



Forest Fire Hazards and Livelihood Vulnerability Assessment of Ghumsur Forests in Ganjam District of Odisha

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ABSTRACT

Background: The livelihood patterns of indigenous tribal communities residing in the Ghumsur forests are intricately interwoven with their dependence on forest-related activities. However, the degradation of forest ecosystems, particularly the incidence of forest fires, exerts a profound impact on the socio-economic dynamics and resilience of these communities. Consequently, an exigent need arises to comprehensively elucidate, evaluate and comprehend the nuanced characteristics of these areas concerning the complex interplay between forest fires and livelihoods.

Methods: A thorough investigation was conducted to evaluate livelihood vulnerability to forest fires in the Ghumsur North Division forests. This assessment utilized the Livelihood Vulnerability Index (LVI), incorporating 34 indicators condensed into six factors for a comprehensive composite index. The factors represented various aspects of vulnerability and were based on tangible indicators reflecting the complexity of livelihood vulnerability. Data sources were primarily used, with indicators standardized on a scale from 0 to 1, where values near 1 indicated higher vulnerability.

Result: The Gallery sub-region is particularly vulnerable due to factors like poor infrastructure, increased reliance on forests, close proximity to forested areas, socio-economic fragility and exposure to extreme weather events. It's crucial to improve adaptive capacity in fire-affected regions to reduce vulnerability to forest fires. Tailored policy interventions should focus on sector-specific development programs and involve communities in adaptation planning to address the link between livelihoods and susceptibility to forest fires.

Key words: Forest fire, Forest, Livelihood, Tribal.

INTRODUCTION

Forests are vital for environmental and human well-being, absorbing carbon dioxide, supporting biodiversity, protecting water catchments (Rajasugunasekar *et al.*, 2023) and providing economic benefits through various functions for humans while also serving as habitat for biodiversity and recreational opportunities (Raut, 2004). Rural populations in countries like India and Pakistan depend on forest resources for jobs (Ali *et al.*, 2020) like gathering fuelwood, wild foods and fodder to support their livelihoods (Vedeld *et al.*, 2007). While this forest income helps reduce poverty, it also poses environmental risks, highlighting the need for alternate income sources linked to factors such as education levels, family size and regional opportunities (Hussain *et al.*, 2019).

Research indicates a global rise in forest area removed by wildfires, particularly in Africa and Eastern Asia (Tyukavina *et al.*, 2022). Wees *et al.*, (2021) found that 38% of global forest loss is due to fires, with regional variations. Chuvieco (2019) emphasizes the impact of biomass burning on ecosystems and the urgent need for improved burn area estimation methods. Additionally, Lierop *et al.*, (2015) discuss various forest disturbances, including wildfires, insect infestations, diseases and severe weather events, exploring their connection to forest loss.

Multiple factors, including natural and anthropogenic causes, have been identified as contributing to forest fires.

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Sevinc *et al.*, (2020) demonstrate that temperature and the month of the year are the most influential variables in predicting the causes of forest fires, with lightning strikes emerging as a significant natural instigator. The association between lightning and forest fires has also been explored by Moris *et al.*, (2020), while Moris *et al.*, (2020) emphasize the crucial role of human activities, such as land use practices and conflicts, in igniting forest fires.

India, specifically its northern, northeastern, central and southern regions, has witnessed a concerning escalation in the frequency and severity of forest fires, resulting in significant economic and environmental

ramifications (Sewak *et al.*, 2021). Notably, Uttarakhand's pine forests are particularly vulnerable to fire incidents, leading to biodiversity loss and disruptions in ecosystem services (Binjola *et al.*, 2022). The year 2016 witnessed a pronounced exacerbation of forest fires in Uttarakhand, causing extensive destruction of forested areas and resulting in human casualties, primarily attributed to adverse climatic conditions and anthropogenic factors (Dwivedi, 2018).

A study by Mishra *et al.* (2022) links forest loss in Odisha's Nabarangpur, Puri, Kendrapara and Kalahandi regions to mining activities, impacting biodiversity and indigenous communities. Notably, the discovery of *Exacum paucisquamum*, a plant species closely associated with tree canopies, in the Bonaigarh forest section Kumar *et al.*, (2022) has underscored the critical importance of forest fire prevention in the area. Chandra *et al.* (2022) emphasize conserving Odisha's tree species to protect endangered flora. Urgent sustainable land-use and conservation measures are crucial for safeguarding the region's biodiversity and forests.

The rapid industrialization and extensive deforestation during the 20th century have accelerated climate change, making it a critical global environmental challenge in the 21st century. Tribal communities view climate change and the degradation of natural resources as significant factors contributing to their vulnerability (Shukla *et al.*, 2023; Prakash *et al.*, 2020). The occurrence of forest fires in

Ghumsur, Odisha represents a significant and potentially escalating issue (Behera *et al.*, 2024). In this regard, Shashi, (2017) sheds light on the increasing occurrence of forest fires in Odisha, particularly in densely populated tribal areas and specific plant species. This escalating trend raises concerns, particularly in light of the potential exacerbation of the situation due to anticipated climate change impacts in the future.

This study uses an index-based approach to assess community vulnerability to forest fires in the Ghumsur forests. The aim is to develop a tailored vulnerability index for the area, bridging local needs with policy-making. The index offers recommendations for collaborative efforts to enhance resilience against natural and human-induced risks. Integrating local insights can lead to more effective policies and planning at higher levels, contributing to a better understanding of social vulnerability in the region.

MATERIALS AND METHODS

Study area

The study area, Ghumsur's forests North Division in Ganjam District, Odisha, is located between latitudes 19°43' to 20°18' N and longitudes 84°21' to 84°50' E. It spans 2,360 sq km, with 40% covered by forests (948 sq km). Fig 1 shows five highlighted zones (R1: Mujagda, R2: Central, R3: Gallery, R4: Tarsing, R5: Jagannath Prasad).



Fig 1: Study area.

The Ghumsur forests of Odisha support indigenous tribal communities like the Kondh, Dongria Kondh and Kutia Kondh who rely on forest resources for livelihood through activities like non-timber product collection and shifting cultivation ("Podu"). Other communities in the area engage in non-forest-related activities such as agriculture, fishing, wage labor in industries, or services, with limited dependence on forest resources.

The households are scattered across the aforementioned five zones. Therefore, a minimum of five households were selected for interviews in each zone, with all households being selected from each village. The total number of participants from R1, R2, R3, R4 and R5 were 10, 20, 15, 5 and 5, respectively. All interviewed households were surveyed after the fire incidents (July-October).

The interviews were conducted in Hindi and the local dialect by researchers themselves, with the support of a local colleague. Typically, interviews were with the head of the household; if absent, the spouse or eldest member was interviewed. An interview schedule was used to ensure consistency and avoid relying on climatic models. Comprehensive insights on livelihood strategies and climatic fluctuations were gathered through discussions with local residents and peers. Each interview averaged 30 minutes. Data was systematically collected using a meticulously developed survey questionnaire covering social, demographic and livelihood aspects, infrastructure, agriculture, water consumption, natural resources and extreme events. Information gathered was coded, cleaned and analyzed using MS Excel and SPSS software. The period of study in this article was in 2024 (from January to March).

The theoretical framework

To ascertain the key factors impacting the livelihoods of the study sample due to forest fires, the Livelihood Vulnerability Index (LVI) was crucial. Developed through consultations with academics, forest fire experts and affected households, this composite indicator integrates social, economic and natural elements. A structured interview schedule, covering demographics, livelihood strategies, agriculture, water sources, natural resources and past fire impacts, was utilized.

The demographic information gathered from respondents included data on the number of affected family members, income, occupation, housing type, livestock ownership, educational background, access to electricity and sanitation facilities. The livelihood strategies section included information on crop diversity, ability to regenerate after burning, timing of agricultural activities, availability of assistance, access to markets, distance from main roads and ability to afford healthcare costs. Additionally, the interview schedule collected data on agriculture, such as land ownership and size, agricultural assets, dependence on agriculture and food self-sufficiency. It also inquired about drinking water sources in cases of reliance on natural water sources. Furthermore, the questionnaire included

information on natural resources (pasture, firewood, fruit cover, leaves) and the extent of the impact of previous fires (severity of damage from past fires on individuals, occurrence of diseases and family deaths).

As previously explained, each of the main factors consists of a set of quantitatively measured indicators. The data was divided according to each forest range into five categories to compare these ranges and determine which range is more vulnerable to fire impacts. This information is beneficial for policymakers and the local community.

Consequently, five factors were formed, corresponding to 34 indicators that make up the main profile of the vulnerability index. All indicators were measurable and comparable across the five ranges. The value of the vulnerability index increases as the susceptibility of the population to fire impacts increases compared to the value of the lowest indicator and vice versa.

$$\text{Index } F_i = \frac{S_v - S_{\min}}{S_{\max} - S_{\min}}$$

Here, S_v represents the average value of the indicator, while $S_{\min}$ and $S_{\max}$ represent the minimum and maximum values of the indicator, respectively, at the respondent level in the studied sample. The average of all indicators, M_v , was calculated to obtain the value of the main factor according to the following equation:

$$M_v = \frac{\sum_{i=1}^n \text{index}}{n}$$

The livelihood vulnerability index (LVI) was calculated as follows:

$$\text{LVI} = \frac{W1.Mv1 + W2.Mv2 + W3.Mv3 + W4.Mv4 + W5.Mv5 + W6.Mv6}{W1 + W2 + W3 + W4 + W5 + W6}$$

Here, $W1-6$ represents the number assigned to each LVI indicator.

RESULTS AND DISCUSSION

This section covers the evaluation of the six problematic factors of the Livelihood Vulnerability Index (LVI): 1) demographic characteristics, 2) livelihood strategies, 3) agriculture, 4) drinking water, 5) natural resources and 6) the extent of the impact of previous fires. Additionally, the constituent indicators for each factor will be explained. The results indicate that each forest area is affected differently by fires compared to others.

Demographic characteristics

The study found that household attributes in the Gallery rang make it more vulnerable to economic risks compared to other districts due to larger household sizes (0.612) and limited employment opportunities (0.412). Despite higher educational attainment, Gallery households living in thatched, wooden-roofed dwellings face increased fire risk.

Both Gallery and other ranges see over 70% of rural populations relying on livestock, impacting milk production and increasing pressure on forests for fodder. Access to basic amenities like sanitation and electricity is crucial for rural adaptability, with toilet access particularly limited in the Galleri area (0.331). Lower electricity access (0.512) in affected areas further hinders social, economic and health benefits (Table 1).

Livelihood strategies

The Gallery rang is highly impacted by forest fires, requiring additional strategies to cope with these events. Both Gallery and other districts have implemented various mitigation strategies, such as crop diversification and cultivation timing, which are crucial for adaptive capacity. Gallery's vulnerability is due to underdeveloped infrastructure (0.139) and limited connectivity to fire protection, leading to longer market access times (0.218) and reduced healthcare services availability during fire incidents (0.3169). Technical support and modern agricultural practices are lacking, underscoring the need for a dedicated forest policy to enhance agricultural practices (Table 2).

Agriculture

The agricultural sector plays a key role in supporting rural livelihoods, especially in communities where it is a vital source of sustenance. Agriculture in India is culturally significant and benefits from favorable climates for rice cultivation. The majority of survey respondents (85%) are small-scale farmers reliant on rain-fed agriculture, facing uniform vulnerability to fluctuations in rainfall. In the Ghumsur forest, recurring forest fires pose challenges to orchards and summer crops, impacting soil health and nutrient levels. Additionally, in the Gallery range, agricultural productivity in less fertile areas struggles to meet local food needs (0.441), heightening concerns around food sufficiency (Table 3).

Drinking water

Forest fires result in the emission of carbon, suspended solids, organic particles and nutrient-rich substances, leading to water pollution. The more households in the Galleri region rely on contaminated water sources, the greater the negative impact. With increased infrastructure, water

Table 1: LVI results of demographic factor.

Indicator	Mujagda	Central	Gallery	Tarsing	Jagannath prasad
Number of affected family members	0.323	0.415	0.612	0.511	0.421
Income	0.245	0.111	0.355	0.212	0.325
Occupation	0.315	0.321	0.412	0.144	0.124
Type of housing	0.333	0.147	0.222	0.321	0.128
Ownership of livestock's	0.112	0.241	0.256	0.255	0.117
Education background	0.314	0.361	0.241	0.387	0.301
Access to electricity	0.413	0.335	0.512	0.211	0.114
Sanitation facilities	0.221	0.210	0.331	0.214	0.215

Source: Research field.

Table 2: LVI results of livelihood strategies.

Indicator	Mujagda	Central	Gallery	Tarsing	Jagannath prasad
Crop diversity	0.321	0.11	0.321	0.114	0.112
Ability to regenerate after burning	0.001	0.108	0.221	0.241	0.112
Timing of cultivation	0.102	0.116	0.321	0.121	0.001
Availability of assistance	0.123	0.114	0.222	0.11	0.212
Access to markets	0.111	0.153	0.218	0.119	0.123
Distance from main roads	0.141	0.023	0.139	0.111	0.110
Ability to bear healthcare costs	0.114	0.014	0.316	0.221	0.117

Source: Research field.

Table 3: LVI results of agriculture factor.

Indicator	Mujagda	Central	Gallery	Tarsing	Jagannath prasad
Land ownership	0.111	0.011	0.332	0.211	0.124
Land size	0.221	0.111	0.321	0.226	0.3
Agricultural assets	0.214	0.212	0.255	0.113	0.111
Dependence on agriculture	0.221	0.225	0.325	0.201	0.101
Food self-sufficiency	0.111	0.251	0.411	0.211	0.123

Source: Research field.

collection times in Galleri range from 0.6 to 1.2 hours, rising to 0.7 to 1.4 during summer (0.314) (Table 4). This has led to intensified collection activities, deteriorating water quality from natural sources and the appearance of black sprouts and taste changes post-forest fires (0.321). Water scarcity worsens during summer, especially in regions affected by disasters (0.222), due to heavy dependence on natural water sources.

Natural resources

Forests are vital for sustaining livelihoods, especially for economically disadvantaged populations in forested areas. Indigenous tribal communities in Ghumsur forests of Odisha heavily rely on Non-Timber Forest Products like firewood, grasses, Mahua flowers and medicinal commodities for economic sustenance. These resources support income-generating activities and meet non-monetary needs by providing essential ecosystem services like soil erosion prevention and water provisioning. Implementing sustainable forest management practices is crucial to preserve ecological balance, safeguard biodiversity and enhance community resilience in the face of challenges.

The increased demand and unsustainable harvesting of natural resources have deteriorated forests in various regions. Collecting fodder and fuelwood now takes 5 to 6 hours per day in studied areas, up from 2 to 3 hours. Residents in fire-prone regions report a rapid depletion of resources. The distance between villages and forests has

grown over the past 8-10 years, intensifying challenges. Forest fires, mainly caused by human activities, have worsened in the Ghumsur forests over the past 7-8 years. Natural factors play a small role, with 10% of fires attributed to temperature, wind, moisture, humidity and dry spells. Other factors like forest composition, topography and soil also influence fire dynamics (Table 5).

Impacts of previous extreme events

Households near Ghumsur forests face heightened vulnerability due to reliance on and proximity to fragile ecosystems. The Gallery and Central ranges, prone to forest fires, show slightly higher vulnerability levels (0.551) with the Gallery exhibiting greater vulnerability. Climate variability compounds the region's fragility and increases exposure to fires, causing injuries, illnesses and fatalities among local populations (Table 6).

- Based on the results obtained, it is recommended that immediate attention and targeted interventions be directed towards the Gallery sub-region. To address these vulnerabilities effectively, it is crucial to prioritize the following actions:

Infrastructure improvement

Enhancing the infrastructure in the Gallery sub-region is essential to bolster its resilience against external threats. Investments in road networks, communication systems and utilities can significantly improve the area's capacity to withstand challenges.

Table 4: LVI results of drinking water factor.

Indicator	Mujagda	Central	Gallery	Tarsing	Jagannath prasad
Usage of natural water	0.212	0.122	0.351	0.001	0.222
Collect of natural water	0.211	0.111	0.314	0.12	0.021
Degradation of natural water	0.211	0.144	0.321	0.111	0.211
Supply of water	0.211	0.211	0.222	0.211	0.122

Source: Research field.

Table 5: LVI results of natural resources factor.

Indicator	Mujagda	Central	Gallery	Tarsing	Jagannath prasad
Fodder and fuelwood collection	0.112	0.111	0.247	0.114	0.114
Forest-based energy	0.214	0.112	0.324	0.182	0.211
Firewood collection	0.156	0.167	0.213	0.111	0.147
Fodder collection	0.175	0.159	0.211	0.122	0.124
Natural resources depletion	0.126	0.147	0.214	0.011	0.111
Natural resource diversification	0.118	0.114	0.321	0.114	0.211

Source: Research field.

Table 6: LVI results of effecting by previous natural calamities factor.

Indicator	Mujagda	Central	Gallery	Tarsing	Jagannath prasad
Forest fire	0.222	0.321	0.551	0.111	0.141
Climate stress	0.213	0.325	0.512	0.211	0.115
Injury or new diseases	0.225	0.211	0.541	0.112	0.211
Family death	0.266	0.321	0.452	0.211	0.212

Forest management strategies

Implementing sustainable forest management practices and reducing reliance on forests can help mitigate environmental degradation and enhance the region's long-term sustainability.

Community engagement and support

Engaging with local communities in the Gallery sub-region is vital to understanding their needs and vulnerabilities. Providing socio-economic support and empowering residents can strengthen their resilience to external pressures.

Disaster preparedness and response

Given the area's exposure to extreme weather events, developing robust disaster preparedness plans and response mechanisms is critical. Training local authorities and residents in emergency protocols can minimize the impact of such events.

By addressing these recommendations proactively, stakeholders can work towards enhancing the resilience and sustainability of the Gallery sub-region, ultimately improving the well-being and livelihoods of its inhabitants.

CONCLUSION

Rural communities in developing countries, particularly forest-dependent ones in the Gallery range, are vulnerable due to reliance on natural resources, poverty and marginalization. Boosting employment through diversification programs, involving NGOs and providing education can enhance resilience by improving livelihood opportunities, decision-making and reducing reliance on subsistence. The Ghumsur forest vulnerability is exacerbated by growing dependence on forests and agriculture, requiring advanced interventions and improved techniques. Government assistance should involve compensating, distributing seeds, providing training, offering interest-free loans and implementing crop insurance. Combating rural poverty involves incentivizing contributions to ecosystem services, especially for fire prevention. Enhancing fire prevention efforts and utilizing advanced monitoring technologies are vital. Implementing forest farming practices and promptly restoring fire-damaged lands are crucial for protection. Engaging local communities actively and sharing information on the impact of forest fires on livelihoods are essential.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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