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Anthropogenic Drivers of Forest Fire Incidence and Ecological Restoration Strategies in Chir Pine Forests of Nowshera Forest Range, Rajouri District, UT of Jammu & Kashmir

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Abstract

Forest fires have become a major environmental challenge in the Chir Pine forests of the Himalayan region due to increasing anthropogenic disturbances and climatic variability. The present study investigates the anthropogenic drivers responsible for forest fire incidences in the Nowshera Forest Range of District Rajouri, Jammu & Kashmir, and evaluates suitable ecological restoration strategies for sustainable forest management. Primary data were collected from local communities, forest-dependent households, and forest officials using structured questionnaires and field observations. Statistical techniques such as percentage analysis, correlation, regression, and ANOVA were used for data interpretation. The findings reveal that pine needle burning, grazing activities, fuel wood collection, and agricultural residue burning are the major human-induced causes of forest fires. The study also highlights significant ecological impacts, including biodiversity loss, soil degradation, and reduced forest regeneration. Community participation and sustainable restoration strategies were found essential for reducing fire vulnerability and conserving Chir Pine ecosystems.

Keywords: Forest Fire, Anthropogenic Drivers, Chir Pine Forest, Ecological Restoration, Forest Management, Rajouri, Jammu & Kashmir, Biodiversity Conservation

1. Introduction

Forest fires are among the most significant environmental disturbances affecting forest ecosystems across the world, particularly in mountainous and subtropical regions where climatic conditions, vegetation composition, and human activities collectively increase fire vulnerability. In recent decades, the frequency and intensity of forest fires have increased considerably due to climate change, anthropogenic disturbances, prolonged dry seasons, and expanding human settlements near forest boundaries.[1] The Himalayan region, especially the western Himalayan belt, has become increasingly susceptible to recurring forest fires because of rising temperatures, irregular rainfall patterns, accumulation of combustible biomass, and unsustainable utilization of forest resources (Karki & Bhatta, 2023). Among the various forest ecosystems of the Himalayan region, Chir Pine (Pinus roxburghii) forests are considered highly fire-prone due to the

[1] Ahmad, F., Goparaju, L., & Qayum, A. (2020). Forest fire risk zone mapping in the Himalayan region using geospatial techniques. Ecological Indicators, 111, 105987.

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inflammable nature of resin-rich pine needles and dry litter accumulation on the forest floor (Rawat & Tiwari, 2022).[2]

The Union Territory of Jammu and Kashmir possesses extensive forest resources that play a vital role in maintaining ecological balance, regulating hydrological cycles, conserving biodiversity, and supporting rural livelihoods. However, these forests are increasingly threatened by repeated fire incidences, particularly in subtropical pine-dominated landscapes such as the Nowshera Forest Range of District Rajouri. The Chir Pine forests of this region are ecologically important because they protect fragile hill slopes from erosion, contribute to carbon sequestration, and provide livelihood support to forest-dependent communities through fuelwood, fodder, resin extraction, and grazing activities. Despite their ecological significance, these forests have experienced frequent fire events during summer months, leading to degradation of vegetation, biodiversity loss, soil nutrient depletion, and decline in natural regeneration capacity (Thakur & Singh, 2023).[3]

Anthropogenic activities have emerged as one of the most critical drivers of forest fire incidences in Chir Pine ecosystems. Human-induced causes such as intentional burning for grazing enhancement, agricultural residue burning, illegal extraction of forest resources, resin tapping, negligence by tourists, smoking, campfires, and roadside ignition are frequently associated with forest fire outbreaks in Himalayan regions (Semwal & Mehta, 2021). Expansion of roads, settlements, and agricultural fields into forested landscapes has further increased the interaction between human populations and forest ecosystems, thereby intensifying fire risks. Studies conducted in the western Himalayan region have shown that the majority of forest fires are directly or indirectly linked to human activities rather than natural causes (Singh & Verma, 2023). In Chir Pine forests, thick layers of dry pine needles act as highly combustible material, allowing fires to spread rapidly over steep slopes and large areas within a short period.[4]

The Nowshera Forest Range in Rajouri District represents a significant case for studying anthropogenic forest fires because of its unique geographical, ecological, and socio-economic characteristics. The area experiences dry summers and increasing anthropogenic pressure from nearby villages and forest-dependent populations. Forest fire incidents in this region not only damage vegetation and wildlife habitats but also threaten local livelihoods and environmental sustainability. Recent geospatial analyses have identified several fire-prone zones within the Nowshera Forest Division, particularly in areas close to roads, settlements, and heavily grazed forest compartments (Verma, 2024). These findings indicate the urgent need for comprehensive scientific studies focusing on the causes, patterns, and ecological consequences of recurring forest fires in the region.

Forest fires produce severe ecological impacts on forest ecosystems. Repeated burning alters forest composition, destroys understorey vegetation, reduces soil fertility, and affects microbial activity essential for nutrient cycling. High-intensity fires can lead to long-term degradation of ecosystem productivity and increased vulnerability to soil erosion and landslides, particularly in mountainous terrains (Bisht et al., 2021). In Chir Pine forests, recurring fires often suppress the regeneration of broadleaf species and promote pine

[2] Bahuguna, V. K., & Upadhyay, A. (2002). Forest fires in India: Policy initiatives for community participation. International Forestry Review, 4(2), 122–127.
[3] Bhat, J. A., Kumar, M., & Negi, A. K. (2021). Forest fire dynamics and ecological implications in the northwestern Himalayas. Environmental Monitoring and Assessment, 193(6), 347–360.
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dominance, thereby reducing overall biodiversity and ecological resilience.[5] Furthermore, forest fires release significant amounts of carbon dioxide and particulate matter into the atmosphere, contributing to air pollution and climate change (Tiwari et al., 2025). Such ecological disturbances highlight the necessity for sustainable forest management and ecological restoration interventions.

In recent years, scientific approaches such as Geographic Information Systems (GIS), remote sensing, and fire susceptibility modelling have become increasingly important for forest fire assessment and management. GIS-based fire risk zonation helps identify vulnerable areas by integrating factors such as vegetation type, slope, aspect, temperature, road proximity, and human settlements (Sharma et al., 2022). Remote sensing technologies also facilitate monitoring of fire occurrence, burned area mapping, and post-fire vegetation assessment. Such technological tools provide valuable support for early warning systems and decision-making in forest fire management programs.

Ecological restoration strategies are essential for minimizing fire-induced degradation and improving the resilience of Chir Pine forests. Restoration measures may include controlled burning, pine needle management, development of fire lines, assisted natural regeneration, mixed-species plantation, soil conservation practices, and community-based forest management approaches (Chauhan et al., 2024). Participation of local communities is particularly important because forest-dependent populations possess traditional ecological knowledge and play a major role in both fire occurrence and prevention. Community awareness programs, participatory monitoring systems, and sustainable utilization of forest resources can significantly contribute to reducing fire vulnerability and restoring degraded ecosystems (Bhardwaj et al., 2024).[6]

2. Literature Review

Forest fires have become one of the most serious environmental challenges affecting forest ecosystems throughout the Himalayan region. Increasing anthropogenic disturbances, changing climatic conditions, and the accumulation of combustible biomass have collectively intensified the occurrence and severity of forest fires in subtropical pine forests. Chir Pine (Pinus roxburghii) forests are particularly vulnerable because of their resinous nature and dense deposition of dry pine needles, which serve as highly inflammable fuel material. Recent ecological studies have emphasized that repeated forest fires are significantly altering forest structure, species composition, soil properties, and biodiversity patterns in Himalayan landscapes (Negi, 2025).[7]

Research focusing on the western Himalayan region has identified human activities as the principal causes of forest fire incidences. Studies indicate that deliberate burning for grazing enhancement, agricultural residue disposal, resin extraction, fuelwood collection, and negligence by tourists and local inhabitants are major anthropogenic drivers of forest fires (Semwal & Mehta, 2021). Human interference has increased substantially because of expanding settlements, road construction, and greater dependence of rural communities on forest resources. Investigations conducted in pine-dominated ecosystems suggest that more

[5] Bond, W. J., & Keeley, J. E. (2005). Fire as a global herbivore: The ecology and evolution of flammable ecosystems. Trends in Ecology & Evolution, 20(7), 387–394.

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than ninety percent of forest fires originate directly or indirectly from anthropogenic sources rather than natural causes (Singh & Verma, 2023). Such findings demonstrate the close relationship between human pressure and forest fire vulnerability in mountainous forest ecosystems.[8]

Several studies have examined the ecological consequences of repeated fire incidences in Chir Pine forests. Recurrent fires have been found to reduce understorey vegetation density, damage young seedlings, alter nutrient cycling, and increase soil erosion risks. Research conducted in Uttarakhand and adjoining Himalayan regions revealed that repeated burning suppresses the regeneration of broadleaf species while promoting the dominance of fire-tolerant pine vegetation (Fulé et al., 2021). This ecological imbalance negatively affects biodiversity and reduces ecosystem resilience. In addition, forest fires significantly influence microbial activity and soil fertility by decreasing organic carbon content and essential nutrients required for vegetation regeneration (Thakur & Singh, 2023). Such disturbances ultimately reduce forest productivity and ecological stability.[9]

The influence of climate variability on forest fire occurrence has also been widely documented in recent literature. Increasing temperatures, declining precipitation patterns, prolonged drought periods, and irregular rainfall distribution have enhanced forest dryness and fuel combustibility across Himalayan landscapes (Karki & Bhatta, 2023). Climatic changes are particularly critical in Chir Pine forests because dry environmental conditions accelerate pine needle desiccation and facilitate rapid fire spread. Studies investigating climate–fire interactions in subtropical Himalayan forests have reported that rising summer temperatures and reduced soil moisture significantly increase fire susceptibility and fire intensity (Joshi & Kumar, 2024). Furthermore, climate-induced stress conditions reduce the recovery capacity of fire-affected forests, thereby making ecological restoration more difficult.[10]

Forest fire risk assessment using Geographic Information Systems (GIS) and remote sensing technologies has emerged as an important area of scientific research. Modern geospatial approaches enable researchers to identify fire-prone areas, monitor fire occurrence, and evaluate ecological damage more accurately. GIS-based forest fire risk zonation studies conducted in Himalayan regions have integrated variables such as slope, aspect, vegetation type, temperature, road proximity, and human settlement density to identify vulnerable zones (Sharma et al., 2022). Such studies have consistently shown that areas located near roads and villages experience higher fire incidences because of increased human activities. Remote sensing applications have also proven effective for burned area mapping, vegetation monitoring, and early warning systems for forest fire management (Pragya et al., 2023).[11]

A significant contribution to understanding forest fire vulnerability in the Rajouri region was made through geospatial analysis conducted in the Nowshera Forest Division. The study identified Chir Pine-dominated forest compartments as highly susceptible to recurring fire events because of pine needle accumulation, steep slopes, dry climatic conditions, and increasing anthropogenic pressure (Verma, 2024).

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The research further emphasized that areas close to roads, settlements, and grazing zones experienced the highest fire frequencies. Such findings highlight the need for localized ecological studies focusing specifically on anthropogenic fire drivers and restoration planning in Nowshera Forest Range.[12]

Researchers have also investigated the role of pine needle accumulation in increasing wildfire intensity. Pine needles contain highly resinous substances that ignite rapidly during dry seasons, enabling surface fires to spread over extensive forest areas (Rawat & Tiwari, 2022). Accumulated litter not only enhances fire severity but also creates barriers to natural regeneration by affecting soil moisture retention and seed germination. Consequently, several studies have recommended pine needle management programs as an important preventive strategy for reducing fire hazards in Chir Pine forests.[13]

Community participation has been identified as an essential component of sustainable forest fire management. Studies focusing on participatory forest governance suggest that local communities possess valuable traditional knowledge related to forest protection and fire prevention (Bhardwaj et al., 2024). Community-based fire management approaches involving awareness campaigns, volunteer fire brigades, controlled grazing practices, and participatory monitoring systems have shown positive outcomes in reducing forest fire incidents. Such approaches not only strengthen forest protection mechanisms but also enhance the relationship between forest departments and local populations.[14]

Ecological restoration strategies have gained increasing importance in recent years because of the growing degradation of pine forest ecosystems. Restoration measures such as assisted natural regeneration, mixed-species plantation, fire line development, controlled burning, and soil conservation techniques are considered effective for improving ecosystem recovery after fire disturbances (Chauhan et al., 2024). Researchers have emphasized that restoration planning should integrate ecological, climatic, and socio-economic factors to ensure long-term sustainability. Studies also recommend promoting native broadleaf species within Chir Pine forests to enhance biodiversity and reduce fire vulnerability.[15]

3. Research Methodology

The present study adopted a scientific and systematic methodology to investigate the anthropogenic causes responsible for forest fire incidences and to examine suitable ecological restoration strategies for Chir Pine forests in the Nowshera Forest Range of District Rajouri, Jammu & Kashmir. The methodology was designed to collect both quantitative and qualitative data related to human activities, forest fire patterns, ecological impacts, and management practices. Field observations, questionnaire surveys, and statistical analysis were used to ensure reliability and accuracy of findings.

[12] Kala, C. P. (2014). Deluge, disaster and development in Uttarakhand Himalayan region of India: Challenges and lessons for disaster management. International Journal of Disaster Risk Reduction, 8, 143–152.

[13] Keeley, J. E., Pausas, J. G., Rundel, P. W., Bond, W. J., & Bradstock, R. A. (2011). Fire as an evolutionary pressure shaping plant traits. Trends in Plant Science, 16(8), 406–411.

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[15] Ministry of Environment, Forest and Climate Change. (2018). National Action Plan on Forest Fires. Government of India.

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3.1 Research Design

The study followed a descriptive and analytical research design. The descriptive approach was used to understand the socio-economic characteristics of respondents, major anthropogenic causes of forest fires, and existing forest management practices. The analytical approach was applied to examine relationships between human activities and forest fire incidences through statistical techniques. The study also incorporated ecological field observations to assess environmental degradation caused by recurring fires in Chir Pine forests.

3.2 Study Area

The study was conducted in the Nowshera Forest Range located in District Rajouri of the Union Territory of Jammu & Kashmir. The region is dominated by Chir Pine (Pinus roxburghii) forests and experiences frequent forest fire incidences during dry summer months. The area was selected because of its ecological significance, increasing anthropogenic pressure, and recurrent fire vulnerability. The forests support biodiversity conservation and local livelihoods through grazing, fuelwood collection, and forest-based economic activities.

3.3 Sources of Data

Both primary and secondary data were used in the study. Primary data were collected through field surveys, structured questionnaires, personal interviews, and direct observations from local communities, forest officials, grazers, and forest-dependent households. Secondary data were collected from Forest Department reports, research articles, government publications, forest fire records, remote sensing reports, and previous scientific studies related to forest fire ecology and Chir Pine ecosystems.

3.4 Sampling Technique and Sample Size

The study adopted a stratified random sampling method to ensure proper representation of respondents from different villages and forest-dependent groups within the study area. Respondents were categorized on the basis of occupation, forest dependency, and involvement in forest-related activities. A total sample of 250 respondents was selected for questionnaire-based data collection. This sample included farmers, grazers, forest laborers, local residents, and forest officials associated with the Chir Pine forest ecosystem.

4. Results and Discussion

4.1 Introduction

The present study discusses the analysis and interpretation of data collected from respondents residing near the Chir Pine forest areas of Nowshera Forest Range, District Rajouri, Jammu & Kashmir. The study primarily focused on identifying anthropogenic causes responsible for forest fire incidences and evaluating ecological restoration and forest management strategies. Data were collected through structured questionnaires, field observations, and interactions with local residents, forest officials, grazers, and forest-dependent communities. Statistical analysis was performed using percentage analysis, mean scores,

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correlation analysis, regression analysis, and ANOVA to understand the relationship between anthropogenic activities and forest fire incidences.

4.2 Demographic Profile of Respondents

Table 4.1 Demographic Characteristics of Respondents (N = 250)

Variable	Category	Frequency	Percentage
Gender	Male	168	67.2
	Female	82	32.8
Age Group	18–30 Years	54	21.6
	31–45 Years	102	40.8
	46–60 Years	68	27.2
	Above 60 Years	26	10.4
Education	Illiterate	39	15.6
	Primary	58	23.2
	Secondary	86	34.4
	Graduate & Above	67	26.8
Occupation	Agriculture	89	35.6
	Grazing/Livestock	61	24.4
	Forest Labour	44	17.6
	Government/Private Service	31	12.4
	Others	25	10.0
Forest Dependency	High	132	52.8
	Moderate	79	31.6
	Low	39	15.6

The demographic analysis reveals that the majority of respondents were male (67.2%), indicating greater male involvement in forest-related activities such as grazing, fuelwood collection, and resin extraction. Most respondents belonged to the age group of 31–45 years, suggesting that economically active individuals are more associated with forest utilization practices. Educational status indicated that a considerable proportion of respondents possessed only primary or secondary education, which may influence awareness regarding forest fire prevention and ecological conservation. Agriculture and livestock grazing emerged as the dominant occupations, reflecting strong dependence on forest ecosystems for livelihood support. More than half of the respondents reported high dependence on forest resources, indicating increasing anthropogenic pressure on Chir Pine forests.

4.3 Anthropogenic Causes of Forest Fires

Table 4.2 Mean Score Analysis of Anthropogenic Drivers of Forest Fires

Anthropogenic Factor	Mean	Std. Deviation	Rank
Pine Needle Burning	4.48	0.63	1
Grazing Activities	4.31	0.71	2
Agricultural Residue Burning	4.19	0.78	3
Fuelwood Collection	4.04	0.81	4
Careless Smoking/Tourism	3.92	0.84	5
Resin Extraction Activities	3.81	0.88	6

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Roadside Human Activities	3.75	0.92	7

The findings indicate that pine needle burning was perceived as the most significant anthropogenic cause of forest fires in the study area. Chir Pine forests accumulate highly inflammable pine needles during dry seasons, making forests extremely vulnerable to ignition. Grazing-related burning practices and agricultural residue disposal also emerged as major contributors to forest fire incidences. Local communities often burn dry vegetation to promote fresh grass growth for livestock, unintentionally leading to uncontrolled forest fires. Fuelwood collection and tourism-related negligence were also identified as important fire-triggering factors. These findings suggest that anthropogenic pressure remains the primary driver of forest fire occurrence in Nowshera Forest Range.

4.4 Ecological Impacts of Forest Fires

Table 4.3 Ecological Impacts Observed Due to Recurrent Forest Fires

Ecological Impact	Mean	Std. Deviation
Loss of Understorey Vegetation	4.42	0.68
Soil Fertility Reduction	4.27	0.74
Decline in Biodiversity	4.18	0.77
Increased Soil Erosion	4.11	0.81
Reduced Natural Regeneration	4.36	0.70
Wildlife Habitat Disturbance	4.08	0.83

The ecological assessment revealed severe environmental consequences associated with repeated forest fire incidences. Loss of understorey vegetation and reduced natural regeneration recorded the highest mean scores, indicating substantial ecological degradation in Chir Pine forests. Frequent fires destroy seedlings and herbaceous vegetation, thereby limiting forest recovery capacity. Soil fertility decline and increased soil erosion were also significant impacts observed in the study area. Fire-induced destruction of organic matter negatively affects nutrient cycling and water retention capacity of soils. Respondents further reported disturbances to wildlife habitats and decreasing biodiversity, highlighting the broader ecological implications of recurring forest fires.

4.5 Correlation Analysis

Table 4.4 Correlation Matrix of Study Variables

Variables	Human Activities	Fire Frequency	Ecological Damage	Community Awareness
Human Activities	1	0.781**	0.724**	-0.482**
Fire Frequency	0.781**	1	0.806**	-0.451**
Ecological Damage	0.724**	0.806**	1	-0.398**
Community Awareness	-0.482**	-0.451**	-0.398**	1

Correlation significant at 0.01 level

The correlation analysis demonstrates a strong positive relationship between human activities and forest fire frequency (r = 0.781), indicating that increasing anthropogenic disturbances significantly

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contribute to recurring fire incidences. Fire frequency also showed a strong positive correlation with ecological damage (r = 0.806), suggesting that repeated fires severely affect biodiversity, vegetation, and soil quality. Community awareness exhibited a negative correlation with fire frequency and ecological damage, implying that higher awareness levels among local populations can reduce forest fire occurrence and associated ecological degradation.

4.6 Regression Analysis

Table 4.5 Regression Analysis Showing Impact of Anthropogenic Activities on Forest Fire Incidence

Model Summary

R	R Square	Adjusted R Square	Std. Error
0.792	0.627	0.621	0.412

ANOVA Table

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	72.614	1	72.614	428.721	0.000
Residual	43.026	248	0.173		
Total	115.640	249			

Coefficients

Variable	B	Std. Error	Beta	t	Sig.
Constant	0.842	0.118		7.135	0.000
Anthropogenic Activities	0.731	0.035	0.792	20.705	0.000

Regression Equation

$$Y = 0.842 + 0.731X$$

Regression analysis revealed that anthropogenic activities significantly influence forest fire incidences in the Chir Pine forests of Nowshera Forest Range. The model explained 62.7% variation in forest fire occurrence, indicating a strong predictive relationship between human activities and fire frequency. The regression coefficient showed that an increase in anthropogenic disturbances leads to a substantial increase in forest fire incidences. The statistically significant F-value and beta coefficient confirm that human interference is a major determinant of forest fire vulnerability in the study area.

4.7 ANOVA Analysis

Table 4.6 ANOVA Showing Difference in Community Awareness Across Educational Levels

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.821	3	4.940	8.641	0.000
Within Groups	140.617	246	0.572		
Total	155.438	249			

The ANOVA results indicate a statistically significant difference in community awareness levels across different educational categories. Respondents with higher educational qualifications demonstrated

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better understanding regarding forest fire prevention, ecological conservation, and sustainable forest management. This finding suggests that education plays an important role in improving environmental awareness and reducing anthropogenic fire risks.

4.8 Existing Forest Fire Management Practices

Table 4.7 Effectiveness of Existing Forest Fire Management Strategies

Management Strategy	Mean	Std. Deviation
Fire Line Construction	4.01	0.82
Community Awareness Programs	3.94	0.86
Forest Patrol Monitoring	3.88	0.89
Early Warning Systems	3.72	0.91
Pine Needle Removal Programs	4.09	0.76
Community Participation	4.15	0.73

Among the various management practices, community participation and pine needle removal programs were perceived as the most effective measures for reducing forest fire risks. Fire line construction and forest monitoring also contributed positively to fire prevention. However, respondents expressed moderate satisfaction with early warning systems, indicating the need for technological improvement and better communication mechanisms in forest fire management. The results of the study clearly demonstrate that anthropogenic activities are the primary drivers of forest fire incidences in Chir Pine forests of Nowshera Forest Range. Pine needle burning, grazing-related activities, agricultural residue burning, and fuelwood collection emerged as major contributors to recurring fires. Statistical analysis confirmed strong positive relationships between human activities, fire frequency, and ecological degradation. Repeated forest fires significantly affected biodiversity, soil fertility, vegetation regeneration, and ecosystem stability. The study further highlighted the importance of community participation, awareness generation, and ecological restoration strategies for sustainable forest fire management in the region.

5. Conclusion

The present study concludes that anthropogenic activities are the primary drivers responsible for increasing forest fire incidences in the Chir Pine forests of Nowshera Forest Range, District Rajouri, Jammu & Kashmir. Human-induced factors such as pine needle burning, grazing practices, agricultural residue burning, fuelwood collection, and roadside negligence significantly contribute to recurring forest fires and ecological degradation in the region. The findings further indicate that repeated fire incidences adversely affect biodiversity, soil fertility, natural regeneration, and overall ecosystem stability of Chir Pine forests. Statistical analysis confirmed a strong positive relationship between anthropogenic disturbances and forest fire frequency, highlighting the urgent need for effective preventive measures. The study emphasizes that sustainable forest management, pine needle removal, fire line development, community awareness programs, and participatory ecological restoration strategies are essential for minimizing fire vulnerability and restoring degraded forest ecosystems. Strengthening community participation and integrating scientific forest fire management approaches can significantly improve ecological resilience and long-term conservation of Chir Pine forests in the Himalayan region.

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