

Traditional Medicinal Knowledge and Climate Change Perceptions: Insights from the Cholanaickan Community, a Particularly Vulnerable Tribal Group in India

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Abstract

This study explores the intricate relationship between traditional medicinal knowledge and perceptions of climate change among the Cholanaickan community, a Particularly Vulnerable Tribal Group (PVTG) in Kerala, India. Using a mixed-methods approach, including surveys, interviews, and field observations, our research shows that medicinal practices and healing traditions are closely tied to the community's local environment, and that climate variability, biodiversity loss, and forest degradation increasingly threaten them. Findings indicate that access to medicinal plants is decreasing, intergenerational knowledge transfer is deteriorating, and younger generations are less engaged in traditional practices. Despite these challenges, the Cholanaickan demonstrate resilience through adaptive strategies rooted in traditional ecological knowledge, such as adjusted foraging patterns, documentation of knowledge, and continued ritual practices. The study highlights the urgent need to protect traditional knowledge, conserve medicinal plant habitats, support knowledge transfer, and integrate Indigenous healthcare into policy planning to enhance climate resilience. Ultimately, safeguarding Indigenous rights and traditional ecological knowledge is critical to preserving traditional practices and culture and to alleviating the impacts of climate change and associated environmental degradation.

1. Introduction

About 476 million, or 6.2 per cent, of the world population (ILO, 2019) residing in more than 90 countries are considered Indigenous Peoples. For generations, Indigenous communities have stewarded their environment through customary norms that govern access and resource use, rooted in principles of responsibility and reciprocity (Gadgil et al., 1993). Over time, Indigenous communities have developed resource use systems that support both ecological sustainability and community continuity. This accumulated body of insight, widely known as Indigenous knowledge or Traditional Ecological Knowledge (TEK), co-evolved with local ecosystems and was sustained through oral traditions such as stories, rituals, and practices (Berkes, 2009 & 2017; Finn et al., 2017; Vijayan et al., 2022). However, Indigenous peoples are also among the world's most marginalised and vulnerable peoples (Nilsson, 2008), and globally they have high exposure to environmental change (Ford et al., 2020). There is a growing recognition that, regardless of living low-carbon lifestyles closely connected to their ecosystems, place-based communities, particularly Indigenous communities, are among the groups most affected by climate change, facing disruptions to their livelihoods and cultural practices as environmental conditions shift (Shaffril et al, 2020; Filho et al., 2021; Reyes-García et al., 2023). This could be attributed to their living in regions exposed to rapid changes in weather patterns, their reliance on natural resources, and unfavorable socio-economic and political conditions (Ford 2012; Bauer et al., 2022; Busch et al., 2025). Similarly, Indigenous Peoples worldwide are also experiencing severe impacts on their health and wellbeing because of climate change and biodiversity loss (Brubacher et al., 2024).

Climate change poses significant risks to forest-dependent Indigenous communities, whose well-being is closely linked to forest ecosystems for subsistence resources such as food and water, traditional medicinal plants, and culturally embedded practices (Rahman & Alam, 2016; Wale et al., 2022; Kareyapath et al., 2026). Climate change can alter the relationships between people and forests by introducing new challenges for natural resources and affecting how local communities utilize and manage them (Wale et al., 2022). For forest-dwelling Indigenous peoples, climate shifts are lived, immediate realities that disrupt ecological rhythms, reshape livelihood practices, alter resource availability, and affect community health and well-being. Indigenous communities' responses to and adaptations to environmental change are closely shaped by their perceptions and interpretations of those changes (Boillat and Berkes 2013; Bauer et al., 2022). Understanding these dynamics is particularly critical in biodiversity

hotspots such as the Western Ghats, where Indigenous communities rely extensively on forest resources for food, shelter, and especially healthcare.

Existing research on Indigenous understandings of climate change demonstrates that local communities interpret environmental shifts through their socio-cultural contexts, rather than through abstract scientific models (Ahmed & Atiqul Haq, 2017). These perceptions, informed by direct observation of direct environment, shape how communities adapt their livelihoods, resource use, and healthcare practices. For example, in India, several tribal groups, including the Soliga, Kadar, and Irula, have demonstrated that ecological knowledge guides climate adaptation through forest management, crop selection, and conservation of medicinal species. However, integrating these local epistemologies into formal climate and health policies remains limited, as institutional frameworks often undervalue non-scientific knowledge systems. Likewise, a key challenge involves integrating these locally grounded knowledge systems with global climate science in ways that preserve the cultural integrity of Indigenous practices (Datta & Kairy, 2024).

One of the many consequences of climate change is its impact on medicinal plants, which are highly sought after in both traditional and advanced medicine (Alum 2024). The use of medicinal plants and traditional medicines forms an integral part of Indigenous peoples' way of life and culture, where they often serve as the primary or sole source of healthcare and well-being, especially in rural areas (Heinrich et al., 1998; WHO 2013; Upa et al., 2023; Ambu et al., 2020). Indigenous Peoples' health systems prioritise holistic forms of care, incorporating environmental, physical, and spiritual aspects into their understanding of well-being. (WHO 2013; Ijatuyi et al., 2025). It encompasses herbal remedies, diagnostic practices, ritual healing, and spiritual purification. Their use is typically rooted in generations of empirical knowledge transmitted orally and encompassing locally adapted practices (Takubessi, et al., 2025). However, climate change and environmental degradation threaten the availability, yield, and therapeutic properties of key medicinal plants (Moisiienko et al., 2019; Groner et al., 2022), undermining both healthcare practices and cultural continuity. Ongoing climate change, combined with the enduring impacts of colonialism, territorial conflicts, forced displacement, forest loss and conversion, declining biodiversity, and the marginalisation of Indigenous knowledge and traditional healthcare practices, continues to erode traditional medicinal knowledge and further worsen health outcomes among Indigenous peoples (Redvers et al. 2023; Perera et al., 2026).

India is home to approximately 104 million Indigenous peoples, officially designated as Scheduled Tribes, who constitute 8.6% of the national population, and the country is widely regarded as one of the world's most climate-vulnerable regions. (Adam et al., 2018; Ministry of Health and Family Welfare & Ministry of Tribal Affairs 2018). Even after seven decades of independence, the country still struggles to close the persistent healthcare gap between tribal and non-tribal communities (Kumar et al., 2020). Further, the health of tribal people has remained neglected and incorporated into rural health care because of incorrect assumptions that their health needs are similar to those of the rural population (Linda et al., 2024). The current health-care system incorporates their health needs with approaches such as differing population norms in tribal areas. Persistent geographical, socioeconomic, cultural, and political inequalities leave Indigenous communities with distinct health challenges that remain largely unaddressed. Climate change and the decline of traditional medicinal resources further intensify these vulnerabilities.

Research indicates that the ethnomedical systems practiced by Indigenous groups in India constitute one of the country's most comprehensive yet rapidly disappearing healthcare traditions (Ahmed et al., 2023; Beura and Raul, 2024). Several studies have documented the richness and cultural significance of traditional medicines and medicinal plants used by diverse communities across India. For instance, Balkrishna et al. (2022) mapped and identified 238 ethnomedicinal plant species used by Indigenous communities in Uttarakhand, attributing this diversity to the communities' extensive traditional ethnomedicinal knowledge for treating a wide range of ailments.

Similarly, Ralte and Singh (2024) reported 102 ethnomedicinal plant species, including trees, herbs, and shrubs, utilized by various ethnic groups in Mizoram, Eastern India, for the treatment of multiple human ailments. Ahirwar and Bhoi (2025) documented approximately 80 medicinal plant species used by the Baiga tribe of Chhattisgarh in Central India. Mary et al. (2012) developed a database detailing 110 plant species commonly used by tribes in Tamil Nadu, South India, for ailments such as fever, asthma, cold, cough, diabetes, diarrhea, dysentery, eye infections, stomachache, wounds, and snake bites. Thus, Indigenous Peoples across India possess extensive knowledge of traditional medicines and healing practices. However, despite this extensive body of knowledge, it remains insufficiently and systematically documented (Datta et al., 2014) and remains underrepresented in academic literature (Ahirwar and Bhoi, 2025). Furthermore, medicinal plants themselves are becoming increasingly scarce (Datta et al., 2014) and traditional medicinal knowledge is also at risk, as younger generations tend to place limited value on it (Balkrishna et al., 2024).

In India, 75 tribal groups have been classified as particularly vulnerable tribal groups (PVTG), distinguished by increased vulnerability due to characteristics such as a pre-agricultural lifestyle, low literacy, economic hardship, and declining populations (Linda et al., 2024). The Cholanaickan community, officially recognised as a particularly vulnerable tribal group and one of India's most isolated and smallest tribal groups, possesses a rich repository of traditional knowledge, including traditional medicinal knowledge (Vahia et al., 2017), which is integral to their cultural identity. Their population is exceedingly small, with estimates indicating fewer than 400 individuals, rendering them highly vulnerable to environmental degradation. Among the Cholanaickan, medicine and environment are inseparable; traditional healing is not only a means of curing illness but also reflects their relationship with the natural world. However, the accelerating impacts of climate change and restricted access to forest resources have begun to disrupt this delicate balance, threatening both the continuity of Indigenous knowledge systems and the community's resilience. Studies indicate that the erosion of traditional ecological knowledge, combined with the increasing unpredictability of extreme weather events, has significantly constrained Cholanaickan communities' capacity to depend on their forest knowledge and traditional practices (Mangalasseri et al., 2025).

Examining climate change perceptions among Indigenous communities such as the Cholanaickan is crucial, as their close ecological relationships offer insights into environmental change that scientific monitoring alone may not capture. Such understanding is essential not only for safeguarding cultural heritage but also for informing policy dialogues on community-based adaptation and health resilience in climate-vulnerable regions. While several studies have documented the diversity of medicinal and edible plants used by the Cholanaickan (Haridas & Kunhikannan, 2020; Koorimannil et al., 2024), a substantive gap remains concerning how the community perceives the impacts of climatic variability on health and the availability and use of traditional medicines, and how these perceptions subsequently inform and shape their adaptation strategies.

Within this context, this study aims to examine the Cholanaickan community's perceptions of the relationships between climate change, health, traditional medicinal knowledge, and adaptation strategies. Specific objectives of the study include: (1) to document their traditional ecological knowledge and their perceptions of climate variability and its impacts on health and medicinal practices; (2) to analyse how climate change affects the availability, seasonality, and use of medicinal plants; and (3) to identify how these shifts shape the community's adaptive strategies.

By concentrating on one of India's most vulnerable Indigenous communities, this research enhances understanding of how Indigenous knowledge can support inclusive, culturally rooted strategies for climate adaptation and sustainable development.

2. Materials and methods

2.1. Study design

The study employed a mixed-methods observational design integrating a questionnaire survey, semi-structured interviews, and field observations (Fig. 1). It examined Cholanaickan perceptions of climatic and ecological change, perceived implications for medicinal resource availability and traditional healthcare, and associated adaptation practices. Quantitative data characterised the distribution of reported perceptions, knowledge categories, and adaptation practices, while qualitative accounts examined their cultural meanings and ecological contexts. The individual respondent constituted the principal unit of analysis. Climate-related variables represented participants' perceptions and experiences rather than instrumentally measured climatic trends. Information on health and medicinal resource availability likewise reflected respondent accounts rather than clinical assessments or systematic ecological inventories. Findings were therefore interpreted as perceived relationships among environmental change, traditional healthcare, and adaptation, without attributing causality.

2.2. Study area

The study was conducted among the Cholanaickan community, a Particularly Vulnerable Tribal Group (PVTG) residing in the Nilambur Valley of Malappuram District, Kerala, within the tropical evergreen forests of the Western Ghats in India, a UNESCO World Heritage site renowned for its exceptional biodiversity and endemism. The terrain is characterised by steep slopes, river valleys, and dense canopy cover. It receives annual rainfall exceeding 3,000 mm and experiences a humid tropical climate with monsoons from June to October. The study landscape encompassed the Karimpuzha Wildlife Sanctuary and adjoining forest areas, covering 15 settlements: Alakkal, Mancheri, Pulimunda, Mannala, Thalippuzha, Panappuzha, Kuppamala, Nagamala, Poochappara, Meenmutty, Achanala, Chempukallu, Manjakallan Puzha, Vilakk Mala, and Irumpin Chola (with 13 settlements located within the sanctuary and its interior forest landscape, and Alakkal and Achanala occupying peripheral areas) (Fig. 2).

The Cholanaickan settlements, locally known as chemmams, are dispersed across remote forest tracts along the Karulai and Vazhikkadavu ranges and are accessible only on foot via forest paths. According to the Government of Kerala's Report on Socio-Economic Status of Scheduled Tribes in Kerala (2013), the population comprises 409 individuals across 101 families, residing in the Grama Panchayats of Amarambalam, Karulai, and Vazhikkadavu. Reported demographic characteristics include an average household size of 4.05, a sex composition of 223 males and 186 females, and a sex ratio of 834 females per 1,000 males, identified as the lowest among Scheduled Tribe communities in Kerala (Government of Kerala, 2013).

Living along tributaries of the Chaliyar River, the Cholanaickan depend heavily on hunting, foraging, subsistence fishing, and collecting non-timber forest products such as honey, tubers, fruits, and medicinal plants. The name "Cholanaickan," derived from chola (forest or stream) and naickan (leader or king), symbolises their deep-rooted connection to forest and water systems. Culturally and linguistically distinct, they speak an oral hybrid dialect that blends Malayalam, Tamil, and Kannada, with no formal script (Jayarajan et al., 2026). They live in rock shelters (aale/kallu alai) or temporary leaf huts in dense forests, often in relatively inaccessible locations that may reduce exposure to wildlife risks. Resource-use territories (chemmam) are traditionally delineated by natural features such as streams, rocks, and hill ridges, and personal identification is frequently linked to territorial names (e.g., Karimpuzha Mathan, Poochappara Ayyappan). Women are similarly associated with territorial identities within a social organisation described as exogamous, patrilineal, and patrilocal.

Plant-based therapies serve as their primary form of healthcare, treating ailments such as fever, infections, digestive disorders, and snakebites. Their ethnomedical knowledge, transmitted orally through observation and apprenticeship, also extends to ethnoveterinary practices, reflecting a holistic worldview that links human and environmental well-being. However, shifts in humidity, soil moisture, and forest composition caused by climate variability have reduced the abundance of key medicinal species near settlements. Younger generations, increasingly engaged in schooling or wage labour, spend less time in the forest and are losing familiarity with medicinal plant identification and preparation techniques, leading to a decline in intergenerational knowledge transmission. Furthermore, forest degradation, illegal logging, and restricted access to protected areas have diminished their subsistence base and reduced dependency on traditional medicines, compelling a gradual reliance on market goods and public health facilities.

2.3. Sampling and participant recruitment

The study used purposive sampling to recruit 68 respondents across the selected settlements. Recruitment sought variation in age, gender, livelihood activity, and community role, including elders, women healers, plant gatherers, honey collectors, and younger community members. Eligibility required permanent residence in a selected settlement and either traditional knowledge relevant to the study or active involvement in forest-based livelihoods, traditional healing, or community governance. Table 1 shows the socio-economic profile of the respondents.

Researchers approached participants directly during initial field visits, with assistance from local guides and, where necessary, forest officials to facilitate access and introductions. The sample included 37 men and 31 women across four age categories: 18–30, 31–45, 46–60, and above 60 years. Some households contributed more than one respondent to capture perspectives across generations and gender roles. Consequently, the 68 respondents did not represent 68 independent households. The sampling strategy prioritised contextual depth and diverse experiences. It was not a household census or a probability sample, and the resulting percentages describe participating respondents rather than population-level prevalence.

Table 1
Demographic and Socio-economic Characteristics of the respondents (N = 68)

Variables	Category	Frequency	Percentage (%)
Gender	Male	37	54.4
	Female	31	45.6
Age Group	18–30	17	25.0
	31–45	24	35.3
	46–60	17	25.0
	Above 60	10	14.7
Family Type	Nuclear Family	49	72.1
	Joint Family	19	27.9
Family Size	1–3 members	14	20.6
	4–5 members	33	48.5
	6 and above	21	30.9
Education Level	Illiterate	41	60.3
	Primary Education	18	26.5
	Informal Traditional Knowledge	9	13.2
Occupation	Hunter–gatherer	30	44.1
	Forest product collector	22	32.4
	Honey collector	9	13.2
	Wage labour	7	10.3
Role in Community	Elder	13	19.1
	Woman healer	11	16.2
	Youth	18	26.5
	Plant gatherer	16	23.5
	Honey collector	10	14.7

2.4. Fieldwork and data collection

Fieldwork comprised 20 visits conducted between June 2025 and May 2026. Visits were organised into three phases to document seasonal contexts and support follow-up verification. Field sessions generally took place between 09:00 and 17:00. The first phase, from June to October 2025, comprised 15 visits focused on the initial survey, documentation of settlement arrangements, and interviews with community members during the monsoon months and subsequent seasonal transition. The second phase, from November 2025 to February 2026, comprised three follow-up visits addressing data verification, forest-product collection, and seasonal livelihood adaptations. The third phase, from March to May 2026, comprised two visits to address remaining data gaps, examine summer resource-gathering practices, and discuss emerging interpretations with community informants.

The questionnaire covered six domains: demographic and socioeconomic characteristics; perceptions of climatic variability; perceived changes in medicinal and related forest resources; reported health changes; traditional ecological and medicinal knowledge; and adaptation practices.

All 68 respondents participated in semi-structured interviews, typically lasting 45–90 minutes. Interviews explored how participants interpreted environmental change through forest activities, seasonal indicators, and traditional medicinal practices. Topics included resource availability, changes in flowering and fruiting, difficulties in medicinal plant collection, and perceived implications for household healthcare. Additional questions addressed oral learning, apprenticeship, ritual instruction, and the roles of elders and other knowledge holders in transmitting medicinal knowledge.

Interviews were conducted in Malayalam, with assistance from bilingual local guides and community facilitators where required. With participants' consent, interviews were audio-recorded when feasible. Detailed contemporaneous field notes supplemented recordings and documented interviews where recording was impractical or culturally constrained. Recorded interviews were transcribed, and Malayalam textual materials were translated into English for analysis. Indigenous botanical and cultural terms were retained where relevant, and their meanings were checked during follow-up visits. Field observations provided contextual information on settlement environments and resource-use practices. Reports of medicinal uses, sensory indicators, and therapeutic effectiveness were treated as ethnographic accounts of knowledge and practice, without implying botanical, pharmacological, or clinical verification.

2.5. Variables and measurement

Demographic and socioeconomic variables included gender, age group, family structure, household size, educational background, occupation, and community role. Formal educational attainment was distinguished conceptually from traditional knowledge because schooling and ecological expertise represent different dimensions of experience.

Climate perception variables addressed rainfall patterns, temperature, water availability, forest ecological change, and wildlife behaviour. Response categories included irregular rainfall, increased heavy rainfall, hotter conditions, earlier drying of streams, seasonal water shortages, altered flowering and fruiting, and changes in wildlife encounters. These measures captured perceived environmental changes rather than estimates of climatic magnitude or trend.

Medicinal resource indicators included difficulty locating medicinal plants, seasonal changes in plant growth, changes in flowering and fruiting, and variation in honey availability. Health indicators comprised reported increases in fever, digestive disorders, heat-related fatigue, and perceived changes in children's frequency of illness. These indicators represented reported health concerns rather than clinically verified morbidity.

Traditional ecological knowledge was categorised as high, moderate, or low using respondent self-assessments, interview accounts, and researcher assessment. The assessment considered familiarity with microclimatic indicators, historical forest changes, and spatial navigation. Medicinal plant knowledge was categorised as extensive, moderate, or limited according to the range of plants identified, knowledge of preparation methods, and experience in traditional healing. Interpretations were checked with community elders and local guides. These categories represented study-specific assessments rather than validated psychometric scales.

Knowledge sources and transmission pathways were also recorded, including intergenerational oral learning, field-based apprenticeship, and ritual or experiential instruction. Adaptation categories included collecting medicinal plants farther inside the forest, drying and storing plant materials, substituting medicinal species, cultivating medicinal herbs near dwellings, undertaking ritual healing, and sharing knowledge within families. The supplied analytical tables contained one adaptation category per respondent; this classification was not interpreted as an exhaustive inventory of all practices undertaken by each person.

2.6. Quantitative analysis

Quantitative data were analysed using IBM SPSS Statistics, version 30. Frequencies and percentages summarised respondent characteristics, climate perceptions, medicinal resource indicators, reported health changes, knowledge categories, and recorded adaptation practices. Percentages were calculated using the number of valid responses to each item, with a denominator of 68 where responses were complete.

Cross-tabulation described the distribution of adaptation categories across traditional ecological knowledge levels. Comparisons accounted for unequal group sizes, and differences in raw counts were not interpreted as evidence of greater adaptation capacity without considering the relevant denominators. Quantitative interpretation remained descriptive and specific to the purposively selected sample. Shared household membership and settlement contexts were recognised as potential sources of similarity between responses. Descriptive differences were not presented as statistically significant associations or causal effects.

2.7. Qualitative analysis and integration

Qualitative materials were analysed thematically using a combined deductive and inductive approach. The analytical corpus comprised translated interview transcripts and contemporaneous field notes. Initial deductive codes reflected the principal interview domains, including climatic variability, medicinal resource availability, reported health changes, traditional knowledge, and adaptation. The team developed additional codes and subthemes inductively from participants' accounts.

The primary researcher iteratively read, coded, compared, and grouped related codes into themes. Comparisons across accounts and settlements examined similarities and differences in experiences of environmental change and traditional healthcare. During follow-up visits, we discussed emerging interpretations and the meanings of culturally specific terms with key community informants and local guides. Representative quotations illustrated participants' perspectives and contextualised the survey findings. The interpretation integrated quantitative and qualitative findings. Survey summaries described the distribution of reported experiences, while narratives explained their meanings within medicinal, cultural, and livelihood practices. The two forms of evidence were interpreted as converging in participants' accounts, rather than as independent confirmation of climatic trends, ecological decline, or treatment efficacy.

2.8. Ethical considerations

Participation was voluntary, and researchers obtained verbal informed consent before interviews. Separate consent was sought for audio recording where applicable. The research respected respondent confidentiality, cultural sensitivities, and the Cholanaickan community's authority over its traditional knowledge, including restrictions surrounding specialised medicinal practices and their transmission. The study documentation records administrative research permission from the Scheduled Tribes Development Department, Government of Kerala (Ref. No. STDD/1789/2025-B2, dated 5 June 2025), and forest research permission from the Kerala Forest Department, Office of the Chief Wildlife Warden (Order No. KFDHQ/5678/2025-CWW/WL10, dated 18 July 2025).

Additional permissions were reported for January 2026 to support continuation and validation activities. These permissions concerned research access and authorisation; institutional research ethics approval or exemption should be reported separately.

3. Results

3.1 Perceptions of Climate Variability and its impacts among Cholanaickan

The findings indicate that most respondents perceive significant changes in local climatic conditions (Table 2), particularly in rainfall patterns, temperature fluctuations, water availability, and local wind systems. About 60.3% of respondents reported irregular rainfall patterns, while 25% observed more frequent heavy rainfall events. Respondents also widely reported rising temperatures, with half indicating that temperatures have increased and nearly one-third reporting hotter summers. Changes in water availability were another major concern, as 55.9% of respondents reported that streams are drying earlier than in the past. In addition, respondents observed changes in ecological indicators such as wildlife behaviour and flowering periods, which have historically guided seasonal understanding. For instance, traditional seasonal markers like *bengoov kalai* and *maruthuv kalai*, identified through the blooming cycles of specific tree species, have long been used by the Cholanaikkans to interpret and adapt to environmental changes. However, elders emphasised that these Indigenous ecological indicators, once reliable for predicting seasonal transitions, are increasingly inconsistent and less dependable amid ongoing climatic variability.

“The forest doesn’t behave like it used to. Earlier, we could predict the rain from the chirping of birds or the flowering of trees. Now the signs come late or not at all. Our medicines depend on timing; without it, we are helpless” (Elder male healer).

Similarly, participants also highlighted rising temperatures as a major concern affecting daily forest-based activities, particularly honey collection, which has become increasingly difficult due to heat stress and reduced availability of flowering resources.

Table 2 Perceptions of Climate Variability among Cholanaickan

Climate Variable	Perception Category	Frequency	Percentage (%)
Rainfall Pattern	Irregular rainfall observed	41	60.3
	Increase in heavy rainfall	17	25.0
	No major change observed	10	14.7
Temperature Change	Temperature increased	34	50.0
	Hotter summers	20	29.4
	No clear change	14	20.6
Water Availability	Streams drying earlier than usual	38	55.9
	Seasonal water shortage	19	27.9
	No major change	11	16.2
Forest Ecological Change	Decline in forest vegetation	29	42.6
	Changes in flowering and fruiting cycles	24	35.3
	No major change observed	15	22.1
Wildlife Behaviour	Increased wildlife encounters	26	38.2
	Wildlife patterns remain similar	23	33.8
	Not sure	19	27.9

3.2 Climate Change Impacts on Medicinal Plant Availability

The results indicate that climate variability has significant implications for medicinal plant availability and community health among the Cholanaickans. Most respondents (60.3%) reported that medicinal plants have become increasingly difficult to locate in their traditional gathering areas (Table 3). Additionally, 25% of respondents observed seasonal changes in plant growth that affect harvesting timing and the effectiveness of traditional remedies. Respondents also widely reported changes in plant phenology, with 42.6% indicating that flowering cycles have shifted and 32.4% noting reduced flowering. For instance, a middle-aged male healer explained the implications of this decline through the preparation of “*maddh*,” a traditional medicinal drink: *“We make our main medicinal drink from crushed herbs, what we call ‘maddh’. We mix the paste with water and drink it to cure fevers, stomach problems, and tiredness. But some plants needed for ‘maddh’ are now difficult to find.”*

Women, who are primarily responsible for collecting medicinal herbs for household use, also face similar challenges. As one middle-aged woman healer noted, *“Before, I could find the herbs I needed within an hour’s walk. Now I go deep into the forest and return empty-handed. Some plants have vanished, or flower too early or too late. It is becoming harder to treat even simple fevers.”*

Another respondent added, *“Some plants we used regularly are not seen in the usual places anymore. We must search in new areas, and sometimes we don’t find them at all.”*

Traditional healers also highlighted a noticeable decline in the availability of medicinal plants used to treat snakebites, which they consider a serious concern for community health. In particular, they referred to “*uthaalabai*,” a unique type of mushroom traditionally used to help recover from snake poison (“*aavumadh*,” in the local language).

This mushroom, once common in specific forest microhabitats, is now increasingly scarce, making it difficult for healers to rely on established treatment practices. *“There was a time when even snake bites could be cured without hospital help. But now even the anti-venom leaves are rare. The plants are drying up fast or being destroyed by forest fires and too much sun”* (Woman healer).

Similarly, 39.7% of respondents reported a decline in honey availability, which plays an important role in traditional healing practices. *“There are months now when not even a single honeycomb is seen,”* shared a female elder, reflecting the growing scarcity of this vital forest resource.

Table 3 Climate Change Impacts on Medicinal Plant Availability and Health among Cholanaickan Respondents (N = 68)

Indicator	Category	Frequency	Percentage (%)
Medicinal Plant Availability	Plants becoming harder to find	41	60.3
	Seasonal change in plant growth	17	25.0
	No major change	10	14.7
Changes in Flowering and Fruiting Cycles	Flowering occurring earlier or later	29	42.6
	Reduced flowering observed	22	32.4
	No change observed	17	25.0
Honey Availability	Honeycombs declining	27	39.7
	Seasonal variability observed	24	35.3
	No major change	17	25.0
Health Changes Observed	Increase in fever cases	28	41.2
	Increase in digestive disorders	19	27.9
	Heat-related fatigue	14	20.6
	No major change	7	10.3
Children’s Health Issues	Children falling sick more frequently	31	45.6
	No major change observed	37	54.4

3.3 Perceived impacts of climate change and shift in medicinal plants on health

Changes in climate and the availability of medicinal plants also appear closely linked to perceived health impacts within the community. Approximately 41.2% of respondents reported an increase in fever cases, while 27.9% observed more frequent digestive disorders. Heat-related fatigue was reported by 20.6% of respondents, reflecting rising temperature conditions in the region. Furthermore, nearly half of the respondents (45.6%) indicated that children are becoming ill more frequently, suggesting increased vulnerability among younger community members. These findings demonstrate how climate variability is perceived to influence both ecological resources and health outcomes in the Cholanaickan community.

"The heat has increased. Our people never used to complain about skin diseases or body weaknesses after work in the forest. Now these are common," observed an elder male respondent, pointing to a noticeable shift in health conditions linked to rising temperatures.

Younger respondents echoed similar concerns, emphasising the growing impact of heat on physical well-being, particularly among children. As one young male respondent noted, *"Children now complain of headaches and tiredness after just a little work in the sun. Earlier, we would play or walk in the forest all day without any trouble. The heat is draining us."* This comparison between past and present experiences highlights a decline in physical resilience, especially among younger generations.

A young mother stressed the health implications of this change, stating, *"When the sun is too strong, and the stream is low, children fall sick faster."* This observation reflects the close link between environmental conditions and community health, where reduced water availability, combined with intense heat, increases vulnerability, particularly among children. Limited access to clean and sufficient water can lead to dehydration, fatigue, and a higher risk of illness, further straining traditional healthcare practices.

Another respondent noted, *"Earlier, water would be there even in the hot months. Now the streams become weak very soon, and we must search for water."* These experiences indicate not only physical hardship but also disruptions to daily routines once structured around stable water availability.

Similarly, they noted that diseases became highly unpredictable. *"Earlier, fever, locally referred to as 'cheerap', was closely associated with the rainy season"* (Elder male respondent).

Rising temperatures were also widely associated with increased fatigue and general illness, referred to locally as *"dannai."* A young male respondent expressed this concern by stating, *"The heat is draining us. And we have no medicine for this kind of tiredness."*

3.4 Climate Determinants of Health Changes

The multiple linear regression analysis indicates that several climate-related factors significantly influence perceived health changes among the Cholanaickan respondents (Table 4). The model explains approximately 52% of the variance in health outcomes ($R^2 = 0.52$), suggesting a strong relationship between climate perception variables and health conditions within the community.

Among the predictors, medicinal plant availability shows the strongest effect on health changes ($\beta = 0.44$, $p < 0.001$). This finding highlights the central role of medicinal plants in the traditional healthcare system of the Cholanaickans, where declining plant availability directly affects the ability to treat illnesses such as fever and digestive disorders.

Temperature perception also demonstrates a significant positive influence on health changes ($\beta = 0.36$, $p = 0.002$). Respondents frequently reported that increasing temperatures contribute to heat fatigue, dehydration, and increased illness among children and elders. Similarly, rainfall perception significantly affects health outcomes ($\beta = 0.31$, $p = 0.003$), reflecting how irregular rainfall patterns influence water availability and environmental conditions that affect disease occurrence.

Water availability changes show a moderate but significant effect ($\beta = 0.27$, $p = 0.008$), indicating that declining stream flow and seasonal water shortages contribute to sanitation challenges and digestive illnesses.

Overall, the regression results demonstrate that climate variability influences community health both directly through environmental exposure and indirectly through its impact on medicinal plant resources, which form the foundation of the Cholanaickan traditional healthcare system.

Table 4 Multiple Linear Regression Analysis of Climate Determinants of Health Changes (N = 68)

Independent Variables	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (Beta)	t-value	Significance (p-value)
Constant	0.84	0.32	—	2.63	0.011
Rainfall Perception	0.28	0.09	0.31	3.12	0.003
Temperature Perception	0.35	0.11	0.36	3.18	0.002
Water Availability Change	0.22	0.08	0.27	2.75	0.008
Medicinal Plant Availability	0.41	0.10	0.44	4.09	0.000

Dependent Variable: Health Changes Observed

3.5 Climate variability, ecological changes and health outcomes

The correlation analysis reveals several meaningful relationships between perceptions of climate variability, ecological changes, and health outcomes among the Cholanaickan respondents (Fig. 3). Rainfall perception shows a moderate positive correlation with changes in water availability ($r = 0.56$) and medicinal plant availability ($r = 0.61$), suggesting that irregular rainfall patterns significantly influence forest water resources and the distribution of medicinal plants. Temperature perception is also moderately correlated with health changes ($r = 0.59$), indicating that increasing temperatures are perceived to contribute to higher incidences of fever, fatigue, and other climate-related health conditions.

Water availability changes demonstrate a strong relationship with medicinal plant availability ($r = 0.64$), reflecting the community’s observation that declining stream flow and seasonal water scarcity affect the growth and potency of medicinal plants. The strongest correlation in the analysis is observed between medicinal plant availability and health changes ($r = 0.67$), highlighting the close connection between ecological resources and traditional healthcare practices. Because the Cholanaickan community relies heavily on forest-based medicinal plants, reduced availability may directly affect the effectiveness of traditional treatments and overall health outcomes.

The correlation results emphasise the interconnected nature of climate variability, forest ecology, and community health within the Cholanaickan socio-ecological system. These findings support the argument that climate change not only alters environmental conditions but also disrupts traditional medicinal systems and health resilience in forest-dependent Indigenous communities.

3.6 Traditional Ecological Knowledge of Cholanaickan community

The Cholanaickan healthcare system is deeply rooted in traditional ecological knowledge, which is transmitted across generations and closely linked to cultural beliefs, spiritual practices, and long-term interaction with the forest. This knowledge includes the identification of medicinal plants, understanding of ecological indicators such as

rainfall, flowering cycles, wildlife behavior, and the seasonal rhythms that traditionally guided healing and resource use.

Survey results show that traditional ecological knowledge remains strong within the community. Nearly 45.6% of respondents reported a high level of ecological knowledge, primarily elders, experienced gatherers, and traditional healers who have accumulated expertise through lifelong forest interaction. Another 36.8% reported moderate knowledge, mostly middle-aged individuals actively involved in forest-based livelihoods such as plant gathering and honey collection. Only 17.6% reported low knowledge, largely younger members who have had fewer apprenticeship opportunities due to environmental changes and shifting livelihood patterns.

Medicinal plant knowledge is also widely distributed, with 39.7% of respondents possessing extensive knowledge of herbal remedies. Elders were identified as the primary custodians of medicinal knowledge (42.6%), followed by women healers (30.9%), highlighting the importance of intergenerational transmission through oral traditions and observation of skilled practitioners.

However, climatic variability and changes in plant availability are affecting this knowledge system. Healers rely on specific stages of plant development for maximum potency, and when these indicators become unpredictable, both treatment availability and effectiveness decline. Even common ailments such as fevers, once easily managed with local remedies, are becoming more difficult to treat. These disruptions weaken traditional knowledge systems that depend on stable environmental patterns and underscore the need to strengthen intergenerational learning to preserve this cultural and ecological heritage.

Table. 4 Traditional Ecological Knowledge and Medicinal Plant Knowledge among Cholanaickan Respondents (N = 68)

Indicator	Category	Frequency	Percentage (%)
Traditional Ecological Knowledge Level	High	31	45.6
	Moderate	25	36.8
	Low	12	17.6
Medicinal Plant Knowledge	Extensive knowledge	27	39.7
	Moderate knowledge	28	41.2
	Limited knowledge	13	19.1
Source of Medicinal Knowledge	Elders	29	42.6
	Woman healers	21	30.9
	Chemmakaran (traditional healer)	11	16.2
	Family members	7	10.3
Knowledge Transmission Method	Oral tradition	44	64.7
	Learning through observation	16	23.5
	Ritual instruction	8	11.8

3.7 Climate Adaptation Strategies Practiced by Cholanaickan

The Cholanaickan community is adjusting its ecological knowledge as environmental patterns become unpredictable. The findings reveal that the Cholanaickan community employs a variety of adaptive strategies to cope with climate-induced ecological changes. The most common strategy reported by respondents (27.9%) involves travelling deeper into the forest to locate medicinal plants that have become scarce near settlements (Table 5). About 23.5% of respondents reported drying and storing medicinal plants for later use, reflecting an adaptive response to seasonal variability. The use of substitute plant species (20.6%) demonstrates the flexibility of the traditional medicinal system in responding to ecological changes. Some respondents (13.2%) have begun cultivating medicinal plants near their homes to reduce dependence on distant forest areas. Beyond practical strategies, ritual practices and knowledge sharing remain important cultural mechanisms that support community resilience.

According to respondents, seasonal cycles like *jhanukalai* and *Maruthuv kalai* no longer follow expected rhythms, leading people to rely on immediate cues such as rainfall, flowering, and wind changes. As one respondent explained, *"The seasons we knew are not the same now. Jhanukalai (Honey Season) does not come when it used to, and even the maruthuv time is confusing. We now watch the rains and flowers closely before deciding when to collect."*

Some individuals now document flowering and fruiting cycles of medicinal plants to cope with irregularity. One respondent noted, *"I have been writing down when plants flower and fruit, especially kurinji and medicinal plants. Earlier we didn't need to write; it was fixed in our memory. Now everything is changing, so this helps me know when to go and search."*

Similarly, resource collection has shifted from fixed seasons to opportunistic timing. People gather honey, mushrooms (Fig. 4), and medicinal plants whenever conditions allow. As respondents explained, *"We cannot wait for the usual time anymore. If we see flowers, we go for honey. If mushrooms appear, we collect them immediately; there is no fixed season now,"* and *"Earlier we knew exactly when to go into the forest for medicine. Now we have to keep checking, because plants and mushrooms come at unexpected times."*

With seasonal indicators becoming unreliable, sensory knowledge such as touch, smell, and visual cues has become central to identifying safe and effective resources. As one healer noted, *"We don't depend only on the season now. We touch, smell, and see the plant to know if it is good,"* while another noted, *"Mushrooms can look the same, but the smell tells us which one is safe and which one is poison."*

Intergenerational knowledge transfer remains selective and lineage-based, guided by elders and the *chemmakaran*. This ensures continuity while allowing adaptation. As elders explained, *"We do not teach everyone. Only those chosen by the elders will learn the real medicine. It must be protected,"* and *"The chemmakaran knows the important treatments. He teaches slowly, over time, so the knowledge is not lost."*

Similarly, to interpret environmental change, community members increasingly observe wildlife behaviour, bird calls, and shifting wind patterns. As one elder explained, *"We watch the forest more carefully now. Animals behave differently, and the winds are not the same as before. These tell us what is changing."* Others added, *"The 'Gali' (Wind) has changed. Earlier we knew the four types of winds and their time, but now they come differently, so we keep observing to understand,"* and *"If birds move early or animals come closer, we know something is not normal. We learn from these signs."*

Community-based healing practices such as *Pidichukodukkal* and *ottenereyakkal* have gained importance as plant availability declines. '(Pidichu Kodukkal' refers to a traditional forehead massage technique used to relieve severe headaches. The procedure is performed by men for male recipients and by elderly women for female recipients.) *Otta ottenereyakkal* is a traditional abdominal massage practice used primarily for children to address stomach-

related discomfort. Within the Cholanaickar community, such discomfort is believed to result from the displacement of internal abdominal organs from their usual positions. The procedure is performed by individuals experienced in traditional massage techniques, with the intention of restoring abdominal alignment and relieving discomfort. As healers shared, *“Our healing begins with our hands. Pidichukodukkal is what we use when medicines are not available,”* and *“For children’s stomach pain, we do ottenereyakkal. We don’t always depend on forest medicine now.”*

Table 5 Climate Adaptation Strategies Practiced by Cholanaickan Respondents (N = 68)

Adaptation Strategy	Frequency	Percentage (%)
Collecting medicinal plants deeper in the forest	19	27.9
Drying and storing medicinal plants for future use	16	23.5
Using substitute plant species	14	20.6
Cultivating medicinal herbs near homes	9	13.2
Performing ritual healing practices	6	8.8
Increasing knowledge sharing within families	4	5.9

3.8 Factors influencing climate adaptation strategies

The multiple regression analysis examined the factors influencing climate adaptation strategies among the Cholanaickan respondents. The model explains approximately 55% of the variance in adaptation strategies ($R^2 = 0.55$), indicating that the selected variables significantly contribute to understanding adaptation behaviour within the community (Table 6).

Among the predictors, traditional ecological knowledge (TEK) emerged as the strongest determinant of adaptation strategies ($\beta = 0.41$, $p < 0.001$). Respondents with higher levels of ecological knowledge were more likely to adopt adaptive practices such as collecting medicinal plants from deeper forest areas, using substitute species, and preserving herbs through drying and storage techniques. This highlights the crucial role of Indigenous knowledge in enhancing community resilience to climate variability.

Medicinal plant availability also showed a significant positive relationship with adaptation strategies ($\beta = 0.35$, $p = 0.002$). As medicinal plants become more difficult to locate, respondents reported adopting alternative strategies such as substituting plant species or expanding their foraging zones. Similarly, rainfall perception significantly affected adaptation behaviour ($\beta = 0.29$, $p = 0.005$), suggesting that individuals who perceive irregular rainfall patterns are more likely to adjust their medicinal plant harvesting practices.

Age also moderately influenced adaptation strategies ($\beta = 0.22$, $p = 0.012$), indicating that older respondents with greater experience in forest environments are more likely to use adaptive techniques. In contrast, gender did not show a statistically significant effect ($p = 0.262$), suggesting that both men and women actively participate in adaptation strategies, although their roles in medicinal knowledge and healthcare practices may differ. Overall, the regression results demonstrate that traditional ecological knowledge and ecological resource availability are key determinants of climate adaptation strategies among the Cholanaickan community, emphasising the importance of preserving Indigenous knowledge systems for climate resilience.

Table 6 Multiple Linear Regression Analysis of Determinants of Climate Adaptation Strategies (N = 68)

Dependent Variable: Climate Adaptation Strategy Index

Independent Variables	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (Beta)	t-value	Significance (p-value)
Constant	0.62	0.29	—	2.14	0.036
Traditional Ecological Knowledge	0.45	0.11	0.41	4.09	0.000
Rainfall Perception	0.26	0.09	0.29	2.88	0.005
Medicinal Plant Availability	0.33	0.10	0.35	3.30	0.002
Age	0.18	0.07	0.22	2.57	0.012
Gender	0.09	0.08	0.11	1.13	0.262

The cross-tabulation analysis (Table 7) indicates a strong relationship between traditional ecological knowledge and climate adaptation strategies among the Cholanaickan respondents. Individuals with high levels of traditional ecological knowledge were more likely to adopt proactive adaptation strategies, particularly those related to forest resource management. For instance, a significant number of respondents with high ecological knowledge reported travelling deeper into forest areas to collect medicinal plants (10 respondents) and drying and storing medicinal plants for future use (8 respondents). These strategies require extensive knowledge of plant distribution, seasonal harvesting practices, and preservation techniques. Respondents with moderate levels of ecological knowledge also participated in several adaptation practices, although to a slightly lesser extent. They frequently reported using substitute plant species (6 respondents) and collecting and storing medicinal plants.

In contrast, respondents with lower levels of traditional ecological knowledge showed limited engagement in complex adaptation strategies. Their responses focused on practices such as knowledge sharing within families and basic plant cultivation near homes. This pattern suggests that ecological knowledge plays a crucial role in shaping the community's ability to respond to environmental changes.

The findings demonstrate that traditional ecological knowledge functions as an important form of adaptive capacity, enabling the Cholanaickan community to respond to climate-induced ecological changes affecting medicinal plant resources and healthcare practices.

Table 7 Cross-Tabulation of Traditional Ecological Knowledge and Adaptation Strategies (N = 68)

Adaptation Strategy	High TEK	Moderate TEK	Low TEK	Total
Collect plants deeper in forest	10	7	2	19
Dry and store medicinal plants	8	6	2	16
Use substitute plant species	6	6	2	14
Cultivate medicinal plants near homes	4	3	2	9
Ritual healing practices	2	3	1	6
Knowledge sharing within families	1	0	3	4
Total	31	25	12	68

4. Discussion

4.1 Climate variability and its impact on traditional medicinal practices

Our findings indicate that climate variability is significantly affecting the availability of medicinal plants that support the Cholanaickan healthcare system. Respondents consistently reported that plants used to treat common ailments such as fever, digestive disorders, and snakebite are increasingly scarce and difficult to find. They linked these observations to changing rainfall patterns, rising temperatures, and disruptions to seasonal growth cycles, all of which affect the abundance and availability of medicinal species. These local experiences align with evidence from other studies showing that climate change, deforestation, and land-cover changes are altering the distribution, abundance, and quality of medicinal plants worldwide (Applequist et al., 2019; Maikhuri et al., 2017). Climate-induced changes in temperature and precipitation have been shown to shift plant habitats and life cycles, threatening species central to traditional healthcare systems. Similar patterns have been documented in the Himalayas, South Africa, and China, where medicinal plants are experiencing altered phenology, habitat shifts, and population declines (Rana et al., 2017; Groner et al., 2022; Wang et al., 2024).

The Cholanaickan healers described these changes based on their experience. For example, a healer explained that some medicinal plants required to prepare maddh, a traditional herbal drink used to treat fever, stomach ailments, and fatigue, are becoming increasingly difficult to find. Women healers similarly reported travelling farther into the forest to find medicinal plants, often returning without the required species. These accounts show that climate variability is not only affecting ecosystems but also impacting the traditional health care practices followed by the communities.

Beyond declining availability, respondents highlighted significant changes in plant phenology and medicinal effectiveness. Traditional healing practices depend on detailed ecological knowledge of when to harvest particular plants to ensure maximum potency. However, healers observed that many medicinal plants now flower earlier, later, or less predictably than before. One healer noted that "some plants have vanished, or flower too early or too late," making it increasingly difficult to treat common illnesses. Such observations suggest that climate variability is disrupting ecological rhythms that traditionally guided the harvesting and preparation of medicines. Similar findings have been reported elsewhere, where climate change has altered flowering periods, growth cycles, and geographical distributions of medicinal plants, affecting their therapeutic use (Rana et al., 2017; Wang et al., 2024).

An equally important concern is medicinal potency. Cholanaickan healers rely heavily on sensory indicators, particularly smell, to assess the quality and effectiveness of medicinal plants. Participants reported that many plants no longer have the strong aroma traditionally associated with therapeutic strength. These changes may reflect shifts in plant chemistry driven by environmental stressors such as rising temperatures, changing rainfall patterns, and soil degradation. Consequently, our study showed that environmental changes are not only reducing medicinal plant abundance but may also be compromising their effectiveness.

Climate variability is also disrupting other natural resources that support Indigenous healthcare and well-being. Participants reported increasingly irregular honey collection seasons (jhanukalai), which they attributed to disruptions in flowering cycles, particularly those associated with kurinji. Honey serves multiple roles within the Cholanaickan community. It functions as an important nutritional resource, a medicinal remedy for digestive disorders and wound healing, a postnatal recovery aid for women, and a vital ingredient in ceremonial practices. Honey and beeswax also hold cultural significance through their use in rituals and in producing traditional musical instruments such as Beedei. Therefore, declining honey availability represents more than environmental loss; it threatens cultural practices, medicinal traditions, and community identity. The resulting shift in dietary patterns and the loss of natural pharmacological agents force reliance on external, often inaccessible, medical systems, eroding the community's autonomous healthcare resilience. (Fernández-Llamazares et al., 2021) Furthermore, eroding these traditional ecological knowledge systems undermines the intergenerational transmission of ethnobotanical wisdom, weakening the social fabric that sustains Cholanaickan identity. (Aswani et al., 2018; Ford et al., 2020) Ultimately, this systemic instability exacerbates socioeconomic marginalisation, as the community loses its primary mechanism for self-sufficiency and the essential cultural markers that define their heritage in a rapidly changing landscape. (Per et al., 2025) The findings demonstrate how climate change can adversely affect interconnected social, cultural, and health systems. Changes in pollination and flowering patterns directly affect household nutrition, healthcare practices, and cultural continuity.

4.2 Emerging health risks associated with climate variability

The study revealed growing concerns regarding the direct health impacts of climate variability. Participants reported more frequent skin problems, exhaustion, heat-related discomfort, and changing fever patterns. Unlike previous generations, who were considered well adapted to forest environments, respondents perceived that rising temperatures are creating new and unfamiliar health challenges.

Several participants described persistent fatigue that affects their ability to carry out daily forest-based activities. One respondent stated, "The heat is draining us. And we have no medicine for this kind of tiredness." This perception is particularly significant because it highlights a gap between changing environmental conditions and existing Indigenous healthcare knowledge. Traditional remedies that have historically addressed common illnesses may be less effective for newly emerging climate-related health conditions.

Respondents also noted that fever patterns have become less predictable. Once associated with periods of heavy rainfall, fevers now occur during unusually hot months. These observations suggest that climate change is altering the relationships between seasonality, disease occurrence, and human health. These findings align with broader evidence linking climate variability to shifts in disease dynamics and heightened health vulnerabilities among Indigenous and forest-dependent populations (Brubacher et al., 2024; Ford, 2012; Horno et al., 2016). Furthermore, the degradation of these biodiversity-dependent resources mirrors a wider pattern of ecological loss that exacerbates chronic physiological stress and increases disease susceptibility across marginalised communities (Brubacher et al., 2024). This cascading degradation, observed globally amid shifting phenological cycles and

pollinator-forage mismatches, forces a reconfiguration of social institutions that have historically relied on stable environmental rhythms to maintain group cohesion (Espen et al., 2023). This erosion of ecological stability compels the community to adapt its social structures, as declining honey availability severs a primary vehicle for traditional knowledge transfer and collective identity formation (Fernández-Llamazares et al., 2015; Reyes-García et al., 2024). Consequently, losing these synchronies disrupts the transmission of ritualised ecological wisdom, leaving younger generations less connected to the ancestral landscapes that once anchored their sense of self and social solidarity (Reyes-García et al., 2024). This systemic collapse of the foraging-based social fabric demonstrates how the loss of non-timber forest resources, such as honey, accelerates the fragmentation of traditional ecological knowledge and weakens the community's collective resilience to rapid environmental change (Héger et al., 2023). This loss of biocultural synchronisation effectively renders traditional adaptation strategies obsolete, forcing reliance on external, often incompatible, health systems that further marginalise the community's ancestral heritage (Santos et al., 2026). Addressing these multifaceted challenges requires a holistic approach that integrates community-led conservation with region-specific adaptation strategies (Shrestha & Shrestha, 2024). Policy interventions must prioritise the revitalisation of these traditional agrifood systems to mitigate the cultural disintegration currently undermining the community's sovereignty and resilience (Pandey et al., 2025).

4.3 Climate Change and the Erosion of Traditional Ecological Knowledge

An important concern emerging from the findings is the gradual decline in the intergenerational transmission of Traditional Ecological Knowledge (TEK) and Medicinal Plant Knowledge (MPK). Community members reported that many younger people are unable to identify key medicinal species or understand their uses, raising concerns about the future continuity of Indigenous healthcare practices. This finding aligns with global trends. Studies from Mexico, South Africa, and other Indigenous contexts show that modernisation, formal education, cultural change, and reduced reliance on traditional livelihoods often erode plant knowledge among younger generations (Benz et al., 2000; Maroyi, 2017; Constant & Tshisikhawe, 2018). Furthermore, biodiversity loss and cultural change often coincide, accelerating the decline of traditional knowledge systems (Cámara-Leret et al., 2019). Within the Cholanaickan community, these concerns are compounded by environmental change. As medicinal plants become rarer and ecological cues less predictable, opportunities for experiential learning likewise diminish. Consequently, climate change threatens not only biological resources but also the knowledge systems needed to use and conserve them.

4.4 Continuity and Adaptation of Traditional Ecological Knowledge

Our study found that, despite these challenges, Traditional Ecological Knowledge remains central to Cholanaickan healthcare practices. Medicinal knowledge is regarded as sacred and transmitted selectively through culturally defined pathways. The chemmakkaran, regarded as the ancestral successor (pingaami), plays a critical role in preserving specialised medicinal knowledge and passing it on to future generations.

Participants emphasised that medicinal knowledge is not openly shared because its effectiveness is closely tied to cultural values, ritual practices, and ancestral authority. As one elder explained, "Medicinal knowledge is not spoken openly. It is sacred, passed down through generations." These practices help preserve the integrity and spiritual significance of Indigenous healing systems.

At the same time, evidence of knowledge adaptation was evident. Some healers have begun documenting flowering periods, seasonal changes, and resource availability in response to growing environmental uncertainty. This

transition represents an important adaptive response, with written observations complementing oral traditions and helping healers navigate changing ecological conditions. These practices illustrate that TEK is not static but adaptive, evolving in response to environmental and social change.

4.5 Cultural Resilience and Collective Responses to Environmental Change

Although environmental changes are creating substantial pressures, the findings indicate that cultural practices continue to support resilience in the Cholanaickan community. Rituals, storytelling, festivals, and community gatherings remain important ways to maintain cultural identity, ecological ethics, and healing traditions. For example, the Beidh festival marks the onset of summer and includes hunting restrictions, symbolising gratitude and respect for the forest. Such practices function as informal conservation mechanisms while reinforcing collective values of stewardship and reciprocity. Participants also emphasised the importance of cooperation and social support during periods of environmental stress. As one elder noted, "Our strength lies in helping one another. Healing is not just about plants; it is about the way we live together." This shows the collective nature of adaptation, in which knowledge sharing, mutual assistance, and social cohesion contribute to community well-being. These findings align with broader research on cultural resilience, which shows that rituals, collective memory, storytelling, and community engagement strengthen adaptive capacity and help communities cope with environmental change (Tidball et al., 2010; Clarke & Mayer, 2016; Quinn et al., 2020). Cultural practices therefore serve not only as expressions of identity but also as practical resources for resilience.

4.6 Recognition of Indigenous Healthcare Systems and Policy Implications

The findings further reveal community concerns about the limited recognition of traditional medicine within mainstream healthcare and policy frameworks. Participants perceived Indigenous healing practices as undervalued despite their continued importance to primary healthcare and community well-being.

This concern reflects broader debates about integrating Indigenous and biomedical health systems. Research suggests that Indigenous healthcare practices offer holistic approaches that encompass the physical, emotional, spiritual, and communal dimensions of well-being (Awoke & Cosendey, 2025). However, barriers such as inadequate documentation, differing health paradigms, and limited institutional recognition continue to hinder integration (Ahlberg, 2017; Barnabe, 2021).

Effective integration requires policies that recognise Indigenous knowledge systems as legitimate and valuable forms of healthcare. Community-led approaches, culturally responsive health programmes, and partnerships between traditional healers and health institutions can improve health outcomes while preserving Indigenous cultural heritage.

5. Conclusions

This study examined perceptions of climate variability, medicinal plant availability, traditional ecological knowledge, and adaptation strategies among the Cholanaickan tribal community in the Nilambur Valley of the Western Ghats. The findings reveal that the community perceives significant environmental changes, including irregular rainfall patterns, rising temperatures, declining water availability, and shifts in forest ecology. These climatic and ecological changes directly affect medicinal plant availability and community health, as traditional healing practices rely heavily on forest-based resources.

The study also shows that traditional ecological knowledge plays a crucial role in shaping the community's climate adaptation strategies. Respondents possessing higher levels of ecological knowledge were more likely to adopt adaptive practices such as expanding foraging areas, substituting medicinal plants, and preserving herbal resources. These findings highlight the adaptive capacity embedded within indigenous knowledge systems and underscore their importance in responding to environmental change. At the same time, declining medicinal plant availability and younger respondents with lower ecological knowledge indicate potential challenges to the long-term sustainability of traditional healthcare systems.

The findings show that the Cholaniackan community's experience is not merely environmental change but a disruption of ecological rhythms that underpin livelihoods, medicinal practices, and traditions. Challenges include declining availability of medicinal plants, shifting phenological patterns, emerging health risks, and the erosion of intergenerational knowledge transfer. Despite these pressures, Traditional Ecological Knowledge, cultural practices, and community unity remain crucial for resilience and adaptation. The study emphasises that protecting Indigenous health involves more than conserving medicinal plants; it also requires safeguarding forest ecosystems, supporting Indigenous healthcare, fostering intergenerational knowledge sharing, and recognising the cultural roots of resilience. Supporting Indigenous ecological knowledge systems is vital for creating effective, culturally sensitive climate adaptation strategies in forest-dependent communities of the Western Ghats.

Declarations

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Declaration of Competing Interests

The authors declare that there are no competing financial interests, personal relationships, or professional affiliations that could have influenced the research, analysis, or interpretation of the findings presented in this manuscript.

Clinical Trial Number: Not applicable

Informed Consent

Informed consent was obtained from all individual participants involved in the study. The participants were informed about the objectives of the research, and their voluntary participation and confidentiality were ensured throughout

the research process.

Authors' Contributions

All authors contributed equally to the conceptualization, methodology, data collection, analysis, interpretation of results, and preparation of the manuscript. All authors have read and approved the final version of the manuscript.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request, subject to ethical considerations and confidentiality requirements related to the indigenous community involved in the research.

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Figures

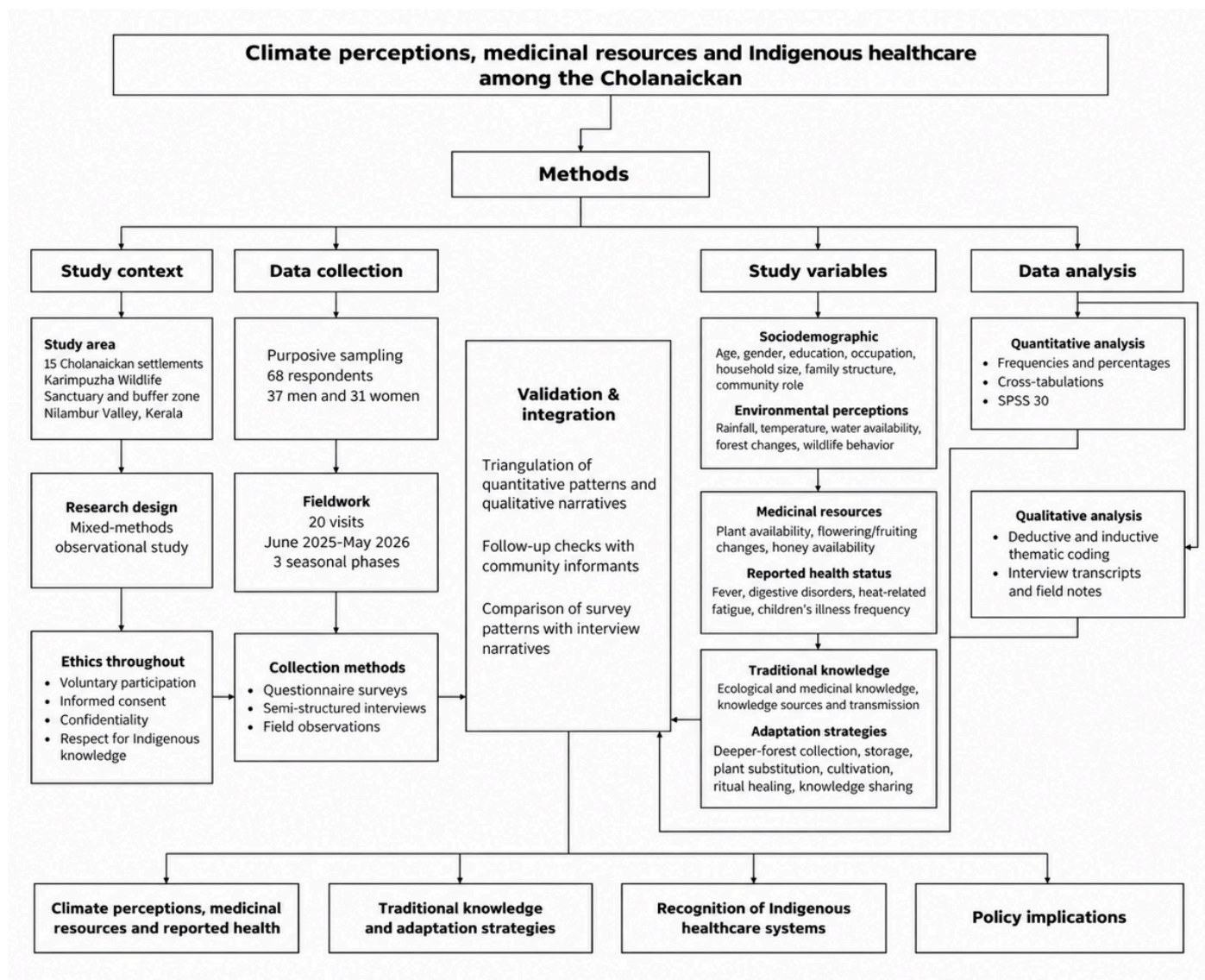


Figure 1

Graphical representation of methodology of climate perception, medicinal resources and Indigenous health care

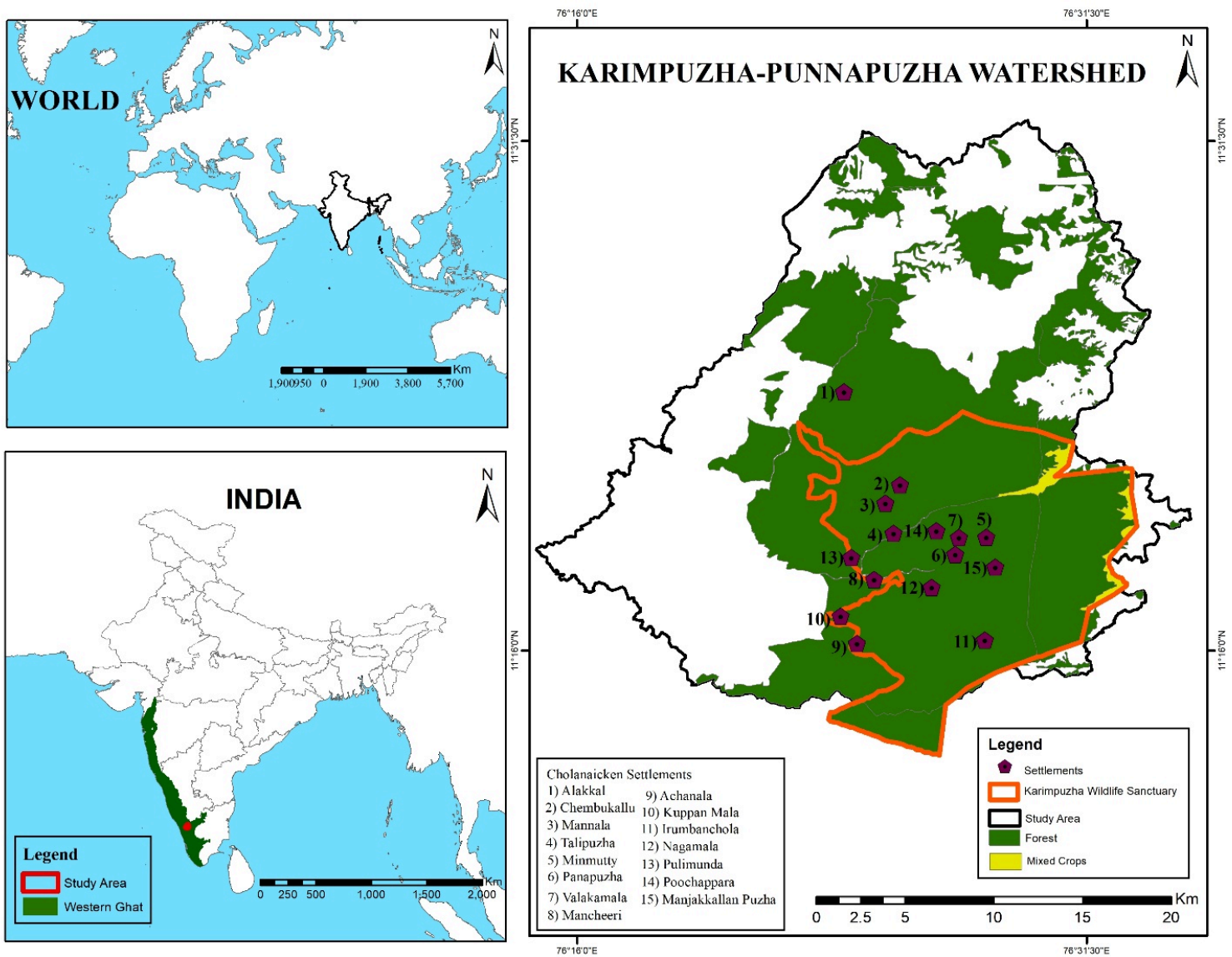


Figure 2

Study area

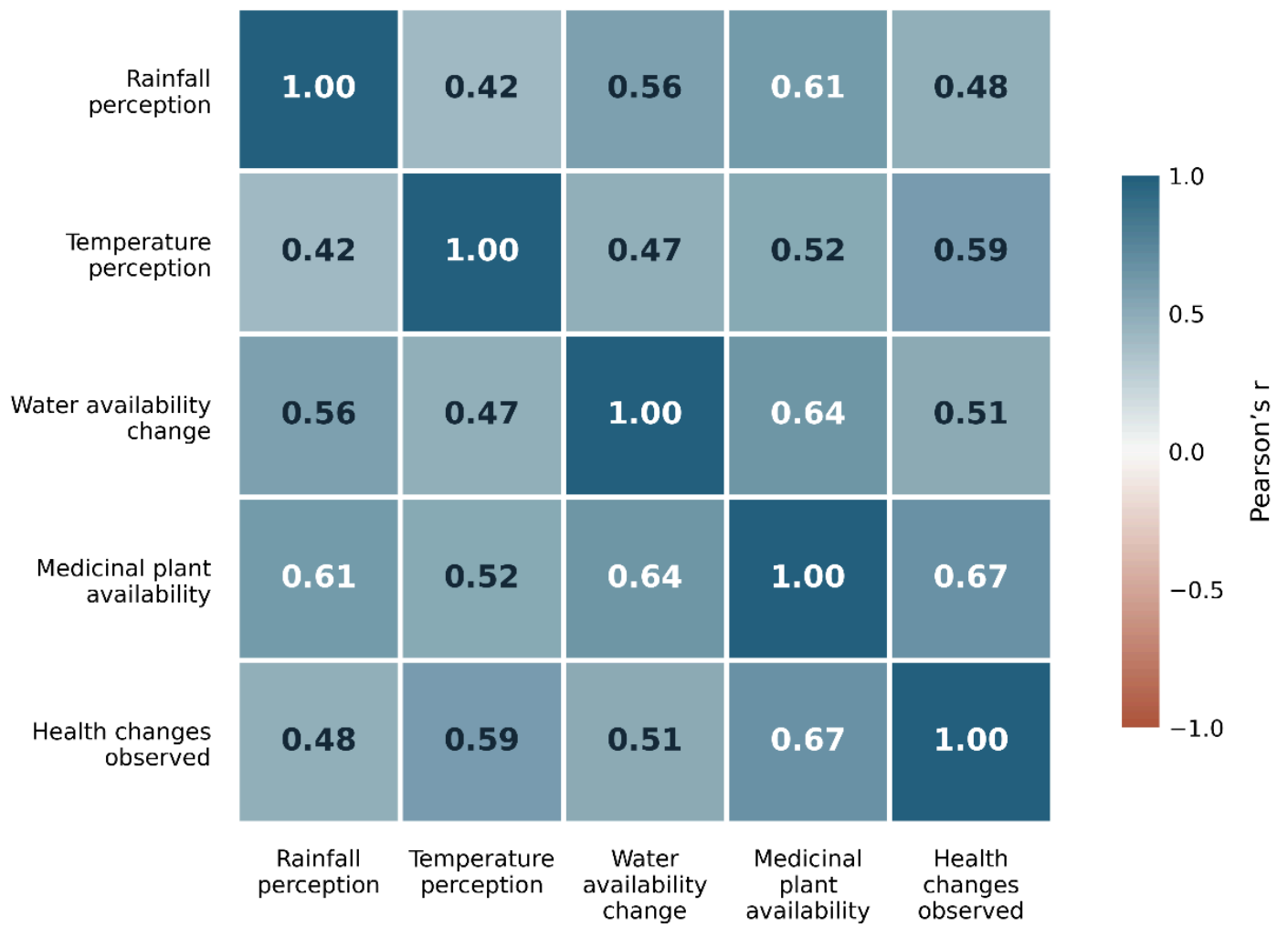


Figure 3

Correlation of Climate Perception, Medicinal Plants, and Health



Figure 4

Different varieties of mushrooms collected and used by the Cholanaickan community