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Forest Fires in Pakistan: Trends, Causes, Impacts, and Mitigation Strategies - A Review and Gap Analysis

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Abstract

In Pakistan, forest fires are a major environmental problem that threatens biodiversity, human settlements, and the climate. This in-depth review brings together the most recent research on forest fire patterns, their causes, their effects on the environment and society. It suggests the ways to prevent and reduce their frequency in different ecological zones of Pakistan. By carefully looking at recent literature, this study finds important gaps in research and propose ways where future research take direction. There is not much research on forest fires forecasting system in Pakistan over the prolonged period of time, which shows how important it is to conduct a full investigation. The review looks at patterns, technological solutions, and management strategies related to forest fires. Important findings show that the increasing number and severity of wildfires, which are caused by climate change, social and economic factors, and people's carelessness, have become a major issue. The rise in global temperatures and changes in rainfall patterns make things drier. At the same time, dangerous human actions like throwing away flammable materials and burning crops in unsafe ways make wildfires even more dangerous. This study gives policymakers, practitioners, and forest managers essential information so that they can make strategies for managing forest fires in Pakistan.

Keywords: Climate Change, Mitigation Strategies, Environmental Impacts, Wildfire Management.

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1. Introduction

Forest fires are now one of the biggest environmental problems in the world. In Pakistan, fires are becoming more common in its many different forest ecosystems. Forest fires and cropland fires, have a big effect on the ecosystem and are a big threat to human life (Shahzad et al., 2024). The country's forests cover only about 5.2% of the total land area, but they are particularly important for protecting biodiversity, controlling the climate, and keeping the economy stable. Dry temperate conifer forests had the most potential for storing carbon (52.67%) in Pakistan, followed by moist temperate mixed forests and sub-tropical broad-leaved forests. Ali et al. (2023) reported that abiotic factors are especially important for figuring out how much carbon is stored in forest ecosystems at different elevations. Forests play a crucial role in capturing carbon, which makes it even more important to protect them from fire, especially when it comes to fighting climate change.

There are many factors that are connected to the increase in the number and severity of forest fires in Pakistan. As Zhang (2025) points out, forest fires are a big threat to ecosystems, society, and the climate system. They are caused by climate change, human activities, and natural factors. To come up with good management plans, you need to understand how these complex interactions work. New technologies have made it possible to predict and manage fires in new ways. Extreme events like forest fires are becoming more common because of the growing effects of climate change and human activity on the environment. As a result, predicting forest fires has become a major area of research, where accurate forecasting technologies are needed to reduce environmental and economic damage caused by forest fires, and protect people and property (Liu et al., 2025).

The goal of this review is to give a detailed insights at forest fire research in Pakistan by looking at current trends, figuring out what causes them, measuring their effects, judging their effectiveness, and pointing out important research gaps that need to be filled in the future.

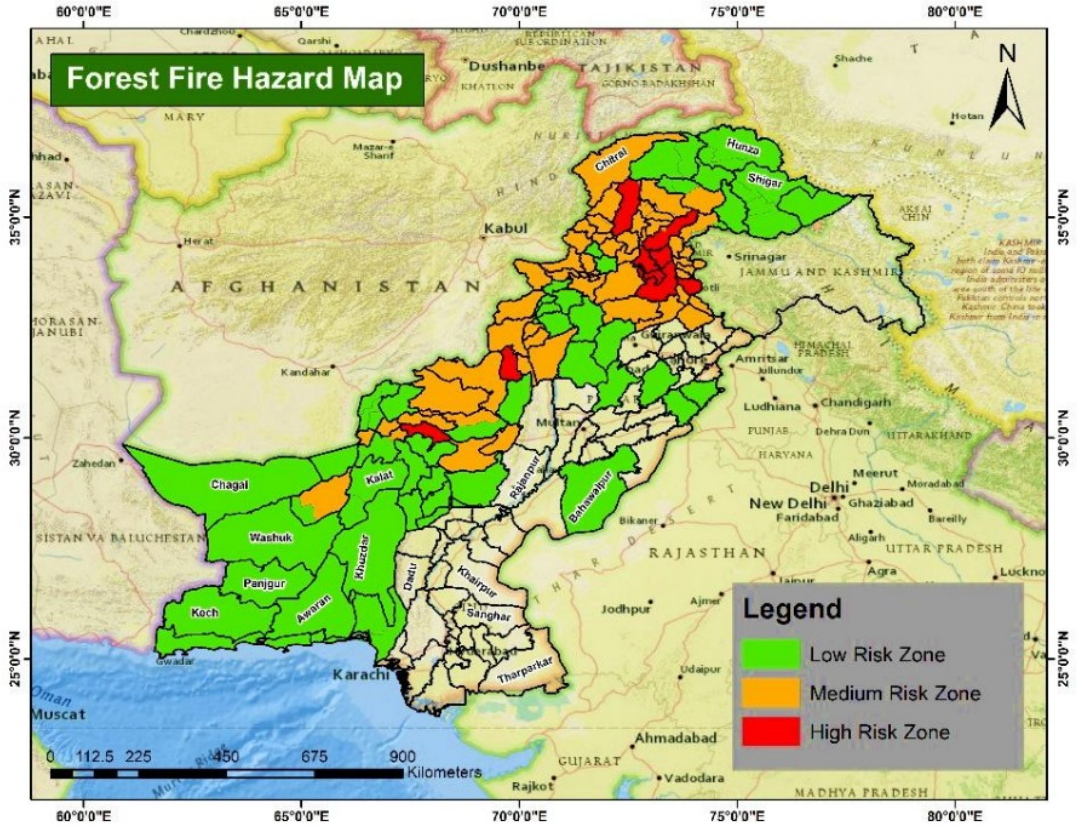

Figure 2. Forest Fire Hazard Map of Pakistan, Source; National Disaster Management Authority of Pakistan (NDMA)

2. Literature Review Methodology

This systematic review follows standard procedures for a thorough review of the literature. The search strategy included a number of academic databases, such as Web of Science, Scopus, Google Scholar, and journals that focus on forestry. "Forest fires Pakistan," "wildfire management," "vegetation fires," "fire prediction," and other related terms were some of the keywords.

The review looks at studies published particularly between 2015 and 2025, with a focus on those done in Pakistani forest ecosystems. The selection criteria included peer-reviewed articles, conference proceedings, and technical reports that looked at forest fires, how to predict them, how to assess their effects, and how to manage them in a way that suited for Pakistan.

3. Current Trends in Forest Fire Occurrence in Pakistan

3.1 Temporal and Spatial Patterns

Shahzad et al. (2024) used machine learning algorithms and data from different sources, including the MODIS Global Fire Atlas dataset, topography and climate data, and different types of vegetation data collected between 2001 and 2022, to show that there are clear patterns in when fires occur in Pakistan. The results indicate that the seasons are changing, and there are frequent fires when it is dry season. The proposed maps that were developed during the study shows the risk of forest fires in Pakistan, by identifying the areas where the forest fire risks are high, moderate, and low. Instead of looking at past fire detections, this study focused on predicting risks (Shahzad et al., 2024). The risk maps give valuable information for future planning related to utilization of resources and ways to prevent frequent forest fires.

The chances of fires occurrence are quite different at various places of Pakistan. Over time, the areas of forest have decreased. A lot of terrible things have happened to the environment because of rapid urbanisation and deforestation. For example, habitats conditions have gotten worse (Hassan et al., 2016). Land-use practices have

change over the time, which has made fires occurrence differently and made areas near cities more vulnerable. The study by Warda Rafaqat et al. (2022) used machine learning, specifically Random Forest (RF), to look at wildfires in Pakistan from 2000 to 2020. This model was more accurate than others and had high AUC scores. Elevation, population density, and specific humidity were the main things that caused the changes related to fire occurrence. Their value changed from place to place, season to season, and every five years. Climate-related factors had the biggest effect on the risk of wildfires (55.2%). Fuel factors like vegetation and socioeconomic data (31.8%) and topography (12.8%) came next. In the winter and spring, elevation was more important, but in the summer and autumn, population and humidity were more important. This study made maps of places that are likely to catch fire, and it came up with different fire management plans for each area based on these different factors. Because of climate and human factors, wildfires are becoming more common in Pakistan. This made it clear that we need enhanced management strategies to stop fires from spreading.

Tariq et al. (2021) found that between 2005 and 2018, the amount of burned forest in Margalla Hills increased drastically from 1.4% to 21.9%. During peak fire seasons, about 7% of the forest cover burned in less than a month. The density of the forest had a big effect on how fast and how long the fire spread. Dense forests made crown fires more intense. The weather, such as the highest temperature and wind speed, had a big effect on how fires will behave, while topography had minimal impact. Because of low road density, it was harder to stop fires, which made them bigger and last longer in remote areas. Fire susceptibility mapping showed that 22% of forests are in areas with a high to very high risk of fire. This shows that forest management and infrastructure need to be improved.

3.2 Fire Frequency and Intensity Trends

Recent research shows that fires are becoming more common in some areas of Pakistan. According to Daraz et al. (2024), climate change, social and economic conditions, and population behaviour when it comes to preventive measures, are making wildfires more common and more dangerous in Pakistan's peri-urban and rural areas. People are less careful about wildfires. These trends are very alarming. Recent data shows that forest fires are happening more often all over the world. This is probably because of climate change. The effect of forest fires are devastating, these fires have damaged economies. According to Ahn et al. (2024), the effects of climate change which make the risk of forest fires in populated areas even higher. This indicates the forest fire management importance.

The study by Tariq et al. (2021) of forest fires in the Margalla Hills, Islamabad, Pakistan, shows that socio-economic factors, especially how many people live there and how close it is to cities, are very strongly linked to the occurrence of forest fires. The kind of forest and the height of the land are also important parts of the environment which make the area susceptible or prone to fires. The study found that the risk of a fire occurrence rise from the 1990s to the 2000s, peaked in the 2000s, and then fell slightly in the 2010s. Both the Maxent and Random Forest (RF) models showed that fires were more likely to happen in places where human activities are prevalent. The RF model outperformed the Maxent model in predictive accuracy. However, it often overestimated that there was a higher chance of a fire occurrence than there really was. Over time, important environmental factors like topographic wetness and precipitation had less of an effect, but population density stayed the most important predictor across all decades. The results show the importance of urbanisation and people’s behaviour in face of the risk of fire. This study also emphasized about importance of specific prevention and management plans around urban-forest interfaces to lower the number of fires in ecologically sensitive region.

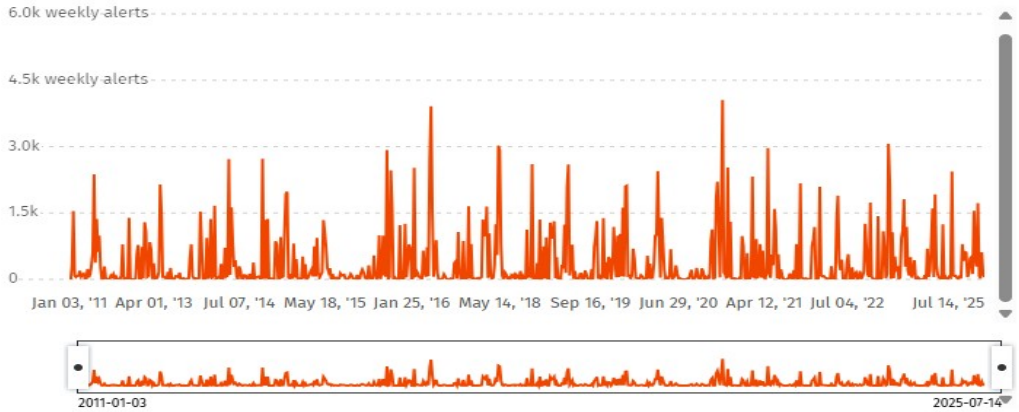

Figure 2. Historical Fire Alerts in Pakistan, between 3rd of January 2011 and 14th of July 2025 Pakistan experienced a total of 257,121 VIIRS (Visible Infrared imaging Radiometer Suite) fire alerts, Source: Global Forest Watch

3.3 Detection and Monitoring Advances

Advancements in fire detection technology have significantly improved monitoring capabilities. Fire significantly influences both the physical and social systems of our planet, highlighting the necessity for precise and current information regarding fire-affected areas. This understanding is essential for comprehending the underlying factors of fire activity and its implications for biogeochemical cycles, climate, air quality, and management strategies. Earth observation satellites play a crucial role by offering timely regional and global insights into fire occurrences, as noted by Chuvieco et al. (2019). Cutting-edge machine learning techniques have demonstrated encouraging outcomes. Prediction models for vegetation fires have shown accuracies between 78.7% and 87.5% for forest fires, 70.4% to 84.0% for cropland fires, and 66.6% to 83.1% for other types of vegetation. Notably, the random forest model achieved the highest accuracy rate of 87.5% for forest fires and recorded the highest AUC value of 93.4%, as reported by Shahzad et al. (2024).

Mehmood et al. (2024) looked at the Chilgoza Pine (*Pinus gerardiana*) forests in Balochistan and found that forest fires caused a lot of damage over 10,156.53 acres, killing a lot of livestock and destroying a lot of property. Land surface temperature (LST), elevation, wind speed (V), and slope are all important factors that affect when fires occur. LST was found to be the most important predictor in all of the models used. The Random Forest (RF) model did better than XGBoost and Logistic Regression at predicting fire susceptibility. It had a validation accuracy of 96.4% and an AUC of 99.1%, which meant it could effectively map high-risk areas and show geographic clusters that are likely to have severe fires. Correlation studies found that there was a moderate negative relationship between elevation and the number of fires and a moderate positive relationship between LST and wind speed. These results give useful information for focused fire management and suggest that RF-based predictive modelling is a strong tool for figuring out how likely a forest fire is to happen in this area, which is sensitive to the environment.

The study by Mohammad Nafees et al. (2024) analyses forest fire incidents in the Northern Mountain Range (NMR) of Khyber Pakhtunkhwa, Pakistan, with an emphasis on the Malakand Division. Using MaxEnt modelling based on 19 bioclimatic variables, the study identifies precipitation during the warmest quarter as the most significant factor influencing wildfire risk, especially highlighting district Swat and adjacent areas as hotspots for forest fires. The analysis reveals that human activities, including intentional and accidental ignitions by locals, combined with climatic factors like dry conditions and rising temperatures, exacerbate fire frequency and intensity. Legislative and governance challenges lie in outdated laws, poor coordination among federal and provincial bodies, insufficient budgets (with fire prevention funding averaging only 3.05% of divisional forest budgets and 0% in Swat), and limited firefighting infrastructure and training. The authors emphasize that local communities are marginalized from forest management, which reduces public engagement and effective fire prevention. To mitigate wildfire impacts, the study recommends updating forest policies, allocating explicit budgets for fire emergencies, enhancing local participation in fire management, improving public awareness programs, and establishing better firefighting infrastructure and communication networks to protect the region's vulnerable forest ecosystems and dependent populations.

The study by Rafaqat et al. (2022) evaluates wildfire occurrences in Pakistan from 2001 to 2020 using global gridded soil properties derived from remotely sensed data. Results show that wildfire frequency (fire count, FC) has a generally negative temporal correlation with soil properties like bulk density, texture, and taxonomy, with stronger correlations in Northern Pakistan than in the south. Combining soil properties with elevation significantly improves the prediction of wildfire occurrences at monthly scales compared to using elevation alone. Soil texture and bulk density are especially influential in Northern Pakistan, where soil properties explain wildfire variations better than elevation. These findings highlight the potential of machine-learned soil properties as valuable indicators for wildfire monitoring and risk estimation in regions with diverse topography and climate.

4. Causes of Forest Fires in Pakistan

4.1 Anthropogenic Factors

In Pakistan, people are one of the main causes of forest fires. Due to global warming the overall temperature is increasing at different areas. At the same time, fire ignited by timber mafia, carelessness of the tourists like, throwing away flammable things in forest, which is dense and dried over a prolonged period, and burning crops in a way that is not safe, make the risk of wildfires even higher. Daraz et al. (2024) say that these problems are most obvious in Pakistan, where a lot of people are poor, there are few resources, and few people have an education, which leads to risky behaviours. Farming methods are a big reason fires occurs. Word co-occurrence networks showed that there is a strong link between fires and changes in land use. This shows change in fires frequency and intensity is related to change of ecosystems and farming practices work. Jurez-Orozco et al. (2017) reported that we need to think about socioeconomic factors, deforestation, and global climate change to better understand why forest fires occurs. The situation is worse because of problems with governance and enforcing rules. The problem gets worse when there is weak governance and bad policy enforcement. According to Daraz et al. (2024), Structural Equation Modelling shows how important local governance, policy enforcement, and community engagement are for making things better.

Figure 3. Forest Fire at Kallar Kahar Scrub Forest, Salt Range of Pakistan, Source: Photo taken by the author.

Mannan et al. (2019) looked at Pakistan's subtropical and moist temperate forests and found that forest fires and the CO2 emissions that is associated with the forest fires, have been getting worse over the past 20 years. In 2009, when conditions were very dry, the average annual CO2 emissions reached 7280 Gg and peaked at 22799 Gg. Mapping the risk of forest fires showed that more than 56% of the area is in zones with a high to extreme risk of fire, primarily driven by anthropogenic factors such as proximity to settlements and roads, which accounted for 85% of fires, while only 2.6% were caused by lightning. The Chirpine (*Pinus roxburghii*) forest is more susceptible to forest fire. The needles dry out in the summer, which are the main component of forest fire act as dry litter. The study focused on the urgent need for enhance fire management strategies to mitigate growing fire threat and carbon emission in the regions.

4.2 Climate-Related Factors

The phenomenon of climate change has become a crucial factor contributing to the heightened risk of fires. Climate change is contributing to weather conditions that favour wildfires in forests. Between 2001 and 2023, there has been a notable rise in forest fire emissions in extratropical regions, which are associated with climate change, counterbalancing the decrease in emissions observed in tropical areas, as noted by Jones et al. (2023).

Temperature and precipitation patterns are essential factors. The phenomenon of climate warming, along with its cumulative effects, is likely to result in an increase in both the frequency and severity of fires, as noted by Wang et al. (2021). The interplay of climatic factors with local topography and vegetation conditions results in a range of fire risk scenarios throughout the diverse landscapes of Pakistan. Dry conditions greatly affect the likelihood of fire occurrence. The rise in forest fires attributed to climate change has resulted in heightened PM2.5 emissions. In regions experiencing elevated ambient temperatures, these changes in meteorological conditions have further exacerbated the occurrence of forest fires, as noted by Romanov et al. (2022).

Naseer et al. (2025) used a Maximum Entropy Model to look at the chances of forest fires in Khyber Pakhtunkhwa, Pakistan, and found that it was exactly accurate, with an AUC of 0.833. Wind (34.2%), rain (33.7%), and temperature (18.9%) were the three most important things that caused fires. The study found that 53% of the area is at elevated risk for fires, especially places like Abbottabad, Mansehra, and Battagram, which have a lot of trees that catch fire easily. These results indicated the importance of targeted fire management and prevention plans in areas that are at risk in order to lessen the effects of forest fires.

4.3 Natural Factors

Natural ignition sources, such as lightning, play a role in fire occurrence, albeit to a lesser degree compared to human influences. Forest fires can arise from multiple sources, including human actions like agricultural burning, campfires, or improperly discarded cigarettes, as well as natural occurrences such as lightning, according to Jodhani et al. (2024). Topographic features play a significant role in shaping fire behaviour and its spread. Investigations were carried out by utilising data from fires occurring between 2017 and 2022, have pinpointed 11 variables, including elevation, slope, aspect, wind speed, population density, and road network, to develop models that integrate both physical and human geographical characteristics, as noted by Konurhan et al. (2025). The characteristics of vegetation influence the susceptibility to fire. The findings demonstrated significant variations in moisture content ratios across various combustibles, suggesting elevated fire risks. Simulations indicated that fire-spread speed, fireline intensity, and flame length are correlated with and increase alongside wind speed and slope, as noted by Shi et al. (2023).

5. Environmental and Ecological Impacts

5.1 Biodiversity and Ecosystem Effects

Forest fires have a big effect on the biodiversity in Pakistan. Jodhani et al. (2024) say that forest fires have serious effects, such as loss of biodiversity, damage to ecosystems, and threats to human communities. Because the country's forest cover is already low, these losses are especially detrimental for conservation efforts. Peruzzi et al. (2023) reported that forest fires are a major cause of desertification, which hurts both agricultural and forest ecosystems. Desertification is a big problem for Pakistan's long-term environmental stability and agricultural productivity. Ecosystem services are greatly affected by fire events. Forest fires destroy forests and areas with trees, causing damage, economic losses, and long-lasting effects on the services that forest ecosystems provide. Posavec et al. (2023) reported that there are different ways to lower the number of forest fires. For example, by investing in fire prevention programs and strictly following adaptive sustainable forest management practices. In 2020, Pakistan recorded 1.37 million hectares of natural forest, which accounted for 1.7% of its total land area. In 2024, there was a loss of 451 hectares of natural forest, which corresponds to 68.2 kilotonnes of CO_2 emissions (Global Forest Watch). The study by Hussain et al. (2016) evaluates the impact of forest fires on vegetation in the sub-tropical Chir pine forest of district Mansehra, Pakistan, revealing that fires negatively affect plant species diversity and Chir pine regeneration and growth. Tree and shrub diversity and evenness were significantly higher in unburned areas, while herbaceous species diversity was greater in burned sites. Chir pine regeneration (saplings and poles) and growth increments in diameter and height were notably higher in unburned areas, indicating forest fires reduce forest productivity and biodiversity. Overall, forest fires cause considerable ecological damage to these pine forests.

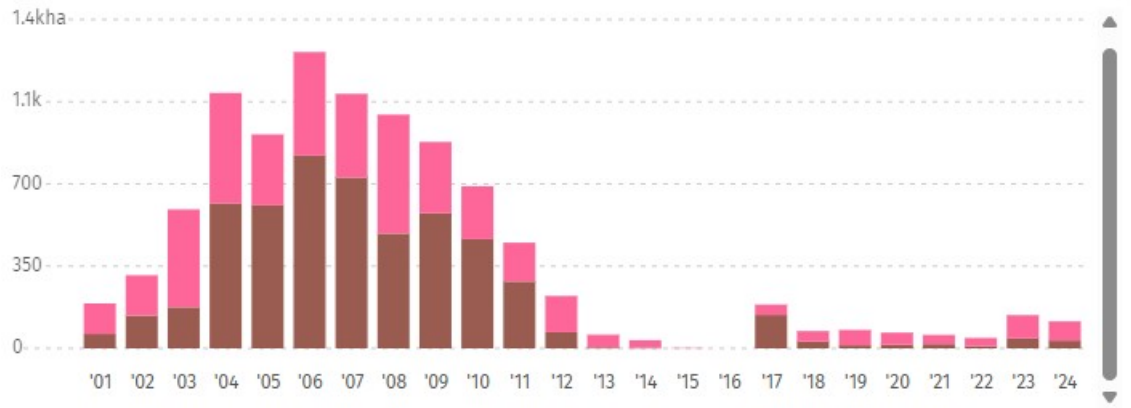

Figure 4. Tree Cover Loss Due to Fires in Pakistan, from 2001 to 2024, Pakistan lost 5.35kha of tree cover from fires (brown) and 4.19 kha from all other drivers of loss (pink). The year with the most tree cover loss due to fires during this period was 2006 with 821 ha lost of fires – 65% of all tree cover loss for that year, Source: Global Forest Watch

5.2 Air Quality and Atmospheric Impacts

Forest fires play a major role in the degradation of air quality. It significantly contributes to air pollution and can lead to severe air quality problems. The cessation of such fires could markedly enhance regional air quality, potentially decreasing population exposure to fine particulate matter (PM2.5) concentrations by 7% and surface ozone concentrations by 5%, as noted by Reddington et al. (2021). Emissions of particulate matter present significant health hazards. According to the Copernicus Atmosphere Monitoring Service, PM2.5 emissions reached 8 megatons in 2021, representing a 78% increase over the average level. This surge in PM2.5 emissions coincided with decreases in air temperature and surface solar radiation, attributed to aerosol saturation with suspended particles, as noted by Romanov et al. (2022). The emissions of carbon resulting from fires play a significant role in the ongoing issue of climate change. This resulted in a 60% rise in carbon emissions from forest fires across global forest ecoregions, as noted by Jones et al. (2023), underscoring the importance of regional fire management initiatives on a global scale.

5.3 Soil and Water Resource Impacts

Fire events have a profound impact on soil properties and water resources. Additional investigations are necessary to explore the causes, intensity, and recurrence of fires, as these factors influence the impact of fire on soil and biota (fire severity). Moreover, the spatiotemporal patterns of forest fires warrant further examination to formulate effective strategies for agricultural production and to anticipate successional pathways following fires, as noted by Jurez-Orozco et al. (2017). The degradation of watersheds poses a considerable issue. Fire-induced erosion and sedimentation have significant implications for water quality and availability, which is especially critical in the context of Pakistan's water-stressed environment.

6. Socio-Economic Impacts

6.1 Human Health Effects

Forest fires present both direct and indirect health risks to the populations in Pakistan. Exposure to PM2.5 could lead to significant public health improvements in various regions, potentially preventing 59,000 premature deaths each year. Analysis indicates that PM2.5 emissions from fires have a disproportionate effect on lower-income communities, as noted by Reddington et al. (2021). Marginalised groups experience unequal consequences. Reddington et al. (2021) illustrate the equity implications of fire management policies in key regions where elevated poverty levels align with significant exposure to PM2.5 from fires.

6.2 Economic Losses

Forest fires generate substantial economic costs. Forest fires are a type of disaster with both human and natural factors that can cause significant damage not only to ecological environments but also to the economy and society in many irreversible ways, with systematic studies on economic losses caused by forest fires lacking in

recent years, Han et al. (2022). Forest fires have led to several economic costs, mainly affecting the incomes of different investors in the forest sector, with the overall cost determined by direct and indirect expenditures as well as the price of fire control and preventative methods, Kalogiannidis et al. (2023). Agricultural impacts represent significant economic losses. Wildfires destroy agricultural land and greatly impact the rural economy and community, Kalogiannidis et al. (2023), particularly affecting rural livelihoods in Pakistan's agricultural regions.

6.3 Social Displacement and Community Impacts

Fire events have the potential to cause population displacement. Chi-square tests revealed a significant correlation between wildfires and migration patterns, highlighting the socio-economic instability triggered by these occurrences, Daraz et al. (2024). The variation in community resilience is notable across diverse regions and socio-economic demographics. Multiple regression analysis indicated that elevated poverty levels significantly heightened negligence, while increased education and better access to resources diminished it. Structural Equation Modelling underscored the essential roles of local governance, policy enforcement, and community engagement in alleviating wildfires, as noted by Daraz et al. (2024).

7. Current Mitigation and Management Strategies

7.1 Technological Approaches

Innovative detection and prediction systems are currently under development and implementation. Frameworks for predicting forest fires that incorporate wireless sensor networks, data analysis, and machine learning have been developed, with SVM models achieving 86% accuracy in classifying forest-fire risk levels using temperature, humidity, wind speed, and rainfall data, according to Zhang et al. (2024). For effective monitoring, remote sensing technologies are very important. Integrated systems that use the Internet of Things (IoT) to find and put out forest fires early use a variety of sensors, including thermal imaging, gas, and heat sensors. Jayakody et al. (2025) reported that these systems use IoT technology for real-time monitoring and communication. They also use image processing techniques and machine learning algorithms to find fires, predict how they will spread, and evaluate the state of the environment. The results of using artificial intelligence show that it has a lot of potential. Combining Crow Search Optimisation with fractional calculus creates a strong optimisation framework that makes AI models more accurate and efficient. According to Moeed et al. (2024), experimental analysis shows that the proposed method is better than other traditional ones, with an accuracy of 99.32% and an error rate of 0.12%.

7.2 Traditional and Ecological Methods

Keeping track of fuel is a key way to keep fires from starting. These inter-connections between fuel management and the building of green fire barriers can prevent the damage from forest fires. Each ecosystem has its own unique ecological traits. The goal should be of thinning fuel to make a fire less intense and dangerous. Green fire barriers, on the other hand, are made to stop fires from starting in the first place. Both methods show that sustainability is important and that they could help the environment and ecological balance in the long run. Controlled fire regimes and prescribed burning can be very good for the environment. Fire regimes show how plants react to wildfires. You can change the risk of fires and how people use the forest resources by changing the plants and treating the fuels sustainably, Moeed et al. (2024).

7.3 Community-Based Approaches

Incorporating local knowledge enhances the effectiveness of management practices. The exploration of public engagement as a means to integrate community-based knowledge, experiences, and practices into disaster risk reduction plans underscores the necessity of enhancing social governance at the local level, Santiago-Gómez et al. (2023). Indigenous knowledge systems offer significant perspectives. Indigenous communities face the greatest impact from wildfires and hold essential knowledge regarding forest management that should be incorporated into modern strategies before it is lost. Collaborating with these communities and making concerted efforts to address climate change provides a promising avenue for reducing the devastation caused by future wildfires, Huq et al. (2024).

The study by Saleem et al. (2024) assessed forest fire vulnerability in the Chir Pine forests of Pallandri, Azad Jammu and Kashmir, revealing high susceptibility to wildfires during May to July due to dense forest stands, accumulation of dry pine needles, and human activities. North- and east-facing slopes were identified as particularly vulnerable because of higher solar exposure and forest density. Smaller tree diameters and closely spaced trees contributed to fire spread through fuel ladders, while NDVI and land cover type were the most influential variables in predicting fire-prone zones. The findings emphasize the urgent need for integrated fire management and community awareness to mitigate ecological and economic losses in the region.

Figure 5. Forest Fire at Sub-tropical Chirpine Forest, Foothills of Himalayas, Pakistan, Source: Photo taken by the author.

7.4 Policy and Institutional Frameworks

Governance structures need to be improved. Getting all stakeholders on board and confident in the action plans for sustainable development and forest conservation is key to success. Menon et al. (2022) noted, this support for environmental management can be achieved by showing stakeholders that the proposed actions will directly or indirectly help them. It is important to improve coordination between sectors. According to Posavec et al. (2023), the study shows that cross-sectoral forest policy measures need to be put in place. This means that state forest companies need to put more money into restoring biological forests in the future. Working together on a global scale opens up a lot of possibilities. Governments must take the initiative to set up and improve bilateral and/or multilateral cooperation and coordination. Kalogiannidis et al. (2023) reported that this includes sharing important money, technology, and training to lessen the effects of forest fires.

8. Research Gaps and Future Directions

8.1 Data and Monitoring Gaps

According to Shahzad et al. (2024), there is currently a dearth of research on the long-term forecast of vegetation fires in Pakistan, which is a crucial knowledge gap that has to be addressed right now. To study fire patterns and predict future trends, we need large datasets that cover extended periods of time. There is sense of unsurety about the capability of the monitoring system in Pakistan. There are big differences in capacity between regions, which shows that more research needs to be done in areas that are not well-represented. Bao et al. (2024) reported that it is especially important to improve how artificial intelligence algorithms are used, such as machine learning, deep learning, and ensemble learning.

8.2 Mechanistic Understanding

It is important to look closely at the complicated connections between climate, human activities, and the occurrence of fire. Shahzad et al. (2024) reported that conventional analysis does not fully explain how each factor affects the occurrence of forest fires. This shows that more advanced analytical methods are needed. Fire behaviour modelling needs improvements with time. More research is needed to find out what causes fires, how devastating these fires are, and how often they can occur. Jurez-Orozco et al. (2017) also reported that the spatiotemporal patterns of forest fires need to be looked at more closely in order to come up with good farming plans and to predict what will happen after fires.

8.3 Technology Development Needs

Real-time monitoring systems need to be expanded. According to Liu et al. (2025), that some of the current challenges and future directions include looking into how to manage wildfire risk data and multimodal deep learning, how to make models easier to understand and explainable, how to combine physics-informed models with machine learning, and how to build digital twin technology for real-time wildfire simulation and fire scenario analysis. Early warning systems need to be better. Supriya et al. (2023) noted, that the results from the proposed frameworks can be useful for making early warning systems for forest fires, but there are still problems with making them work together and making them bigger.

8.4 Socio-Economic Research Priorities

More thorough methods are needed for vulnerability assessments. Daraz et al. (2024) noted, that research gives us important information about the social and economic factors that affect wildfires in Pakistan and helps us come up with specific ways to stop them. But more in-depth studies of the population are needed. We need to improve the way we assess the economic value of ecosystem services that are affected by fire. According to Han et al. (2022), there haven't been enough systematic studies in recent years on the economic losses caused by forest fires, especially when it comes to looking at these losses over time and space.

8.5 Climate Change Adaptation

Future climate scenarios necessitate enhanced modelling precision. The significant influence of climate change on wildfire prediction requires the integration of comprehensive climate data into predictive models, as highlighted by Bao et al. (2024), especially concerning the varied climatic zones of Pakistan. It is essential to develop adaptation strategies tailored to various forest types. It is essential for forest management practices to adopt climate-adaptable silviculture measures to safeguard forests and forest land, as noted by Posavec et al. (2023). However, there is a scarcity of specific recommendations tailored to the forest types found in Pakistan.

8.6 Management and Policy Research

Comprehensive management strategies necessitate assessment. Linear regression indicated that wildfires have a significant effect on regional climate indicators, highlighting the necessity for integrated management strategies, as noted by Daraz et al. (2024), yet comprehensive assessment frameworks remain insufficient. There is a pressing need for the standardisation of policy effectiveness assessments. Effective management and mitigation strategies are essential, with knowledge management systems designed to enhance decision-making, promote knowledge exchange, improve coordination among stakeholders, and broaden access to pertinent information, Unik et al. (2024).

9. Recommendations for Future Research

9.1 Immediate Research Priorities

Development of a Comprehensive Fire Database: Create a standardised, centralised repository for fire incidents, their causes, and impacts throughout the forest regions of Pakistan.

Climate-Fire interaction Studies: Investigate the intricate relationships between climate variations and fire dynamics across various forest types in Pakistan.

Socio-Economic Impact Assessment: Formulate detailed methodologies for evaluating the complete economic and social implications of forest fires.

9.2 Medium-Term Research Goals

Technology Integration Platforms: Create cohesive systems that merge satellite monitoring, ground sensors, and AI prediction models to enhance fire management strategies.

Community Resilience Studies: Examine elements that strengthen community resilience against fire impacts and formulate evidence-based intervention strategies.

Investigation into Ecosystem Recovery: Analyse patterns of ecosystem recovery following fire events and formulate restoration protocols tailored to various forest types.

9.3 Long-Term Strategic Research

Climate Adaptation Strategies: Formulate forest management techniques tailored to prospective climate scenarios that align with Pakistan's unique environmental context.

Regional Cooperation Frameworks: Develop collaborative research initiatives for fire management among South Asian nations encountering comparable challenges.

Integrate fire management with comprehensive sustainable forest management and climate mitigation goals.

10. Conclusions

According to this thorough analysis, forest fires in Pakistan provide a complicated, multidimensional problem that calls for integrated measures that incorporate traditional knowledge, technical innovation, and adaptive management techniques. Studies provide important insights for the scientific community and decision-makers, enhancing comprehension of these changes and aiding in wildfire mitigation efforts. The analysis reveals notable advancements in fire detection and prediction technologies, highlighting the potential of machine learning methodologies. Nonetheless, significant gaps in knowledge persist, especially regarding long-term monitoring, the mechanistic understanding of fire-climate-society interactions, and the creation of context-specific management strategies.

Key findings show that the main causes of fires in Pakistan are human factors, specifically socioeconomic circumstances and agricultural practices. The impacts of climate change are becoming more significant, leading to conditions that are more conducive to fires and intensifying pre-existing vulnerabilities. Successful mitigation necessitates collaborative actions at various levels, encompassing advancements in technology, active community participation, and necessary policy changes. Government needs to actively set up and improve cooperation and coordination between different regions. Process for common people and forestry professionals should be easier to learn about new, technology, and training to lessen the effects of forest fires. Future research needs to fill in the gaps in what we know and come up with useful ways to manage fires that work with Pakistan's unique social and economic situation and environment. The best way to achieve long-term fire management is to combine scientific research with traditional knowledge and community-driven management strategies. This review lays the groundwork for making informed policy decisions and points out important areas where research funding can help Pakistan improve its ability to prevent, manage, and recover from forest fires.

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