Assessment of Human-Induced Forest Fires and Sustainable Management Approaches for Restoration of Chir Pine Ecosystems in Nowshera Forest Division, UT of Jammu & Kashmir

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Abstract:
Forest fires have become a major environmental concern in the Chir Pine forests of the Himalayan region due to increasing anthropogenic disturbances and changing climatic conditions. The present study assesses human-induced forest fire incidences and sustainable management approaches for restoration of Chir Pine ecosystems in the Nowshera Forest Division, Jammu & Kashmir. 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-related activities, fuelwood extraction, and agricultural residue burning are the major anthropogenic causes of forest fires in the study area. The study further highlights severe ecological impacts, including biodiversity loss, soil degradation, reduced natural regeneration, and wildlife habitat disturbance. Community participation, pine needle management, awareness programs, and ecological restoration strategies were identified as essential for sustainable forest fire management and ecosystem conservation.

Keywords: Forest Fire, Chir Pine Ecosystem, Anthropogenic Activities, Sustainable Forest Management, Ecological Restoration, Nowshera Forest Division, Biodiversity Conservation

Introduction

Forest fires are among the most severe environmental disturbances affecting forest ecosystems across the world, particularly in mountainous and subtropical regions where climatic conditions and human activities increase fire susceptibility. In recent decades, the Himalayan region has experienced a significant rise in the frequency and intensity of forest fires due to climate change, prolonged dry seasons,[1] increasing temperatures, and anthropogenic pressures on forest resources. These fires not only destroy vegetation and wildlife habitats but also contribute to soil degradation, biodiversity loss, carbon emissions, and ecological imbalance (Karki & Bhatta, 2023). The western Himalayan region, especially the Chir Pine (Pinus roxburghii) dominated

[1] Negi, G. C. S. (2025). Chir Pine forests of Western Himalaya are under stress because of combined effects of resin extraction, recurrent fire and climate change: A viewpoint. International Journal of Ecology and Environmental Sciences, 51(1), 7–14. https://doi.org/10.55863/ijees.2025.0504

forests, has become highly vulnerable to recurring fire incidences because of the inflammable characteristics of pine needles and increasing human interference in forest landscapes (Negi, 2025).[2]

Chir Pine forests occupy a substantial portion of subtropical Himalayan ecosystems and play an important ecological and socio-economic role. These forests are widely distributed across the lower Himalayan regions of Jammu & Kashmir, Himachal Pradesh, and Uttarakhand, where they contribute to soil conservation, carbon sequestration, hydrological regulation, and biodiversity maintenance. In addition, local communities depend heavily on Chir Pine forests for fuelwood, grazing, resin extraction, and other livelihood activities. However, recurring forest fires have emerged as a major threat to the sustainability and ecological stability of these forests. Research studies have indicated that Chir Pine ecosystems are naturally fire-prone because of the accumulation of resin-rich pine needles that ignite rapidly during dry weather conditions (Rawat & Tiwari, 2022).

The Nowshera Forest Division in District Rajouri of the Union Territory of Jammu & Kashmir represents one of the ecologically significant forested regions dominated by Chir Pine vegetation. The area experiences dry climatic conditions during summer months, making forests highly susceptible to fire outbreaks. In recent years, forest fire incidences in the Nowshera region have increased considerably due to expanding human settlements, grazing activities, agricultural expansion, road construction, and increasing dependency of local populations on forest resources. Human-induced activities have emerged as the principal causes of forest fires in the region, as natural causes such as lightning are comparatively less common in subtropical Himalayan forests (Semwal & Mehta, 2021).[3]

Anthropogenic forest fires are generally associated with intentional or accidental human activities. Practices such as burning of dry grass for livestock grazing, agricultural residue burning near forest boundaries, careless disposal of cigarettes, campfires, tourism-related negligence, and resin extraction contribute significantly to fire ignition and spread in Chir Pine forests (Singh, 2026). In many rural areas, local communities intentionally set fire to forest litter to stimulate fresh grass growth for grazing purposes. However, due to steep slopes, dry vegetation, and strong winds, such fires often become uncontrollable and spread over large forest areas. Studies conducted in Himalayan regions have revealed that the majority of forest fires originate from anthropogenic disturbances rather than natural environmental processes (Bar et al., 2021).[4]

The ecological impacts of recurring forest fires are extensive and long-lasting. Repeated fire events damage understorey vegetation, reduce biodiversity, alter forest composition, and suppress natural regeneration of broadleaf species. Frequent burning also leads to depletion of soil nutrients, reduction in microbial activity, and deterioration of soil structure, ultimately affecting ecosystem productivity (Bargali et al., 2025). Research conducted in Himalayan Chir Pine forests has shown that recurrent fires increase soil erosion and reduce organic carbon content, thereby making ecosystems more vulnerable to degradation and desertification processes (Devi et al., 2026). Forest fires further disturb wildlife habitats and contribute to atmospheric pollution through the release of greenhouse gases and particulate matter.[5]

Climate change has further intensified forest fire vulnerability in Himalayan ecosystems. Rising temperatures, prolonged drought conditions, irregular rainfall patterns, and declining soil moisture create

[2] Verma, R. (2024). A geospatial risk map of forest fires: A case study in Nowshera Forest Division, District Rajouri, Jammu and Kashmir, India. International Journal of Multidisciplinary Research and Growth Evaluation, 5(6), 565–582.

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favorable conditions for rapid fire ignition and spread (Joshi & Kumar, 2024). Climate-induced drying of forest litter and vegetation significantly increases fuel availability in Chir Pine forests. Studies suggest that subtropical Himalayan forests are becoming increasingly susceptible to large-scale fires because of the combined effects of climate variability and anthropogenic disturbances (Muhammad et al., 2025). Therefore, understanding the interaction between human activities and environmental conditions has become essential for effective forest fire management.[6]

Modern technologies such as Geographic Information Systems (GIS) and remote sensing have become important tools for forest fire assessment and monitoring. GIS-based fire risk zonation techniques help identify fire-prone areas by integrating variables such as slope, vegetation type, temperature, proximity to roads, and settlement density (Sharma et al., 2022). Remote sensing technologies also assist in burned area mapping, fire detection, and post-fire ecological assessment. A geospatial study conducted in the Nowshera Forest Division identified several highly vulnerable fire zones associated with anthropogenic pressure and pine needle accumulation (Verma, 2024). Such scientific approaches are valuable for developing early warning systems and effective fire management strategies.

Sustainable forest management and ecological restoration are critical for reducing forest fire vulnerability and improving ecosystem resilience in Chir Pine forests. Ecological restoration strategies such as pine needle management, fire line construction, mixed-species plantation, assisted natural regeneration, and community participation can significantly reduce fire risks and restore degraded forest landscapes (Fulé et al., 2021). Researchers have emphasized that involving local communities in forest conservation programs enhances fire prevention efficiency because rural populations possess traditional ecological knowledge and maintain direct interaction with forest ecosystems (Bhardwaj et al., 2024). Community awareness programs and participatory forest management approaches are therefore essential for sustainable restoration of fire-affected Chir Pine forests.[7]

1. Literature Review

Forest fires have emerged as one of the most significant ecological disturbances affecting forest ecosystems across the Himalayan region. Increasing climatic variability, prolonged dry seasons, and anthropogenic pressure on forest resources have intensified the frequency and severity of forest fire incidences in subtropical pine forests. Chir Pine (Pinus roxburghii) forests are particularly vulnerable because of the accumulation of resin-rich pine needles that act as highly combustible fuel during dry weather conditions (Rawat & Tiwari, 2022). Researchers have emphasized that recurring forest fires not only degrade vegetation cover but also alter ecological processes, biodiversity patterns, and soil properties in Himalayan ecosystems (Negi, 2025).[8]

Several studies have identified anthropogenic activities as the primary causes of forest fire outbreaks in the Himalayan region. Human-induced disturbances such as intentional burning for grazing enhancement, fuelwood collection, agricultural residue burning, careless smoking, tourism-related negligence, and resin extraction have been widely associated with fire ignition in Chir Pine forests (Semwal & Mehta, 2021). Expansion of human settlements and road networks near forested areas has further increased human–forest interactions, thereby enhancing forest fire vulnerability. Research conducted in Himalayan landscapes demonstrated that most forest fire incidents are directly linked to anthropogenic causes rather than natural

[6] Sharma, R., Kanga, S., Nathawat, M. S., & Singh, S. K. (2022). GIS and remote sensing-based forest fire risk zonation in Himalayan forest ecosystems. Environmental Challenges, 8, 100573.

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climatic events (Bar et al., 2021). Such findings indicate that human activities continue to be the dominant factor influencing forest fire occurrence in subtropical pine ecosystems.[9]

Ecological studies focusing on Chir Pine forests have revealed severe environmental impacts associated with recurrent forest fires. Frequent burning damages understorey vegetation, suppresses regeneration of broadleaf species, and promotes fire-tolerant pine dominance, thereby reducing biodiversity and ecological resilience (Fulé et al., 2021). Fire disturbances also influence nutrient cycling processes by reducing soil organic matter and microbial activity. Research examining soil physicochemical properties in Himalayan forests found that repeated fires significantly reduce soil fertility, moisture retention capacity, and organic carbon content (Bargali et al., 2025). Similar investigations in Garhwal Himalayan Chir Pine forests reported substantial fluctuations in soil nutrients following fire disturbances, which negatively affect vegetation recovery and ecosystem productivity (Vishvamitera & Nautiyal, 2022).[10]

The relationship between climate change and forest fire vulnerability has also received increasing attention in recent years. Studies suggest that rising temperatures, irregular rainfall patterns, prolonged drought conditions, and declining soil moisture are contributing significantly to increased wildfire risks in South Asian mountain forests (Karki & Bhatta, 2023). Climatic stress conditions accelerate drying of pine needles and forest litter, making Chir Pine forests highly susceptible to ignition and rapid fire spread. Research investigating fire dynamics in subtropical Himalayan forests concluded that climate variability combined with human activities has intensified both the frequency and severity of forest fires in the region (Joshi & Kumar, 2024). Furthermore, climate-induced ecological stress reduces the regenerative capacity of fire-affected ecosystems, thereby increasing long-term environmental degradation.[11]

Modern geospatial technologies such as Geographic Information Systems (GIS) and remote sensing have become valuable tools for assessing forest fire vulnerability and ecological impacts. GIS-based forest fire risk zonation studies have integrated variables such as slope, aspect, vegetation type, temperature, proximity to roads, and settlement density to identify highly vulnerable fire-prone zones (Sharma et al., 2022). Remote sensing approaches have also facilitated monitoring of burned areas, vegetation loss, and temporal fire patterns across Himalayan landscapes. Integrated spatial analysis conducted in the western Himalayan region demonstrated that human settlements, road accessibility, and pine forest distribution are among the most important determinants of forest fire susceptibility (Pragya et al., 2023).

A significant contribution to understanding forest fire vulnerability in the Rajouri region was provided through geospatial assessment of the Nowshera Forest Division. The study identified Chir Pine-dominated forest compartments as highly susceptible to repeated fire incidences because of steep slopes, dry climatic conditions, pine needle accumulation, and increasing anthropogenic pressure (Verma, 2024). Areas located close to roads and human settlements were found to experience the highest fire frequencies. Such findings highlight the importance of localized ecological studies for understanding region-specific anthropogenic drivers and sustainable management requirements.[12]

Researchers have also examined the influence of pine needle accumulation on fire intensity and ecosystem degradation. Pine needles contain highly inflammable resinous compounds that facilitate rapid surface fire spread during summer seasons (Rawat & Tiwari, 2022). Excessive litter accumulation creates a continuous fuel layer across forest floors, increasing the probability of large-scale fire outbreaks. Studies

[9] Joshi, R., & Kumar, M. (2024). Forest fire dynamics and climate vulnerability in subtropical Himalayan forests. Environmental Monitoring and Assessment, 196(2), 114–129.
[10] Semwal, R. L., & Mehta, J. P. (2021). Human-induced forest fire disturbances and biodiversity loss in Himalayan Chir Pine forests. Current Science, 121(5), 621–628.
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[12] Rawat, Y. S., & Tiwari, P. (2022). Pine needle accumulation and increasing wildfire risks in western Himalayan ecosystems. Indian Forester, 148(9), 875–884.

investigating controlled burning practices in Chir Pine forests reported that repeated uncontrolled fires significantly reduce understorey vegetation density and affect natural regeneration patterns (Kumar et al., 2022). Consequently, pine needle management has been suggested as an important preventive strategy for reducing fire hazards.[13]

Community participation has emerged as a critical component of sustainable forest fire management. Research focusing on participatory forest governance emphasized that local communities possess traditional ecological knowledge regarding forest conservation and fire prevention (Bhardwaj et al., 2024). Community-based management strategies such as awareness campaigns, volunteer fire brigades, participatory monitoring systems, and controlled grazing practices have shown positive results in minimizing fire incidences. Such participatory approaches not only improve forest protection efficiency but also strengthen cooperation between forest departments and local populations.[14]

Sustainable ecological restoration strategies have gained increasing significance in response to growing degradation of Chir Pine ecosystems. Restoration measures such as fire line construction, assisted natural regeneration, mixed-species plantation, soil conservation techniques, and pine needle removal programs are considered effective approaches for restoring ecological stability in fire-affected forests (Fulé et al., 2021). Researchers have emphasized the importance of integrating ecological, climatic, and socio-economic considerations into restoration planning for ensuring long-term sustainability of Himalayan forest ecosystems.[15]

3. Research Methodology

The present study adopted a systematic and scientific methodology to assess human-induced forest fires and sustainable management approaches for restoration of Chir Pine ecosystems in the Nowshera Forest Division, Jammu & Kashmir. The methodology was designed to collect reliable information regarding anthropogenic fire causes, ecological impacts, and restoration strategies through field surveys, questionnaire methods, and statistical analysis. Both social and ecological dimensions of forest fire management were considered in the study.

3.1 Research Design

The study followed a descriptive and analytical research design. The descriptive approach was used to understand demographic characteristics, anthropogenic fire causes, and management practices adopted in the study area. The analytical approach was used to examine relationships between human activities and forest fire incidences through statistical techniques. Ecological observations were also included to assess environmental degradation caused by recurring forest fires.

3.2 Study Area

The study was conducted in the Nowshera Forest Division located in District Rajouri of the Union Territory of Jammu & Kashmir. The area is dominated by Chir Pine (Pinus roxburghii) forests and experiences frequent forest fire incidences during dry summer months. The region was selected because of its ecological importance, increasing anthropogenic pressure, and repeated fire disturbances affecting biodiversity and forest regeneration.

3.3 Sources of Data

The study utilized both primary and secondary data sources. Primary data were collected through structured questionnaires, personal interviews, and field observations from local communities, forest-

[13] Bhardwaj, A., Kumar, A., & Rana, N. (2024). Community participation and forest fire management in Himalayan forest landscapes. Forest Policy and Economics, 161, 103120.
[14] Karki, R., & Bhatta, L. D. (2023). Climate change and increasing wildfire vulnerability in South Asian mountain forests. Climate Risk Management, 41, 100528.
[15] Devi, J., Sharma, P., & Bisht, R. (2026). Impact of fire frequency and elevation on soil carbon dynamics in Himalayan Chir Pine forests. Journal of Environmental Management, 352, 120145.

dependent households, grazers, and forest officials. Secondary data were obtained from Forest Department reports, government records, research journals, forest fire statistics, and published literature related to forest fire ecology and management.

3.4 Sampling Technique and Sample Size

A stratified random sampling technique was adopted for selecting respondents from different villages and forest-dependent groups within the study area. Respondents were categorized according to occupation, forest dependency, and involvement in forest-related activities. A total sample of 300 respondents was selected for the study to ensure proper representation of local populations associated with Chir Pine forest ecosystems.

3.5 Data Collection Tools

A structured questionnaire was used as the main data collection tool. The questionnaire included demographic questions, Likert scale-based statements, and close-ended questions related to anthropogenic fire causes, ecological impacts, awareness levels, and sustainable forest management practices. Field observations and informal discussions were also conducted to gather ecological information regarding fire-affected forest areas.

4. Results and Discussion

The study focuses on identifying major anthropogenic causes responsible for forest fire incidences, assessing ecological impacts on Chir Pine ecosystems, and evaluating sustainable forest management approaches. Data were collected from local residents, forest-dependent communities, grazers, farmers, and forest officials through structured questionnaires and field observations. Statistical tools such as percentage analysis, mean score analysis, correlation, regression, and ANOVA were used for interpretation of findings.

4.1 Demographic Profile of Respondents

Table 1: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	198	66.0
	Female	102	34.0
Age Group	18–30 Years	61	20.3
	31–45 Years	128	42.7
	46–60 Years	79	26.3
	Above 60 Years	32	10.7
Education	Illiterate	46	15.3
	Primary	72	24.0
	Secondary	104	34.7
	Graduate & Above	78	26.0
Occupation	Agriculture	108	36.0
	Livestock Grazing	72	24.0
	Forest Labour	51	17.0
	Government/Private Service	39	13.0
	Others	30	10.0
Forest Dependency	High	164	54.7
	Moderate	92	30.7
	Low	44	14.6

The demographic analysis indicates that the majority of respondents were male (66%), reflecting greater male participation in forest-related occupations such as grazing, fuelwood collection, and agricultural activities. Most respondents belonged to the economically active age group of 31–45 years, indicating substantial involvement of working populations in forest utilization activities. Educational analysis showed that a large proportion of respondents had only primary or secondary education, which may affect awareness regarding ecological conservation and fire prevention practices. Agriculture and livestock grazing were the dominant occupations, highlighting strong dependence on forest ecosystems for livelihood support. More than half of the respondents reported high dependence on forest resources, suggesting increased anthropogenic pressure on Chir Pine forests in the Nowshera Forest Division.

4.3 Human-Induced Causes of Forest Fires

Table 2: Mean Score Analysis of Anthropogenic Drivers of Forest Fires

Anthropogenic Factors	Mean	Std. Deviation	Rank
Pine Needle Burning	4.52	0.61	1
Grazing-Related Burning	4.38	0.67	2
Agricultural Residue Burning	4.24	0.73	3
Fuelwood Collection Activities	4.11	0.78	4
Careless Smoking/Tourism	3.98	0.81	5
Resin Extraction Activities	3.86	0.85	6
Roadside Human Activities	3.79	0.89	7

The results reveal that pine needle burning emerged as the most significant anthropogenic cause of forest fires in the study area. Chir Pine forests accumulate large quantities of highly inflammable pine needles during dry seasons, increasing fire vulnerability. Grazing-related burning practices ranked second, as local communities often intentionally burn forest litter to promote fresh grass growth for livestock. Agricultural residue burning near forest boundaries also contributed substantially to fire spread. Fuelwood extraction and tourism-related negligence were identified as additional causes responsible for recurring fire incidents. These findings confirm that anthropogenic disturbances remain the dominant factor influencing forest fire occurrence in Nowshera Forest Division.

4.4 Ecological Impacts of Forest Fires

Table 3: Ecological Impacts of Recurrent Forest Fires on Chir Pine Ecosystems

Ecological Impacts	Mean	Std. Deviation
Loss of Understorey Vegetation	4.47	0.64
Reduced Natural Regeneration	4.41	0.68
Soil Fertility Degradation	4.29	0.72
Increased Soil Erosion	4.17	0.79
Biodiversity Decline	4.12	0.83
Wildlife Habitat Disturbance	4.06	0.85

The ecological assessment demonstrated severe environmental degradation resulting from recurrent forest fires. Loss of understorey vegetation and reduced natural regeneration recorded the highest mean values, indicating that repeated burning significantly affects forest recovery processes. Fire disturbances destroy seedlings, herbs, and shrubs, limiting biodiversity restoration and ecological stability. Soil fertility degradation and increased erosion were also major consequences observed in fire-affected areas. Repeated burning reduces organic matter content and weakens soil structure, making hill slopes vulnerable to erosion.

Wildlife habitat disturbance and biodiversity decline further indicate long-term ecological consequences associated with uncontrolled forest fires.

4.5 Correlation Analysis

Table 4: Correlation Matrix of Study Variables

Variables	Human Activities	Fire Frequency	Ecological Damage	Community Awareness
Human Activities	1	0.796**	0.738**	-0.468**
Fire Frequency	0.796**	1	0.824**	-0.442**
Ecological Damage	0.738**	0.824**	1	-0.397**
Community Awareness	-0.468**	-0.442**	-0.397**	1

Correlation significant at 0.01 level

The correlation analysis revealed a strong positive relationship between human activities and forest fire frequency (r = 0.796), indicating that increasing anthropogenic pressure significantly contributes to forest fire occurrence. Fire frequency also showed a strong positive correlation with ecological damage (r = 0.824), suggesting that repeated fire incidences intensify environmental degradation in Chir Pine ecosystems. Community awareness displayed a negative correlation with both fire frequency and ecological damage, implying that higher awareness and participation of local populations can reduce fire vulnerability and improve ecological conservation outcomes.

4.6 Regression Analysis

Table 5: Regression Analysis Showing Impact of Human Activities on Forest Fire Incidence

Model Summary

R	R Square	Adjusted R Square	Std. Error
0.804	0.646	0.641	0.398

ANOVA Table

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	86.741	1	86.741	547.322	0.000
Residual	47.238	298	0.158		
Total	133.979	299			

Coefficients

Variable	B	Std. Error	Beta	t	Sig.
Constant	0.774	0.102		7.588	0.000
Human Activities	0.748	0.032	0.804	23.395	0.000

Regression Equation

$$Y = 0.774 + 0.748X$$

The regression analysis confirmed that human-induced activities significantly affect forest fire incidences in the Nowshera Forest Division. The model explained 64.6% variation in forest fire occurrence, indicating a strong predictive relationship between anthropogenic disturbances and fire frequency. The regression coefficient demonstrated that increasing human activities directly increase the probability of forest

fire outbreaks. The statistically significant F-value and beta coefficient clearly establish anthropogenic pressure as a major determinant of fire vulnerability in Chir Pine forests.

4.7 ANOVA Analysis

Table 6: ANOVA Showing Difference in Community Awareness Across Educational Categories

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.924	3	5.641	9.784	0.000
Within Groups	171.005	296	0.578		
Total	187.929	299			

The ANOVA results indicate a statistically significant difference in awareness levels across educational groups. Respondents with higher educational qualifications demonstrated greater understanding regarding forest fire prevention, ecological conservation, and sustainable management practices. The findings suggest that education and environmental awareness programs can play an important role in minimizing anthropogenic fire risks in the study area.

4.8 Sustainable Forest Management Approaches

Table 7: Perceived Effectiveness of Sustainable Forest Management Strategies

Management Strategies	Mean	Std. Deviation
Pine Needle Removal Programs	4.34	0.65
Community Participation	4.28	0.69
Fire Line Construction	4.16	0.73
Forest Patrol Monitoring	4.03	0.79
Mixed Species Plantation	4.11	0.76
Early Warning Systems	3.92	0.84
Awareness Campaigns	4.21	0.71

The findings indicate that pine needle removal programs and community participation were perceived as the most effective sustainable management approaches for reducing forest fire vulnerability. Respondents believed that removal of inflammable pine litter can significantly minimize fire spread in Chir Pine forests. Community-based forest protection initiatives and awareness campaigns also received high support, highlighting the importance of participatory forest governance. Fire line construction, mixed-species plantation, and monitoring systems were considered essential for ecological restoration and long-term sustainability of forest ecosystems.

The results of the study clearly demonstrate that human-induced activities are the primary causes of recurring forest fires in the Chir Pine ecosystems of Nowshera Forest Division. Pine needle burning, grazing-related activities, agricultural residue burning, and fuelwood extraction emerged as the major anthropogenic drivers of forest fire incidence. Statistical analysis confirmed strong positive relationships between human activities, fire frequency, and ecological degradation. Recurrent fires significantly affected vegetation regeneration, soil fertility, biodiversity, and wildlife habitats. The study further highlighted the importance of sustainable forest management approaches such as pine needle removal, community participation, awareness programs, and ecological restoration strategies for reducing fire vulnerability and conserving Chir Pine ecosystems in the Himalayan region.

5. Conclusion

The present study concludes that human-induced activities are the major contributors to recurring forest fire incidences in the Chir Pine ecosystems of the Nowshera Forest Division, Jammu & Kashmir. Anthropogenic factors such as pine needle burning, grazing-related fires, fuelwood extraction, agricultural residue burning, and roadside human negligence significantly increase fire vulnerability and ecological degradation in the region. The findings reveal that repeated forest fires adversely affect biodiversity, soil fertility, natural regeneration, understorey vegetation, and wildlife habitats, thereby threatening the ecological stability and sustainability of Chir Pine forests. Statistical analysis confirmed a strong positive relationship between anthropogenic disturbances and forest fire occurrence, emphasizing the urgent need for effective preventive and restoration measures. The study further highlights that sustainable forest management approaches including pine needle removal, fire line construction, community participation, awareness campaigns, mixed-species plantation, and ecological restoration programs are essential for reducing fire risks and improving ecosystem resilience. Strengthening scientific forest management practices along with active involvement of local communities can significantly contribute to long-term conservation and sustainable restoration of Chir Pine ecosystems in the Himalayan region.

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