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Original article

# Burning forests, drying springs: local perceptions and the changing Himalayan ecosystem in Uttarakhand, India

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ABSTRACT

The change in the Himalayan Forest landscape is not just an ecological concern but also a deeply social one. Chir Pine's (*Pinus roxburghii*), once planted and promoted for timber value and economically important has now disrupted the ecological balance of the region. This study investigated the rural perceptions of local residents of Himalayan villages in the state of Uttarakhand, India, revealing Chir Pine's dominant nature and aggressive spread. The voices of villagers echoed this aggressive spread, raising concerns about its far-reaching impacts on the region's climate-forest interactions. The study utilised qualitative ethnographic fieldwork with a theoretical framing deduced from political ecology. The fieldwork was conducted between 2023-24 in Uttarakhand, which included a sample size (n=110) across 12 Himalayan villages with a blend of in-depth interviews, focus group discussions, and participant observations. The study explored how local communities interpret this ecological and climatic shift. The findings suggest that Chir Pine not only alters landscapes but also community ecological memories, rural people, agricultural patterns, and rural ecological knowledge systems. The local people's perceptions narrate their experiences of disappearing springs, decreasing fodder availability, increasing forest fires, and the slow death of mixed forests turning into Chir-dominated forests. Rather than treating local perceptions as anecdotal, this study positions them as critical data points that offer early warning signs of broader socio-environmental and climatic stress.

KEY WORDS: Himalayan Forests, Chir Pine (*Pinus roxburghii*), rural perceptions, Political Ecology

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## 1. Introduction

The variable climate of Himalayan forests and extensive biodiversity are the silent guardians of countless forest-dependent communities. Communities in the Himalayan region possess knowledge of their surroundings, they recognize shifts in biodiversity, water sources, and forests well before such changes are formally documented (Reyes-García et al., 2024). Many such changes are sensed from experiences and are remembered in the stories of mountain communities. Several studies have revealed that the perceptions of rural people sooner or later align with the recorded changes like temperature increase, rainfall variability, perceptions about availability water resources (Platt et al., 2021; Sharma & Shrestha, 2016; Uprety et al., 2017; Vedwan & Rhoades, 2001). Similar perception-based approaches have been widely used to examine the socio-economic and environmental implications of dominant plant species in Indian biodiversity, capturing how local communities interpret ecological change (Rai & Vanlalruati, 2022). The perceptions of forest change and climate variability often serve as early warning indicators

of climatic disturbance (Lehner & Stocker, 2015). This study explores how such shifts are understood and narrated by the people living through these changes, particularly concerning the impact of the increasing dominance of Chir Pine (*Pinus roxburghii*, one of the most important conifers in the Himalayan region) (hereafter referred to as Chir) in the lower-middle Himalayan region. Through a political ecology lens, this article builds on the local rural perceptions of this silent yet aggressive spread of Chir trees and the associated impacts on daily life, agriculture, and climate.

Ecologically, the Himalayan region is covered in tropical and temperate forests, which includes a variety of tree species, including evergreen and deciduous trees. Apart from Chir pine, other tree species in the region include *Cedrus deodara* (Deodar), *Myrica esculenta* (Kafal), *Quercus leucotrichophora* (Banj-Oak), and *Rhododendron arboreum* (Buransh) (Bisht & Bhatt, 2016). Chir, once planted and promoted for timber value, was considered ecologically and economically important, but has now disrupted the ecological balance of the region (Nautiyal, 2015). Historical instances have shown that the spread was intentionally driven by colonial forestry practices, which prioritized commercial timber value over ecological balance, and were later reinforced by state-led afforestation schemes that favoured quick-growing monocultures (Guha, 1985; Richardson, 1998). This led to their aggressive spread, displacing other native species like Banj-Oak (hereafter Banj), critical for water retention and ecological balance (Bisht, 2021; Nautiyal, 2015). Thus, it becomes imperative to understand the spread of Chir and its impact on the climate, society, agriculture, and geohydrology in the Himalayan region of Uttarakhand.

In this research, we conducted ethnographic fieldwork across the villages of Garhwal and Kumaon. The theoretical framework of political ecology was utilized to develop an understanding of the multi-faceted impacts and explored how ecological change is never neutral. The results call for grounded, participatory approaches to forest governance that benefit not just biodiversity, but also the voices of those who live within the forest.

### 1.1. Study region

The study was located in Uttarakhand, a predominantly rural and mountainous state in the Indian Himalayas. Uttarakhand covers around 1.6% of India's total geographical area (India State of Forest Report (ISFR), 2019; Uttarakhand Biodiversity Board (UBB), 2023), with an estimated population of 1.22 crore, of which 69.77% live in rural areas. Forest dominates the landscape, covering roughly 64 to 71% of the Uttarakhand state's geographical area of 53483 sq. km (ISFR, 2019; UBB, 2023; Census of India, 2011). Due to its mountainous terrain, the climate is mostly temperate, becoming tropical in the plains. The average annual rainfall is 1550 mm (UBB, 2023), with snowfall being sporadic and limited to areas above an elevation of 1800-2000 m. The mean annual temperature ranges between 13 and 18°C in the elevation belt of 1000-2000 m.

To understand long-term ecological imbalance and its impacts, samples were collected from two districts, Pauri Garhwal and Almora (Fig. 1), in the unique geographical setting of Garhwal and Kumaon Himalayas, respectively. Pauri Garhwal, situated in the Garhwal division of Uttarakhand, has 15 administrative blocks, with its headquarters at Pauri located at a height of 1650 m., and has a population of 687271 (District Administration Pauri Garhwal, 2024), with 59% of the total district land as forest area. Almora, a district in the Kumaon division of Uttarakhand, is situated at 1,638 meters above sea level, with a total population of 622506, and 41.6% of the total district land as forest area (District Administration Almora, 2024). The study focused on the regions across varied altitudinal belts between 500-2000 meters. The two geographical divisions of Garhwal and Almora are chosen to support the local perceptions, which are not limited to one region, but also echoed across other regions that face similar climatic and ecosystem impacts.

## 2. Literature insights and theoretical perspectives

A literature review was organized to study the association between the dominant nature of pine and its impact on climate and society. The literature review is divided into sections. First, the socio-ecological consequences of species showing invasive tendencies, with instances from the world. Second, discussing the spread of Chir pine and its impacts on natural ecosystems, and later, impacts on human societies. The final section explores the link with the theoretical foundation of Political Ecology.

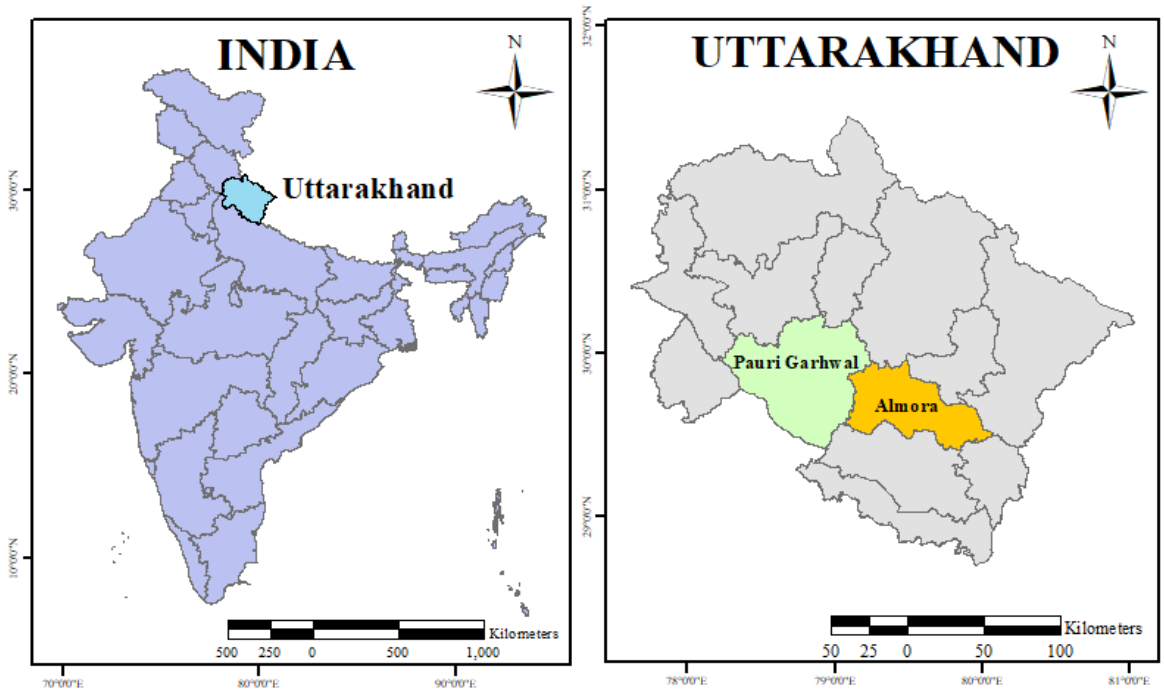


Fig. 1. Map showing the districts of the study region (Source: created by authors)

### 2.1. Instances from the world

The notion of the aggressive spread of pine species is not new; several scholarly works have noted the spread and its impacts. Pine dominance has obstructed efforts to conserve other native species (POLICELLI ET AL., 2023) and also altered fire regimes, impacting the local traditional way of living and livelihoods. Over the past two decades, many nations have observed the dominant nature of pines, and millions of dollars have already been spent on restoration efforts (POLICELLI ET AL., 2023). In the southwestern United States (US), native species have expanded their range and altered fire regimes (ARCHER, 1989). Many species of the pine family have been identified as invasive, species like Scots pine (*Pinus sylvestris*), Monterey pine (*Pinus radiata*), Ponderosa pine (*Pinus ponderosa*), Austrian pine (*Pinus nigra*), and lodgepole pine (*Pinus contorta*), have already been identified as aggressive post-disturbance colonizers (GLOBAL INVASIVE SPECIES DATABASE (GISD), 2024). Pines tend to spread into abandoned agricultural lands; instances from north-eastern Europe and the southeastern US show that pines have invaded such sites within 10 years of abandonment, a similar issue in Chile has been noticed, where plantations of Pine have invaded natural ecosystems (RICHARDSON, 1998), and such encroachments impact the biodiversity and the local environment.

### 2.2. Replacement of Banj-oak forest with Chir-pine

In the Central Himalayan region, one of the dominant species of Chir trees is replacing the Banj tree (NAUTIYAL, 2015; SINGH & SINGH, 1986). The scholarly works also mentioned the plantations of Chir trees against Banj trees, as *"Chir grows faster as compared to Banj and other miscellaneous species, the inferior broad-leaved species will be replaced by valuable ones, the larger oaks will be removed before the fellings, to facilitate better Chir reproduction. Chir trees spread into extensive Banj forests areas"* (GUHA, 1985: 5). Himalayan local communities hold a firm belief that the native broadleaf forests offer superior water provisioning services compared to the monoculture Chir forests (DAS ET AL., 2019). The comparison of forest soils around Banj with those around Chir show moisture and nutrient-deficient sites around Chir in the lower and middle Himalayas (KUMAR ET AL., 2013; MANRAL ET AL., 2020; TYAGI ET AL., 2023). The lack of comprehensive environmental and historical bioclimatic data and the influence of political sensitivities lead to significant gaps in knowledge and understanding. Chir hinders the development of climate change adaptation strategies (SOLARZ ET AL., 2023). Looking at this through a political ecology lens reveals that these challenges reflect the complex interplay between environmental

governance, power dynamics, and socio-political structures.

### 2.3. Theoretical framework

Political Ecology provides the theoretical foundation to understand the ecological aspect associated with arising environmental issues, the conservation and control of resources, and efforts towards sustainability (ROBBINS, 2020). Political Ecology allowed us to analyze groups which benefitted from the spread of Chir, and the impact of the perspectives of the involvement of local communities (TAYLOR, 2015). The narrative of arising environmental issues further scrutinizes the ecological interconnections and how they are deeply intertwined with historical perspectives of the Himalayan regions. This notion of ecological interconnections had shaped the region's environmental landscape (BLAIKIE, 2008). The narratives around arising environmental issues and ecological interconnections provides a counter-discourse to prevailing explanations of deforestation or ecological change, revealing that even environmental change is socially and politically constructed to the advantage of powerful people, further relating it to the dominance of Chir (PEET & WATTS, 2004). Interpreting the case of the aggressive spread of Chir in Pauri Garhwal and Almora, it appeared that it is not just an ecological issue but also a political-economic one, with a focus on prioritizing the economic value of Chir for timber and resin (GUHA, 1985). The state-led afforestation favoured commercial interests over the multiple environmental and social needs.

This theoretical apprehension conceptualized the environmental changes such as disrupted traditional water sources, degraded agricultural land, and ecological shifts like changes in local climate-forest interactions (BLAIKIE, 2008). This article focuses on the importance of local knowledge, and political ecology centres perceptions based on everyday narratives (ROBBINS, 2020). The political ecology framework helps in explaining the impact of Chir's aggressive nature within the broader context of environment-driven transformation and climate-forest interactions across distinct socio-ecological settings.

## 3. Methodology

This research employed a qualitative approach that explored lived experiences and perceptions of local communities, and examined their socio-economic, agricultural, and eco-hydrological contexts. The study deliberately shifts from treating ecological change as purely scientific, and instead provides a narrative from local residents. Primary data was collected through ethnographic fieldwork (carried out in 2023-24), and used participant observations, in-depth interviews, and focus group discussions (FGD). Purposive sampling was chosen for the study, which was determined based on the notion to capture diverse perspectives across villages, and also accounted for their social, agricultural, and environmental impacts. Fieldnotes were organized by age, gender, themes, and occupational demographics.

The analysis followed a thematic approach, which began with the careful translation of transcripts and fieldnotes, which captured the emerging broad themes around the perceived changes in forest types, water in the natural water streams, local climates with increasing summer temperatures and forest fires. After detailed reviewing and refining, patterns were drawn to reach the final themes. The themes were then identified through cross-checking between interview data, FGDs, and field observations, and were further triangulated with secondary sources. The primary criteria for participant selection included the extent of their ecological memory of the village based on their long-term residence in the village, which was attained with the help of samples across different age groups and thus with people having different experiential knowledge. The key informants helped in the initial interactions with the residents. Participants were selected based on their everyday work associated with forests, water sources, and agricultural land. Women were deliberately included in the study and several FGDs were women-only to create space for gendered narratives (e.g., on fuelwood collection, water fetching/carrying, and burden of household works). The principle of data saturation was applied while surveying the villages and while conducting in-depth interviews and focus group discussions. The principle helped in establishing boundaries during interviews and the repeated experiences, perceptions and emerging patterns in participants' perceptions guided the decision on when to stop data collection. The sample size also varied from village to village, depending on the diversity of the population in the remote villages; thus, the approximate sample size reached 110 across 12 villages, as shown in Fig. 2. Villages were selected on the basis of the presence of a natural water source, village population, and

nearby visible Chir or broadleaf forests. The villages selected had more than 10 households, having taken into account the nature of the topographically scattered and clustered settlements in the mountain regions. To understand, analyse, and correlate findings, the triangulation method was employed by combining ethnographic observations and the experiences of participants. The data collected across three age groups further validated the changes in the ecosystem based on the ecological memory of local people. Table 1 provides an overview of the sites in the study region, along with the sample sizes (not the households).

Table 1. Description of study region sites (Source: Field visit by the authors during 2023-24)

| | Number of villages | Total sample population | Male | Female | Age ≤ 35 | Age 36–55 | Age ≥ 56 |
|---|---|---|---|---|---|---|---|
| Pauri Garhwal | 6 | 60 | 26 | 34 | 12 | 26 | 22 |
| Almora | 6 | 50 | 24 | 26 | 9 | 23 | 18 |

## 4. Results

This section probes into the local perception of the spread of a single species of Chir pine and its potential impact on the natural functioning of the climatic and eco-geo-hydrological cycles of the region. It further focuses on people's perceptions based on the impacts of the spread of the Chir pine in comparison with Banj, and the altered forest-fire regimes. During focus group discussions, especially with elders, one narrative echoed across both districts: *"Our hills were once filled with Banj, Buransh, and Kafal. There was always water in the Gadhera (sloped small streams, which are vital in providing fresh water to villages, supporting local agriculture, and contributing to the region's overall water system). Now they are dry, and only Chir trees remain"* (*Fieldnotes*, 2023-24*).* This memory was shared, repeated, and mourned, and forms the basis of how communities comprehend this ecological change.

### 4.1. Perceived changes in climate and forests

There was climate change long before there were humans, and the myriad impacts of climate change are leaving an imprint on every aspect of human life (CALVIN ET AL., 2023). The climate change perceptions gathered through in-depth interviews and FGDs were focused on the relationship between climate change and the spread of Chir as attributed by respondents. The communities consider this to be an aggressive spread and should be taken as a warning sign of deeper climatic imbalance, as the elderly group particularly shared their experiences of changes. People recall that Banj and mixed forests were cooler with more soil moisture, resulting in streams and springs which lasted longer in the summer.

Elderly respondents narrated the spread as evidence of noticeable changes in the local climate. They believed that rising temperatures and changing precipitation patterns created favourable conditions for the expansion of Chir on the areas which were previously dominated by broad-leaf forests. A recurring sentiment among participants, discussing the dominance of Chir across villages, expressed that *"Chir is not a native but a destroyer of Banj Forests"* (*Fieldnotes,* 2023-24). These perceptions are summarized in Fig. 2, and are based on the changes noted in the extent of the Chir vegetation and associated impacts from Pauri Garhwal and Almora. Overall, 85% of respondents perceived an increase in Chir vegetation (n=110).

Villagers associate the dominance of Chir with increased soil dryness, reduced biodiversity, and an increase in forest fires. Forest fires have emerged as a major hazard and a challenge for the local people. Fire not only destroys biodiversity but also disrupts the traditional livelihoods that depend on forest resources. Respondents believe fires are both a result of rising temperatures and human negligence. The fire spreads quickly through the wind, dried leaves and burning pine cones which fall on surfaces and roll downhill onto the lower slopes. Also, about 82% of respondents claimed there had been a significant increase in the number of forest fires (Fig. 2). According to locals, even a small piece of bark remains with a little fire spark burns for longer. The increased frequency and intensity of forest fires undermine the resilience of local communities that rely on the forest for their livelihoods. In an FGD-5 with women in Almora, their voices shared what they have been seeing for

ages: *"Whenever there's a forest fire, it spreads even more. The fire destroys our broadleaf trees, but Chir somehow survives, and once the fire is over, it's the first to come back. The Banj turn to ash, but Chir stands tall again"* (*Fieldnotes,* 2023-24). Participants showed an ecological awareness, but they did not frame Chir's dominance in technical terms. The observed experiences echoed: *"This Chir, it grows where nothing else does, even on bare rocks or dry soil where no other tree dares to grow, Chir takes over,"* said an elderly man from Pauri, as he gazed at the slopes that once flourished with mixed trees *(Fieldnotes,* 2023-24). For locals, forest fires are therefore understood not merely as natural disturbances, but as recurring incidents impacted by the dominance of Chir.

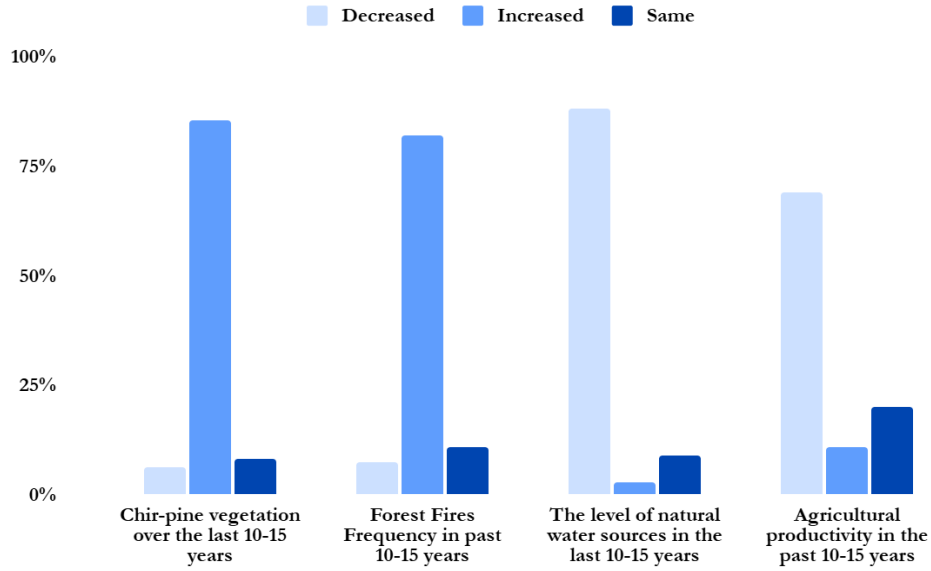


Fig. 2. Respondents' perceptions of changes in Chir vegetation and related impacts (n=110) (Source: Fieldwork observations, 2023-24); *Perceptions and percentages indicate the proportion of respondents who perceived the listed changes and are based on fieldwork responses, they do not represent direct ecological measurements

4.2. Hydro-ecological impacts and water availability

Following the perceptions of forest and fire dynamics, this section examines how communities relate these changes to shifts in water availability. Respondents shared that springs are drying up early, and many small water sources have completely disappeared. This change, in the villagers' view, is linked to the changing forest cover. Several residents echoed the same thought: *"In Banj forests, it used to be cool, water stayed, but in Chir forests, everything dries up, soil, air, and even water"* (*Fieldnotes,* 2023-24). *The* elderly group also shared that *"the mountain slopes of the villages used to be covered with Banj majorly, it kept our natural Gadhera flowing, but now it's just a thick layer of dry pine needles"* (*FGD-3, Fieldnotes,* 2023-24). The respondents from Pauri Garhwal spoke about the gradual drying of *Gadheras* in the past decades, owing to an increase in the dominant Chir forest landscape. During *FGD-2 and FGD-1*, respondents had consistent stories about the gradual drying up of traditional water sources, and stating that in the past, they used to flow throughout the year. Such observations are also directed towards the ecohydrological impact of Chir. Respondents during FGD-4 shared that the Chir's roots don't hold water the way broadleaf trees (Banj trees) used to. Across both of the regions, the rapid increase in Chir and the decline of mixed broad leaf forest resulted in reduced water levels in *Gadhera*. 88% of the respondents (Fig. 2) also narrated the same experience of significant decrease in the natural water sources.

The in-depth interview with a government official from the agricultural department, who had grown up in the region, also revealed that *"Earlier, cattle would graze freely under the oak forests. Now, Chir needles cover everything, making the area dry, sharp, and slippery. Cows slip on them and get hurt. We've even fallen on those slopes. The green grass gets buried beneath these needles, so the animals don't find food. And when it rains, the water doesn't reach the soil properly; it soaks into the dry Chir carpet instead, and our Gadheras dry up. It's not just the trees that changed, our whole way of living is disappearing"* (*Fieldnotes,* 2023-24). The insights

revealed that the thick carpet of dry pine needles, which makes the soil drier and slippery, is hindering the natural seepage of rainwater into the ground. Women, in particular, often spoke about walking longer distances due to the drying springs, which increased the burden of taking their livestock longer distances in search of good fodder and natural water sources. Overall, the villagers' voices have one commonality, the growth of Chir and the decline of broadleaf species are not just environmental changes, but they are changing how people live, farm, and access water. They believed that the change in forest composition, combined with broader climatic shifts, deteriorated the natural water stream, impacted the rejuvenation process, and altered daily practices related to farming, herding, and household water use.

### 4.3. Livelihoods, agriculture, and everyday life

Changes in forest composition impact everyday livelihoods, particularly agriculture, fodder collection, and livestock management. Women who collected wood for fuel and fodder reported an additional travel distance of 3-4 km to collect broadleaf fodder compared with ten years ago. Respondents also highlighted the shift in forest cover from broadleaf-dominated mixed forests to Chir monocultures. During an FGD-6 and 7, with local farmers in Almora, they shared about the shift to alternative agriculture instead of food crops, as food crops require more water, and are highly dependent on rain or groundwater. It revealed that people are no longer interested in agriculture due to lower productivity, while such annotations were further discussed with villagers, they echoed the overlapping opinions regarding agricultural productivity, as shown in Fig. 2, with 69% of the participants reporting a decrease in agricultural productivity. A farmer shared his observation when he walked towards his field, *"The soil under the Chir tree feels hotter and slippery. Back when we had more broadleaf trees, the soil used to stay moist and cool. Now, the rain also runs off, and landslides have increased"* (*Fieldnotes,* 2023-24). Livestock grazing was also described as increasingly difficult, with dense layers of pine needles covering pasture grasses and creating slippery ground for animals.

The common sentiment perceived by people is that Chir is an ecological threat. It is not just about the loss of biodiversity, but about the loss of a way of life and disruption of long-standing ways of living, including subsistence farming, fodder availability, and everyday interactions with the forest. As one participant reflected*, "We all were surrounded by agricultural fields, now it's only Chir. We never used to buy fodder before, there was enough around our homes. Now, with the Chir trees everywhere, the green grasses and leafy trees have disappeared. We have to travel far or spend money for our livestock during the dry season"* (*Fieldnotes,* 2023-24). Chir is remembered not as a tree of belonging but as a tree that has taken over. Such numerous experiences embedded in the mountains are associated with the spread of Chir, the perceptions showed the impact on water resources, agriculture, and degradation. Conversations with villagers linked agriculture, which is highly dependent on climate conditions and forests. Such statements mirror the experiences of this transformation and associated issues that policy-oriented models are only beginning to quantify.

## 5. Discussion

For people of rural Uttarakhand, the forest is more than an ecological space. It plays a key role in their social, cultural, and economic lives. Field insights revealed that Chir pine is not just another species, but an encroacher. "*It grows where nothing else does*," said one elderly respondent. While *Pinus roxburghii* is native to the Himalayas, it is listed in the Global Invasive Species Database (GISD) as invasive in South Africa (GISD, 2024). Moreover, Chir is a native Himalayan species but the nature of its spread is highly debated, as some scholarly works mentioned it as native (Attri et al., 2017; Kumar & Garkoti, 2021; Nautiyal, 2015; Pandey & Nautiyal, 2025), and some debate it as a major dominant species with invasive tendencies (Bhandari et al., 2024; Das et al., 2019; Khan & Arya, 2017; Singh et al., 2024; Singh & Thadani, 2023; Tyagi et al., 2023; Zobel & Singh, 1997). We treat these facts through community-attributed perceptions and further triangulate with secondary data to highlight convergent patterns.

The shallow-rooted, drought-tolerant nature of Chir thrives on rocky, nutrient-poor slopes as shared by respondents, is discussed and validated in many scholarly works (Nautiyal, 2015; Farjon, 2017; Tyagi et al., 2023; Zobel & Singh, 1997). Locals described the Chir spread as a curse on their region, which is now less diverse and less productive (Das et al., 2019), as it results in decreased water, agriculture, and soil moisture. Other scholarly works shed light on Chir as it displaces the slower-

growing broadleaf trees (like Banj), which play a crucial ecological role in stabilizing soil, retaining water, and moderating temperature (SAXENA & SINGH, 1984; BISHT, 2021; NAUTIYAL ET AL., 2020). A quantitative ecological study further validated these local perceptions, documenting that Chir forests support the lowest biodiversity, often being reduced to a single dominant tree species. In contrast, mixed broadleaved-conifer forests and Banj-Deodar forests exhibit significantly higher diversity (PATHAK ET AL., 2021). Such findings mirror villagers' experiences, where Chir-dominated landscapes are described as biologically empty and socially unproductive. Transition from mixed forests to Chir-dominated landscapes is seen as a departure not only from ecological diversity but from a way of life.

### 5.1. Climate, water, and environmental change

In the era of global warming (term used by the UN Secretary-General on July, 2023) where increasing temperatures have been observed in the mountain regions. The highest temperatures reached more than 32 to 35 degrees Celsius in the summers of 2024 during fieldwork in Pauri Garhwal (JUNE WEATHER IN PAURI, UTTARAKHAND, 2024), which went beyond the previous summer records. Interpreting these patterns, the role of climate change in exacerbating Chir's dominant tendencies cannot be overlooked. Warmer temperatures, erratic rainfall, and longer dry spells are increasingly favourable to Chir's growth (ZOBEL & SINGH, 1997; BHANDARI ET AL., 2024). Chir pollinates relatively quickly, resulting in decreasing the scope for other species of native broadleaf to grow (BANERJEE, 2023). Chir is relatively more drought-resistant (NAUTIYAL, 2015; FARJON, 2017; TYAGI ET AL., 2023; ZOBEL & SINGH, 1997), outcompeting other species that require cooler temperatures and consistent moisture, which was also perceived by the residents. This triangulation between ethnographic observations, literature, and climatic observations makes a compelling case that local knowledge should be treated not just as anecdotal but as critical information in policy making. Further linking the ethnographically gathered evidence to the data released by the Government of India also supported the change in the forest types of the region, as shown in Tables 2 and 3. Table 2 shows that Chir-pine trees in the state of Uttarakhand have increased significantly without any Chir plantation drive. Our data provide the evidence for an increase and its direct relation to forest fires in the two districts, as shown in Table 3, with an increase in repeated and continuous forest fires. The triangulation of rural perceptions with the data and ethnographic observations clearly showcases the increase in forest fires and the link with the increasing number of Chir trees. Scholarly work also mention that several government policies and laws also preserve the pine trees in India, like any other trees, which is contributing to promoting the monoculture of pines in the Himalayas (BANERJEE, 2023). Interpreting the spread of Chir and its impact on the changing climate is both a consequence and a driver of the altered ecological balance.

Table 2. Increase in number of Chir Trees (in '000) (Source: Forest Survey of India, 2023)

| Species | 2019 | 2021 | 2023 |
|---|---|---|---|
| Chir-Pine | 167,274 | 179,367 | 193,883 |

Table 3. The number of Forest Fires Detected during 2022-23 (Source: Forest Survey of India, 2023); *Number of fire/hotspot detections recorded by SNPP-VIIRS

| District | Forest fire detected during 2022-23 | Forest fire detected during 2023-24 |
|---|---|---|
| Almora | 786 | 2,810 |
| Pauri Garhwal | 928 | 3,193 |

### 5.2. Forests as social landscapes: Interlinkages through lived experience

The loss of Banj forests as perceived by local communities and participants represents more than a biodiversity loss. It reflects a detachment from the long-established relations of socio-ecological memories (NAUTIYAL ET AL., 2020). In a sense, this loss is experienced as an erosion of lived knowledge and intergenerational memory, rather than being solely an environmental factor. Through the lens of Political Ecology, the aggressive spread of Chir can

be understood not only as the outcome of natural succession, but is mainly the result of decades of policy decisions, commercial priorities, colonial legacies, and state-driven afforestation programs that prioritized commercially valuable species for timber and resin (NAUTIYAL, 2015). Such imposition of forestry has excluded local knowledge and disrupted community-managed forest traditions. A crucial question that emerges is, who benefits from a forest dominated by Chir? Preliminary perceptions based on the ethnographic fieldwork insights also directed that state forestry objectives prefer the ease of planting pines instead of broadleaf trees for the increased forest cover data. Political ecology allowed us to comprehend this spread as a consequence of historical power dynamics and environmental mismanagement, where the economic interests of the state have overridden the ecological and social needs of local populations.

Forest fires are not a new phenomenon in the mountains, yet over the last few years, they have increased significantly, and the dry Chir needles are the major reason for the extensive spread of fires. This perception aligns with emerging literature; Chir's dry needle litter is highly inflammable, and its fire-resistant bark enables the tree to survive where others perish (FULÉ ET AL., 2021; BANERJEE, 2023). Moreover, fires tend to increase the local temperatures and impact the crops, winds, and climate. Ethnographic fieldwork enabled us to gain an understanding of the complex relationship between climatic and ecological factors and how they interact, leaving implications for social consequences. Fig. 3 outlines how different climatic variables influence Chir growth, ecological balance, and the socio-economic dimensions of forest-dependent communities. This expansion of Chir cannot be overlooked and is a part of a longer-term transformation in temperature, rainfall, and forests as experienced over generations. The voices of the people of Pauri Garhwal and Almora offer critical rural knowledge that is often overlooked in policy and academic discussions, which underscores the need for policy responses and community-level initiatives.

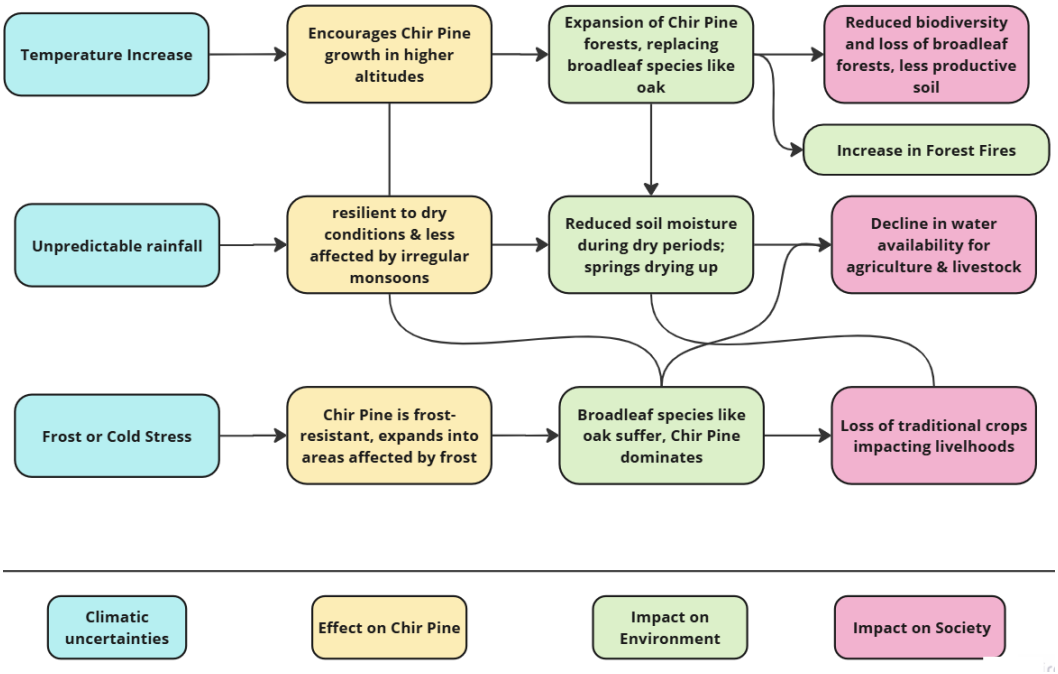


Fig. 3. Summarized overview of ethnographic fieldwork (Source: Fieldwork observations, 2023-24)

## 6. Conclusions

This research contends that the growing dominance of Chir in Uttarakhand is more than an ecological shift. Aggressive expansion of Chir has not only reshaped the landscapes of the lower and central Himalayas but also impacted water resources, agriculture, and the livelihoods of local communities in Pauri Garhwal and Almora. It has changed the everyday rhythm of life. This study situates the ecological dominance of Chir within a broader framework, using people's perceptions as both

method and meaning, with a perceived increase of 85% over last 10 years (n=110). Widely accepted as native, it is still debated ecologically and socially due to its current dominance, spread, and impacts. Notably, participants across Pauri Garhwal and Almora do not speak of "invasion" in scientific terms, but they narrate their experiences of disappearing springs, vanishing fodder, increasing forest fires, and the slow death of mixed forests where Banj once stood tall. These stories, when woven together with the theoretical foundations of political ecology, tell us that Chir is not just transforming the ecology, it is reshaping social life, gender roles, agricultural practices, and experiences of climate. From such conclusions flow several concrete implications that follow directly from respondents' concerns and the triangulated evidence of loss of more beneficial forest species, which are vital for water retention and biodiversity-supporting properties. Strengthening participatory forest governance is essential by involving village forest communities so that local priorities are addressed.

Chir is also associated with frequent forest fires that destroy biodiversity and create favourable conditions for it to return stronger. Community-based fire management should be prioritized along with traditional knowledge and experiences, like planting relatively beneficial broadleaf species, and monitoring abandoned agricultural fields. The dominance of Chir brought irreversible changes in the region. The dominance of Chir is not just the outcome of its ecological resilience, but also of social and political neglect. To mitigate the impacts, the traditional knowledge of local communities and their understanding of the forest should be incorporated into forest management decisions and policy-making.

## Limitations of the study

*This study relies primarily on perception-based qualitative data. The research did not engage in a scientific analysis of the water retention capabilities of different forest species or provide quantitative data on soil moisture dynamics. The study thus recognizes its limitation in not engaging with the scientific analysis of soil dynamics, groundwater levels, or biodiversity loss. It deliberately prioritises human perceptions and lived experiences.*


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