted in $16 billion in economic losses and spewed a high amount of greenhouse gas emissions (Haniy et al., 2019).

Area Under Forest Fire

As of 2021,fires had burned 353,222 ha of forest land in Indonesia (Jong, 2021), whereas, in 2020, 296,942 ha of forest land was burnt (Ministry of Environment and Forestry, 2020). In consecutive years, West Nusa Tenggara and East Nusa Tenggara Provinces have under gone major fire incidents (Jong, 2021).

Types of Forest Fire

Tropical peat swamp forest fire is common in Indonesia. The peat-land fires occurred in three stages—surface fire, shallow peat-land fire, and deep peat-land fire. The risk of fire on the peat-land is increased greatly by drainage, which lowers the water table, exposing a greater volume of dry peat to combustion (Page et al., 2013; Hayasaka et al., 2020).

Key Ecosystems Susceptible to Forest Fires

Tropical peat swamp forests are the most susceptible to forest fires. Peat is highly extinguishable and doesn't get burnt in one forest fire, so the occurrence of forest fires in that region increases (Loisel and Gallego-Sala, 2022). These forests have been converted to agricultural and oil palm plantations in recent years, further pushing their vulnerability to fire. Reduced canopy cover, decreased species richness, and high tree mortality are among the effects of fires on peat swamp forests (Yeager et al., 2003). The genera that dominate the burnt ecosystems are Pheidole, Reticulitermes, and Solenopsis (Wasis et al., 2018). Indonesian tropical peat-lands form 36% of the world's total peat-land area, which hold 28.1 gigatons of carbon, thus being a major potential source of greenhouse gases if burnt (Ribeiro et al., 2021). Besides, the negative impacts of forest fires include increased greenhouse gas (GHG) emissions, regional trans boundary haze pollution, and a reduction in productivity by reducing biodiversity and storage of terrestrial carbon (Saharjo, 2022).

Key Institutions Involved in Forest Fire Prevention and Management

The three broad sectors responsible for the restoration of forest fire-affected areas are the government sector, the NGOs, and the private initiatives (Wicaksono, 2017). The responsible institutes are listed below:

Table 2.3.1.

Tree Cover Loss of due to Forest Fires in G20 Countries (2001-2021)

1.	The Peatland Restoration Agency
2	Ministry of Environment and Forestry
3	Regional/Local Government
4	Coordinating Ministry for Maritime and Investment Affairs
5	Coordinating Ministry for Politics Law and Security Affairs
6	Coordinating Ministry for Economy Affairs
7	Ministry of National Development Planning/National Development Planning Agency

8	Ministry of Agriculture
9	Ministry of Public Works and Public Housing
10	Ministry of Marine Affairs and Fisheries
11	Ministry of Agrarian Affairs and Spatial Planning/National Land Agency
12	Ministry of Home Affairs
13	Ministry of Finance
14	Ministry of State Apparatus Empowerment and Bureaucratic Reforms
15	The Executive Office of President
16	Geospatial Information Agency
17	Gov Technical implementing unit of central/regional/local government
18	Nongovernmental Organisations
19	Concession holders.

Community Involvement And Engagement In Forest Fire Management

Transforming traditional methods into a more sustainable system became one of the strategies of livelihood revitalization for the community who lived near the peat-land (Nugroho et al., 2021). Zero-burning peat-land preparation, non-drainage peat-land use management, and eco-friendly commodities were some the activities encouraged by the Peat-land Restoration Agency (PRA) or Badan Restorasi Gambut (BRG). The Indonesian government established PRA under Presidential Regulation Number 1 of 2016 after the incidence of severe forest fires in 2015 (Wicaksono and Zainal, 2022). Further, PRA launched 1000 community livelihood revitalisation packages involving more than 29,600 community members in their programmes (Gambut, 2021).

Capacity Building Initiatives

The Forest Research Institute in Indonesia, with other organisations, headed tree species plantations in the degraded land. They used Agro-silvo-fishery, mycorrhizal fungi, creation of buffer zones, and other ways. The main tree species used in the initiative were Dyera polyphylla, Shorea balangeran, Tristaniopsis obovate, Dyera polyphylla, Alstonia scholaris (Yuwati et al., 2021; Geisen and Sari, 2018). The World Bank funded Indonesia in the 1980s to start a transmigration programme displacing people from forest fire-prone overpopulated regions to underpopulated ones (WITS, 1990). It had allocated $560 million for the transmigration program over the previous decade. It planned to allocate $680 million of fresh funds for the establishment of "nucleus estate and smallholder" (NES), which was small farmers growing commercial crops and selling them to the government (The World Bank, 1986).

JAPAN

Overview

Japan is an island country in East Asia. Located in the Pacific Ocean, it lies east of China, Korea, and Russia, stretching from the Sea of Okhotsk in the north to the East China Sea in the south. Its capital and largest city is Tokyo.

From the subtropics in the south to the subarctic in the north, the Japanese archipelago runs over 3,000 km. Hokkaido, Honshu, Shikoku, and Kyushu make up the majority of Japan's land area, although clusters of smaller islands maintain comparatively high levels of biodiversity. However, Japan is a densely populated, industrialized country, but biodiversity is still very high. As a result, the archipelago has been categorized as one of the world's 36 biodiversity hotspots (Mittermeier et al., 2005).

In Japan, the forest cover is spread across 25 million hectares which is2/3 of the national land.

Among the total forest cover, about 40% is covered by planted forest (Forestry Agency Ministry of Agriculture, Forestry and Fisheries, Japan, 2021; Forestry Department Food and Agriculture Organization of the United Nations, 2007).

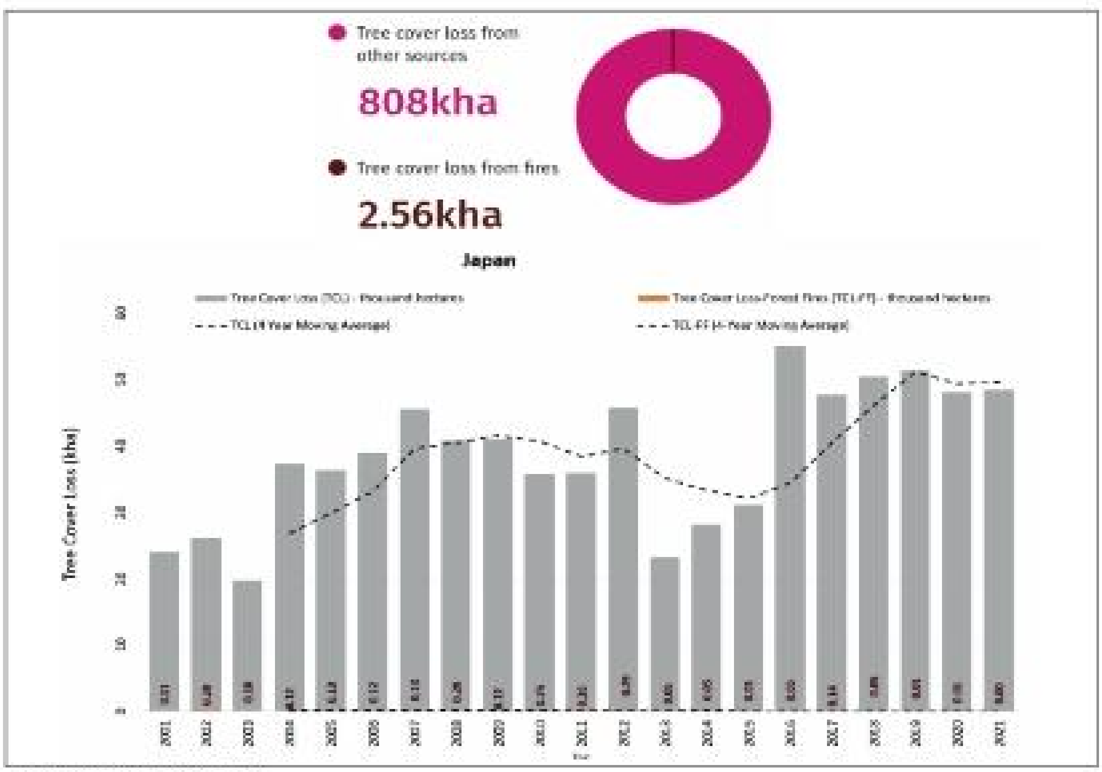


Figure 2.3.5.

Tree cover and tree cover loss due to forest fires in Japan (2001-2021)

Source: *Global Forest watch*

Area Under Forest Fire

Yearly 3,000 to 5,000 forest fires occur in Japan that ruins 2,000-5,000 ha of forest area (Nakagoshi,2001; Satoh et al., 2004). The fire densities in Japan are about 8 fires per 1000 km2 per year (Satoh et al., 2004). Goto & Suzuki (2013) in their paper has discussed the estimation of forest fire from 1979to 2008 for 30 years. It was shown in their result that the area burnt in 1983 was 6473 ha and in2006 it was 336 ha (Goto & Suzuki, 2013). According to the annual forest report 2021, in the year2020, a total of 1,239 forest fires occurred that affected and burned 449 ha of forest. Most forest fires occur in the winter and spring and the main cause of the forest fire is carelessness using fire by people (Forestry Agency Ministry of Agriculture, Forestry and Fisheries, Japan, 2021).

Causes of Forest Fire

The two main reasons for the forest disturbances in Japan are typhoons and forest fires. The majority of forest fires in Japan are caused by human activity. The chances of a fire in the spring are the highest as the air in the early spring gets dry and the litter accumulates, which serves as the fuel for the forest fire (Nakagoshi, 2001). In north Japan, the increase of fires in spring delays due to snow compared with the south (Satoh et al., 2004). According to Nakagoshi (2001), the chances of forest fire are different in different sites of Japan, usually when there is low precipitation and humidity. About 99.9% causes of forest fires in Japan are man-made, caused by human activity, including the improper use of fire for farming and reforestation, open-air fires, and the burning of trash, cigarettes, and fireworks. Lightning also starts forest fires in Japan sometimes (Nakagoshi et al., 1987).

Key Ecosystems Susceptible to Forest Fires

Fires not only result in the devastating destruction of the flora and bio-community, but they also impair the ability of forests to preserve their environment (Nakagoshi, 2001). The Seto island of Japan is the most susceptible area to forest fire, as it has the most dry weather. Dicranopteris linearis and Gleichenia japonica are the herbaceous ferns that are grown in this region predominantly, and the dead plants material that makes up the fuel for the forest fire are the reason for most of the forest fires of this region (Nakagoshi et al., 1987). Change in the soil composition due to forest fires is one of the factors that is responsible for the change in the whole ecosystem. The soil microbes that depend on the soil environment for their survival get affected due to the forest fire and vice versa. They alter the soil composition that in turn affects the whole ecosystem (Eldridge, 1998). When the soil properties change due to the forest fire, the carbon (Kniker, 2006) and nitrogen cycle of the terrestrial ecosystem also gets altered, which influences the soil-atmosphere exchange of major greenhouse gases (GHGs) like carbon dioxide, methane and nitrous oxide (Kim et al., 2011).

Key Institutions Involved in Forest Fire Prevention and Management

During the Edo era in 1648 in Japan, the Japanese fire Services got started by the government. The Fire and Disaster Management Agency (FDMA) is the fire institution at the national level. The overall number of local fire departments in Japan is 1706, there are 807 fire department headquarters there, and there are 157,860 active firefighters nationwide. There are 2,380 volunteer firefighting groups and 888,900 volunteer firefighters overall. Additionally, there are 23,180 local chapters (Fukami & Hisamoto, 2010).

In Japan, wildland fire suppression is the responsibility of the local fire departments in towns, cities, and villages. Support methods for large fires are available, which include dispatching the fire departments of nearby cities, towns, and villages as well as the Japan Self-Defense Forces (UNECE & FAO 2002).

Role of Research and Academic Institution in Generating Relevant Knowledge

There are various research and academic institutes which are working for generating relevant knowledge on forest fires. In the Tokyo University of Science, The Center for Fire Science and Technology (CFSaT) was established in 1981. The center works for the Advanced Fire Safety Science and Technology where they promote fire safety research, education and engineering (Advance Fire Safety Science and Technology, n.d.). The National Research Institute of Fire and Disaster of Japan works for the continual application of fire and disaster prevention research and development based on the long-term goal (National Research Institute of Fire and Disaster, n.d.).

Community Involvement and Engagement in Forest Fire Management

The fire service of Japan is established as a community-based municipal fire service that performs the tasks like firefighting, emergency, and rescue services. The Fire and Disaster Management Agency (FDMA) and fire departments of the country provide fire services in the cities, towns, and villages (Fire Service System in Japan, n.d).

Capacity Building Initiatives

The national forest fire prevention campaign, an initiative of the Fire and Disaster Management Agency and the Forest Agency, is held concurrently with the spring national fire prevention campaign in order to promote public awareness and the efficacy of fire prevention. This annual educational campaign aims to spread the message about preventing forest fires through educational activities primarily geared toward hikers, locals, and elementary school and junior high school students. Banners and posters are placed in stations, municipal buildings, and at the entrances to mountain routes. Training and study sessions on fire prevention are conducted (UNECE & FAO, 2002).

Figure 2.3.6.

An educational poster to spread awareness about forest fires

Source: *UNECE & FAO, 2002*

RUSSIA

Overview

- The area of boreal forest burned annually in Russia is many times that in North America, and the fire pixel count is much greater (Wooster, 2004). The application of various remote sensing instruments has shown that the average vegetation wildfire area in Russia for 1998–2010 accounted for 8.2 ± 0.8 × 106 ha, with about two-thirds of wildfires occurring on forest lands and half on forested lands (Shvidenko, 2013).
- In Russia, the peak fire season normally starts in the middle of May and lasts for around 18 weeks. During 2022 and 2023, 15,736 VIIRS fire alarms (high confidence) were received. Russia lost 76.0 million hectares of tree cover between 2001 and 2021, which is 10% less than it was in 2000, and produced 14.2Gt of CO_2e emissions.

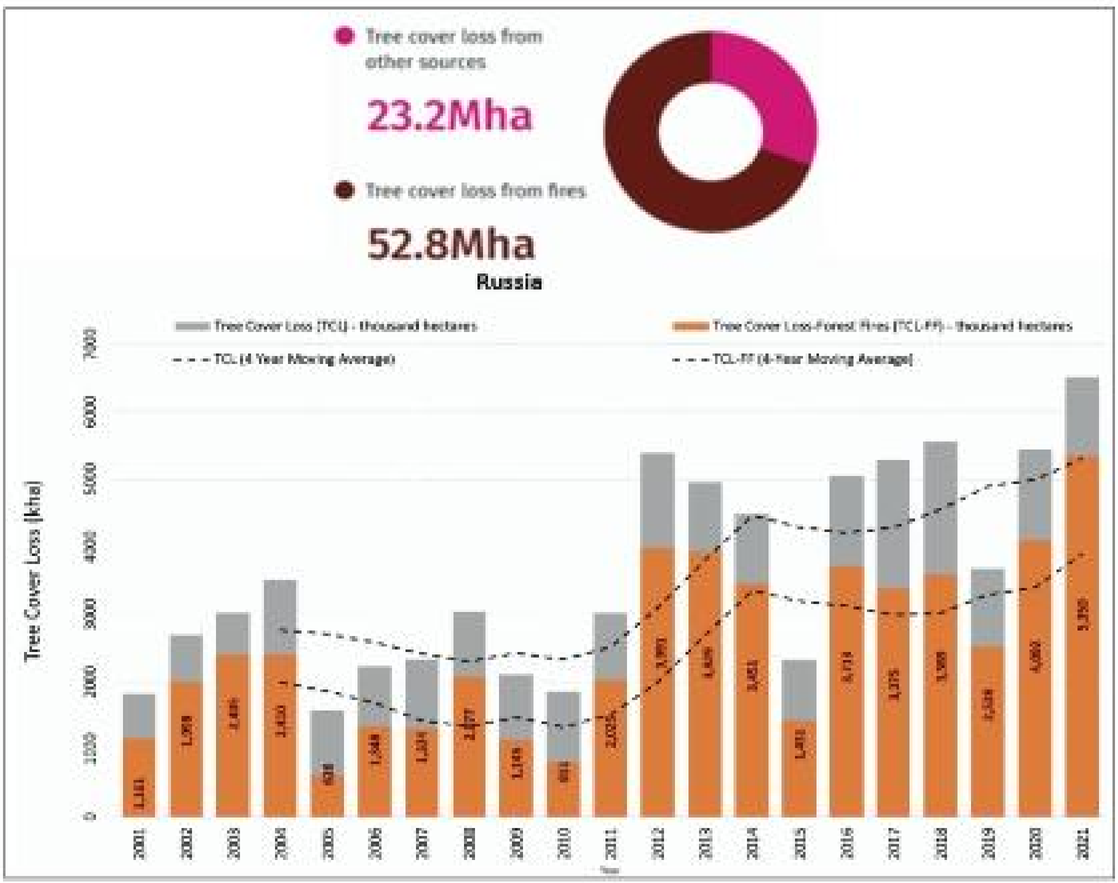


Figure 2.3.7.

Tree cover and tree cover loss due to forest fires in Russia (2001-2021)

Source: *Global Forest watch*

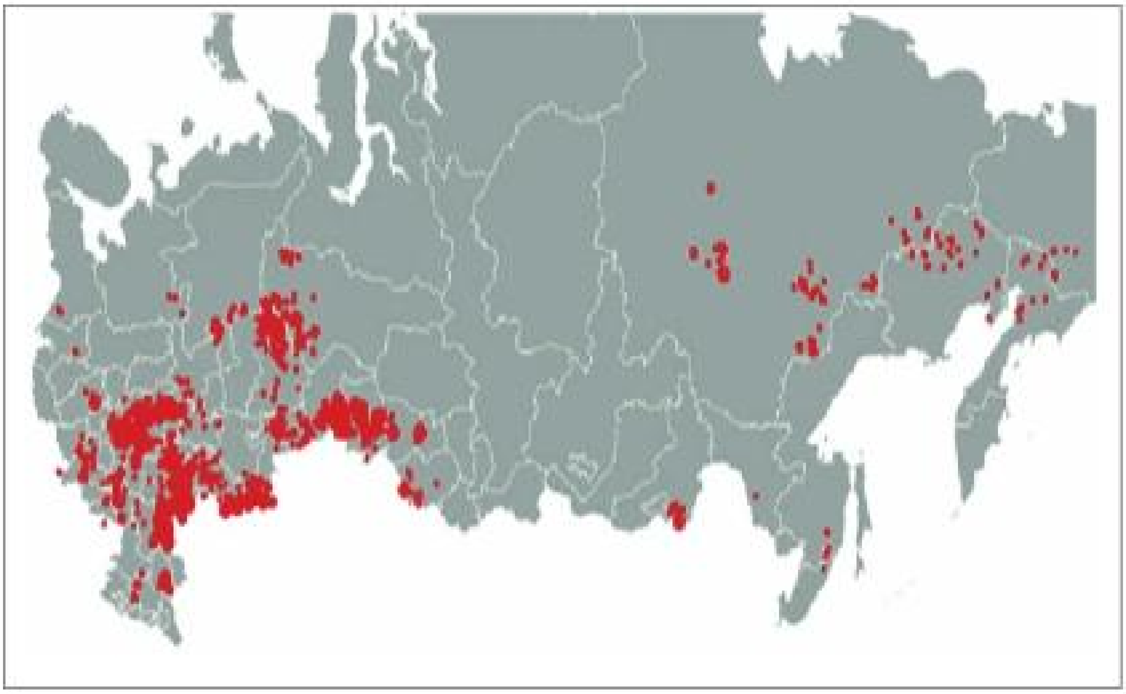


Figure 2.3.8.

Wildfire intensity across Russia (2010)

Source: *Source: http://fires.kosmosnimki.ru/.18*

- Wildfires caused 68% of the loss of forest cover (out of 76 Mha) and 60.5% of emissions (out of 14.2 Gt CO2e). During the most recent five years (2017-2021), forest loss and emission shares were 37.7% and 41.5%, respectively, and 2021 saw the most severe forest fire, which resulted in a loss of 5.36 Mha. However, the year with the most fires on record was 2008, which resulted in a 24 Mha loss of tree cover.
- During summer months, forest fire is a persistent problem in Russia. Surface, ground, and crown fires are widely distributed in the country. Peatfires are difficult to control in the country. Siberia and the country's Far East, which are home to more than 80% of Russia's forests, are where more than 80% of the country's fires occur.

Key Ecosystems Susceptible to Forest Fires

- Russia's forests are important from an ecological, economic, and cultural perspective. Russia has a sophisticated system for categorizing the use and cover of wooded regions. The Russian Forest Fund (RFF) includes all territories under governmental management (FF) and is divided into two main categories: forest-lands and non-forestlands (Shvidenko, 2000). Russia, with over 45% (761 Mha) of its total geographical area is covered by natural forests.
- Taiga (Boreal) forests, mixed, deciduous (wide-leafed), and coniferous forests are the main types of woods in the nation. Taiga or boreal forest, is made up of evergreen conifers like spruce, pine, and fir and is rich in biodiversity. Boreal forests are particularly susceptible to forest fires because they contain a large amount of flammable material, such as deadwood and dry needles. Coniferous and deciduous trees like birch, aspen, and larch make up mixed forests. Coniferous woods are found in Russia's northern and eastern regions and are predominately made up of coniferous trees like pine, spruce, and larch. Deciduous forests are only found in the southern regions and are made up of oak, maple, and beech.

- In Russia, a large part of forests grows in the permafrost areas. In the region, it has also seen a clear impact of climate change on the spread, severity, and altering nature of wildfires. The frequency of catastrophic fires that cover tens and hundreds of thousands of hectares across vast geographic areas has increased as a result of this climate trend, which has also caused the degradation of forest ecosystems, the loss of biodiversity, the disruption and destruction of the raw material base of the forest industry, and the emergence of specific weather patterns on the vast areas that have a negative impact on the economy and infrastructure and worsen the living conditions. This would likely result in a major loss of forested land and the impoverishment of the forest cover over a long period of time given the rise in the amount of dryness in the environment and the thawing of permafrost (Shvidenko, 2013).
- Large portions of Russia's southern region are covered with grasslands, often known as steppe ecosystems, which are prone to flames, particularly during dry or droughty seasons or times. The country's peat-lands are rich in organic materials, but they are also prone to fire and stay on fire for a long time since it is difficult to put it out. The majority of the country's northern region is covered by the tundra habitat, which has a cold and dry climate. Even though tundra fires are uncommon, when they do happen, they can burn for a very long time because the flora takes a long time to regenerate.

Causes for forest fires in Russia

- Ninety percent of forest fire in the fire-monitored area is due to anthropogenic factors, and thus the implementation of selected fire management measures can reduce the forest burned area annually by upto 20% (Korovin, 1989). Further, the management of boreal forest systems to conserve and sequester terrestrial carbon should comprise of the establishment of plantations, thinning, improvement of harvesting practices, and soil management (Winjum et al., 1992). The organic material of living ground cover in micro elevations and partially in micro depressions is entirely destroyed by medium- and high-intensity ground fires; the regeneration of live ground cover on burned sites is very gradual and does not stop even after 56 years (Prokushkin, 2011).
- During summer months, forest fire is a persistent problem in Russia. Surface, ground, and crown fires are widely distributed in the country. Peatfires are difficult to control in the country. Siberia and the country's Far East, home to more than 80% of Russia's forests, are where more than 80% of the country's fires occur. Because of the lack of fire monitoring and control and the low population density in distant locations, fires are frequently not put out (Stephens et al, 2014). Economically driven arson, which happens when wood dealers urge or bribe people to purposefully start fires to increase allowed salvage logging in southern Siberia, is a growing problem (FAO 2006).
- Mega fires frequently replaced the fire-excluded ponderosa pine (Pinus ponderosa) forests in Yosemite National Park with shrub lands and grasslands (Thode et al. 2011). People are building and living in dangerous locations and are not taking adequate fire protection measures (Stephens et al., 2015).
- Russian forest fires can be extremely difficult because of their isolated locations, scarce resources, and severe weather. Urbanization, the post-Soviet reform of the public forest management system, financial constraints, and falling trends in forestry activities are only a few examples of the local socioeconomic and political conditions throughout the past few decades. These elements are anticipated to play a significant role in predicting Siberian forest fire trends going forward (Narita et al., 2021).
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Key Institutions Involved in Forest Fire Prevention and Management in Russia

- The International Forestry Institute in Moscow has created a GIS in collaboration with other academic institutions since it is the most efficient way to analyze the temporal and spatial structure of Russian forest fires and their ecological effects on the structure and dynamics of boreal forests (Korovin,1996).
- At the country level, the Ministry of Natural Resources and Environment developed national forest fire prevention plans and coordinate forest fire prevention. However, the federal forest agency have been working towards the prevention of forest fire through field-level interventions including creation of fire lines and maintenance, which includes the removal of deadwood, brush, etc. There is regional forest fire centres (10 in number), responsible for fire prevention and management in their respective regions.
- These centres are also responsible for the issue of fire warning and coordination of firefighting. Over on all, Rosleskhoz, the Federal Forestry Agency's regulatory and supervisory body, ensures compliance with forest fire prevention regulations and coordinates with regional forest fire centers to respond to forest fires. Forest fire is one of the emergencies and receive response from the emergency Ministry also.
- The Russian government responded by implementing a number of short-term policy efforts to enhance the management of forest fires Sidortsov (2011), including more investments in fire suppression and prevention equipment, organizational changes in federal responsibilities for fire prevention and firefighting, and more transparency and accountability by posting satellite photographs of all territories affected by forest fires.

Role of Research and Academic Institution in Generating Relevant Knowledge

- Several research publications related to the post-fire restoration following are the few research outcomes of forest fire restoration in the country.
- Vegetative regeneration (re-sprouting) of the same burned individuals and the establishment of new individuals through seed germination are the two primary processes by which plants can recover from fire (Vallejo, 2012). Both the processes of vegetative and generative shoot regeneration and growth were more active in the fire-damaged plant community than in the unburned plant community. This resulted from decreased species competition and substrate regrowth in the post-fire plant community (Suleymanova et al., 2019). However, the development of a new generation of trees depends on the fire intensity, characteristics of tree species, number of survived trees, the initial post-fire abundance of herbaceous plants and shrubs, and the general forest-growing conditions (Komarova, 2013). During the first years, fire creates a favourable ecological niche for the self-seeding of coniferous and broad-leaf species, and regeneration processes can follow different directions in the formation of the future planting composition, and that depends on soil and hydrological conditions (Danilov et al., 2019).

- According to soil and hydrological circumstances, a study by Danilov et al. (2019) on the forecast succession pattern of post-fire restoration in the landscape of the Tikhvin Ridge proposed the following for forest fire restoration. In Sandy soil, pine-birch forest stands or pine with the participation of birch forest stand; in Sandy loam humid soil and Sandy loam excessively humid soil, pine-birch forest stands mixed with spruce forest stand or pine-birch forest stand; in Loamy soil, pine-birch with the participation of spruce stand; pine-birch with an admixture of spruce or spruce-pine with the participation of birch; in Loamy clay soils, spruce with birch and pine forest stand and Peaty soils, pine with the participation of birch forest stand.
- In the deciduous Broadleaved-Korean pine and dark Coniferous-Korean pine forests of the Southern and Middle Sikhote-Alin Mountains, post-fire rehabilitation has been researched between 1975 and 2006. In roughly 200 burn sites, which had been devastated by fires over various years, dynamics of abundance, productivity, the age structure of plant populations, and organization of plant communities have been studied (Komarova and Lee). They (Komarova and Lee) learned on the 15 locations of various ages, the species composition, number, and depth profiles of viable fern seeds and spores in litters and soils were examined.

Community Involvement and Engagement in Forest Fire Management

- In Russia, the Federal Forestry Agency (Rosleskhoz), which collaborates with other governmental agencies, NGOs, and local communities, is primarily in fire control charge of restoring regions devastated by forest fires.
- The restoration by the Rosleskhoz involves mainly the promotion of natural regeneration, planting, application of soil stabilizers, and monitoring the recovery of the ecosystem.

Capacity Building Initiatives

- Like other countries, Russia too follow standard practices that includes public sensitization and awareness creation and engaging the local community, investing in research and innovation for forest fire restoration and management, including new equipment, etc.
- Also started investing in advanced fire detection and suppression systems, initiated dialogue with other countries for technology transfer, etc.
- Training and education to the stakeholders, organizing seminars and workshops are also being organized to improve the capacities of the stakeholders.
- The state's capacity frequently determines the amount spent on fighting fires. The expense of putting out flames has decreased since 2014 as a result of a lack of budgetary resources (financial crisis). The approach of fighting forest fires has altered since 2017.

All fires are recorded by the Department of Forest Relations, but if they endanger communities, they will be put out (Narita et al, 2021).

KINGDOM OF SAUDI ARABIA

Overview

- The Kingdom of Saudi Arabia is a quadrilateral landmass and the fifth-largest country in Asia, covering two-thirds of the Arabian Peninsula with a total geographic area of around 2,15,0000 to 2,217,949 Km2 (Abo-Hassan, 1981; Alfarhan et al., 2021). High altitude mountains (Jabals) (up to 3050 m asl), valleys (wadis), meadows (Raudhas), salt pans (Sabkhas), lava areas (Harrats), deep sands (Nafud), and drainage canals are just a few of the diverse ecosystems found in Saudi Arabia (Alfarhan 1999).
- According to the FAO (2020), 37% are primary forests, and 63% are other naturally regenerated forests. Western escarpment mountains in Yemen are home to forests and dominated by a dense evergreen canopy of mature trees reaching 30 m, dominated by Combretum molle and Terminalia brownie (Scholte et al., 1991; Wood, 1997), and other large tree species, *Acacia johnwoodii, Commiphora kataf,* both

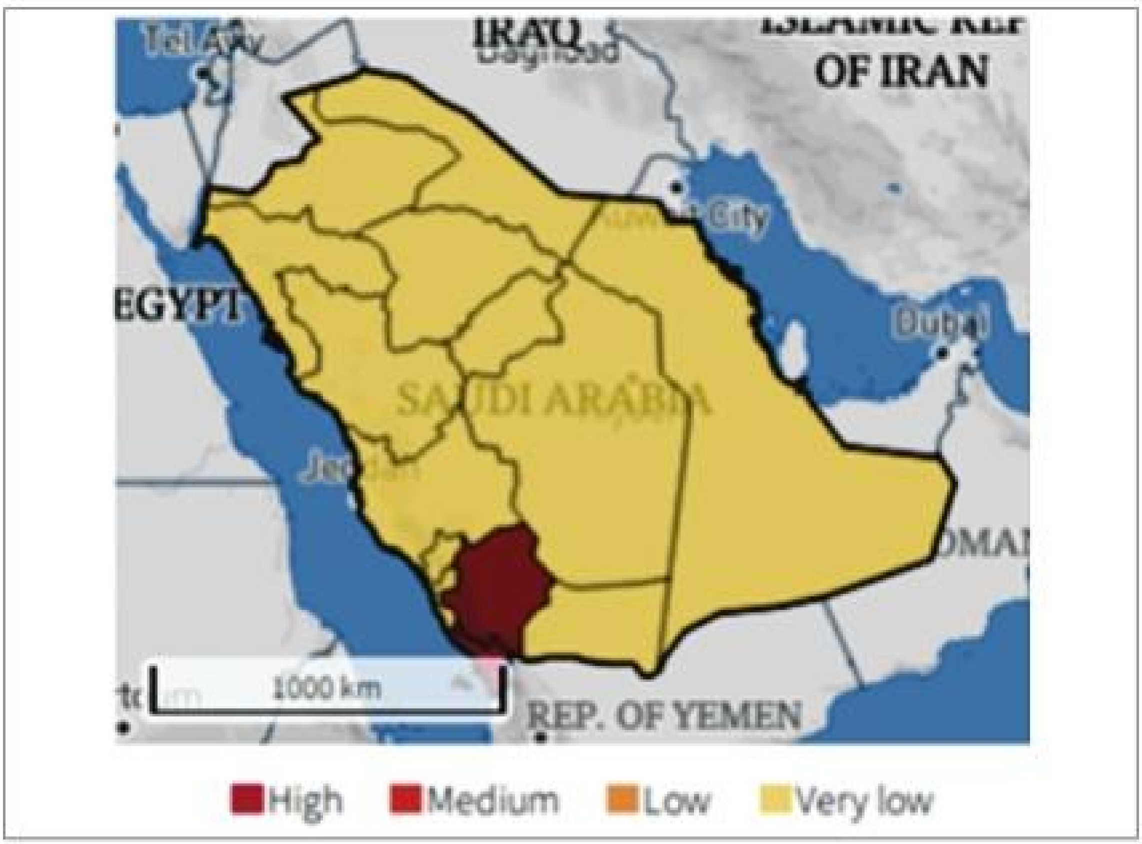


Figure 2.3.9.

Forest Burnt area

Source: *World Bank*

Yemeni endemics, Ficus ingens, Ficus vasta, Ficus sycomorus and *Breonadia salicina* and *Mimusops laurifolia* (Friis, 1992; Hall et al., 2008). Patches of valley forest are found in isolated valleys between 500 and 1000 m on Jabal Raymah, Jabal Melhan (Milhan), and Jabal Bura (the largest area of valley forest), in Wadi Liyah in Khawlan Ash-Sham and in the Haraz mountains (Wood, 1997). Overall the most dominant families are Fabaceae and Poaceae due to arid and extreme arid climate adaptation (Chaudhary, 2001). The vegetation cover in the area is xerophytic (EL-Ghanim et al., 2010).

- The worst year for fires in Saudi Arabia was 2005, when 110000 ha of land was destroyed. In 2022, 280 ha of land will have burned there. Due to human activity, seasonal forest fires are more common in the southwest; the peak fire season often starts in late February and lasts for several weeks. The Visible Infrared Imaging Radiometer Suite (VIIRS), a system for reporting fire alerts, is used across the country to inform and manage forest fires.

- Over a five-year period (1999-2003), 315 forest fires occurred in the natural forests of the Al-Baha and Aseer regions, resulting in the destruction of 22161 hectares of forest, comprising 158,811 trees. 92 percent of these fires were started by human activity (Al-Shehry, 2004). Additionally, 0.13 th. ha of forestland was affected by fire in 2017 (FAO, 2020), with 2005 recording the most fires at 110 th. ha.

- The main fire season in Saudi Arabia normally starts in late February and lasts for around 52 weeks. Between November 8th, 2021, and October 31st, 2022, 313 Visible Infrared Imaging Radiometer Suite (VIIRS) fire alerts were reported, all of which were of high confidence. Compared to years prior to 2012, this is typical. Between November 4th, 2019, and October 31st, 2022, Saudi Arabia got 14,390 VIIRS Alarms fire alerts (www.globalforestwatch.org). Two hundred eightyacres of land have burned in Saudi Arabia so far in 2022. When compared to totals from years' prior, dating back to 2001, this amount is average.

Key Ecosystems Susceptible to Forest Fires

- Rainfall in most of Saudi Arabia is insufficient to support much vegetation, few trees grow, and the majority of the country is classified as desert. (Abo-Hassan, 1981). Drought-resistant plant species are widely spread in Saudi Arabia and distinguished from plants in non-dry conditions at the morphological, anatomical, and physiological levels. Conservation of these species could help to keep the amount of water used for agriculture in the world stable (Alfagham et al., 2022).

- Southwest Saudi Arabia is where you'll find the country's actual forests. The Ministry of Agriculture estimates that the nation has 27,000 km2, or 1.2 percent, of woods in the nation. Around 21,000 km2 of this area is dispersed throughout the Sarawat mountain range in the southwest (NCWCD and JICA, 2006). There are only 2.7 million hectares of these forests left in Saudi Arabia's mountains, mostly in the inaccessible, distant, and steep regions (NCWCD, 2005). The Sarawat mountain range in the southwest is home to over 80% of the country's natural forest, according to FAO (2020), which also noted that 37% are primary forests and 63% are of other naturally regenerated forests. The country, has30000 hectares of protected land, 158000 ha of mangroves, and 360000 ha (37%) of primary forest (FAO, 2020). The forests of the country can broadly be classified into broad-leaved dry, humid, and coniferous forests.

- Forest fires have been more common in Saudi Arabia's southwestern area in recent years. Southwest Saudi Arabia has seen an increase in forest fires in recent years. They believe it poses a significant threat to the entire plant population, especially to natural forests. Broadleaf trees, which can tolerate fire, may survive, whereas sensitive plants like conifers, which are high in resin, may perish. Fire has a distinct effect on the species makeup of the forest.

- Mixed forests make up the majority of the forest system in southwest Saudi Arabia, and the biggest threats to it are fire and cutting (ACSAD, 2003). Seasonal forest fires are becoming more common in the southwestern region as a result of rural growth and human activity (NCWCD, 2005).
- The southwest of Saudi Arabia has seen an increase in recent months in forest fires. They view it as a serious threat to the overall plant cover, particularly the natural forests. Fire has a specific impact on the species composition of the forest because it can cause the sensitive, resin-rich conifers to go extinct while leaving behind the broad leaved trees that can withstand fire.
- The Saudi Arabian woods, which serve a range of purposes, are governed by the Forest and Pasture Law. According to national reports that affect climate balance, a variety of activities pose a growing threat to the diversity of plants, including cutting down trees for fuelwood, overgrazing and/or poor management of rangeland resources, pollution, poor natural regeneration, widespread dieback of Juniperus species woodlands, unchecked forest fires, climate change, drought, etc. (Thomas, 2011).

Causes for Forest Fires in Saudi Arabia

- In Saudi Arabia, majority of the landscape is desert and associated with Oil and Natural Gas. Forest fire is referred to as wildfire, and it is often caused by human activities, including campfires, fireworks, electric equipment, etc. Hot and dry weather conditions are also increasing the risk of forest fire along with lightning strikes during thunderstorms. Slash and burning practice of cultivation in a few regions is also a reported cause of forest fires in the country.
- The southwest of Saudi Arabia has seen an increase in recent months in forest fires. They view it as a serious threat to the overall plant cover, particularly the natural forests. Fire has a specific impact on the species composition of the forest because it can cause the sensitive, resin-rich conifers to go extinct while leaving behind the broadleaved trees that can withstand fire. Keep in mind that historically, forest fires have not usually been the primary causes of forest destruction and have instead been seen as one of the components of environmental equilibrium. Therefore, the issue is with those forest fires that are primarily ignited on purpose by people (Aref and El-Juhany, 2000).
- According to the data that is currently accessible to this programme, the wildfire hazard is rated as high in the region of high project-developed areas. This means that in any given year, there is a larger than 50% probability of coming across weather that could support a significant wildfire that is likely to cause both property destruction and human fatalities. Hence, the high risk of wildfires needs to be considered in project planning decisions, project design, construction, and emergency response planning techniques. Be aware that harm can result from ember storms and low-level surface fires in addition to direct flame and radiation exposure. Strong winds and wind-borne debris may compromise the structural integrity of infrastructure during intense fire weather occurrences.

Key Institutions Involved in Forest Fire Prevention and Management in Saudi Arabia

- Al-Katly (2008) suggested setting up a national body to look after and develop Saudi Arabia's woods. Researchers from King Saud University and the Ministry of Agriculture worked along with experts from the King Abdulaziz City for Science and Technology (KACST) Space Research Institute.
- A Juniper woodland in the Asir Mountains in the Raydah region, 15 kilometers west of Abha City, was classified as a unique nature reserve by the NCWCD in 1989. In addition, from 1999 to 2002, the NCWCD carried out the "Joint Study Project for the Conservation of Juniper Woodlands" in collaboration with the Japan International Cooperation Agency (JICA).
- The General Authority of Meteorology and Environmental Protection (GAMEP) in Saudi Arabia is in charge of keeping an eye on the weather and giving alerts and warnings for potential forest fires.
- Saudi Arabian Civil Defense is also being engaged in extinguishing forest fires, also for creating public awareness along with Saudi Arabian National Guard is responsible for protecting the country's natural resources, including forests, and providing assistance in managing and extinguishing forest fires.
- The Ministry of Environment, Water and Agriculture, Saudi Arabiais being responsible for forest conservation and management, developing policies and strategies for forest fire prevention and mitigation in the country.
- Saudi Arabian Wildlife Authority is responsible for fire prevention and management in the wildlife and their habitats.

Role of Research and Academic Institution in Generating Relevant knowledge

- Encourage the conduct of scientific research in the fields of silviculture, forest management, forest pathology, forest ecology, watersheds, wildlife, wood technology, and others that are related to forests.
- According to the United Nations Environment Program (2001), the primary drivers of biodiversity loss include species introduction, habitat degradation, overexploitation, and pollution. Hema Bani Sar, a traditional system, provides advantages in preserving soils and vegetation density. It is one of the oldest known methods of protecting plant life (Zahran and Younes, 1990).
- The conservation of all the wildlife in the Kingdom is the responsibility of the National Commission for Wildlife Conservation and Development (NCWCD), which has taken a two-pronged strategy. The first step in repairing damaged ecosystems is the declaration of protected areas. Second, if it is within the historic range of a particular species, it conducts captive breeding programmes for endangered native species for reintroduction into these protected regions (Johannesburg Summit, 2002).

Community Involvement and Engagement in Forest Fire Management

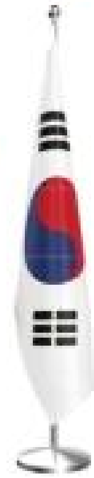
The various linked government sectors, as well as the communities, must work together and support initiatives to restore the degraded forestland. As tools for rehabilitation, protection, silvicultural techniques, and sustainable management must be adopted (El-Juhany, 2009) to encourage the recovery and restoration of harmed ecosystems.

Capacity Building Initiatives

Proposals were made as guidelines to cope with the protection of natural forests in Saudi Arabia's southwestern regions (Aref and El-Juhany, 2000) and they are:

- For recruitment purposes, halt the construction of roads in the forest. To develop them and/or control fires, it is more desirable to allow access to remote areas of forests.
- Rebuild any agricultural terraces that have fallen into disrepair as a result of abandonment or heavy rainfall. In order to prevent rainfall from evaporating away from trees and other plants, it is essential to collect and use it.
- Limiting urban expansion in towns, cities, and villages close to forests while seeking alternatives in areas with little or no tree cover.
- Instead of deforesting regions within forests, locate places that are suitable for afforestation or replanting and devote them to the establishment of parks and recreational facilities.
- Increase the amount of educational programmes about the significance of forests and the need to protect them in the media (TV, press, broadcast, and others). It is also advantageous to host symposiums and scientific conferences on the growth and preservation of natural forests and to invite experts in the field from both inside and outside the nation.
- To create the seedlings needed to fill in gaps in the woods, expand the development of forest nurseries nearby, with a focus on removing alien seedlings to reduce epidemics of local species.
- Define the locations and names of the woods, and erect warning signs close to them to deter illegal actions like cutting and fire-starting. Maps of these woodlands must be made and submitted to the appropriate authorities in order to safeguard them against invasion. By instructing programmers under the guidance of professionals, you may improve the skills of people who plant trees.
- In addition to educating firemen to handle such flames, provide proper measures for containing forest fires, such as observation towers, water tanks, and any other fire control methods.

REPUBLIC OF KOREA



Overview

The Korean peninsula is situated in the centre of the North Western Pacific, between 33°7′ and 43°1′ north latitude and 124°11′ and 131°53′ east longitude, sharing a boundary with China and Russia to the north and the Japanese archipelago to the south. The Korean peninsula covers 221,000 km^2, of which 45% is occupied by the Republic of Korea (ROK). Agriculture accounts for 20% of the total land area in the Republic of Korea, while forests account for 64%. The average standing forest tree volume is 47.5 m^3 per ha in total forest lands and 57.3 m^3 per ha in timber forests, respectively. The Korean forests can be divided into warm-temperate, cool-temperate, and Sub boreal forest zones. Around 85% of forests are cool temperate forests.

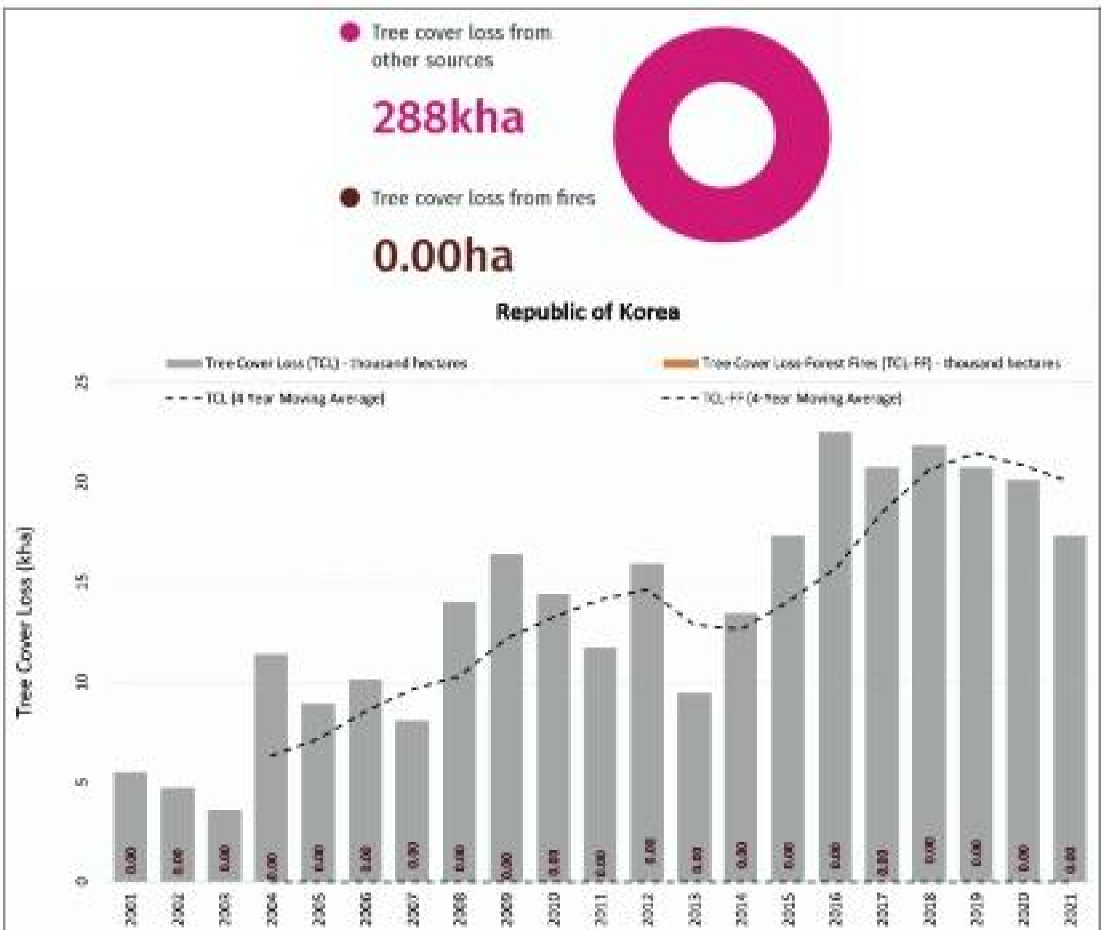


Figure 2.3.10. Tree cover and tree cover loss due to forest fires in Republic of Korea (2001-2021)

Source: Global Forest Watch

Sub boreal forest ➡	**Temperature:** 5? and lower. **Forests:** Coniferous. **Species:** *Abies spp.* (Fir), *Picea spp.* (Spruce), *Larix spp.* (Larch); *Juglans mandshurica* (Walnut).
Cool temperate ➡	**Temperature:** 6? -13? . **Forests:** Broadleaved deciduous trees **Species:** *Quercus spp.* (Oak), *Fraxinus spp.* (Ash), *Pinus densiflora* (Pine), *Zelkova spp.*
Warm temperate ➡	**Temperature:** higher than 14? . **Forests:** Deciduous, mixed or coniferous forests. **Species:** *Quercus actua* (Oak), *Castanopsis cuspidate* and *Camelia japonica.*

Figure 2.3.11.

Forest types of South Korea

Source: *https://www.worldforestry.org/wp-content/uploads/2015/11/korea_s.lee.pdf*

Area Under Forest Fire

Coniferous forest zones, especially pine forests, which are sensitive to forest fires, account for around 42% of all forests in South Korea, where woods cover 64% of the total land area. As a result, Korea is located in areas where forest fires can begin and spread. So far, in 2022, 300ha of land in South Korea has burned. This figure is consistent with previous years dating back to 2001. The year with the most fires was 2011, with 20k ha. South Korea had 4.38 million hectares of natural forest in 2010, accounting for 51% of its total land area. It has lost 12.8 hectares of natural forest by 2021 (Global Forest Watch, 2021).

Types of Forest Fire

A forest fire begins to burn at its ignition point, which varies based on fuel, geography, and wind direction and leaves distinct scars on tree trunks, crowns, grasses, boulders, cans, and fences known as indicators. Such characteristics serve as the foundation for determining the type of forest fire. There are two categories of causes for forest fires: human action and natural elements. In Korea, forest fires are mostly caused by human activity rather than by a natural occurrence like lightning (Van Wagner, 1987). The majority of forest fires are caused by human activity, including fires started by mountaineers (42%), straw burning in rice paddies or farmland (18%), etc. The East Coast Fires of 2000 was the Republic of Korea's most devastating wildfire ever recorded. It was caused by a spark from burning trash and destroyed 23,794 hectares of land (Han et al., 2021).

Key Ecosystem Susceptible to Forest Fire

About 63.2% of Korea's total land area is covered by forests, out of which 97% is covered with conifers that are particularly vulnerable to mega-fires (Korea National Arboretum Annual Report, 2017). Climate change, ignition sources, duration of the fire season, vegetation structure, changes in land use, and institutional limitations for sustainable forest or fire management could all have an impact on fire risk (Forest Resource in Korea). The woods of three eco-regions, Kangwon coast, Woolyong coast, and Hyungsan-Taewha coast(astern coastal region of South Korea), are prone to fire due to insufficient rainfall (Son et al., 2006). The country has a temperate climate characterized by four distinct seasons (Carpenter, 2000). Spring and autumn are relatively short, while summer and winter are rather long (Carpenter, 2000). Both terrestrial and marine ecosystems are home to a wide range of species with great biodiversity (Hong et al., 2021). The Korean Peninsula hosts 4,500 different species of plants. The majority of lands are covered with deciduous broad-leaved and coniferous trees, except for evergreen broad-leaved forests on Cheju Island and in the little sub-tropical strip along the southern coast (Kang et al., 2013). The majority of conifer species in the nation are pines; others are spruces, larches, and yews. Abeliophyllum distichum (white forsythia or Korean abelia), a shrub from the olive family, and Korean fir (Abies koreana) are examples of indigenous plants (Kim et al., 2007). The Faunal structure of Korea is similar to northern and northeastern China. Even in remote locations, tigers, leopards, lynx, and bears, which were once widely distributed, are now all extinct. There are about 380 different bird species in the nation, the majority of which migrate seasonally (Kim et al., 2014). The DMZ area protects hundreds of bird species, including the imperial red-crowned and white-naped cranes, and is also home to Asiatic black bears, lynxes, and other wildlife (Kim et al., 2008).

Key Institutions Involved in Forest Fire Prevention and Management

The Korea Forest Fire Management Service Association: : It is a special corporation founded in 2015 to support the creation of policies and the promotion of technologies for preventing forest fires, such as education, training, research, and cross-border technical information exchange on preventing forest fires. The association provides education and training for forest fire prevention personnel and forest fire prevention projects to protect people's lives and property, as well as valuable forest resources, while pioneering and developing new fields such as forest fire prevention and Forest Fire Area Inspection (KFFMSA, 2015).

National Institute of Forest Science: Since it started as the Forestry Experiment Station on August 23, 1922, the National Institute of Forest Science has steadily conducted various research on forest, forestry, and the wood industry as the only national research institute under the Korea Forest Service, with an objective to develop and disseminate forest science and technology for people's well-being, healthy environment, and global forestation, leading the green growth.

Korean Forest Service: The Korea Forest Service (KFS) is an independent agency specializing in forestry that is overseen by the South Korean Ministry for Food, Agriculture, Forestry, and Fisheries. To prevent forest fires across the country, the KFS has established the national forest fire control centre, and each regional forest fire control centre in 270 provinces.

Role of Research and Academic Institution in Generating Relevant Knowledge

The National Institute of Forest Science aims to create future value for forests through innovation in forest science and technology. It creates knowledge for managing forest fires and compiles relevant information. The information and knowledge are shared across society for future growth (Dhamdhree et al., 2015).

Community Involvement and Engagement in Forest Fire Management

Songgye has a long history in ROK as a form of public participation in forest management."Songgye" is a traditional social institution used by local citizens to maintain forests during Korea's late Chosun Dynasty (almost 300 years ago) (Chun et al., 2009). Songye has rules and restrictions that are similar to the Municipal government legislation that is currently in effect. Sanlimgye was established in accordance with Songgye's history. Toward the end of the 1950s, a total of 21,628 Sanlimyges were established, with over 2 million members (Choi et al., 2008). The main measures to manage forest fires is to raise public awareness through public and educational activities, to manage forest fires through legislation, to develop firefighting teams, and to develop an enabling framework for society to prevent forest fires, as well as to reinforce infrastructural development and preparedness for fires in high-risk areas.

Capacity Building Initiatives

AFoCO Regional Education and Training Center (RETC) organizes various types of training courses regularly to cater to policymakers, technical-level officials, researchers, members of local communities, and the general public. The training on forest fire management includes fire safety and behaviour, fire prevention and suppression, fire inspection, fire information systems, and drone technology. The RETC also offers community courses as well as customized courses.

2.4 REGION : AFRICA

SOUTH AFRICA

Overview

- The huge central plateau that makes up about two-thirds of South Africa is flanked in the east by mountain ranges known as the escarpments. From there, a large midland of rocky hills and valleys leads to a small coastal plain.
- From the year 2001 to 2021, an estimated 116 kha of tree cover was lost in South Africa due to forest fires. This is in addition to 1.41 Mha of tree cover lost during the same period due to other reasons. During this period, 2017 was the worst, with an estimated 20.5kha lost due to forest fires (Global

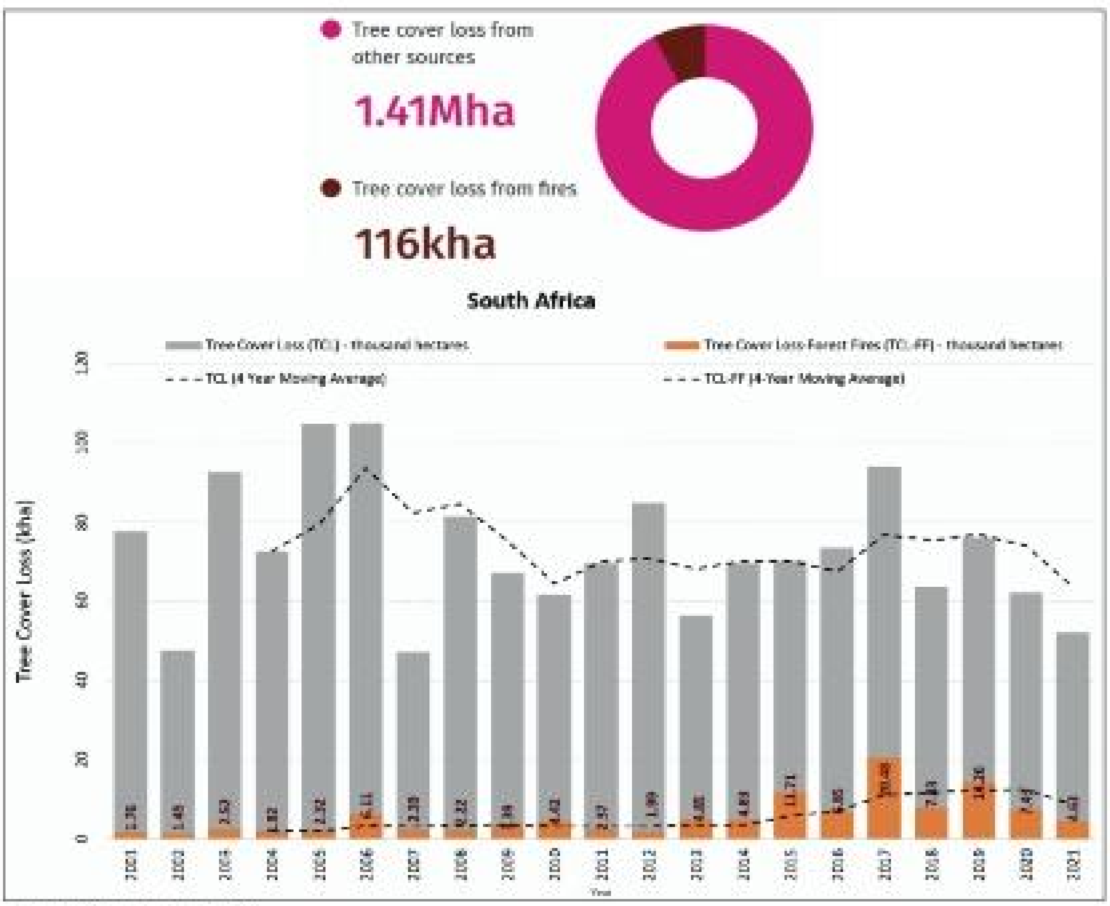


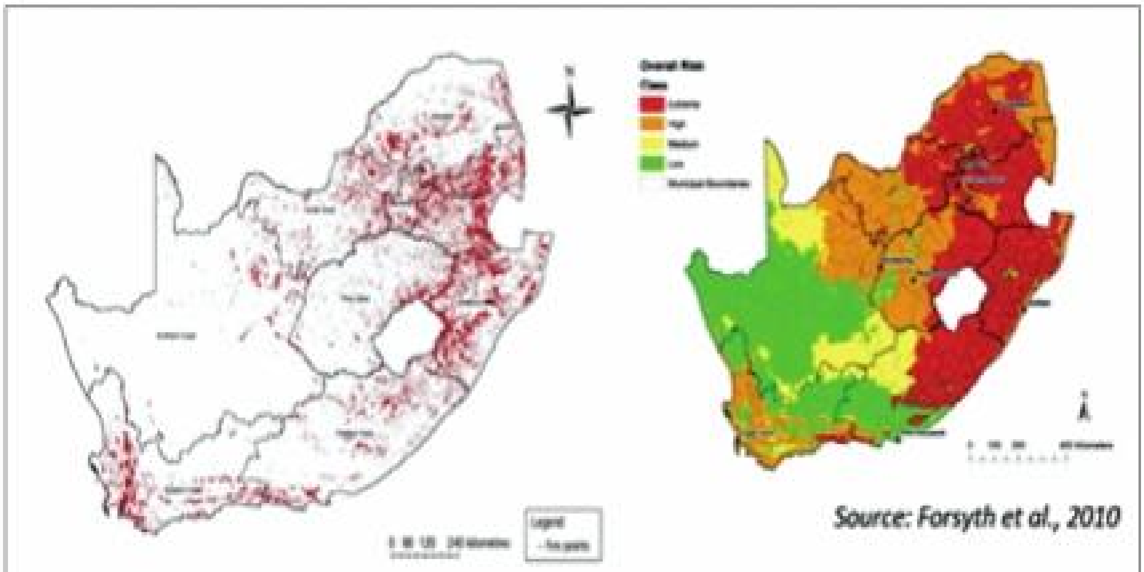
Figure 2.4.1.

Tree cover and tree cover loss due to forest fires in South Africa (2001-2021)

Source: *Global Forest watch*

Forest Watch 2023). The graph shows the forest lost from 2001 to 2021 due to forest fires. The brown indicates forests due to forest fires. From the year 2001 to 21, forest fires were responsible for 7.6% of tree cover loss in South Africa. Western Cape had the highest rate of tree cover loss, with around 3.88 kha lost on average in a year (Global Forest Watch 2023).

- From the year 2001 to 21, forest fires were responsible for 7.6% of tree cover loss in South Africa. Western Cape had the highest rate of tree cover loss, with around 3.88 kha lost on average in a year (Global Forest Watch 2023).
- The map shows the area under forest fire in South Africa. The other map shows the area which is prone to forest fires. The above map is taken from a 2010 report by CSIR on National Veld fire risk assessment.



Source: Forsyth et al., 2010

Source: Strydom & Savage, Spatio-temporal analysis of fires in South Africa 2016

Figure 2.4.2.

Area under forest fire in South Africa in 2010

Key Ecosystems Susceptible to Forest Fires

- According to the report published by FAO in 2015 for the XIV world forestry conference in Durban, forest land in South Africa covers just over 40 million hectares (about 36.7%) of the total land area. The total land area in South Africa is estimated to be around 122 million hectares (FAO, Southern Africa's forests and people. investing in a sustainable future 2015).
- Most fires have occurred in the Northeast mountain grasslands and Mountain Fynbos. It has to be noted that this is from 2003 to 2013. The fire-ecology types of Natural Forests, Thicket, and Sparse Arid Woodland are fire-sensitive.
- Forest fires have had a lot of impact on society and the economy, in addition to the environment. For example, North West FPA in 2016 recorded losses worth R 15 000 000. The Eastern cape fire

protection association has also come up with an estimate for losses. They estimate that damage of more than R643 899 839 had incurred over a two-year period from 2016-18. During the same period, the loss of 210 livestock, 3 vehicles, and 82 structures were also recorded. (State of the forests report 2018 - Gov.za 2018)

- Forest fires also cause smoke pollution, which can affect the health of communities living nearby. Local communities also suffer from the loss of thatch grass, which is important for the local community. The fires become dangerous when it becomes extreme or out of control. Some amount of controlled fires are beneficial for forest management. Air quality can go down with an excess release of carbon monoxide, carbon dioxide, and other greenhouse gases. This can also increase the chances of climate change. Local communities also suffer periodically from the loss of important resources, such as thatch grass, in wildfires (Forsyth et al., 2010).
- There are also negative health effects from extensive, untimely fires, such as smoke pollution under conditions of atmospheric stability during winter on the Highveld of Gauteng and Mpumalanga. (Forsyth et al., 2010). Forest fires can also destroy the structure of surface soil horizons. The heat generated by forest fires can also cause soil erosion, loss in soil fertility, and sedimentation of river channels and wetlands downstream (Forsyth et al., 2010). Some ecosystems are prone to invasion by alien plant species after fires. The fynbos is an example of this. They are more prone to forest fires.

Causes for Forest Fires in South Africa

Most of the forest fires in South Africa happen during the summer months. During these times, it is hard to control the fires. Wildfires (veld fires) are bushfires that fall within and outside the urban areas and can spread out of control. Government agencies state that most forest fires are caused by human activities. Others include natural occurrences, for example Lightning. Under the conditions of amount of fuel, dry material, wind, inter-winding of the canopy, etc., forest fires can spread faster (Western Cape Government, Wildfire season 2023)

The following Table 5.3(Source - State of the forests report 2018 - Gov.za 2018) shows the area of land that has been destroyed by forest fires and the reason for the fires.

Table 2.4.1

Area of land destroyed by forest fires and the reason for the fires (2015-2018)

Causes of fires	2015/16		2016/17		2017/18		Total area (ha)
	Area (ha)	% affected	Area (ha)	% affected	Area (ha)	% affected	
Natural	747	5	5 232	32	4 681	27	10 660
Accidental	4 652	33	3 356	21	4 049	23	12 057
Arson	3 254	23	2 188	14	4 563	26	10 005
Unknown	5 570	39	5 368	33	3 972	23	14 910
Total	**14 223**	**100**	**16 144**	**100**	**17 265**	**100**	**47 632**

Source: DFFE Annual CTRPRP Reports 2016, 2017, 2018

Key Institutions Involved in Forest Fire Prevention and Management in South Africa

- When it comes to forest management, the Department of Forestry, Fisheries, and the Environment (DFFE) has the ultimate say. They are in charge of the forest management and resources of South Africa.
- When it comes to legislation, the National Veld and Forest Fire Act, 1998, (Act No.101 of 1998). It outlines the mandate and responsibilities of both public and private bodies in respect of wildfires. The objectives of the legislation were to prevent veld, forest, and mountain fires across South Africa. (State of the forests report 2018 - Gov.za 2018).
- Many regions in South Africa have UFPAs (Umbrella fire protection Associations) which help and support FPA (Fire protection associations) at a regional level. For example, in Eastern Cape, there is an Eastern Cape Umbrella fire protection association (Legislation - ECUFPA 2023)
- Wildfire Fire Training Center Africa (WFTCA) - it started off as a joint venture in 2002 between the Global fire monitoring Center (GFMC) and local capacities in South Africa. Here, the concept of the Training Center was born at the foundation meeting of the Regional Sub-Sahara Wildland Fire Network (Afri Fire Net) in Pietermaritzburg. The WFCTA offers training- and education opportunities for a wide range of fire managers, fire management trainers, and extension officers from all African countries south of the Sahara and for international guests, with exposure to large-scale prescribed burning operations and firefighting (GFM Cadmin & GFM Cadmin, 2017).

Role of Research and Academic Institution in Generating Relevant Knowledge

- Academic and research institutes have been instrumental in producing pertinent knowledge to control forest fires in South Africa.
- There are a few organizations, universities, and institutions that perform studies on the causes of forest fires, the effects of forest fires on the environment and local economies, as well as the prevention, control, and management of forest fires.
- A few more areas where research is being done include the use of remote sensing data for identifying forest fires and fire alerts, among other things. A small amount of research is also attempting to influence the creation of forest policies, especially fire management.

Community Involvement and Engagement in Forest Fire Management

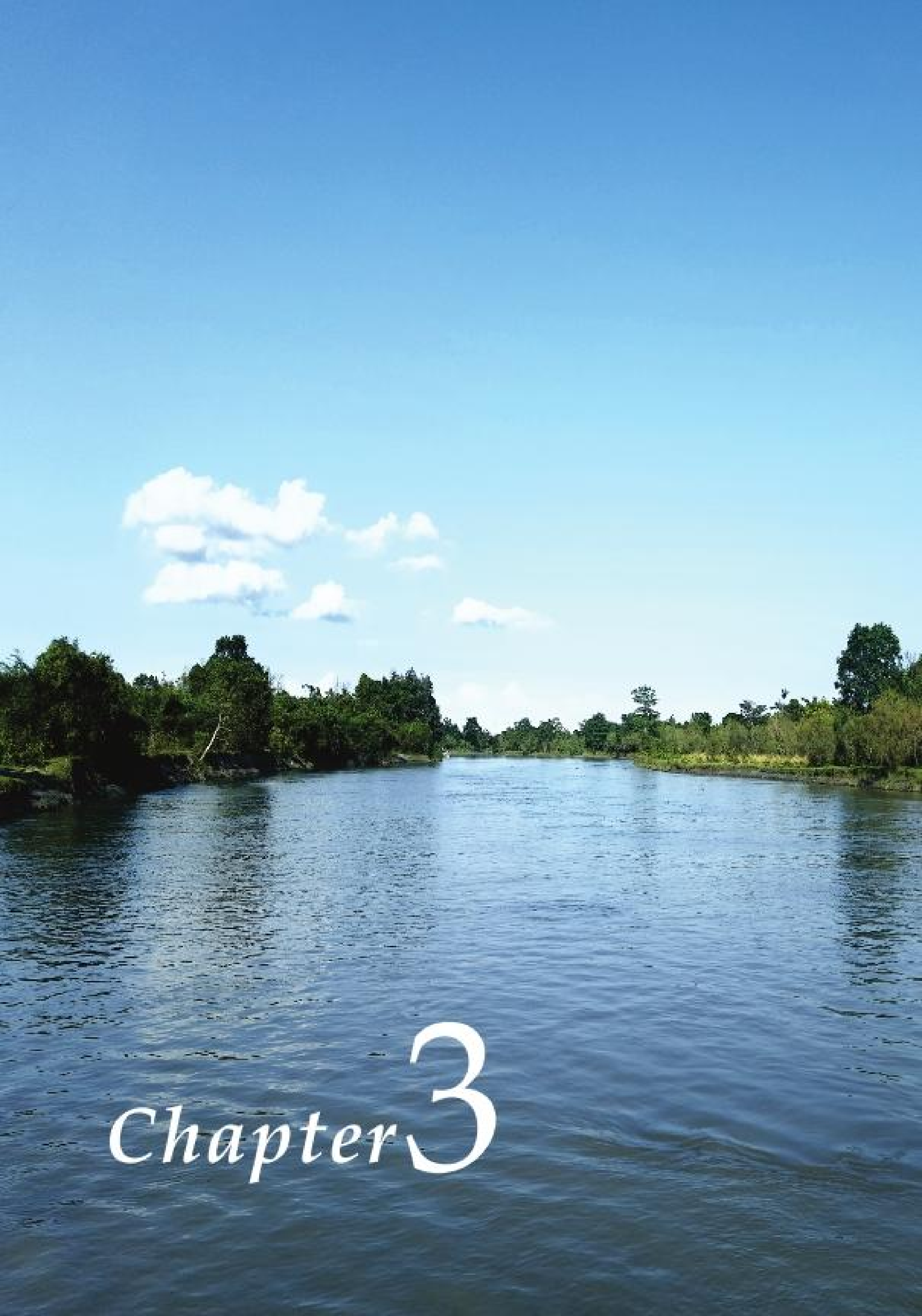
- Since human activity is the primary source of all fires in the nation, community-based initiatives and the right use of fire as a management tool are essential. The old methods of preventing fires in customary lands are now mostly ineffective. In order to properly employ fire as a management tool at the landscape level, it is necessary to educate the local population and equip stakeholders at all levels with training.
- Burkina Faso, Mozambique, Namibia, and South Africa all have CBFiM programs (Goldammer et al., 2002). The projects demonstrate that, in order to significantly improve the fire situation at the local level, a community approach is likely the only viable, long-term answer.

- Working on Fire (WoF), a national South African fire management initiative, has developed a people-centred strategy.
- Working on Fire (WoF), a national South African fire management program, has developed a people-centred approach to fire management that gives socially excluded people training and empowerment.

Capacity Building Initiatives

- Firefighters, forest rangers, and other personnel managing forest fires receive training from academic institutions. The instruction covers methods for putting out, managing, and avoiding forest fires and how to employ technology for monitoring and early detection.
- The SADC and surrounding sub-Saharan nations are in charge of fighting fires, along with the Ministries of Environment, Agriculture, and Rural Development.

Given their lack of resources, cooperation in the management of fires has become institutionalized in many African nations. Ethiopia was the starting point for international cooperation in sub-Saharan Africa's fire emergency management from February to April 2000. (Goldammer, 2000). Eventually, regional coordinated actions were started in 2002 with the establishment of Afri Fire Net. In collaboration with regional partners in South Africa, the Wildland Fire Training Center Africa was formed. Over the past few years, several international training courses have been successfully held in collaboration with the governments of Germany, Finland, Mozambique, Norway, FAO, and UN-ISDR. On July 7, 2005, a regional conservation agreement was signed at the Congo Basin Forest Summit.



Chapter 3

3

BEST PRACTICES AND SUCCESS STORIES OF RESTORATION OF FOREST FIRE AFFECTED AREAS FROM G20 MEMBER COUNTRIES

3.1 AUSTRALIA

Seed Banking in bushfire affected regions: The Council of Heads of Australian Botanic Gardens is seed banking across bushfire affected regions to future-proof native plant species. 476 out of the 670 seedlings, which were raised from 12 priority plant species by project partners, have been reintroduced to the wild, placed in seed production orchards or provided to community groups for planting in bushfire affected areas (Australian Government Department of Agriculture, Water and the Environment, 2021).

Targeted feral animal control: In the Greater Blue Mountains World Heritage Area, targeted feral animal control over 1.4 million hectares has been undertaken, as 60 % of the area was affected by the bushfires. The protection of the habitat is conducted by Hunter Local Land Services and partners, as they also enable recovery in fire affected areas. The particular combination of aerial and ground-based programs supports animals including Koala, Manning River Helmeted Turtle and Brush-tailed Rock-wallaby, as well as Threatened Ecological Communities (Australian Government Department of Agriculture, Water and the Environment, 2021).

Bee hotels are being installed by the Australian Native Bee Association and citizen scientists, in fire impacted areas all around Australia. They are artificial nests, aimed to mimic the pre-made holes and cavities in trees created by wood-boring beetles that cavity-nesting bees use. The monitoring is conducted monthly during the bee activity season to check occupancy. The bees hotels have never before been used in areas that have been destroyed by fire, but they are an important part of the recovery of pollinators as they forage on flowering regrowth (Australian Government Department of Agriculture, Water and the Environment, 2021).

3.2 CHINA

Title: Ecological Restoration Monitoring of Mangroves in Shenzhen Estuary

Responsible Organizations: Shenzhen Municipal Bureau of Planning and Natural Resources, China,

Brief Summary:

Shenzhen River Estuary Mangrove Wetland is situated between two Ramsar Wetlands of International Importance: the Shenzhen Futian Mangrove and the Hong Kong Mai Po Mangrove. It serves as a crucial habitat for tens of thousands of migratory birds in the East Asia-Australasia International Migratory Bird Flyway, and is also home to rare and endangered wild animals such as the Eurasian otter (Lutra lutra). This wetland serves as one of the significant wetland ecosystems of international importance in South China. Nearly 17 ha of mangrove wetland have been restored from 2017 to 2022, providing living space for the growth of native mangrove plants and water birds, and enhancing the overall biodiversity of the region.

Description:

Main Measures:

1. Preliminary research, and collection, integration and utilization of basic data.
2. Carry out the investigation and monitoring of the ecological physical and chemical environment, hydrological dynamics and biodiversity of the ecological restoration area, focusing on the water quality environment, sediment environment, benthic organism, plankton, birds, mangrove vegetation, etc. of the mangrove ecosystem.
3. Based on the detailed investigation and monitoring, the effects of mangrove ecological restoration in Shenzhen Estuary are evaluated, and the effects and shortcomings of the restoration are analyzed, providing a demonstration reference for the urban, provincial and even domestic mangrove ecological restoration, and laying a foundation for the establishment of scientific and effective management measures for exotic mangroves.
4. Data sorting and analysis: make statistics and analysis on all the data obtained, obtain comprehensive monitoring data of mangrove ecosystem in Shenzhen Estuary, evaluate the effect of ecological restoration by analyzing the monitoring data, and put forward relevant suggestions on the protection, restoration and management of mangroves in Shenzhen Bay and Shenzhen City.

Lessons Learned:

1. Providing examples of the ecological restoration of areas taken by exotic mangrove plants. Particularly for artificial pure forests, measures included tree species conversion, tidal creek, and intertidal zone restoration.
2. Enhancing wetland biodiversity and providing stable estuarine wetland habitats for water birds and mammals, such as Eurasian otters and leopard cats.
3. Collaborating with enterprises, public, universities, and government entities, to demonstrate the ecological restoration of biodiversity with full social participation.

Title: Ecological restoration practice in Gulang Babusha Forest Farm

Responsible Organizations: Gulang Babusha Forest Farm, Ministry of Water Resources

Brief Summary:

Babusha Forest Farm in Gulang County is a collective forest farm initiated and established by joint household contract in 1981. Over the past more than 40 years, three generations of the "six old men" in Babusha Forest Farm have experienced great hardships to fight against desertification.

Description:

Babusha is located in the north of Gulang county, and the southern edge of Tenngeli Desert, with an area of 5,000 m^2. In the early 1980s, there was no population here due to severe aeolian sand. In 1981, six old men named Guo Chaoming, He Falin, Shi Man, Luo Yuankui, Cheng Hai and Zhang Runyuan in Tumen Town who were over 50 years old, set up a collective forest farm by joint household contract, embarking on a long journey of tenacious struggle against the desert. Over the past more than 40 years, three generations of the "Six Old Men" have made persistent efforts to control desert. A green ecological sand-fixation barrier, 10 km long from north to south and 8 km wide from east to west, has been built on the southern edge of Tenngeli Desert.

1. Persisted on large-scale management. Relying on the key ecological projects, the government has carried out large-scale afforestation projects in the sandstorm frontier and the main sand-mouth areas.
2. Attached high importance to afforestation and management. The Forest Farm adopted the management mode of "artificial promotion + natural regeneration".
3. Public participation. A model of "Internet + combating desertification" was established and promoted. A network for nationwide compulsory tree plantation has been set up.
4. Scientific and technological support. The forest farm has strengthened cooperation and exchanges with scientific research institutions, and set up several teaching and practice bases of combating desertification in Badusha for students from University, which has offered strong technological support for combating desertification.

Lessons Learned:

1. Persisted on large-scale management. Relying on the key ecological projects, the government has carried out large-scale afforestation projects in the sandstorm frontier and the main sand-mouth areas.
2. Attached high importance to afforestation and management. The Forest Farm adopted the management mode of "artificial promotion + natural regeneration".
3. Public participation. A model of "Internet + combating desertification" was established and promoted. A network for nationwide compulsory tree plantation has been set up.
4. Scientific and technological support. The forest farm has strengthened cooperation and exchanges with scientific research institutions, and set up several teaching and practice bases of combating desertification in Badusha for students from University, which has offered strong technological support for combating desertification.

Reference:

Gulang Babusha Regional Ecological Management Plan (2020-2025)

Title: The ecological restoration of the burned areas in the Great Xing'an Mountain Forest Areas

Responsible Organizations: National Forestry and Grassland Administration

Brief Summary:

The Great Xing'an Mountains Forest area is one of the key state-owned forest areas in China, with eight national nature reserves under its jurisdiction. Since 2003, there have been two huge forest fires, which have formed a large area of burned ground. Local authorities have taken multiple measures to speed up the process of forest vegetation restoration in the burned areas. From 2006 to 2010, 29333.92 hectares of artificial vegetation were restored in the burned areas, of which 15589.72 hectares of tree planting, 2517.3 hectares of direct seeding, and 11226.9 hectares of natural regeneration acceleration.

Description:

Main measures taken include:

1) Innovate mechanism and mobilize enthusiasm. Market competition mechanism was introduced in the forest production management, engineering approach of forest restoration was carried out in the burned area, unit cost of vegetation restoration production was adjusted, and the enthusiasm of forest producers was effectively mobilized.
2) Emphasize on training and perfect system. A variety of activities have been carried out, such as professional training, employee training and technical training. Several technical standards have been formulated, compiled into the "Compilation of Forest Project Management Measures of Great Xing'an Mountains Forestry Group Company", and issued for execution, forming a scientific and standardized restoration process.
3) Strengthen supervision and ensure quality. Design and management were strictly investigated to achieve scientific and reasonable planning. Technical staff follow-up operation and three-level acceptance system were implemented, improving management and protection mechanism, as well as establishing sound technical archives.

Lessons Learned:

Results achieved include: Ecological, social and economic benefits in this region have been further improved. First, improved ecological environment created favorable conditions for the expansion of wild animal and plant populations, enhanced overall function of forests and advanced residents' living environment. Secondly, awareness of forest protection and restoration were elevated, job opportunities related to vegetation restoration were provided and thus eased employment pressure. Thirdly, forest coverage rate and forest quality were increased, chance of natural disasters were reduced, leading to better agricultural development of Songnen Plain and achieving the purpose of increasing yield and revenue.

Title: The Restoration and Reconstruction of Chilechuan Grassland in China

Responsible Organizations: M-Grass Ecology and Environment (Group) Co.,Ltd, China

Brief Summary:

Chilechuan Grassland, located in the piedmont alluvial fan at the southern foot of the Yinshan Mountains in Hohhot, Inner Mongolia Autonomous Region, has suffered from large-scale damage because of unreasonable long-term utilization such as excavation of sand and stones, reclamation and abandonment of farmland. Based on field investigation, M-Grass Ecology and Environment (Group) Co., Ltd. divided restoration areas according to the types of degraded ecosystems. Combined with the characteristics of the local original and stable ecosystem, the team adopted artificial grassland planting and natural grassland improvement techniques to restore abandoned land around the city. Now the restored Chilechuan grassland has formed a stable grassland ecosystem, increased species diversities, improved the environment around the city, and become a good place for leisure and cultural tourism.

Description:

According to the topography, water resources, vegetation and other conditions of this area, the M-Grass team designed and developed the deserted land to simulate the appearance of the natural grassland and restore the ecological function of the Chilechuan grassland. In the process of the project implementation, the team selects the cost-saving engineering measures, using natural precipitation as much as possible, maintaining the original terrain, selecting native plant species and planting them at right combinations, and introducing animals and insects into the ecological restoration process to build a biological habitat. The vegetation and soil conditions were surveyed and monitored in the restoration site regularly every year. M-Grass provides a comprehensive set of applicable technologies for the restoration of degraded vegetation which is seriously damaged around the city in the grassland area.

Lessons Learned:

The restoration project established a team of experts on grassland, ecology, water conservancy, soil and other aspects. During the process, this project piloted those measures in a small area, then promoted and demonstrated them to larger areas, and solved problems on-site, providing a scientific and feasible technical path for damaged grassland restoration. After implementing the project, the grassland ecosystem has been restored, and the diversities of plants and animals have increased significantly. As a model of ecological restoration around the city in the grassland area, the restored grassland has functions of ecology, production and living, provides places for people to enjoy leisure activities.

References:

DB15/T 1251-2017 Technical regulation of grassland revegetation for waste land

3.3 EUROPEAN UNION

GREECE (PELOPONNESE REGION)

Title: Restoration of *Pinus nigra* forests on Mount Parnonas (Greece) through a structured approach

Responsible Agencies/ Institutions: Goulandris Natural History Museum/Greek Biotope - Wetland Centre in cooperation with the Decentralised Administration of the Peloponnese - Western Greece & Ionian Sea, the Decentralised Administration of Macedonia - Thrace and the Management Body of Mount Parnon and Moustos Wetland

Brief Summary:

The devastating wildfires that burst out in summer 2007 throughout Greece burnt huge areas of natural vegetation and affected thousands of people. They destroyed nearly all the black pine forests found on the south of Mount Parnonas. Black pine trees do not have serotinous cones (in which seed release is triggered by fire). Because of the release of seeds in the winter, they do not maintain a seed bank when summer wildfires occur. For this reason, this species has a very low potential for regeneration following wildfires. The production of plants for black pine forest restoration started in spring 2009 and their nursing continued until 2011. Some 800,000 plants were produced. A total of 13 plots were selected to monitor natural regeneration, while 20 plots were selected to implement and monitor the restoration activities. Restoration works started in December 2010 and lasted until May 2012. About two-thirds of the burnt area was restored. This allowed restoring the economic value of the black pine forest as a source of logging. The local community has also benefited from the return of apiculture and the area's improved recreational value.

Description:

To address the effects of the 2007 fire on black pine forest on Mount Parnonas and to improve the planning of post fire restoration of black pine forests in general, the project LIFE PINUS (LIFE07 NAT/GR/000286) was proposed in 2008 and implemented from 2009 to 2013.

The main objectives of the project were:

- the demonstration of the application of a structured approach to restore burnt areas of the priority habitat type "Mediterranean pine forests with endemic black pine".
- the restoration of 290 ha of the priority habitat type "Mediterranean pine forests with endemic black pine" in "Oros Parnonas (kai periochi Malevis)".

To restore the burnt priority habitat type "Mediterranean pine forests with endemic black pine" at the Oros Parnonas (kai periochi Malevis) the project adopted an integrated approach, starting with the assessment of the current situation, carrying through to planning and implementation of measures, and ending in monitoring of their effectiveness.

For more information: https://webgate.ec.europa.eu/life/publicWebsite/project/details/2900

Lessons Learned:

The project carried out restoration measures on 290 ha of *Pinus nigra* forest in Parnon (68% of the burnt area of the priority black pine habitat on site).

The pioneering structured approach devised by the project followed specific steps: preparatory actions, mainly fire impact assessment on the target habitat type; the drafting of the forest restoration steps; the carrying out of technical studies; the design of the monitoring system and the establishment of monitoring plots. A total of 13 plots were selected to monitor natural regeneration and 20 plots were selected to implement and monitor the restoration activities. The preparatory actions were followed by the restoration actions; in particular plant production from collected seed under technical guidance, the planting of seedlings and the caring and protection of the plants.

The restoration of the burnt forest on Parnon will restore its economic value as a source of logging. The local community will also benefit from the return of apiculture and the area's improved recreational value. The After-LIFE plan takes into account the threat presented by climate change and the fact that the burnt area lies on the southern distribution limits of the target habitat type, redoubling the need for active conservation efforts.

The structured approach is applicable to other similar post-fire restoration efforts throughout the country and the Mediterranean region. The strength of this approach is that it can be implemented by forest management authorities, utilising existing human and non-human resources.

CYPRUS

Title: Improving the conservation status of the priority habitat type 9560* (Endemic forests with *Juniperus* spp.) in Cyprus

Responsible Agencies/ Institutions: Department of Forests, Ministry of Agriculture, Natural Resources and Environment of Cyprus, Open University of Cyprus, Frederick University, Cyprus, and AKTI Project and Research Centre, Cyprus

Brief Summary:

The JUNIPERCY project contributed to the consolidation of knowledge concerning the protection, restoration, monitoring and evaluation for Endemic forests with *Juniperus* spp.' in Cyprus, a habitat threatened by natural regeneration, fire, fragmentation, leisure activities, climate change and dust.

Specifically, the project aimed to understand, quantify, and halt the natural and anthropogenic threats contributing to habitat degradation; design and implement actions for habitat protection and long-term restoration; and provide support for better environmental governance in Natura 2000 network sites through stakeholder involvement.

Description:

The JUNIPERCY project's primary objective was to promote and enable the long-term conservation of endemic forests with *Juniperus* spp. in Cyprus. This is the first project to target this habitat in its known locations in Cyprus, within three Natura 2000 network sites.

The habitat was mapped, demarcated, and protected in three Natura 2000 network sites: Madari-Papoutsa, Chersonisos Akama, and Troodos National Forest Park. Following the creation of detailed maps, monitoring and habitat management plans were developed, and the impacts of visitors assessed and reported, for the three habitat locations.

The project aimed to put into practice, test, evaluate and disseminate actions and methodologies that were previously unfamiliar to the Cypriot geographical, ecological, and socio-economical context. Specifically, the project aimed to understand, quantify, and halt the natural and anthropogenic threats contributing to habitat degradation; design and implement actions for habitat protection and long-term restoration; and provide support for better environmental governance in Natura 2000 network sites through stakeholder involvement.

The project's preparatory work documented the extent, ecological characteristics, and natural and anthropogenic threats affecting the Juniperus forest habitat in Cyprus for the first time.

Concrete conservation actions were implemented to provide sustainable management and effective habitat restoration. Enhancement of the habitat's conservation status was affected by replanting with saplings of all four *Juniperus* spp., protecting (e.g. micro-fencing) and irrigating the saplings, erecting barrier fencing to restrict vehicle access and protect against uncontrolled grazing (e.g. goats), clearing competitive vegetation and removing dried biomass, constructing fire-breaks to prevent the spread of forest fires, and putting in place two water tanks and fire protection signage. To restore the habitat's floristic composition and structure, characteristic species other than Juniper were planted and sustainable control of seed/fruit predators applied. This floristic diversity helped to deter colonisation by invasive exotic species, while areas of the non-native invasive *Robinia pseudoacacia* were removed at Troodos. Protection from erosion with small-scale relief modifications, and shading of young saplings, were also done. The project demonstrated best practice and produced habitat protection and restoration guidelines.

Ex situ conservation and propagation of the four *Juniperus* spp. took place through the collection of seed and the establishment of protocols on storage, germination, growth and planting out.

Local communities near the sites were involved and informed of the benefits of preserving the habitats for visitors, through workshops with stakeholders, and the development and presentation of environmental education material and activities at local schools. The project bought socio-economic benefits through enhanced visitor experience. Forest personnel were informed of the importance of the *Juniperus* species and trained in habitat protection and reforestation.

Reference: LIFE10 NAT/CY/000717

https://webgate.ec.europa.eu/life/publicWebsite/project/details/3458.

SPAIN

Title: Restoration of burnt endemic pine woods and recovery of its threatened flora and fauna (INAGUA)

Responsible Agencies/ Institutions: Government of the Canary Islands. Directorate-General for Nature Protection and City Council of Gran Canaria, Spain

Brief Summary:

The Special Protected Area (SPA), Sites of Community Importance (SCI) and Natura 2000 area 'Ojeda, Inagua y Pajonales' is included in the Biosphere Reserve of Gran Canaria and represents an excellent example of the habitat Macaronesian Pine Forest. The area is ecologically vulnerable, with a large number of endemic species and significant birdlife.

In 2007, the area was devastated by an intense fire. About 14% of the area was greatly affected, 80% was partially affected, and only around 6% was untouched by the fire.

The recovery of the ecosystem needs close monitoring. Species with small population size may need extra help to boost their conservation status and ensure their survival in the long term. INAGUA aims to support the recovery and conservation of the habitat through practical restoration measures and the improvement of long-term conservation and recovery management.

Description:

The objective of the LIFE project was to supplement the natural recovery of burnt areas of endemic Macaronesian pine woods (Habitat 9950) in the protected area of Ojeda, Inagua y Pajonales. The project aimed to enhance the conservation status of several threatened plant species and the population of blue chaffinch through habitat restoration and other management actions. Surviving pines were to be protected and restored to help their propagation, with goat and rabbit populations controlled to allow natural regeneration. Further aims were the establishment of a fire plan to reduce future risk and a plan to assess the monitoring of habitat recovery, an exchange of experiences between managers facing similar problems, and the design of an awareness-raising campaign concerning the value of Macaronesian pine woods.

The Inagua project had direct positive effects on the conservation status of the endemic Macaronesian pine woods in the Biosphere Reserve of Gran Canaria and its threatened bird and plant species. The project also provided a series of tools, knowledge and best practices that will be of high value for the area's long-term management and recovery. Practical conservation measures, such as the reduction of grazing pressure and habitat enhancement, have speeded up the recovery of habitat damaged by the severe fire event in 2007. A major practical outcome is the recovery of the blue chaffinch (*Fringilla teydea*) population, back to an optimal pre-fire level of around 280 individuals. The project updated and completed a Blue Chaffinch Recovery Plan (which was first drafted in the framework of project LIFE98 NAT/E/005354) using information collected during the field studies; this was officially approved in November 2013. The project has also improved the conservation status of the most threatened endemic plant species: *Dendriopoterium pulidoi*, *Teline rosmarinifolia*, *Helianthemum bystropogophyllum*, *Limonium sventenii* and *Isoplexis isabelliana*. Most of these species were in a critical state due to the fire before the project (e.g., *Isoplexis isabelliana* was down to four individuals in the wild), but they started an impressive recovery as a result of restoration activities, though this was lower for *Dendriopoterium pulidoi* due to difficulties in accessing and fencing the sites.

Lessons Learned:

A particular challenge the project had to overcome to implement activities was working in very remote, hardly-accessible mountainous areas.

Field sampling and data collection are being continued post-LIFE. This is particularly important for assessing the pine wood restoration process after fire events, as few definitive conclusions could be reached during the relatively short duration of the project. Continuing some actions, such as the control of goats, will also be necessary. The project has importantly contributed to the implementation of the Habitats and Birds Directives.

Reference: LIFE07 NAT/E/000759

https://webgate.ec.europa.eu/life/publicWebsite/project/details/2872

Title: Ecological restoration Garajonay National Park and its surroundings, after the great fire of 2012 (LIFE+ GARAJONAY VIVE)

Responsible Agencies/ Institutions: TRAGSA and ULL (University of La Laguna), Spain

Brief Summary

In August 2012, the Spanish island of La Gomera experienced the most ecologically damaging wildfire to affect the Canary Islands for several decades. Nearly 20% of the surface of Garajonay National Park – a UNESCO World Heritage Site – was burned, totalling over 740 ha. The wildfire burned the largest ever area of laurel forest in the archipelago, including vast areas of ancient laurel forests of high ecological value. The fire also resulted in a great loss of soil quality, caused a serious deterioration of water catchment functions and directly affected many populations of threatened species. Moreover, the fire adversely affected the natural hydrological cycle of the forests, on which the island depends for its water supply.

The LIFE+ GARAJONAY VIVE project aimed to develop the means to reduce the risk of wildfires in the Canary Islands and to support the natural regeneration of laurel forest habitats already affected by fire and their dependent species.

Description:

The project planned to improve the knowledge base on wildfires and laurel forest regeneration. On the basis of this initial research, the project team aimed to draft strategies to prevent and tackle forest fires more effectively and to restore the targeted habitats. During the implementation phase, the team aimed at introducing measures to reduce the incidence of fires and facilitate the extinguishing of fires should they occur. The habitat restoration strategy was planned to cover at least the affected area of the Garajonay National Park. Given the fact that many fires – including the devastating one in 2012 – were caused by (deliberate) human action, the project hoped to engage local communities on the island of Gomera to raise their awareness of the impact and cost of wildfires to society and the natural environment.

The LIFE+ GARAJONAY VIVE achieved its objectives of supporting the natural regeneration of laurel forest habitats and the recovery of populations of threatened species damaged by the fire of 2012 on the Spanish island of La Gomera, in the Canary Islands, as well as reducing the risk of future wildfires.

To facilitate the recovery of populations of threatened species, census, monitoring and seed collection work focused on plant species particularly affected by the 2012 wildfire (e.g., *Limonium dendroides, Euphorbia lambii, Cistus chinamadnesis* subsp. *gomerae, Sambuscus palmensis* and *Woodwardia radicans*). To aid their recovery, work also involved reinforcement of populations, control of feral cattle and removal of invasive alien species. To reduce the risk of future wildfires, the beneficiaries undertook actions to improve knowledge about their behaviour, and applied measures derived from the project publication 'Fire Prevention Plan for the island of La Gomera' and the various local plans for self-protection against fires. The beneficiaries also increased awareness in La Gomera about the problem of forest fires and their implications for laurel forest ecosystems and surrounding populations, through the design of strategies of social prevention against forest fires.

The project team created an innovative strategy for the effective prevention of fires in rural and forest areas, optimising the interventions and the management of vegetation to reduce combustibility instead of the traditional creation of firebreaks. Experimental tests were carried out to improve management techniques, including improvement in the quality of plants used for plantations, plantation techniques, and the management of scrub to encourage its protective role for regeneration and reforestation. The knowledge and experience gained from these tests enabled the beneficiaries to successfully implement the conservation actions.

Restoration works will also have a positive effect on the hydrological cycle, favouring the infiltration of rainwater into the ground, which is essential for the availability of water resources for wildlife, and will contribute to reducing the emission of greenhouse gases.

Reference: LIFE13 NAT/ES/000240

https://webgate.ec.europa.eu/life/publicWebsite/project/details/4137

SPAIN AND PORTUGAL

Title: Erosion prevention and flora Restoration of burnt FOREST areas through innovative fungal-technosol solution (LIFE REFOREST)

Responsible Agencies/ Institutions: Foundation of the Multisectoral research technology centre, Spain; Forestry Association of Portugal; University of Aveiro, Portugal; HIFAS da Terra S.L., Spain; INDUTEC INGENIEROS, S.L.U., Spain; Forestry Association of Galicia, Spain; and Tratamientos ecológicos del noroeste S.L., Spain

Brief Summary:

The general objective of the LIFE REFOREST project was to mitigate the impact caused by erosion and soil loss in areas affected by forest fires, by applying an innovative technosol based in organic waste inoculated with fungal species. This solution has been implemented in burnt areas of Galicia and the Center-North region of Portugal, two of the Europeans areas most affected by forest fires (in fact, 80% of the area burnt in Europe in located in the south of Europe/Mediterranean region) to help recover key functional parameters from burnt soil (organic matter content, microbial activity, etc.) to its initial values.

Description:

To help regenerate areas scarred by forest fires, LIFE REFOREST used a Technosol, or soil derived from organic waste (including cereal straw, sawdust and wool) treated with fungal species.

LIFE REFOREST has installed 3 pilots in Galicia and the North of Portugal. After initial tasks of characterisation and system design, in October 2019 the consortium installed two pilot areas of about 200 m^2, one in the Communal Forest of Nespereira, in the Galician municipality of Pazos de Borbén (Pontevedra) and the forests if Albergaria (Aveiro) in the central region in Portugal.

The selection of this two first locations was done after a monitoring of the forest fires that took place in the summer of 2019, with the aim of selecting areas with risk of erosion, due to the fire intensity, the lack of vegetation and a moderate inclination.

Both pilot areas are divided in nine plots, randomly positioned. Three of those are equipped with the barriers developed in the LIFE REFOREST project, while other three have been treated with mulching, -currently used technique-, with the objective of comparing the system developed in the project, with other erosion mitigation techniques. Finally, the remaining 3 plots have received no treatment, and they serve as control plots. To complete the validation of the system under different conditions, on October 2020, a third pilot was installed in Penouços (Sever do Vouga – Aveiro), in an area that suffered a fire on the previous weeks.

In numbers, more than 200 m^2 of burnt forest has been protected with bio degradable tube-shaped mycotechnosol with the aim of achieving a fast restoration of the vegetal cover, and reducing up to 2.5 times the flow of water runoff., minimizing the impact of water over the soil and the speed of the runoff.

The results obtained show a clear reduction of the erosion with the Refores Tube system developed in LIFE REFOREST, with an erosion that is between 70-77% less than in the area without treatment in the areas under study. In relation to mulching, the validated system presents an erosion slightly higher in the Nespereira pilot, and smaller in Albergaria and Penouços, however these differences are within the deviation observed in the different samplings.

References

LIFE17 ENV/ES/000248: LIFE 3.0 - LIFE Project Public Page (europa.eu); NEWSLETTER_LIFE_REFOREST_v Final-ENG.pdf (lifereforest.com)

3.4 FRANCE

Title: Quick post-fire risks Assessment

Responsible Organizations: National Forest Service (NFS)

Brief Summary:

Quick and basic evaluation of damages caused by fires on vegetation and of capacity of the landscape to be affected by erosion, in order to implement quick measures of soil protection and to evaluate the difficulties of regeneration.

Description:

- After a fire, before thinking about regeneration, the priority is to evaluate the other natural risks: erosion, floods, rock fall (often pre-existing and mitigated by the presence of vegetation cover, and re-activated by its loss). Moreover, the soil protection is very important because it is useless to try to restore the forest if its soil is lost.
- The quick production of cartography of the fire contour and severity (using DNBR obtained from SENTINEL2 satellite images) crossed with data describing the landscapes (pre-fire vegetation, slopes, watersheds, value-at-risk…) is used to make a quick evaluation. This evaluation is useful to define which actions (tree felling or not, fascines, mulching…) are needed and where, and to try to find fundings to implement these actions. It is important to make prioritization because we have to optimize the affectation of the few funds available.
- Quick evaluation and quick implementation are key, because the first rains after the fire are often very destructive for the soil.
- Only after having taken care about the soil, we can consider regeneration. The evaluation can also be used to evaluate the possibility of natural regeneration (which depends on the species previously existing and the severity of the fire), as we mainly prefer accompanied natural regeneration rather than plantation (used quickly for communication and public awareness, or later after evaluation of natural regeneration success).

Lessons Learned:

Still in development and improvement so not enough feedback currently.

References:

Cooperation project EPYRIS in south-west of Europe : https://epyris.es/

3.5 INDIA

Title: Forest Fire Management in Yellapurra Division, Karnataka. (Adapted From: Prashanth et al., 2020)

Responsible Agencies: Forest Department, Karanataka

Description of the Area:

One of the main forest regions in the Western Ghats is Yellapura, which is located in the Karnataka district of Uttara Kannada. Uttara Kannada being the only district in Karnataka that is 80 percent forested and is located in the Western Ghats. The Yellapura taluk has the most forest cover, with 87% of the total land being covered by trees. More than 70% of the forest's land is made up of dry deciduous woods, which are divided into 3 subdivisions and 6 ranges. Widespread grown teak is extremely susceptible to forest ground fires. In the drier months, forest fires can happen in any forest, and they play a significant role in influencing the vegetation and terrain.

Nature and Occurrence of Forest Fires:

For this region the months of June, July, and August have the most rainfall, with random showers in October. As a result, there is a lengthy dry season lasting 7 months during which little to no rain falls. There is a higher risk of forest fires in the drier months.

Actions:

The Forest Department of the region initiated community based approached to prevent and control the incidences of Forest Fires in the region. The measures taken were a mixture of the community involvement and Capacity Building approach. Some of them have been listed as below:

1. **Awareness Programmes:** awareness programmes were initiated at schools at division level to make students aware about the harms and preventive measures for forest fire, the schools were also encouraged to report any such incidents. Posters were deployed at community places where general public can sight them easily and be aware of the Dos and DON'Ts for the forest fire incidents.
2. **Local Authorities Meetings:** Meetings of all 111 Village Forest Communities (VFCs) of Yellapura Forest division were conducted to raise awareness. Along with these, leaders of Gram Panchayats were also taken into confidence for the purpose of creating awareness.
3. **Beedhi Nataks:** Street Plays were conducted in almost all the divisions to sensitize the general public.
4. **Fire Control Room:** A round-the-clock fire control centre was set up at the DCF office, and the department's phone number was extensively disseminated throughout the nearby villages.
5. **Door to door campaign:** By adopting a vow in the name of their local deity, Lord Manjunateshwara, the Forest Department and Sri Dharmasthala Grameena Abhivruddhi Sangha developed pamphlets to

discourage communities from engaging in any criminal activity in the forest, such as igniting forest fires, stealing, or poaching.

Along with these, measures such as Oath- taking, building of forest fire watch towers, distribution of approximately 5000 calenders to create a sense of community between locals and forest department was also done, and giving away of awards to Village Forest Communities (VFCs) for actions related to forest fire prevention were also adopted.

Results for Community Awareness Programmes:

Prior to the use of community-based techniques, reports of forest fires made up around 5–7% of the total forest area, and FSI notifications were always received in 4-digit format. Before the community awareness programme, only hired watches, labourers, and department staff were involved in the fire extinguishing procedure, which resulted in a very lengthy reaction time for forest fires. Additionally, a greater area was affected by forest fires. The graph shows that the number of fire alarms in the years 2018–19 has significantly decreased since the community-based measures were put in place. In the Yellapura division, there were 5% fewer fire alerts in 2018 than there were in 2017. In addition, compared to 0.046% in 2017–18, the area burned by fire decreased to 0.019% in 2018–19. It was evident from the results that the burnt area as a result of forest fires in 2018–19 drastically decreased by more than 58%. This demonstrates that the response time to put out the fire was sped up. As a result of raising local residents' awareness prior to the fire season, major fire incidents were also reduced to an appallingly low level. Additionally, there were fewer instances of natives starting fires. All of the aforementioned initiatives demonstrate how dramatically better reporting, putting out, and managing forest fires have been made possible by community-based techniques.

Title: Restoration of Forest Fire Impacted areas in Bandipur Tiger Reserve

Responsible Organizations: Karnataka Forest Department

Brief Summary:

At Bandipur Tiger reserve, on a pilot basis, Eco-restoration of Forest fire affected areas were undertaken after 2019 major fire incident in GS Betta Range. Efforts were being made to restore 340 ha out of 2150 ha of burnt area.

Forest fire in the various beats of GS Betta Range complete burning of Ground cover, herbs and majority of shrubs and bamboo which resulted in destruction of saplings, seeds in the soil bed and suppression of native floral species, but fire loving invasive weed species like *Lantana camara* and *Senna spectabilis* flourished without any competition. Abundant growth of *Lantana camara* and *Senna spectabilis* made the habitat impenetrable for other native grass, herbs and shrubs species resulted in poor biodiversity.

A combination of these factors has led to most of the fire-affected plots having high *L. camara* density within 12-18 months after the fire.

Description:

Post-fire Recovery Efforts

There was a need to restore the forest ecosystem in the forest fire affected areas in GS BEtta Range after 2019 fire. An initiative was taken to restore the fire affected areas on pilot basis. Out of 2150 ha of Forest fire affected area due to 2019 forest fire incident, 340 ha was selected for Eco restoration project. The main focus was on the removal of *Lantana camara*, other emerging and critical invasive species like *Senna spectabilis* in Forest Fire affected areas of GS Betta Range followed by establishment of native species through positive intervention. A total of 14 restoration plots totaling 340 ha have been taken up for restoration during the period from 21st November 2019 to till date.

The *L. camara* removal was carried out using the Cut Root-stock method. The main advantage of this method adapted was that there is no disturbance to the soil and therefore dormant *L. camara* seeds in the sub-soil are not disturbed. Also, there is no collateral damage to native vegetation and this facilitates faster regeneration of the plot after the removal of *L. camara*. Removed *L. camara* bushes are upturned and left to dry which is the standard protocol in the Cut Root-stock method. The removal started at the highest elevation points and gradually continued downwards side, so that *L. camara* seeds do not flow downwards during the monsoon.

In areas with medium *Lantana* density, the removal of invasive species resulted in the availability of space, sunlight and nutrients enables native vegetation to revive naturally. In the case of dense *L. camara* or areas with barren patches, dibbling of seeds of bamboo, grass and shrub species were carried out. Collection of seeds of different species of grasses, shrubs and tree species is carried out during the seeding season. The seeds are cleaned and processed and stored safely for dispersal post the monsoon. Seed collection and processing is an important part of the restoration calendar of activities. Enumeration of floral diversity at periodic intervals is also carried out to assess the degree of revival of native plant species. Based on this corrective steps were planned e.g. species gaps that have to be filled. Repeated removal of invasive species for 3-4 years also forms a critical part of the restoration and maintenance efforts.

Lessons Learned:

In the restored plots, the diversity of adult trees is moderate with around 65 species observed. However, abundance is low in the case of almost all species. This is typical of *L. camara* invaded areas due to suppression of recruitment over a long period.

Good recruitment of over 60 tree species is observed, with presence of seedlings and juvenile plants. This includes many important species like *Acacia chundra*, *Acacia sinuata*, *Aegis marmelos*, *Albizia lebbeck*, *Bauhinia racemosa*, *Boswellia serrata*, *Butea monosperma*, *Diospyros montana*, *Grewia tillifolia*, *Dalbergia lanceolaria*, *Ixora pavetta*, *Limonia monophylla*, *Naringi crenulata*, *Pterocarpus marsupium*, and *Santalum album* etc.

More natural recruitment progression is expected after the removal of *L. camara*, with more species appearing in due course through propagules from in-situ adult trees as well as seed migration from other areas aided by dispersal agents like elephants. These species are present in sapling condition only and there were very few big trees due to the major fire. In due course of time, if the habitat is protected from forest fires, it can be transformed into a dense woodland.

There is good diversity and abundance of under-storey plant habits of shrub, herb, climber etc. post removal of *L. camara*, with over 200 species observed. This is typical response to removal of invasive species, with the

Figure 3.1

Intense re-emergence of *Lantana camara* and *Senna Speactbilis* typical of fire affected plots

Figure 3.2

Three years after forest fire incident of 2019: Forest fie affected area GS Betta range

release of space, sunlight and nutrients leading to a "recruitment euphoria", particularly of fast-establishing plant habits like herbs and shrubs. The re-emergence is facilitated by both in-situ propagules and seed migration. While many shrub species are perennial, a majority of the herb species are seasonal.

There is good re-emergence of *Dendrocalamus strictus* in some of the restored plots. However, presence of *Bambusa bambos* is low.

A total of 355 plant species were observed in the restored plots. Around 22 endemic species and 6 threatened species were also observed. Good presence of plants foraged upon by elephants and other herbivores is also observed.

3.6 INDONESIA

Title: East Kalimantan Restoration

Responsible Agencies: East Kalimantan Municipal Corporation

East Kamilstan, in Indonesia is an area which was susceptible to forest fires repeatedly. The fires were triggered by the dry spell years of the ENSO, illegal logging and plantation in the region. The Integrated Forest Fire Management Project (IFFM), jointly implemented by the provincial forestry service, Indonesian Ministry of Forestry and the German Agency for Technical Co-operation (GTZ), has developed fire management capacities in East Kalimantan. The participation of local communities was fundamental to the fire management concepts. The challenges faced were that people living within protected areas burned the forest in retaliation for being denied access and use of the forests. Fire was used as a weapon in land-use conflicts between communities and concession or plantation companies. A total of 60 villages were given fire management training, providing information on fire occurrence and fire danger criteria. This helped the community develop oneness with the forest, and let go of the earlier resentment (Feuerbacher et al., 2021).

Tobelo people living in the 265 sq km area of Halmahera have been facing the problem of fast dwindling land under their control. Part of their forest land was earmarked for the government's transmigration program. Most of them were displaced, and the remaining populations had to face various threats, including illegal logging in their ancestral forest areas. Outsiders enter and cut down the forest, selling them for at least 1 million rupiah per cubic meter. The community is fighting back through participatory mapping, a process that acknowledges most indigenous groups' lack of formal title to the land. When proposals are submitted for a piece of land, they come prepared with maps to claim their land. Tobelo people meticulously research their history, carry out surveys and hand sketch the boundaries of their land. These maps are then submitted for collective approval by the community. The tribe believes the forests are home to its ancestors, and must therefore never be destroyed, something for which they work meticulously and also set examples to follow (Jong, 2018).

Restoration of forest and biodiversity in the heavily degraded landscape due to fierce forest fire in Sungai Wain of East Kalimantan is one the success stories of forest restoration in Indonesia. The restoration plan demanded collective action from various stakeholders, including Municipal Corporation, the NGOs, the international bodies and general public of the city (van Oosten et al., 2014). The municipality has developed an active approach to involve stakeholders in formal planning procedures and implementation of management plans, while the private sector has taken care of the bulk of the investments required. Sungai Wain protection forest management committee was formed and representation from all the stakeholders was ensured. The collective action provided the entire landscape with a new identity as a provider of green space and clean air for the inhabitants of Balikpapan City (van den Dries, 2013). Forest expansion was also envisaged through the establishment of a multi-functional buffer zone, offering surrounding communities the opportunity to collect non-timber forest products and practice agro-forestry. The creation of the Botanical Garden as a tourist attraction also highlights this multi-functional approach, as it contributes to the bio-cultural identity of the area. Funding for these activities is provided by the government, and the industries operating within the landscape (van Oosten et al., 2014).

3.7 ITALY

Title: Green firebreaks

Responsible Organizations: Regions

Brief Summary:

This type of intervention consists in creating a strategically placed strip, where dense, abundant or flammable vegetation is modified for the purpose of reducing the fuel load and its flammability. The modification does not provide for the complete elimination of the vegetation present: the reduction of the biomass takes place at the expense of the shrubby vegetation; the trees are only partially affected with finalized thinning to separate the crowns.

Description:

The maintenance of a large part of the topsoil on the one hand presents the disadvantage of a less effective containment of the flame front, on the other hand allows to considerably reduce the force of the wind. Indeed, often, inside the strips there are conditions for the circulation of dangerous winds.

Another positive effect of the release of part of the tree component is the action of shading exercised by the plants and the consequent containment of the spread of invasive vegetation. This decreases costs maintenance and guarantees the correct functionality of the strips for longer. The maintenance of the tree cover also allows the maintenance of protective function of the soil and the mitigation of the landscape impact, making this type of avenue is preferable in natural parks.

Lessons Learned:

Active firebreaks are intended to slow down the fire and facilitate the work of the extinguishing teams. The active strip it is therefore not designed to stop fire, but only to slow it down and contain it the intensity within limits defined by the possibility for the teams on land to carry out direct attack on the flame front.

References:

Authors: *Carlo Blasi, Antonio Maturani, Giovanni Bovio, Marco Marchetti, Piermaria Corona (2004):*

Title: *Incendi e complessità ecosistemica. Dalla pianificazione forestale al recupero ambientale*

ISBN 88-7621-497-6

Title: Closer to nature post-fire management

Responsible Agencies: Regions

Brief Summary:

After the major wildfires in 2017, the Piedmont Region decided to develop a tool allowing for an objective evaluation of the damage and the allocation of financial resources. Regional Law 4/2009 on forestry provides (Art. 17) that the Executive Board may approve extraordinary intervention plans for reasons of public utility and urgency. Therefore, in December 2017, the Regional Executive Board provided the necessary guidelines for the preparation of an extraordinary plan for restoring areas affected by forest fires, with the following objectives:

- defining priorities and intervention techniques for the restoration of the forest cover;
- identifying areas for which regional authorization was justified, allowing for the use of public resources for restoration; identifying and locating interventions aimed also at preventing the risk of future forest fires.

Description:

Using the fire severity analysis, minimum and maximum cost scenarios have been defined for each forested area, based on the level of mechanization assumed, the volume of timber cut and cleared, the volume of timber used for building palisades, and the active restoration activities (seeding or planting). Guidelines have been developed on possible types of post-fire intervention to be carried out in forests and for the restoration of road networks, waterways, and hiking trails. The guidelines have been designed according to forest category, fire severity, predominant function or intervention area, and priority of intervention. Specific silvicultural prevention guidelines can be accessed at the following link: https://www.regione.piemonte.it/web/temi/ambiente-territorio/foreste/tutela-bosco-territorio/piano-straordinario-interventi-per-gli-incendi-boschivi-2017

Figure 3.3 Deadwood management after a severe forest fire in mountain beech forest in the southern Alps

Figure 3.4 Tree saplings planted to restore forest cover after a severe a severe forest fire in mountain beech forest in the southern Alps

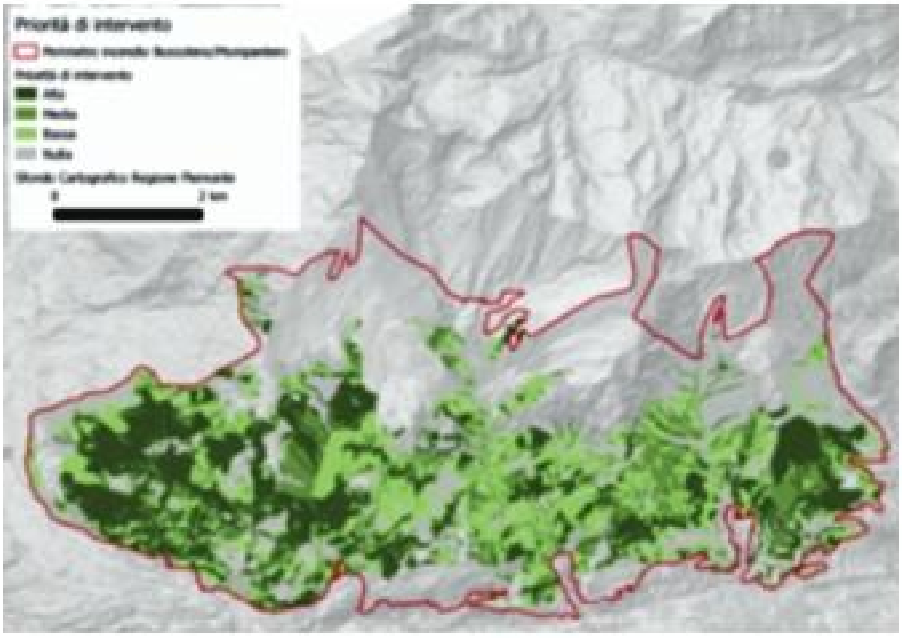


Figure 3.5

Intervention priorities for post-fire restoration after large forest fire in the Southern Alps in 2017

Lessons Learned:

After a wildfire, before undertaking any intervention that could alter natural dynamics, it is essential to analyze the spatial distribution of severity and the potential loss of functions that humans expect from the affected population, evaluating the potential for natural reconstitution in relation to the strategies for renewing present species.

The restoration plan does not include a general clearing of areas with maximum severity through salvage logging. The importance of the ecological role of deadwood in supporting protective functions and facilitating natural recovery processes has always been safeguarded in all planned interventions. The plan aims to improve the future population's resistance and resilience to wildfires, identifying restoration practices that reduce the risk of future forest fires (e.g. by facilitating the regrowth of less flammable species particularly at sites where fire intensity is expected to increase – alignment of slope and dominant winds).

Title: Bio-engineering interventions and vegetation response

Responsible Agencies: University of Sassari Department of Agricultural Sciences

Brief Summary:

The case study confirms that simple, nature-based and low-cost bio-engineering measures using local materials and consistent with traditional building experiences contribute effectively to post-fire site restoration.

Description:

Fire may undoubtedly be considered as the principal long-term perturbation influencing the entire distribution of the Canary Islands pine (*Pinus canariensis* C. Sm.), an endemic conifer species that regenerates both by seed and by epitomic shoots growing from the lower trunk after a perturbation. In *Pinus canariensis* C. Sm., numerous adaptive traits can be related to fire resistance: thick bark, long needles, thick buds, tall growth habit, deep rooting, longevity, serotiny, and sprouting capability. Even though the ecological adaptation to fire allows for a relatively rapid regeneration, wildfire may induce abrupt ecological changes and soil losses. On the Canary Islands, during the 30 July - 2 August 2007 wildfire, about 18.000 hectares of forest were destroyed. After the event, in order to avoid erosion, a series of mixed check dams (wooden elements and stones with a core filled with forest residues) were built in the gullies created by the surface runoff. The mixed dam consists of vegetal debris used as vertical stakes (mainly burned logs of *Erica* sp. and *Myrica faya* Aiton), horizontal logs (mainly from burned *Pinus canariensis* C. Sm.), and biodegradable rope to tie the stakes and logs together as a trench while anchoring the whole structure to adjacent trees. This innovative structure can provide several benefits for erosion control such as reduction of the channel slope and, thus, of water speed and detachment capacity; promotion of infiltration and sedimentation; reduction in resources and construction time by using on-site material; enhancement of the colonization of vegetation due to the biodegradable nature of most of its components. The advantages of a mixed check dam are its notable sediment storage capacity, mainly for large material such as vegetal debris or rocks; high adaptability of the design and the components to the environment conditions; notable vegetation recovery and colonization of the channels (Tardio-Cerrillo and Caballero-Serrano 2009, Tardio-Cerrillo and Garcia-Rodriguez 2016). The survey of the vegetation, carried out in the study area, offers some details, for the characterization of populations and forest affected by different types of anti-erosion interventions considered and how these affect the post-fire regeneration of forest species. The results of the research made it possible to understand the good practice of the use of mixed dams in the post-fire area due to the numerous advantages found in the study:

1. Notable sediment storage capacity, mainly large material as vegetable debris or rocks;
2. High adaptability of the design and the components used to the environment conditions;
3. Notable vegetation recovery and colonization of the channels due to the nature of its components (Neris et al. 2016). The data suggest that, where mixed check dams are present, this type of post fire management favors the development (density and absolute cover) of the regeneration of *Pinus canariensis* C. Sm.

Lessons Learned:

Our observations confirm that simple, nature-based and low-cost bioengineering measures, which use local materials and are consistent with traditional building experiences effectively contribute to site restoration. The rationale behind these interventions was that once the sediment entrapment is initiated and a more stable soil system is developed behind the retaining structure, colonization by the local plant species can begin and a new recovery dynamic would be created. It is therefore very likely that, several years after the fire, the components of the biodegradable nature of these mixed controls may also facilitate plant colonization (Tardio-Cerrillo and Caballero Serrano 2009).

References:

Lovreglio, R, Giadrossich, F, Scotti, R, Murgia, I, Tardio, G, Mickovski, S & Garcia-Rodriguez, JL 2020, 'Observations on different post-fire bio-engineering interventions and vegetation response in a Pinus canariensis C. Sm. forest', Annals of Sylvicultural Research, vol. 45, no. 1. https://doi.org/10.12899/asr-2034

Figure 3.6

Restoration through Bioengineering

Title: Shaded fuelbreaks

Responsible Agencies: Regions

Brief Summary:

This type of green infrastructure consists in creating a strategically placed strip, where dense, abundant or flammable vegetation is modified for the purpose of reducing the fuel load and its flammability. The modification does not provide for the complete elimination of the vegetation present: the reduction of the biomass takes place at the expense of the shrubby vegetation; the trees are only partially thinned to separate the crowns. The infrastructure included water points and a road large enough to let fire fighters access with trucks.

Description:

The maintenance of a large part of the topsoil on the one hand presents the disadvantage of a less effective containment of the flame front, on the other hand allows to considerably reduce the force of the wind. Indeed, often, inside the strips there are conditions for the circulation of dangerous winds.

Another positive effect of the release of part of the tree component is the action of shading exercised by the plants and the consequent containment of the spread of invasive vegetation. This decreases costs maintenance and guarantees the correct functionality of the strips for longer. The maintenance of the tree cover also allows the maintenance of protective function of the soil and the mitigation of the landscape impact, making this type of avenue is preferable in natural parks.

Lessons Learned:

Active shaded fuelbreaks are intended to slow down the fire and increase the efficacy and security of fire fighting teams. The active strip it is therefore not designed to stop fire, but only to slow it down and contain the fire front intensity within the suppression capacity.

Figure 3.7 Shaded fuelbreak in Tuscany Region in Mediterranean pine forests exposed to crown fire.

Figure 3.8 Variable retention harvest in a shaded fuelbreak in the Piemonte Region in Alpine dry conifer forests exposed to crown fires.

3.8 REPUBLIC OF KOREA

Title: Korean practices on restoration of areas hit by huge wildfires and study on establishment of restoration process

Responsible Agencies: Korea Forest Service

Brief Summary:

The government of the Republic of Korea devised plans appropriate to economy, environment, community and culture, and expanded participation of private sector in order to restore areas hit by huge wildfires that broke out in Korea last year. To this end, its forestry agency named the Korea Forest Service (KFS) has made an effort to collect opinions from various stakeholders to set up the plans, improve systems to support and implement the restoration, and come up with systems of supporting laws or schemes to attract private companies and the public that have interest in planting trees as ESG management and social contribution activities.

In addition, Korea established the "Long-term Ecological Research Site" domestically (Goseong-gun and Samcheok-si, Gangwon-do Province), and has proceeded two activities below through long-term monitoring to identify the proper plans on post-fire restoration after huge fires happened in Goseong-gun (1996) and the eastern coast (2000). Through the monitoring, the country has looked into differences between naturally- and artificially-regenerated areas and pros and cons of each approach, and presented healthier and more appropriate restoration model.

Description:

Restoration of fire affected areas

Operation of consultation meeting: The Korea Forest Service (KFS) has established and operated a consultation meeting of post-fire restoration to promote communication between multi-stakeholders. The consultation meeting is joined by experts, local communities, forest-related groups, NGOs such as "Forest for Life" and "Korean Federation for Environmental Movement". Through their consultations, a decision-making tree has been revised to choose areas and method (natural/artificial) of restoration properly, considering various factors such as requests of forest owners, sites to be naturally regenerated, and six forest functions (timber production, water conservation, forest disaster prevention, natural and living environment conservation, recreational forest, landscape planting, erosion control, fire-resistant forest, etc.). And the KFS has shared developments of policies and raised the public awareness by utilizing various channels including symposium and discussion through press briefing and Youtube livestreaming.

Improvement of System

The Korean government has enhanced and implemented systems to support and conduct the restoration activities. In May 2022, guidance on emergency logging was revised and the criteria for supporting and implementing the restoration were announced.

Before the emergency logging, briefings have been held for local community, civic groups, and academia while making a consensus with them along with clearer explanation on target areas and restoration method by damage level (e.g. natural regeneration for areas with minor damage). And the Korea has supported entire cost of planting trees only for the regions targeted for artificial regeneration according to the current restoration plans. For forests logged before the plans were established, supports proceed in the existing way (incl. cost-bearing of forest owners).

Participation of Private Sector

In Korea, there are a number of private companies and the public that have growing interest in plating trees as ESG management and social contribution activities. So, the Korea's government has endeavored to come up with ways to attract their participation further. To this end, Korea has established systems to bring about various collaboration on restoration activity. And the government has supported the activities through campaigns, projects on state-owned management, and cooperation agreement.

Moreover, Korea has identified new practices on post-fire restoration using private sectors' technologies such as metaverse. For instance, there was an event that if planting a tree in the virtual space (metaverse), two trees will be planted in the real fire-hit areas. In April 2022, 10,000 trees were planted to restore one of the areas (Andong-si, Gyeongsangbuk-do Province), which recovered forests of seven hectare.

Monitoring of Research Sites

Background: Korea's post-fire restoration mechanism took a great turn as two large wildfires occurred in Goseong-gun and the eastern coast in 1996 and 2000 respectively. Since then, comprehensive discussions have begun to proceed to have systematic forest restoration to develop the existing restoration framework. There was a need for long-term monitoring for the sites recovered from fire-caused damages as opinions differed on the restoration method (natural and artificial regeneration) in the discussions.

Description: Korean forest institute named National Institute of Forest Science (NiFoS) set the "Long-term Ecological Research Site" of 100 ha and 4,000 ha in Goseong-gun (1997) and Samcheok-si (2001)

Figure 3.9

Tree planting in Metaverse

Tree planting in Metaverse

Figure 3.10

Pilot research sites for long-term monitoring

Pilot research sites for long-term monitoring

respectively and has proceeded monitoring in order to look into the restoration of fire-hit areas comprehensively. And the research organization has conducted the study by monitoring changes in ecosystem hit by forest fires in terms of differences between restoration method, vegetation, soil, and wildlife so as to create a restoration process.

Findings: The long-term monitoring has helped to identify pros and cons of restoration method (natural/artificial restoration) and provide information to support decision makers to decide and implement the restoration activities proper to the damaged areas.

Next steps: The Korea Forest Service (KFS) has a plan to study not only individual tree but also forest ecosystem and effect of ecosystem service in stages through the long-term monitoring of areas recovered from wildfires.

Lessons Learned:

Through the restoration process, the Korean government has been able to have more appropriate measures and plans on the restoration of fire-hit areas by collecting opinion systematically from various stakeholders such as environmental groups, local communities, and experts. And Korea has established the restoration plans that enable to prevent excessive logging and restore each area according to regional characteristics by improving laws and systems in a timely and flexible manner.

In addition, cooperation with private sector is able to attract the public to the restoration activities, which leads to the raised public awareness and domestic companies to promote ESG management. For establishing the balanced and proper restoration plans, it's essential to have comprehensive analysis of forests being restored and materials for changes in forest ecosystem including ecological succession process.

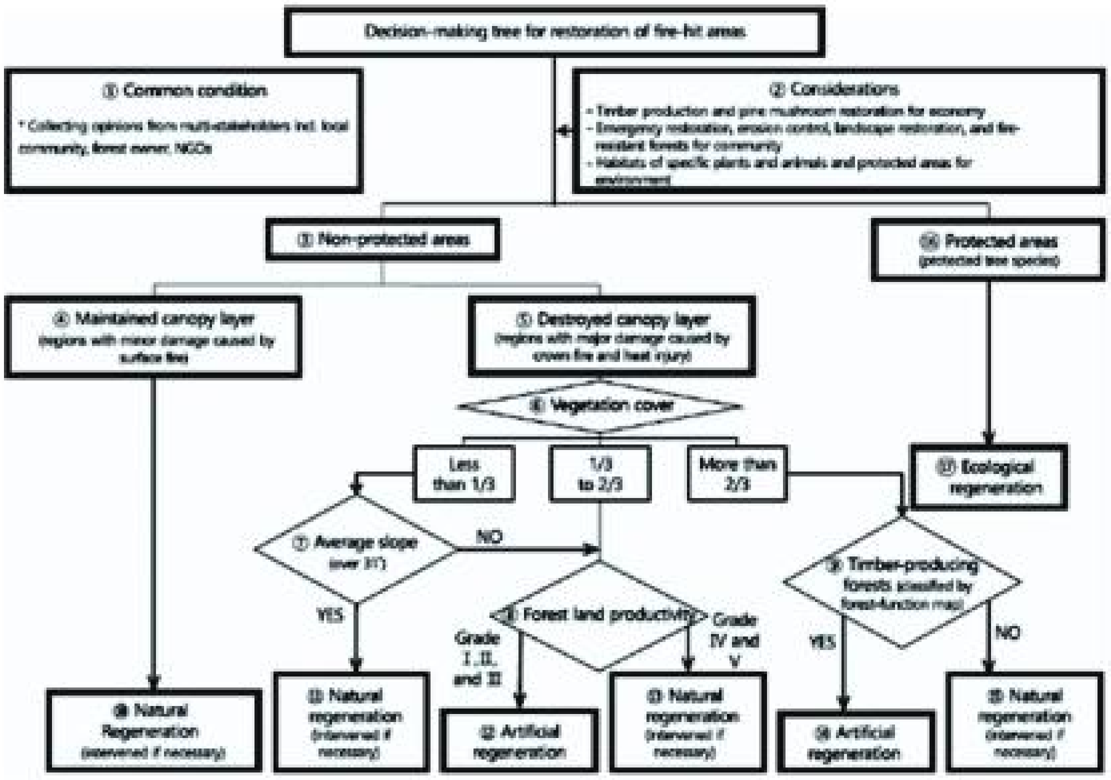


Figure 3.11

Decision-making tree for restoration of fire-hit areas, Korea Forest Service, 2022

Case I: Rehabilitation of forest ecosystems of Korean Kangwon Eco-region damaged by forest fire (Shin and Lee, 2004).

A major producer of pine mushrooms, the Kangwon eco-region is situated in the centre of the eastern coast of the Korean peninsula and experiences frequent and substantial forest fires. The region experiences cool summers and mild winters, and it receives the most of its rainfall in the fall and winter months, with only a little amount in the spring and summer months. During the spring of 1996, the region saw the largest forest fire on record in Korea, which was surpassed by a fire six times larger in 2000. Following the 1996 fire, the Korea Forest Research Institute intensively examined burnt places, employing data on regional flora and fauna, climate, geology, landform, forest soils, hydrology, pests, and pine mushrooms to formulate core principles for post-fire restoration. The institute also built a 100-hectare long-run ecological research site to study the dynamics of forest ecosystems following fire. It was observed that the quality of the stream water was recovered in a year, but the fire's influence on the soil lasted much longer and region experienced severe soil erosion and fertility decline three years post fire. Majority of the plantations thrived successfully with proper stocking; nevertheless, it was critical to grow larch (*Larix leptolepis*) in valleys or on the foothills of mountains. After fire, oak sprouts (mainly *Quercus mongolica*) developed swiftly in all sites, however in the case of black-locust coppice (*Robinia pseudoacacia*), planted trees were unable to take control without artificial care. However, because the area is dry and receives more light, it appeared that the burning transformed the woods on the slopes into pine (*Pinus densiflora*) forests.

Case II: Post-fire restoration in Baekdu mountain range (Lee et al., 2014).

The Baekdu mountain range, lying in the eastern coastal range of Republic of Korea had a significant, widespread forest fire in April 2000, which destroyed 23,794 ha of forested land over the course of 9 days. Due to a deficiency of sprouting sources, only 30% of the study hillslope regenerated with native plant species by June 2002, 2 years after the fire. *Quercus mongolica*, *Quercus serrata*, and *Quercus variabilis*, among oak species, dominated the majority of the recovered stands. Other tree species belonging to the Leguminosae family, such as *Robinia pseudoacacia*, *Lespedeza cyrtobotrya*, and *Albizia julibrissin*, as well as bracken ferns, such as *Pteridium aquilinum* var. were also established. Therefore In 2002, six treatments hydro seeding, ground seeding, tree planting, vegetation sacks, sodding and log erosion barriers were installed and the results were compared to those from an untreated site in terms of vegetation covering and sediment output. It was found that hill slope requires at least 4 years regaining surface soil stability through the return of native plant species. However, surface soil stability was attained more quickly with the rehabilitation methods. The hydro seeding and vegetation sack treatments in particular, which provided seed stability and a fast growth rate, were extremely successful in early recovery despite repeated high-intensity rainfall.

3.9 MEXICO

Title: Restoration of areas affected by forest fires to recover natural biodiversity.

Responsible Organizations: National Forestry Commission (CONAFOR)

Brief Summary:

CONAFOR, through the "Support Program for Sustainable Forestry Development", particularly through component III Forest restoration of strategic micro-watersheds, carries out activities to counteract land degradation processes, including those caused by forest fires. The areas affected by forest fires represent a priority for restoration actions given that degradation of natural resources is reduced or stopped and that these practices promote natural regeneration and encourage the establishment of new forest cover through reforestation.

Figure 3.11

Polygon under forest restoration actions through Component III Restoration in micro-watersheds for indigenous peoples 2022. A) Satellite view of the general conditions of the property; B) Panoramic view of the area affected by fire. Views of the polygon subject to forest restoration actions in the Ejido San Alonso, Urique, Chihuahua, 2022. A) Satellite view of the property, B) Panoramic view of the attention site.

Description:

Through the "Support Program for Sustainable Forestry Development", particularly component III. Forest restoration of strategic micro-watersheds, CONAFOR intervenes in forest ecosystems by carrying out specific activities to counteract land degradation processes affected by anthropogenic factors, with forest fires being a recurring cause. In this sense, the most appropriate and required practices for the restoration of the land are determined, highlighting actions of conservation and soil restoration works, reforestation with native species, biodiversity management practices, and protection of areas, maintenance of the actions, among others.

The areas affected by forest fires represent priority areas for attention through the execution of restoration actions; with these, the degradation of natural resources is reduced or stopped. Soil is affected by the loss of vegetation cover and it derives in the erosion and dragging of materials. Restoration practices promote natural regeneration and encourage the establishment of new forest cover through reforestation.

Lessons Learned:

CONAFOR has directed attention strategies to areas affected by fires, from fire control to, where appropriate, the rehabilitation of the affected area. The monitoring of these restoration processes is given through different programs that guide resources for the execution of specific projects to recover damaged areas. In parallel, these priority attention areas are identified and the affected areas are geographically integrated.

3.10 KINGDOM OF SAUDI ARABIA

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

Responsible Agencies: NCVC (National Center for Vegetation Cover)

Brief Summary:

The project aims to rehabilitate both forests which were destroyed by wildfires by studying the affected areas and creating reforestation plans including cleaning the affected areas from wildlife residues, soil preparing, seed collection, and supplying seeding in the areas to be cultivated.

Description:

First stage: study of sites and soils and development of reforestation plans in cooperation with scientific team and professional forest experts from Saudi Universities.

Figure 3.12

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

Second Stage: preparation of sites for reforestation works, including the preparation of agricultural soil and fertilization, as well as the obtention, transportation, planting, and storage of the seedlings in a nursery at the reforestation site.

Third Stage: rehabilitation of the affected sites.

Fourth Stage: Irrigation maintenance and patching over a period of 12 months.

Lessons Learned:

Enforcing legislation and increasing monitoring to ban setting fires during the summer period.

3.11 TÜRKIYE

Title: Bal ı kesir – Ayval ı k Forest Fire (2006)

Responsible Organizations: Ministry of Agriculture and Forestry, General Directorate of Forestry

Brief Summary:

The forest fire started on July 03, 2006 and continued for 5 days. 168 hectares of forest area burned. 28 hectares of the burned forest area was regenerated naturally. 122 hectares were regenerated artificially. (Sowing and planting). 167.000 saplings were planted on the field and 250 kg of seeds were sowed.

Description: Postfire Restoration

Lessons Learned:

1. Importance of restoration - assisted natural regeneration - especially in red pine.
2. To establish mixed stands with coniferous and broad leaved tree species instead of pure stands.
3. To manage restoration activities in stands partially (stand sizes must be between 300-500 hectares). Not to allow planned whole adjacent stands.
4. To establish fire strips, buffer zones with different local less flammable broadleaf plants and cypresses in and around fire sensitive or fire effected forests surrounded by residential areas, roads, villages and farmlands.

Figure 3.13

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

Title: Antalya – Taşag ı I Forest Fire (2007) Restoration

Responsible Organizations: General Directorate of Forestry

Brief Summary:

The forest fire started on July 31, 2008 and continued for 5 days. 15.795 hectares of forest area burned. 4.015 hectares of the burned forest area was regenerated naturally. 5.618 hectares were regenerated artificially. (Sowing and planting). 7.000.000 saplings were planted on the field and 50.000 kg of seeds were sowed.

Description: Postfire Restoration

Lessons Learned:

1. Importance of restoration - assisted natural regeneration - especially in red pine
2. To establish mixed stands with coniferous and broad leaved tree species instead of pure stands.
3. To manage restoration activities in stands partially (stand sizes must be between 300-500 hectares). Not to allow planned whole adjacent stands.
4. To establish fire strips, buffer zones with different local less flammable broadleaf plants and cypresses in and around fire sensitive or fire effected forests surrounded by residential areas, roads, villages and farmlands.

Figure 3.14

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

Title: Denizli – Buldan Forest Fire (2000) Restoration

Responsible Organizations: General Directorate of Forestry

Brief Summary:

The forest fire started on July 14, 2000 and continued for 5 days. 1.458 hectares of forest area burned. 713 hectares of the burned forest area was regenerated naturally. 555 hectares were regenerated artificially. (Sowing and planting). 400.000 saplings were planted on the field and 600 kg of seeds were sowed.

Description: Postfire Restoration

Lessons Learned:

1. Importance of restoration - assisted natural regeneration - especially in red pine
2. To establish mixed stands with coniferous and broad leaved tree species instead of pure stands.
3. To manage restoration activities in stands partially (stand sizes must be between 300-500 hectares). Not to allow planned whole adjacent stands.
4. To establish fire strips, buffer zones with different local less flammable broadleaf plants and cypresses in and around fire sensitive or fire effected forests surrounded by residential areas, roads, villages and farmlands.

Figure 3.15

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

Title: Mugla – Bodrum Forest Fire (2006) Restoration

Responsible Organizations: General Directorate of Forestry

Brief Summary:

The forest fire started on June 21, 2006 and continued for 30 days. 2.601 hectares of forest area burned. 1.971 hectares of the burned forest area was regenerated naturally. 245 hectares were regenerated artificially. (Sowing and planting). 410.000 saplings were planted on the field and 385 kg of seeds were sowed.

Description: Postfire Restoration

Lessons Learned:

1. Importance of restoration - assisted natural regeneration - especially in red pine
2. To establish mixed stands with coniferous and broad leaved tree species instead of pure stands.
3. To manage restoration activities in stands partially (stand sizes must be between 300-500 hectares). Not to allow planned whole adjacent stands.
4. To establish fire strips, buffer zones with different local less flammable broadleaf plants and cypresses in and around fire sensitive or fire effected forests surrounded by residential areas, roads, villages and farmlands.

Figure 3.16

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

Title: Mugla – Marmaris Forest Fire (2002) Restoration

Responsible Organizations: General Directorate of Forestry

Brief Summary:

The forest fire started on August 15, 2002 and continued for 33 days. 1.321 hectares of forest area burned. 1.171 hectares of the burned forest area was regenerated naturally. 150 hectares were regenerated artificially. (Sowing and planting). 250.000 saplings were planted on the field and 8.750 kg of seeds were sowed.

Description: Postfire Restoration

Lessons Learned:

1. Importance of restoration - assisted natural regeneration - especially in red pine
2. To establish mixed stands with coniferous and broad leaved tree species instead of pure stands.
3. To manage restoration activities in stands partially (stand sizes must be between 300-500 hectares). Not to allow planned whole adjacent stands.
4. To establish fire strips, buffer zones with different local less flammable broadleaf plants and cypresses in and around fire sensitive or fire effected forests surrounded by residential areas, roads, villages and farmlands.

Figure 3.17

Reforestation of the Ghlamah mountain forest in Tanoumah and A'al Mefreh mountain forest in Al Sawdah

3.12 UNITED STATES OF AMERICA

Title: US Forest Service Forest Management Programs

Responsible Organizations: United States Department of Agriculture Forest Service

Brief Summary:

The overriding objective of the US Department of Agriculture's Forest Service's forest management program is to ensure that National Forests are maintained in an ecologically sustainable manner. Forest management objectives include ecological restoration and protection and research and product development, fire hazard reduction, and maintenance of healthy forests.

Description:

USFS National Reforestation Strategy: The National Reforestation Strategy outlines the goals and objectives necessary for successful reforestation on national forests. These goals and objectives build a robust framework to increase the pace and scale of reforestation to address existing needs, anticipate future events, and meet the provisions of the recently passed REPLANT Act (Public Law 117–58). Five goals describe actions needed throughout the reforestation process while the sixth goal emphasizes the importance of strategic communication and developing a shared understanding of reforestation. The Forest Service will develop national and regional 10-year implementation plans with specific actions for each goal. Three overarching principles guide the strategic framework and describe the approach the Forest Service will take to implement this strategy and fulfill requirements of the REPLANT Act.

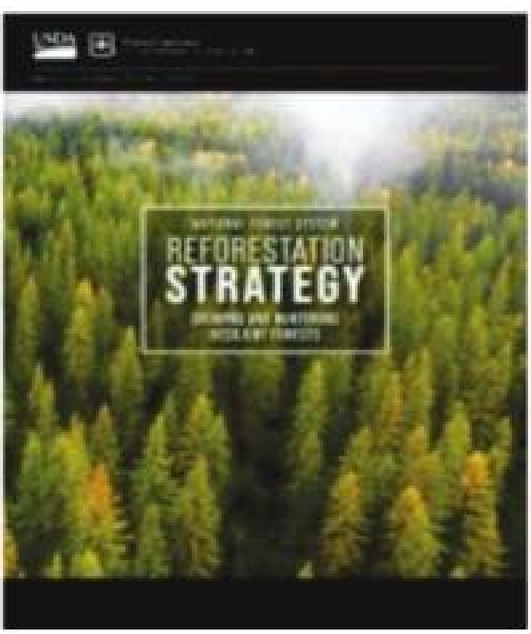


Figure 3.18

Aponderosa pine seedling is planted after the Sunrise Fire on the Lolo National Forest in Montana. USDA Forest Service photo by Caitlin Bailey.

Figure 3.19

Sweet Creek Milepost 2 Fire in 2020, Oregon Department of Forestry photo by Marcus Kauffman

Burned Area Emergency Response (BAER): After a fire, the first priority is emergency stabilization in order to prevent further damage to life, property or natural resources on Forest Service lands. The stabilization work begins before the fire is out and may continue for up to a year. The longer-term rehabilitation effort to repair damage caused by the fire begins after the fire is out and continues for several years. Rehabilitation focuses on the lands unlikely to recover naturally from wildland fire damage. The Burned Area Emergency Response (BAER) program is designed to address these emergency situations through its key goals of protecting life, property, and critical natural and cultural resources. The objective of the BAER program is to determine the need for and to prescribe and implement emergency treatments on Federal Lands to minimize threats to life or property resulting from the effects of a fire or to stabilize and prevent unacceptable degradation to natural and cultural resources.

RAVG program -Tool for evaluating post-fire vegetative condition: The RAVG program provides assessments of vegetation conditions (burn severity) following large wildland fires on forested National Forest System (NFS) lands. RAVG products are intended primarily for use in assessing fire-related reforestation needs. RAVG data help staff on local units prioritize areas for further assessment and support reforestation funding requests and decisions. They facilitate post-fire vegetation management decision-making by reducing planning and implementation costs. RAVG data also serve a variety of related Agency objectives, such as wildlife habitat analysis and salvage harvest planning.

Watershed Condition Framework is a tool for assessing the health and restoration needs of watersheds. The Watershed Condition Framework establishes a new consistent, comparable, and credible process for improving the health of watersheds on national forests and grasslands. This framework will help focus our efforts in a consistent and accountable manner and facilitate new investments in watershed restoration that will provide economic and environmental benefits to local communities. The technical guide provided the protocol for the agency's first national assessment of watershed condition across all 193 million acres of National Forest System lands.

Software and technical guides for restoration work to facilitate fish passage in roaded areas. • Aquatic Organism Passage: FishXing - This software is intended to assist engineers, hydrologists, and fish biologists in the evaluation and design of culverts for fish passage. It is free and available for download.

Technical Guide for Field Practitioners: Understanding and Monitoring Aquatic Organism Passage at Road-Stream Crossings (PDF).

Lessons Learned:

- USFS Collaborative Forest Landscape Restoration Program (CFLRP) Resource Library, including guides, reports, case studies, and videos on restoration best practices - https://www.fs.usda.gov/restoration/CFLRP/resource-library.php
- USFS Restoration website, with links to reports and workshop outcomes on restoration best practices - https://www.fs.usda.gov/restoration/index.shtml.

3.13 SOUTH AFRICA

Title: The Knysna Fires of 2017

Responsible Organizations:
Santam, University of Stellenbosch, CSIR, Western Cape Disaster Management Centre

Brief Summary:

The Knysna fires were arguably the worst wildfire disaster in South Africa's history. The social and economic impacts will be felt by Knysna and its inhabitants for years to come. The Knysna fires were a perfect storm. A range of meteorological, bio-physical and institutional factors came together to create the disaster. But the underlying risk drivers are replicated throughout the Western Cape, and in other provinces, creating the potential for similar wildfires elsewhere - as evidenced by extensive wildfires in Hessequa, Mossel Bay, George and Knysna Municipalities in November 2018 and the Overberg in January 2019.

Description:

Post-fire Recovery Efforts

Recovery efforts were centred on the Garden Route Rebuild Initiative (GRRI). The GRRI sought to optimise efforts to "Build Back Better". Given the scale of the damage to housing, infrastructure and the environment, the extensive humanitarian support needs, and the large number of role-players gearing up to respond, the GRRI was envisaged as the anchor for a comprehensive, integrated reconstruction and recovery effort for the Garden Route.

The initiative aimed to create a multi-disciplinary, inter-governmental and multi-sectoral platform to align and maximise recovery and rehabilitation efforts. It brought together national, provincial and local government, state-owned enterprises, community members, civil society organisations and the private sector in seven sector-based working groups to design and implement recovery projects. The GRRI had six workstreams:

- Humanitarian assistance
- Reconstruction
- Infrastructure rehabilitation
- Environmental management
- Business support
- Skills development

The initiative represented a good example of inter-governmental cooperation. It also brought together role-players that would not have usually engaged with one another, which built relationships between stakeholders. However, as discussed in greater detail in RADAR's technical report, weaknesses included additional demands placed on governmental stakeholders and inadequate engagement with municipal partners. However, arguably, the greatest obstacle to 'Building Back Better' was obtaining funding for recovery efforts, along with slow disbursement of allocated funds.

This obstacle was most prominently illustrated in the Environmental Management Workstream. Environmentalists realised early on that there was a pressing need to stabilise slopes denuded by the fires to prevent landslides and erosion and to remove alien vegetation, which if not effectively controlled would increase fuel loads and suppress the recovery of the biodiversity and natural ecosystems in the invaded areas. Building on donations from the public, the GRDM provided R700 000 for slope stabilisation efforts, but the National Disaster Management Centre was approached to provide an additional R37 million to finance ambitious programmes to prevent the regeneration of alien plant species. The National Treasury ultimately committed R54 million for environmental work through its drought relief fund, but only in November 2018 – 16 months after incident.

The absence of funding prevented implementation of the envisaged projects. Knysna Municipality independently obtained funding from the Department of Environmental Affairs and Development Planning (DEADP), and by late 2018 had cleared approximately 600 hectares of municipal land, although most burned land was not cleared. Most stakeholders feel that the absence of funding will exponentially increase fuel loads in areas affected, with many commenting that fire risk is higher now than before the fires. In addition, clearing now will be considerably more expensive, as vegetation is older and better established. Funds also needed to be spent by the end of the 2018/19 financial year, leaving very little time for planning and resourcing the rehabilitation efforts.

Lessons Learned:

Two positive outcomes of stabilising the steep slopes, and allowing the vegetation to re-establish itself rapidly, were:

1) Minimised localised mud-slides, thereby preventing homes and infrastructure being flooded in the weeks and months after the fire; and (b) it also limited the amount of silt from the burnt area that would be deposited in the environmentally sensitive Knysna Lagoon.

2) No formal and comprehensive record of the re-vegetation process is being kept, missing an excellent opportunity to learn from what worked, what did not, and what to improve in the future. The funding of such monitoring should become part of the rehabilitation measures, including clarifying who should be doing such monitoring.

3) Resource Recovery: Despite successes, the GRRI surfaced several challenges undermining recovery. Unresponsive funding mechanisms represent a core blockage in the recovery process, preventing time-critical activities that will speed recovery and reduce risk. Lengthy procurement procedures also frustrate efforts to rehabilitate infrastructure, for instance. The experience of the environmental workstream and the asbestos removal project suggest an urgent need for more responsive, quick-release funding mechanisms (i.e. within days or weeks) that do not require the funds to be spent within a given financial year. This research also highlights the importance of transparency and buy-in.

4) The economic cost of the Knysna fires was enormous. Even though official figures probably under-represent the cost of the fires, the losses sustained by government and the insurance and forestry industries highlight the destructiveness of large fires - and the value of investing in risk reduction. The return on money spent on efforts to prevent destructive wildfires and mitigate their impact is exponential compared to the costs of not acting. The losses sustained by insurance companies, in particular, underscore the benefits that the insurance industry could gain by being more pro-active, particularly given anticipated increases in the frequency and severity of fires due to global warming.

5) The fires had a profound impact on Knysna's residents and economy, and recovery is happening slowly. Many of the homes and businesses damaged or destroyed were not insured or were under-insured, and people are struggling to rebuild. The findings highlight a 'missing-middle' of people who have been left in a precarious position by the fires. A key challenge lies in knowing how to support these households, who currently fall through gaps in existing social safety nets. The insurance industry could play a role by exploring insurance options that are more affordable and tailored to the needs of pensioners and others in this group.

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Chapter 4

4

WAY FORWARD

4.1 Fast-tracking Restoration of Forest Fire Affected Areas Under the Indian G20 Presidency

Scientific evidence indicates that fire regimes are being altered due to climate change, land-use, and population change driving an increase in the frequency and magnitude of fire events worldwide (UNEP, n.d.). The IPBES Assessment on Land Degradation and Restoration finds that land degradation is a major contributor to climate change, with deforestation alone contributing about 10% of all human-induced greenhouse gas emissions (IPBES, n.d.). Another major driver of the changing climate has been the release of carbon previously stored in the soil, with land degradation between 2000 and 2009 responsible for annual global emissions of up to 4.4 billion tonnes of CO_2. Forest fires accelerate rates of carbon loss from soils and therefore increase the frequency and intensity of forest fires posing a widening threat to both climate and land.

Fires have been responsible for 27% of the tree cover loss globally between 2001 and 2021. G20 countries represent ~80% of the world's forests and have lost over 112 million hectares of tree cover due to forest fires between 2001 and 2021 (Global Forest Watch, n.d.), with Russia, Canada, United States, Brazil and Australia representing the largest areas lost due to tree cover loss during this period.

Currently, with regard to the five integrated phases of emergency management of wildfires, outlined under the Sendai Framework for Disaster Risk Reduction 2015-2030, UNEP reports disproportionate spending on response with very little spending on recovery (UNEP, n.d.). With the most recent IPCC report indicating that weather conducive to wildfires ("fire weather" – hot, dry, and windy) is becoming more frequent in some regions and is predicted to increase with higher levels of global warming, it further suggests the need to make investments towards preparedness measures that can yield significant benefits. Forest landscape restoration can be an effective tool to increase forests' resilience and lower the negative impacts of wildfires in preparing for wildfires. For instance, rewetting peat-lands and wetlands can crucially reduce wildfire risk. With the threat that global wildfires pose, there is a critical need to understand better the behavior of wildfires in different ecosystems and under a changing climate.

Furthermore, while efforts have been made for the adoption of integrated approaches to fire management (IFM) there is limited incorporation of ecological and socio-economic concerns within National Fire Management Plans and Strategies, particularly in addressing concerns of ecosystem restoration as an important avenue to work towards climate, land and biodiversity goals and targets. This is evident with the limited investment in the recovery of forest-fire-affected areas.

To effectively address the worldwide challenges confronting forests, international collaboration is imperative. Although there have been many efforts, initiatives, and bilateral arrangements in relation to international cooperation on forest fire management, very few have matured into stable collaborative efforts that serve as a foundation for international cooperation on forest fire management.

G20 cooperation on the restoration of forest-fire-affected areas will therefore contribute significantly towards fast-tracking global commitments on fire management and land restoration.

Table 7.1

Framework for Integrated Forest Fire Management

System Process Components	System Tools
REVIEW - ANALYSIS OF THE FIRE PROBLEM 1. Fire Likelihood Ignition history 2. Consequence of Fire on • Economic, Social & Environmental • Intensity, Spread Rate, Duration • Vulnerability & Value 3. Ecological context of fire	• Maps (vegetation, topography, tenure, assets, roads, ignition distribution etc.) • Fire behavior prediction tools • Spatial databases • Demographic information • Cultural & social context of fire • Ecological response to fire (fire histories, fire effects • information, fire regimes)

RISK REDUCTION – PREVENTION 1. Ignition Reduction Strategies • Regulate fire use, educate fire users, alternatives for fire • use, technology improvements, development planning • controls 2. Impact Mitigation Strategies • Fuel reduction (e.g. by burning, grazing & other means) • Reduce asset vulnerability (e.g. construction standards) • Establish/maintain containment features (e.g. fuel breaks) 3. Fire Use Strategies • Ecosystem maintenance • Fire regime restoration	• Fire use laws/regulations, enforcement • Planning controls • Education programs • Fire behavior guides, ignition & control resources, planning & reporting tools. • Firebreak construction guides • Building construction codes • Ecological fire training • Fire use education
READINESS - PREPAREDNESS TO FIGHT FIRES 1. **Strategies** • Early Warning/Predictive systems • Community warning mechanisms • Detection and response infrastructure • Communications systems • Mobilisation & co-ordination plans • Response triggers and levels • Competent fire control staff	• Climate, weather monitoring & prediction • Fire Danger Rating system • FDR public notification means • Detection/suppression needs assessment • Fire detection, suppression & communications resources • Fire training systems and tools
RESPONSE - FIRE FIGHTING OPERATIONS 1. Detection and Reporting 2. First Response 3. Containment and Control 4. Mop Up and Patrol 5. Command and Control	• Response mobilization plans • Operational responsibilities & procedures. • Strategic information access tools • Decision support tools • Operational management systems

RECOVERY POST FIRE

1. Community Welfare assistance
2. Economic loss reduction (e.g. salvage logging and replanting, infrastructure repair)
3. Environmental repair

- Damage assessment tools
- Recovery assistance plans

Developed by Metis Associates in 2000, presented at the World Forestry Congress, Quebec, in 2003, and updated since.

Enhancing G20 cooperation in fire management can assist countries in:

- Implementation of relevant international agreements, conventions, declarations, processes, and voluntary agreements in regional, national, and local policies and actions
- Achievement of greater integration of policies, plans, management, and monitoring among sectors at the regional, national, and local levels
- Improve available knowledge, information, and data within countries on the extent and impacts of fire on a range of forest and non-forest ecosystems as a basis for decision-making
- Increase the efficiency of fire management (land use and fire use, prediction, prevention, preparedness, rapid response to and control of fires, and mitigation and restoration/rehabilitation following them)
- Enhance capacity-building in fire management and post-fire recovery as a means to reduce the risk of forest fires
- Create a framework and mechanisms for international donor support to fire management stakeholders in need.

It is recommended that G20 countries cooperate on the restoration of forest fire-affected areas to reduce risks from wildfires and enhance the recovery of biodiversity. Taking into consideration the five integrated phases of emergency management of wildfires, i.e., review and analysis, risk, reduction, readiness, and response articulated under the Sendai Framework along with the common principles for a shared vision of ecosystem restoration laid out under the UN Decade on Ecosystem Restoration and the objectives of the Global Land Initiative, the following is recommended as a way forward for G20 countries on post-fire restoration based on best-practices from G20 countries.

4.2 Global Coordination

There is a need among G20 countries to develop protocols on forest fire response and recovery to fight the growing concerns of forest fires collectively. Procedures are required to identify assets available, the extent of loss, and damages, particularly with regards to ecosystem services and biodiversity loss within each G20 member country in supporting possible country demands as and when they are required. A global coordination center can be created along with a few regional coordination centres to improve the effectiveness of support provided in a timely manner. Towards that end G20 member states can:

- Support the motion to revise UNFCCC reporting of GHG emissions so Nationally Determined

Contributions better account for fire activity outside natural disturbance regimes. Currently, countries are only required to report GHG from fire when related to newly deforested lands, not from fires in standing forests; this can be considered a loophole, especially considering that most fires on Earth are human-caused and that a significant portion of the world's fire activity happens because of deforestation.

- Collaborate in assisting the establishment and upkeep of national fire databases. These databases should include fire size, cause, date, costs, damages, fatalities, injuries, pre-existing mitigation efforts, post-fire restoration efforts, successes, and lessons learned. Reliable data collected by governmental agencies can be derived to produce critical information and knowledge helping understand the evolution of fire regimes, risks, quantification of economic losses, and options for post-fire recovery.
- Prioritize the application of data openness principles in order to enable collaboration among various stakeholders and levels of fire governance. This practice can facilitate transparency and build trust, ultimately contributing to the effective implementation of the 2030 Agenda and its goal of leaving no one behind. By embracing data openness, different actors can work together more efficiently to respond to and recover from fires, enhancing the overall effectiveness of these processes.
- Enhance the sharing of best practices on reducing fuel loads, particularly at the community level, by building consensus on and implementing existing standards available within G20 countries. Several standards aim to reduce fuel load in strategic locations around communities to limit fire spread or reduce fire intensity, and subsequent damages.
- Promote the adoption of Ecosystem-based Approaches, which benefit all aspects of vulnerability reduction, and, more generally, risk reduction (also called Eco-DRR). This can be achieved through ecosystem restoration or conservation of species and natural areas.

4.3 Postfire Restoration Framework

To build consensus and collaboration among G20 member states on post-fire restoration, it is recommended that a G20 framework for postfire restoration is agreed upon. Guiding principles as proposed in Postfire Restoration Framework for National Forests in California by USDA, 2021 can be used to plan the restoration framework with established monitoring norms. The framework comprises of six Guiding principles as described below:

Guiding Principles

i) Restoration of key ecological processes

ii) Consideration of the landscape context

iii) Promotion of regional native biodiversity

iv) Sustenance diverse ecosystem services

v) Establishment of a prioritization approach for management interventions

vi) Incorporation of adaptation to agents of change

Furthermore, five processes make up the post fire restoration framework, which results in the creation of a post fire restoration portfolio. These include the following:

1) Bringing together a team, identifying priority resources, and defining desired conditions;

2) Collection and analysis of pertinent spatial data;

3) Development of postfire restoration flowchart to identify restoration opportunities;

4) Development and incorporation of a list of potential management actions that take advantage of these opportunities

5) Development of a portfolio of potential restoration actions and the prioritization of actions.

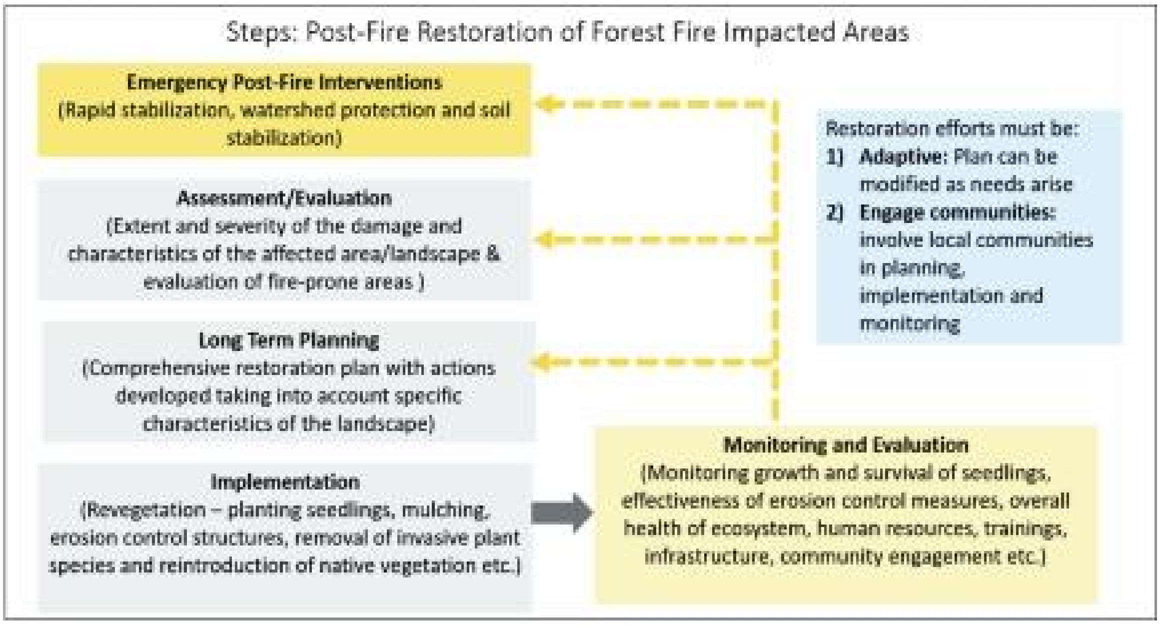

Figure 7.1

Post-Fire Restoration of Forest Fire Impacted Areas

4.4 Identification of Research Needs:

- G20 member countries should prioritize expanding, maintaining and sharing knowledge from long-term ecological research (LTER) sites to monitor the evolution of ecosystems and their fire regimes. As climate change is expected to cause shifts in vegetation and potentially impact wildfire activity, monitoring by LTER networks can help understand the consequences of these changes. This monitoring might include collecting data on post-fire forest recovery, changes in ecological structure and ecosystem services, and shifts in fire behaviour, in addition to monitoring forest health. The outcomes of such monitoring networks can inform decisions about where fire regime restoration is needed or where fire exclusion is necessary.

- Capturing, demonstrating, and valuing nature's services need to become standard in wildfire risk assessment, particularly in understanding the extent of loss and damages of forest fires on ecosystem services and biodiversity. Fire reporting should go beyond the area burned as the main metric for fire management towards other metrics such as avoided losses or ecosystem enhancement. The application of global valuation frameworks such as the Total Economic Valuation (TEV) Framework, The Economics of Ecosystems and Biodiversity (TEEB) should be promoted among G20 countries to further this cause.

- Due to a lack of monitoring programs on Integrated Fire Management and limited socioeconomic data, it is difficult to develop comprehensive forest-livelihoods studies. To address this, G20 member states can collaborate to create more robust research studies that shed light on the risks and factors contributing to successful IFM implementation. By developing fire science research programs focusing on post-fire restoration techniques, G20 countries can better advance and monitor the progress and success of IFM, particularly in restoring areas affected by forest fires.

- Acknowledgement and promotion of research regarding fire-dependent historical landscapes in understanding the historical role of fire at the sub-national level. Such research can provide key insights on how human activity can help restore landscapes to sustainable and safe levels of fire activity. Research indicates that traditional approaches to fire management are cost-effective in comparison to modern fire suppression and post-disaster recovery. Targeting historical landscape restoration through traditional fire use must be integrated in international efforts for forest restoration as part of the UN Decade on Ecosystem Restoration.
- Recommend to international organizations the need for dedicated funding for collaborative projects aimed at fire disaster reduction, in particular in social and economic sciences as disasters happen because of human presence, poor development planning, failures of adaptation, and lack of risk management measures. Dedicated IFM funding should be directed towards countries and/or communities that need it the most.

4.5 Technologies for Restoration of Post-Fire Affected Areas

Digital technology solutions with remote capabilities have been used extensively in environmentally sensitive industries such as mining or oil and gas, however, are increasingly being used to keep forests and biodiversity safe from fires. Over time several technologies have been put to use to predict and minimize the spread of fires across the globe.G20 countries can offer such opportunities by facilitating technology sharing, transfer and providing support in capacity development. This shall also include the provisioning of funding support to help developing countries acquire the technology that would suit their requirement based on specific geographic conditions. Using proper technology will help the developing countries reduce tree cover loss from forest fires and further minimize socioeconomic and biodiversity loss. G20 collaboration should therefore look to increase knowledge on existing technological advances and promote the transfer of technologies for reducing forest-fire risk and aiding post-fire recovery processes, including:

- Technologies such as AI have tremendous capability for forest fire forecasts, while IoT can give real-time information about the situation in the forest and hence the likelihood of fires.
- Virtual reality to provide safe training for smoke-jumpers or wildland firefighters who may be required to respond in isolated places to battle wildfires.
- Drones have the potential for early detection, emergency response, and restoration after a fire. Drones fitted with specialized infrared cameras are used to track the growth of potentially dangerous flames, and satellites, and custom algorithms are utilized to locate them. Furthermore, drones have the capacity to create maps overnight that may be used by emergency personnel first thing in the morning. This allows aircraft to perform other crucial tasks.
- Sharing of reseeding technologies used in G20 member countries
- Advanced robotic technology can replace human intervention in wildfires and reduce the loss of lives from wildfires.

4.6 Gandhinagar Information Platform

In order to bring forward the implementation of various initiatives and targets on restoration of degraded land, India's G20 Presidency has proposed the Gandhinagar Implementation Roadmap (GIR) enabled by the Gandhinagar Information Platform (GIP) to collaborate on restoration action on the identified landscapes of forest fire and mining affected areas. Countries may choose to, on a voluntary basis, adapt the roadmap to ensure globally aligned actions on restoration of forest fire degraded lands.

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