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Research Article

Non-timber forest products in management of tribal livelihood of Eastern Himalayan Region: A sustainability analysis

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Abstract
The North Eastern region of India is home to unique and diverse species of Non-Timber Forest Products (NTFPs), which are a rich source of income and play an important role in the living traditions of its people. The study was conducted in Meghalaya (East Khasi Hills, Ri-Bhoi) and Nagaland (Mokokchung, Peren), selecting two districts per state. From 20 villages across four Rural Development blocks, 250 respondents were proportionately chosen based on household availability. The study employed an exploratory research design using panel data and a purposive sampling technique, with the survey conducted during 2021-22. The study found that income from NTFPs contributed to socioeconomic sustainability in Nagaland, whereas Meghalaya faced an unsustainable scenario. NTFP income was deemed unsustainable due to monetary value fluctuations and inflation. Among the 47 identified NTFPs, broom grass, bamboo, mushroom, bamboo shoot, and snail were highly preferred for their demand and profitability. The vulnerability index indicated that Asian honeybee (3.57), betel leaf vine (3.40), and wild black pepper (3.13) were ecologically very vulnerable due to overuse, low regeneration, and indiscriminate harvesting. Some species were moderately vulnerable, while most were less vulnerable. Strict regulation by local conservation bodies, traditional institutions, and the state forest department is essential to prevent illegal forest destruction. The Ministry of Tribal Affairs, GOI, should expand Van Dhan Vikas Kendras (VDVKs) under TRIFED to enhance value addition, branding, and marketing, ensuring sustainable livelihoods and fair returns for forest-dependent communities.

Keywords: Non-Timber Forest Products, Eastern Himalayan, Meghalaya, Nagaland, Socioeconomic and Ecological sustainability

INTRODUCTION

Non-timber forest products (NTFPs) are other than round wood, or timber can be defined as biological material that may be extracted from natural ecosystems, natural forest plantations, or in agroforestry systems used in households, marketed, or has social-cultural or spiritual significance (Wickens, 1991; FAO, 1992, 1995). According to FAO (1992), NTFPs are all biological materials other than timber extracted from the forest for human use. NTFPs include all tangible products, natural, crafted, or processed, derived from forests or any other land under similar use other than timber. They also include foods, medicines, oils, resins, gums, tannins, bamboo, fuel wood, charcoal, and wild meat sold and consumed either at local, national, regional, or international levels. NTFPs are also known as minor forest products or non-wood products, broadly defined to include all forest products except timber, wood chips, pulp, and wood-based panels (FAO, 1992). The NTFPs are important source of income for the poor in many countries. In India, around 50 million people are dependent on NTFPs for their subsistence and cash income (Shaanker *et al.,* 2004; Adepoju and Salam, 2007). The use of Non-Timber Forest Products is an age-old practice of human beings in India specially in

Eastern Himalayan Region. In the upliftment of the rural economy, the role and contribution of NTFPs are crucial because of their richness in biodiversity as a source of food, fodder, fibre, fertilizers, herbal products, construction materials, cosmetics, and cultural products of perfumes, medicines, paints *etc*. (Chopra, 1993). NTFPs are vital to rural households in their contribution to health, food, energy, and other aspects of rural welfare (Suleiman *et al.,* 2017). The main motivation for collecting NTFPs is economic gain: both men and women collect minor forest produce to sell it locally or abroad at markets or through intermediaries who transport these goods on behalf of producers/consumers/dealers (Jones *et al.* 2021).

The North-East region of India is home to unique and diverse species of flora and fauna. Its traditional medicinal plants, hardwood trees, and animals are rich sources of income for sustainable c conservation (Shankar and Rawat, 2013). It also plays an important role in the traditions of its people. Both Meghalaya and Nagaland are the two states in Northeast India that have economically strong communities coming together to make sustainable use of their natural resources, including Non-Timber Forest Products (NTFP), which remain largely untapped despite their potential for socioeconomic development (Shaanker *et al*. 2004). The income from NTFPs is vital for the livelihood of indigenous communities. However, large-scale deforestation is slowly affected by these economies due to the rapid development of tourism, mining, and timber industry (Meinhold and Darr, 2019). In both the states, there is a strong tradition of sustainable utilization of forest resources and harvesting. The sustainability of these resources depends on how well they can be managed sustainably by local communities. In this line, the present study was designed to study NTFPs in livelihood management in Eastern Himalayan states systematically. The study also highlights the issues of sustainability pertaining to NTFPs management regarding socioeconomic and ecological sustainability.

MATERIALS AND METHODS

Study area

The study estimated socioeconomic and ecological sustainability by identifying the vulnerability status of the NTFPs collected by the villagers. The study was undertaken in two Eastern Himalayan states, Meghalaya and Nagaland. The study was conducted by utilizing exploratory research design. Panel data were collected through a purposive sampling technique. Meghalaya and Nagaland states were selected due to the presence of abundant biodiversity. In Nagaland, approximately 60 percent of the population residing in and around forests depends on Non-Timber Forest Products (NTFPs) as a crucial source of sustenance (Longkumer *et al*., 2020) (Zingkhai, 2015).These two states are also significant within the Eastern Himalayan region regarding NTFP availability. Two districts were purposively chosen from each state: East Khasi Hill and Ri-bhoi districts from Meghalaya, and Mokokchung and Peren districts from Nagaland. The districts were selected based on the presence of NTFPs and the uniqueness of their forested areas. Furthermore, one block from each district was selected purposively, considering NTFP availability. In Meghalaya, the study focused on the Umsning block from Ri-bhoi district and the KhatarshnongLaitkroh block from East Khasi Hills. Similarly, in Nagaland, the study included the Mangkolemba block from the Mokokchung district and the Peren block from the Peren district.

Sample size

Five villages were chosen from each block in both districts to collect data, guided by the significance of NTFPs in these areas. This resulted in a total of 20 villages for the study from the four blocks of four districts. Within these 20 villages, a total of 250 respondents were selected proportionally based on the number of households available in each village.

Socioeconomic sustainability

To assess socioeconomic sustainability, Stanley *et al.* (2012) applied an economic threshold approach, evaluating two key aspects: the extent to which household cash incomes or use values (expressed in dollars) align with an international poverty benchmark or an alternative wage measure. The daily earnings Y of an individual gatherer were analyzed to the widely recognized international absolute poverty threshold of $1.90 per day per person (adjusted for purchasing power parity, PPP) as defined by the World Bank (2015). Therefore, the consideration was done for each study if:

Y_i (per person daily NTFPs income) $ PPP > $1.90 $PPPday^{-1}capita^{-1}$

The following criteria were taken into consideration while evaluating socioeconomic sustainability:

The income values reported by NTFP gatherers, including both cash and non-cash earnings, were initially recorded in the local currency. These values were then converted into U.S. dollars using the applicable exchange rate and a Purchasing Power Parity (PPP) conversion factor. An "adjusted scale size" was applied to standardize household size. The annual per capita income from Non-Timber Forest Products (NTFPs) was determined by dividing the total annual household income by the adjusted household size. Additionally, the daily per capita income from NTFPs was calculated, and the adjusted income—based on PPP rates—was compared against the international poverty benchmark of $1.90 per day (or ₹38.38 per capita per day in PPP terms) (Note- In 2023, India's PPP conversion factor

was 20.20 INR per international dollar. This means $1.90 had the same purchasing power as approximately 38.38 INR in India).

Ecological sustainability

Ecological sustainability was assessed based on a framework developed by Sada (2007), which is a rapid species vulnerability assessment based on the community's socio-ecological knowledge and field-based scientific evidence was utilized. These frameworks integrate socioeconomic information on use patterns with the species' natural history (Evariste and Aloys, 2016). A key informant was utilized to document the Indigenous ecological knowledge of the local community on NTFPs, keeping in mind the following:

Primary Commercially Exploited NTFPs

The plant parts used, the usage, the mode of collection, the development stage of the plant parts (organ) collected, the knowledge of the reproductive biology of the plants, their perception about species abundance in the forest, and the local conservation practices.

Construction of a semi-structured interview schedule based on the selected (main) NTFPs species to establish the ranking of the NTFPs based on the following 11 criteria (Sada, 2007):

Market demand
Profit margin
Availability
Impact of harvesting on species survival
Time required for harvesting
Regenerative potential
Contribution to income
Employment opportunities
Processing technology
Interest
Accessibility and uses

Each criterion was scored using a 3-categorized ranking system, 1 standing for low, 2 for moderate, and 3 for high (Evariste and Aloys, 2016). For the calculation of NTFPs susceptibility, a rapid vulnerability assessment was developed as a quick way of organizing both scientific information and local knowledge about NTFPs species to determine whether a species is vulnerable in the resource use zone considering the following parameters-

The use frequency (P1)- calculated as the number of households reporting a specific use divided by the total number of households-the vulnerability of a given species increases with its popularity and use,

The different types of usages of the species (P2) - the higher the number of different usages of a given species, the higher the harvesting pressure,

The plant part used - (P3)- The vulnerability of a species depends on the ability of the plant part collected to regenerate rapidly or not,

The mode of collection (P4) - gathering of fallen plants' parts will have lesser effects on the plant than harvesting on standing plants,

The stage of development of the organ is collected (P5)- Plant organs collected at maturity will have lesser effects than if they were collected earlier.

Relative frequency (P6)- The overall vulnerability of a given species is determined as the cumulative value of vulnerability scores for all the parameters considered, using the following formula:

$$(VI) = (VP_1 + VP_2 + VP_3 + VP_4 + VP_5 + VP_6)/6 \quad \text{....Eq.1}$$

The scoring of vulnerability parameters was done based on a 3-categorized ranking system as follows:

Source: Betti (2001)

Vulnerability Index (VI)	Degree of vulnerability
< 2	Less vulnerable (present use condition)
2 ≤ VI < 2.5	Moderate vulnerability
VI ≥ 2.5	Highly vulnerable

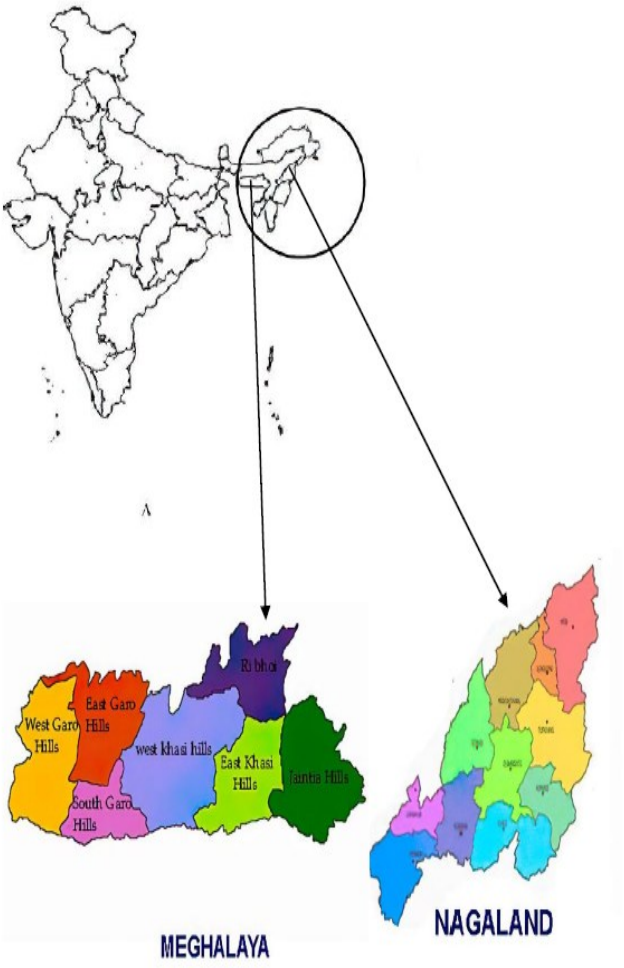

Fig. 1. *Map showing the study area of Eastern Himalayan states of Meghalaya and Nagaland*

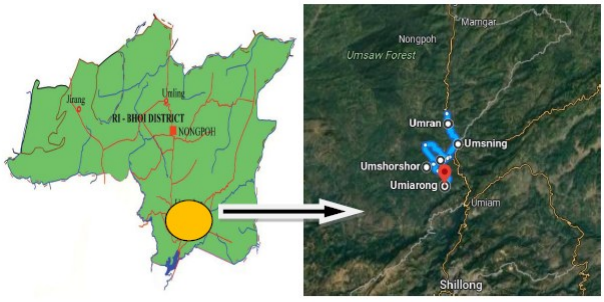

Fig. 2. *Map of Ri bhoi district and selected villages*

Fig. 3. *Map of East Khasi Hills District and selected villages*

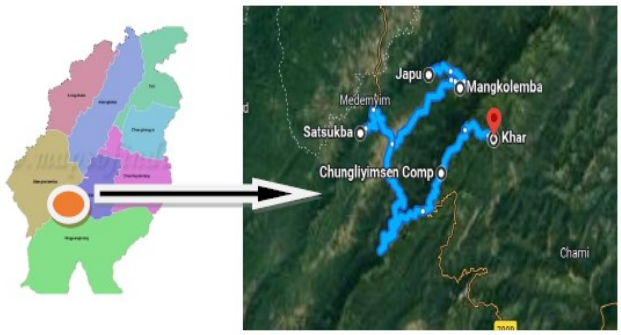

Fig. 4. *Map of Mokokchung district and selected villages*

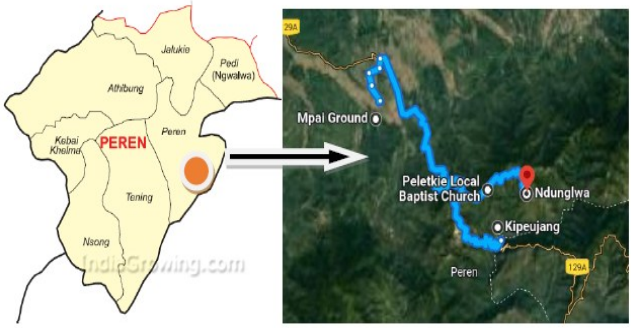

Fig. 5. *Map of Peren district and selected villages*

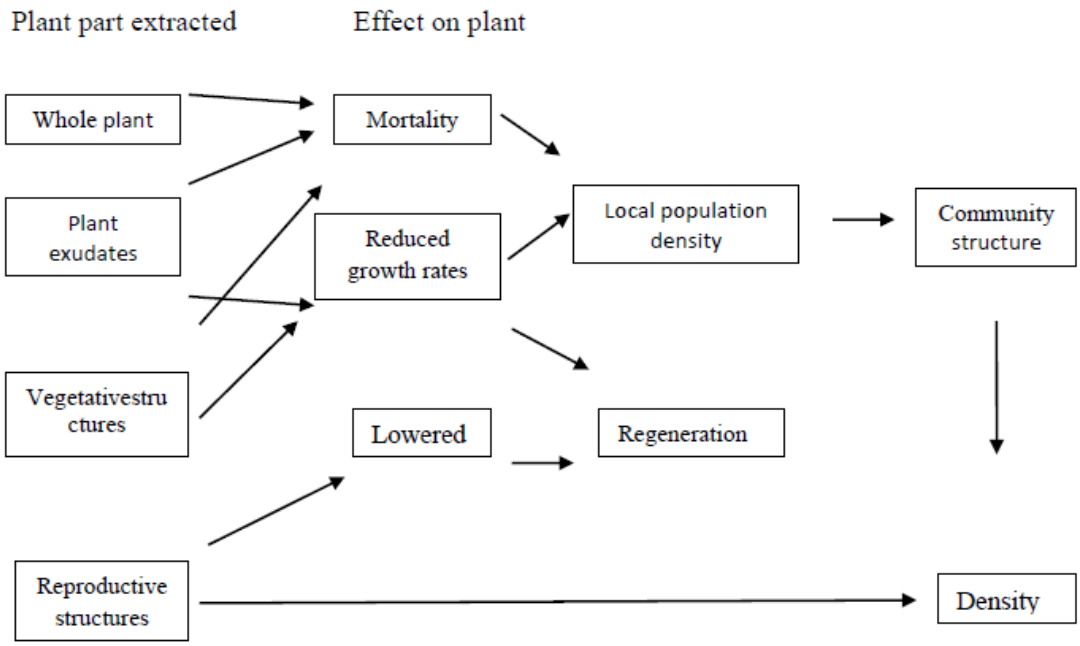

Fig. 6. *Possible ecological impacts of Non-Timber Forest Products (NTFPs) extraction (Ghazala and Soumya, 2004)*

RESULTS AND DISCUSSION

Contribution of Non-Timber Forest Products (NTFPs) towards income and employment generation in the study areas

Agriculture income dominated the share in the household income in both the states contributing about 44.29% of the total household income followed by income from NTFPs (40.71%), income from wages (11.36%), and income from allied activities (3.64%). However, the households' significant share of cash income was from NTFPs (44.46%) in the Eastern Himalayan Region. This indicates that in the study area, households collected quite a significant amount of NTFPs, and as a result, they earned a significant amount of income through the sale of NTFPs, which is called cash income. Tynsong *et al.* (2012) also reported in Southern Meghalaya that the contribution of NTFPs to the local people's cash income was highest in the case of poor families (9.89%), followed by middle-

income families (3.34%) and the least for the higher income families (1.34%). Chiphang *et al.* (2020) reported from the villages of Ri-bhoi district of Meghalaya and they found that income from NTFPs collection has the second largest share at22.05% followed by crop production at 14.61%, labour at 9.16%, and livestock at 8.44%. In the case of non-cash income (*i.e.*, the value of materials consumed at home), agriculture contributed the most, followed by NTFPs income. Longkumer *et al.* (2020) reported on the contribution of non-timber forest products in Mokokchung district of Nagaland, where the highest contribution of annual income obtained was from wage employment (45.7%) followed by NTFPs (30%). However, the household's major share of cash income was from NTFPs (44.46%) from the study area, as depicted in Table 1. Overall, of the total average of 280.74 employed days, agricultural activities constituted 44.33%, followed by days involved in NTFPs collection (25.80%), wage activities (17.84%), and allied activities (10.43%). However, Longkumer *et al*. (2020) reported from Mokokchung district of Nagaland that wage earners generated the highest employment among the households (33.50%), followed by NTFPs (29.10%) and agriculture (22.50%), yet NTFPs created a significant number of man-days in the study area which is also depicted in Table 2.

Socioeconomic sustainability

The study investigates the socioeconomic sustainability of NTFPs in the Eastern Himalayan states of Meghalaya and Nagaland. Income from NTFP can significantly help satisfy the nation's need for food and livelihood. On the other hand, one must also recognize its socioeconomic contribution, which can facilitate sustainable development (Sangma and Lalnundanga, 2018). Hence, considering all these, the study seeks to proceed with the null hypothesis that states that income from NTFPs helps increase socioeconomic sustainability.

The study reported values from NTFPs gatherers (both cash income and non-cash) and presented in local currency. The average household size was converted to the “adjusted scale size” of household members using the OECD square root scale method. The annual income from NTFP was adjusted per person per working day and was modified as per the scale-adjusted, per-person PPP$ value from NTFPs at an annual income level period represented in Indian rupees. Table 3 presents the income from Non-Timber Forest Products (NTFPs) in Meghalaya at a person^{-1} level day^{-1}, compared to the international absolute poverty line of USD$ 1.90 capita^{-1} or ₹44.10 day^{-1} capita^{-1}, as measured by purchasing power parity (PPP) and international comparisons, according to the World Bank's data from 2015. In Meghalaya, the income from NTFPs account-

Table 1. Distribution of income (₹ annum^{-1}) in the selected states

Source	Meghalaya				Nagaland				Overall			
	Cash income	Non-cash income	Total income	S.D of Total Income	Cash income	Non-cash income	Total income	S.D of Total Income	Cash income	Non-cash income	Total income	S.D. of Total Income
NTFPs	36596.59 (45.27)	37698.77 (39.66)	74295.36 (42.24)	21967.87	65638.56 (44.03)	12504.23 (25.28)	78142.79 (39.36)	29249.37	51117.58 (44.46)	25101.50 (34.74)	76219.08 (40.71)	35822.97
Agriculture	21866.46 (27.05)	57366.85 (60.34)	79233.31 (45.04)	30763.61	49663.36 (33.31)	36952.45 (74.72)	86615.81 (43.62)	32512.90	35764.91 (31.11)	47159.65 (65.26)	82924.56 (44.29)	41462.28
Wage	15027.38 (18.59)	-	15027.38 (8.54)	8089.28	27527.38 (18.46)	-	27527.38 (13.86)	39223.95	21277.38 (18.51)	-	21277.38 (11.36)	10638.69
Allied activities	7351.18 (9.09)	-	7351.18 (4.18)	4277.01	6262.18 (4.20)	-	6262.18 (3.15)	10490.46	6806.68 (5.92)	-	6806.68 (3.64)	3403.34
Total	80841.61 (100.00)	95065.62 (100.00)	175907.23 (100.00)	91271.76	149091.48 (100.00)	49456.68 (100.00)	198548.16 (100.00)	11476.67	114966.55 (100.00)	72261.15 (100.00)	187227.70 (100.00)	93613.85

Note: Values in the parentheses represent the percentage; NTFPs (Non-Timber Forest Products)

Table 2. Composition of annual employment of sample households (Mandays household^{-1} year^{-1}); (Values in the parentheses represent the percentage

S.No.	Source	Meghalaya	Nagaland	Overall
1.	NTFPs	60.92 (23.75)	83.96 (27.53)	72.44 (25.80)
2.	Agriculture	117.11 (45.66)	131.76 (43.20)	124.44 (44.33)
3.	Wage	42.70 (16.65)	57.47 (18.84)	50.09 (17.84)
4.	Allied Activities	35.74 (13.93)	31.80 (10.43)	33.77 (12.03)
	Total	256.47 (100.00)	305.00 (100.00)	280.74 (100.00)

NTFPs (Non-Timber Forest Products)

Table 3. Socioeconomic sustainability threshold of income from NTFP against international absolute poverty line in Meghalaya

District	Annual income from NTFP (₹household^{-1})	Average household size	Adjusted Annual income from NTFP (₹person^{-1})	Income from NTFP (₹person^{-1}day^{-1})	Adjusted income as per PPP rate (₹ person-1day^{-1})	PPP threshold level (₹person-1day^{-1})	Remarks
East Khasi Hills	70012.48	5.75	1492.47	6.13	21.57	44.11	Unsustainable
Ri bhoi	78578.23	4.47	3932.67	16.16	58.09	44.11	Sustainable
Overall	74295.36	5.11	2053.22	8.44	30.34	44.11	Unsustainable

Table 4. Socioeconomic sustainability threshold of income from NTFPs against international absolute poverty line in Nagaland

District	Annual income from NTFP (₹household^{-1})	Average household size	Adjusted Annual income from NTFP (₹person^{-1})	Income from NTFP (₹person^{-1}day^{-1})	Adjusted income as per PPP rate (₹ person^{-1}day^{-1})	PPP threshold level (₹person^{-1}day^{-1})	Remarks
Peren	76144.29	4.34	3717.03	11.08	39.83	44.11	Unsustainable
Mokokchung	80141.29	3.28	10430.78	29.15	104.79	44.11	Sustainable
Overall	78142.79	3.81	5118.13	14.75	53.02	44.11	Sustainable

Table 5. Socioeconomic sustainability threshold of income from NTFP against international absolute poverty line (Overall)

State	Annual income from NTFP (₹household^{-1})	Average household size	Adjusted Annual income from NTFP (₹person^{-1})	Income from NTFP (₹person^{-1}day^{-1})	Adjusted income as per PPP rate (₹ person^{-1}day^{-1})	PPP threshold level (₹person^{-1}day^{-1})	Remarks
Meghalaya	74295.36	5.11	2053.22	8.44	30.34	44.11	Unsustainable
Nagaland	78142.79	3.81	5118.13	14.75	53.02	44.11	Sustainable
Overall	76219.08	4.46	3831.72	10.50	37.74	44.11	Unsustainable

ed to ₹30.34 person^{-1} day^{-1}, indicating an unsustainable scenario whereby this income level is inadequate to lift individuals above the international absolute poverty line.

On the other hand, Table 4 displays the income from NTFPs in Nagaland, also measured against the international absolute poverty line of USD$ 1.90 day^{-1} capita $^{-1}$or ₹44.10 day^{-1} capita^{-1}. In Nagaland, the income from NTFPs reached ₹53.02 person^{-1} day^{-1}, reflecting a sustainable socioeconomic status. This indicates that the NTFP income in Nagaland is sufficient to support individuals above the international absolute poverty line. Table 5 presents a comprehensive view of the income derived from Non-Timber Forest Products (NTFPs) in the two Eastern Himalayan states, compared to the internationally recognized absolute poverty threshold of USD $1.90 day^{-1} capita^{-1}or ₹44.10day^{-1} capita^{-1}. The data reveals an alarming scenario wherein the earnings from NTFPs have proven insufficient to elevate individuals beyond the global poverty benchmark.

However, it is important to consider various factors, such as the current monetary value and inflation, which may impact the sustainability of NTFP income. Considering these factors, it becomes apparent that the overall income generated from NTFPs in both states is incapable of sustaining individuals above the international absolute poverty line of USD$ 1.90 day^{-1} capita^{-1}. In a study conducted in Imo State, Nigeria, by Ekwugha and Onyema (2014), it was found that approximately 12.00% of the respondents were living below the poverty line, defined as earning less than $1.90 day^{-1}. Among this group, around 7% relied predominantly on Non-Timber Forest Products (NTFPs) for their livelihoods. Notably, all the individuals engaged in NTFPs reported a positive contribution from these activities to their overall household income, indicating the significant impact of NTFPs on their economic well-being. This suggests that the income from NTFPs alone is insufficient to provide a sustainable livelihood. One potential contributing factor to this insufficiency could be the disparity in average household sizes between Meghalaya and Nagaland.

Ecological sustainability

Over-exploitation of Non-Timber Forest Products (NTFPs) can lead to the depletion of stocks, primarily because of growing populations and rising market demand. However, the commercialization of Non-Timber Forest Products (NTFPs) can provide a powerful incentive for conserving valuable species and their natural habitats. When local communities or individuals can derive income through sustainable harvesting and selling NTFPs like medicinal plants, wild mushrooms, or rare herbs, they often have a vested interest in ensuring the long-term health of the ecosystems supporting these resources. This economic incentive aligns with conservation goals and can lead to better management practices. Bluffstone *et al.* (2011) highlighted how the sustainable harvesting of NTFPs in Madagascar contributed to forest conservation efforts by promoting community involvement and reducing deforestation pressures. According to Tynsong *et al.* (2012), an argument suggests that extracting Non-Timber Forest Products (NTFPs) can positively impact forest sustainability. This is because NTFP extraction benefits impoverished rural communities economically while promoting biodiversity conservation. Additionally, a report from the Food and Agriculture Organization (FAO) in 2009 emphasized the potential of NTFPs to improve both livelihoods and biodiversity conservation (FAO, "Non-Wood Forest Products"). In summary, the commercialization of NTFPs can foster a win-win scenario where economic benefits drive conservation efforts. Ticktin (2015) outlined key principles for assessing NTFP harvesting sustainability, emphasizing that species' life history traits—such as reproductive rates, growth patterns, and ecosystem interactions—determine their resilience. Sustainable extraction requires harvesting within regenerative limits to ensure both economic and ecological benefits. Moreover, Baumflek (2016) examined the sociocultural, economic, and ecological dimensions of sustainable forest management for NTFPs in the United States. Their findings emphasize the importance of integrating traditional ecological knowledge with scientific research to ensure sustainable harvesting. They highlighted that community-based management strategies, such as rotational harvesting and habitat preservation, contribute to maintaining ecological balance while supporting rural economies. The study also underscored the need for policies that protect harvester rights and promote equitable market access for small-scale NTFP collectors.

Preference for collection of Non-Timber Forest Products

The ranking of Non-Timber Forest Products (NTFPs) based on preference was determined based on a set of 11 selected criteria. These criteria included market demand, margin/profit, availability, impact of harvesting on species' survival, time required for harvesting, regenerative potential, contribution to income, potential for employment, processing technology, interest, and accessibility and uses. Each criterion was assessed using a 3-categorized ranking system, where a score of 1 represented low preference, 2 indicated moderate preference, and 3 denoted high preference.

Table 6 presents the preference scores and rankings of the NTFPs collected in Meghalaya. Among the 22 NTFPs collected and identified in the state, plant-based products such as broom grass (22.64), bamboo

Table 6. Ranking of Non-Timber Forest Products (NTFPs) collected from Meghalaya based on preference

Sl.No	NTFP	NTFPs Preference Score	Rank
1	Broom grass	22.64	1
2	Bamboo	21.70	2
3	Mushroom	20.29	3
4	Bamboo shoot	19.01	4
5	Pinewood	18.58	5
6	Wild apple	13.70	6
7	Bayberry	11.97	7
8	Indian gooseberry	11.06	8
9	Betel leaf vine	11.03	9
10	Tez patta	10.68	10
11	Banana buds	10.35	11
12	Indian plum	8.30	12
13	Ferns	6.66	13
14	Asian honeybee	5.95	14
15	Giant Indian fig	4.41	15
16	Thatch leaf	4.20	16
17	Bag flower	3.80	17
18	Burmese grape	3.58	18
19	Kanthior	1.60	19
20	Brown shrimp	1.15	20
21	Flying lizard	1.08	21
22	Common carp	0.47	22

NTFPs (Non-Timber Forest Products)

(21.70), and bamboo shoot (19.01) were highly preferred due to their strong market demand and profitability. Shankar (2022) in his study highlighted the economic viability of cultivating broom grass in the Darjeeling Himalaya, noting its adaptability and high market demand generating as high as net revenue of US$ 3374 (₹296100.89) ha-1 for a six-year plantation cycle (five harvests) making it a highly preferred product On the other hand, NTFPs such as bag flower (3.80), burmese grape (3.58), and *kanthior* (1.60) were regarded as less favored. Regarding animal-based NTFPs, mushrooms (20.29) and Asian honeybee (5.95) were highly preferred due to their favorable attributes. However, brown shrimp (1.15), flying lizard (1.08), and common carp fish (0.47) were deemed less preferred due to their low price and limited availability (Fig 7).Chiphang *et.al* (2020) identified broom grass and bay leaf (Tezpatta) as significant contributors to employment, generating 2 and 1 man-days per quintal per year, respectively. Price forecasting using the ARIMA model indicated that broom grass prices were projected to decrease from ₹2,891.66 per quintal in late November to ₹2,687.46 per quintal by late December 2018 from two villages in Ri-Bhoi district of Meghalaya. Lallawmkimi *et al.* (2023) studied the Aizawl Market, Mizoram, and identified key factors affecting NTFP collection and trade, including geographical location, transportation facilities, seasonality, price, and demand. These factors directly influence the preferences and economic viability of NTFP collection.

Table 7 provides an overview of the inclination towards collecting Non-Timber Forest Products (NTFPs) in Nagaland, along with their corresponding NTFP preference scores and rankings. Among the plant-based NTFPs, bamboo shoots, broom grass, and bamboo emerged as the most highly favoured options, obtaining preference scores of 25.50, 24.86, and 21.71, respectively. These plant-based NTFPs were predominantly chosen due to their potential to generate significant sales profits. On the other hand, certain plant-based NTFPs, such as common walnut, *ketibu*, and Indian nightshade, were regarded as less preferred options, with preference scores of 3.82, 3.17, and 1.81, respectively. In animal-based NTFPs, snail and mushroom stood out as the highly preferred choices, attaining preference scores of 21.90 and 19.42, respectively. These animal-based NTFPs garnered significant favourability owing to their perceived economic advantages. Conversely, certain animal-based NTFPs, including frog, jungle fowl, and wild pig, were regarded

Table 7. Ranking of NTFPs (Non-Timber Forest Products)collected from Nagaland based on preference

Sl. No	NTFPs	NTFPs preference score	Rank
1	Bamboo shoot	25.50	1
2	Broom grass	24.86	2
3	Snail	21.90	3
4	Bamboo	21.71	4
5	Mushroom	19.42	5
6	Tree bean	17.98	6
7	Wild apple	17.78	7
8	Indian gooseberry	17.50	8
9	Chocolate Mahseer	16.55	9
10	Colocasia	14.98	10
11	Wild black pepper	13.10	11
12	Ferns	11.22	12
13	Toko patta	9.74	13
14	Pinewood	9.62	14
15	Betel leaf vine	9.23	15
16	Chinese sumac	9.15	16
17	Asian honeybee	7.56	17
18	Myrobalan	4.55	18
19	TsumaNgai (fish)	3.97	19
20	Porcupine	3.97	19
21	Common walnut	3.82	20
22	Frog	3.51	21
23	Jungle fowl	3.18	22
24	Ketibu	3.17	23
25	Wild pig	2.24	24
26	Indian nightshade	1.81	25

as less preferred alternatives, obtaining preference scores of 3.51, 3.18, and 2.24, respectively (as illustrated in Fig 8). A study by Das *et al.* (2022) identified five major groups of NTFPs collected by forest dwellers in Nagaland: wild fruits, wild vegetables, medicinal plants, fuelwood, and other categories, including broom grass and wild meat. The study found that wild vegetables were the most collected NTFPs, with 97% of respondents engaging in their collection, followed by other categories at 87%. Konyak et al. (2021), in their findings in the Mon district of Nagaland, documented the use of 43 plant species across 26 families by the Konyak tribe. These NTFPs serve various purposes, including food, medicine, and construction materials, highlighting their integral role in daily life and cultural practices. The Asteraceae family was particularly prominent among the utilized species.In summary, the collection preferences for NTFPs in Nagaland indicated a strong inclination towards plant-based NTFPs such as bamboo shoots, broom grass, and bamboo, primarily driven by their potential for yielding substantial profits. On the other hand, snails, and mushroom emerged as the highly preferred animal-based NTFPs due to their economic viability. Conversely, NTFPs such as common walnut, *ketibu*, Indian nightshade, frog, jungle fowl, and wild pig were deemed less favoured options within the context of Nagaland's NTFPs collection practices.

Non-Timber forest products vulnerability

Sada (2007) developed a framework for measuring ecological sustainability, which involved conducting a rapid species vulnerability assessment based on a combination of the community's socio-ecological knowledge and field-based scientific evidence. In the context of Meghalaya, this framework was utilized to assess the ecological vulnerability parameters of various Non-Timber Forest Products (NTFPs) (Saha and Sundriyal, 2010). Table 8 presents the results of ecological vulnerability parameters of NTFPs collected in Meghalaya. Among the NTFPs considered, the Asian honeybee exhibited the highest overall use frequency among the respondents, scoring 14.56 on the scale,

Table 8. Ecological vulnerability parameters of the Non-Timber Forest Products (NTFPs) collected in Meghalaya

NTFPs	Use frequency (P1)	Species usages(P2)					Parts used(P3)						Regenerative potential (P4)	Stage of development of the parts collected (P5)			Total score
		food	medicine	fuel wood	other	score	stem bark	fruit	leaves	roots	others	score		Early	Matured	Score	
Burmese grape	2.35	*	-	-	-	1	*	*	-	-	-	2	1	*	*	2	8.35
Bag flower	1.17	*	*	-	-	2	-	-	*	*	-	2	3	-	*	1	9.17
Giant Indian fig	1.17	*	-	-	-	1	*	*	*	*	-	4	2	-	*	1	9.17
Indian plum	0.39	*	-	-	-	1	*	*	*	-	-	3	2	*	*	2	8.39
Banana buds	1.37	*	-	-	-	1	-	*	-	-	-	1	3	*	*	2	8.37
Bayberry	1.17	*	*	-	-	2	*	*	*	*	-	4	1	*	-	1	9.17
Indian gooseberry	2.35	*	*	-	-	2	-	*	*	-	-	2	2	-	*	1	9.35
Kanthior	0.20	*	-	-	-	1	-	*	-	-	-	1	2	-	*	1	5.2
Broom grass	5.48	-	-	-	*	1	*	-	-	-	-	1	3	*	*	2	12.48
Bamboo shoot	1.96	*	-	-	-	1	*	-	-	-	-	1	1	*	*	2	6.96
Ferns	0.39	*	*	-	-	2	-	-	*	-	-	1	3	-	*	1	7.39
Thatch leaf	0.59	-	-	-	*	1	-	-	*	-	-	1	2	-	*	1	5.59
Bamboo	2.74	-	-	*	*	2	*	-	-	-	-	1	3	*	*	2	10.74
Pinewood	1.96	-	-	*	*	2	*				*	1	2	*	*	2	8.96
Wild apple	1.37	*	*	-	-	2	-	*	*	-	-	2	1	-	*	1	7.37
Betel leaf vine	6.07	*	*	-	-	2	-	-	*	-	-	1	1	-	*	1	11.07
Bay leaves	3.13	*	*	-	-	2	-	-	*	-	-	1	1	-	*	1	8.13
Asian honeybee	9.30	*	*	-	-	2	-	-	-	*	*	2	3	*	*	2	18.3
Brown shrimp	1.17	*	*	-	-	2	-	-	-	-	*	1	2	*	*	2	8.17
Common carp	0.39	*	-	-	-	1	-	-	-	-	*	1	3	*	*	2	7.39
Flying lizard	1.37	*	*	-	-	2	-	-	-	-	*	1	3	-	*	1	8.37
Mushroom	3.13	*	*	-	-	2	-	-	-	-	*	1	2	-	*	1	9.13

* - indicate the score

Table 9. Vulnerability index of Non-Timber Forest Products **(**NTFPs) collected in Meghalaya

S. No.	NTFP	Vulnerability Index (VI)	Remarks
1	Asian honeybee	2.43	Moderately vulnerable
2	Broom grass	2.08	Moderately vulnerable
3	Betel leaf vine	1.85	Less vulnerable
4	Bamboo	1.79	Less vulnerable
5	Indian gooseberry	1.56	Less vulnerable
6	Bag flower	1.53	Less vulnerable
7	Giant Indian fig	1.53	Less vulnerable
8	Bayberry	1.53	Less vulnerable
9	Mushroom	1.52	Less vulnerable
10	Pinewood	1.49	Less vulnerable
11	Indian plum	1.40	Less vulnerable
12	Banana buds	1.40	Less vulnerable
13	Flying lizard	1.40	Less vulnerable
14	Burmese grape	1.39	Less vulnerable
15	Brown shrimp	1.38	Less vulnerable
16	Bay leaves	1.36	Less vulnerable
17	Ferns	1.23	Less vulnerable
18	Common carp	1.23	Less vulnerable
19	Wild apple	1.23	Less vulnerable
20	Bamboo shoot	1.16	Less vulnerable
21	Thatch leaf	0.93	Less vulnerable
22	Kanthior	0.87	Less vulnerable

NTFPs (Non-Timber Forest Products)

followed by Asian broom grass (12.48) and betel leaf vines (11.07). The mushroom and bay leaves also displayed relatively high usage, scoring 9.13 and 8.13, respectively. These scores indicated that the local communities extensively utilized these NTFPs. These scores reflect not only the large degree of utilization but also the low regenerative potential of these products. Furthermore, it was noted that these NTFPs were harvested at various stages of development, indicating that collection occurred regardless of the part's maturity. In summary, the assessment of the ecological vulnerability parameters of NTFPs in Meghalaya reveals that the Asian honeybee, betel leaf vine, mushroom, and bay leaves were the most utilized products among the respondents. Lynser and Tiwari (2016) documented the use of 172 NTFPs from 139 plant species in rural Meghalaya, highlighting their diverse applications in food, medicine, and fuelwood. These products play a crucial role in daily life, but extensive harvesting raises concerns about their ecological impact. Similarly, Mipun *et al.* (2019) explored the role of NTFPs in healthcare and livelihood security among the Karbi tribe in Northeast India, emphasizing the significance of traditional knowledge systems in resource utilization. Their study underscored the need to integrate indigenous practices into conservation strategies to ensure ecological sustainability. Together, these studies highlight the intricate balance between the dependence on NTFPs for livelihoods and the necessity of sustainable harvesting practices to maintain ecological integrity.

The ecological vulnerability status of NTFPs collected in Meghalaya (Table 9) was assessed using a vulnerability index score, with Asian honey bee and broom grass scoring 2.43 and 2.08, respectively, indicating moderately vulnerable. All other NTFPs were seen as less vulnerable. Asian honey bee and broom grass were seen as popular but have low regenerative potential, making them moderately vulnerable. They can be harvested at any stage and have multiple uses, like honey and bee larvae for Asian honey bees and high market demand for broom grass (as depicted in Fig 9).The state government and stakeholders, like the Apiculture Mission of Meghalaya, can organize training programs for sustainable beekeeping practices to address this. This includes hive management, bee health, honey extraction, and habitat preservation education for local communities. Oldroyd and Nanork (2023) highlighted that deforestation and excessive hunting pressure are significant threats to local honey bee populations in Southeast Asia. The study emphasizes the

Table10. Ecological vulnerability parameters of the Non-Timber Forest Products (NTFPs) collected in Nagaland

NTFPs	Use frequency (P1)	Species usages(P2)					Parts used(P3)						Regenerative potential (P4)	Stage of development of the parts collected (P5)			Total score
		Food	Medicine	Fuel wood	other	score	stem bark	fruit	leaf	root	other	score		Early	Matured	Score	
Colocasia	8.14	*	-	-	-	1	-	-	-	-	-	0	2	*	*	2	13.14
Myrobalan	5.51	*	*			2	-	*	-	-	-	1	3	*	*	2	13.51
Indian gooseberry	5.51	-	*	*	-	2	*	*	*	-	-	3	3		*	1	14.51
Ferns	1.05	*	-	-	-	1	*	-	*	-	-	2	1	*		1	6.05
Wild black pepper	10.76	*	*	-	-	2	-	*	-	-	-	1	3	*	*	2	18.76
Pinewood	2.62	-	-	*	-	1	*					1	3	*	*	2	9.62
Ketibu	3.94	*	*	-	-	2	*	-	*	-	-	2	3	*	*	2	12.94
Indian nightshade	0.52	*	*	-	-	2	-	*	*	-	-	2	3		*	1	8.52
Chinese sumac	3.94	*	*	*	-	3	-	*	-	-	-	1	3	*	*	2	12.94
Bamboo shoot	1.84	*	-	*	-	2	*	-	-	-	-	1	2	*	*	2	8.84
Common walnut	1.05	*	*		-	2	-	*	*	-	-	2	3	*	*	2	10.05
Bamboo	18.37	-	-	*	*	2	*	-	-	-	-	1	1	*	*	2	24.37
Wild apple	1.57	*	*	*		3	-	*	-	-	-	1	3	*	*	2	10.57
Toko patta	4.99	-	-	-	*	1	-	-	*	-	-	1	2	*	*	2	10.99
Tree bean	1.84	*	-	*		2	*	*	-	-	-	2	3	*	*	2	10.84
Broom grass	5.51	-	-	*	*	2	*	-	-	-	-	1	2	*	*	2	12.51
Betel leaf vine	13.39	*	-	-	-	1			*			1	3	*	*	2	20.39
Asian honeybee	13.39	*	*	-	-	2					*	1	3	*	*	2	21.39
Chocolate Mahseer	1.05	*	-	-	-	1					*	1	3	*	*	2	8.05
Tsuma Ngai (fish)	6.04	*	-	-	-	1					*	1	2	*	*	2	12.04
Wild pig	3.41	*	*	-	-	2					*	1	3	*	*	2	11.41
Jungle fowl	2.10	*	*	-	-	2					*	1	3	*	*	2	10.10
Frog	2.89	*	*	-	-	2					*	1	2		*	1	8.89
Porcupine	1.05	*	*	-	-	2					*	1	3	*	*	2	9.05
Mushroom	2.10	*	*	-	-	2					*	1	2	*	*	2	9.1
Snail	2.10	*	-	-	-	1					*	1	2		*	1	7.1

* - indicate the score; NTFPs (Non-Timber Forest Products)

Table 11. Vulnerability index of Non-Timber Forest Products **(**NTFPs) collected in Nagaland

S. No.	NTFP	Vulnerability Index (VI)	Remarks
1	Asian honeybee	3.57	Highly vulnerable
2	Betel leaf vine	3.40	Highly vulnerable
3	Wild black pepper	3.13	Highly vulnerable
4	Bamboo	2.43	Moderately vulnerable
5	Jungle fowl	2.38	Moderately vulnerable
6	Indian gooseberry	2.35	Moderately vulnerable
7	Myrobalan	2.19	Moderately vulnerable
8	Ketibu	2.16	Moderately vulnerable
9	Chinese sumac	2.16	Moderately vulnerable
10	Broom grass	2.09	Moderately vulnerable
11	Wild pig	2.05	Moderately vulnerable
12	Tsuma Ngai (fish)	2.01	Moderately vulnerable
13	Colocasia	1.86	Less vulnerable
14	Toko patta	1.83	Less vulnerable
15	Tree bean	1.81	Less vulnerable
16	Wild apple	1.76	Less vulnerable
17	Common walnut	1.68	Less vulnerable
18	Pinewood	1.6	Less vulnerable
19	Mushroom	1.52	Less vulnerable
20	Porcupine	1.51	Less vulnerable
21	Frog	1.48	Less vulnerable
22	Indian nightshade	1.42	Less vulnerable
23	Chocolate Mahseer	1.34	Less vulnerable
24	Bamboo shoot	1.31	Less vulnerable
25	Snail	1.18	Less vulnerable
26	Ferns	1.01	Less vulnerable

NTFPs (Non-Timber Forest Products)

need for sustainable harvesting practices and forest conservation to protect these pollinators.

Table 10 provides a comprehensive overview of ecological vulnerability parameters for Non-Timber Forest Products (NTFPs) in Nagaland. Notably, plant-based NTFPs like betel leaf vine and bamboo scored 20.39 and 19.78, respectively, indicating high utilization. Among animal-based NTFPs, the Asian honeybee scored 21.39, and jungle fowl scored 14.25. Overall, Asian honeybees (21.39), betel leaf vines (20.39), and bamboo (19.78) ranked highest, which is crucial for the local tribal population. These NTFPs have limited regenerative potential, raising concerns for long-term sustainability due to continuous harvesting. Harvesting at any developmental stage exacerbates strain on regrowth and disrupts the local ecosystem balance. Das *et al.* (2023) studied forest dwellers in Nagaland and identified key factors influencing the collection of NTFPs. The research found that traditional norms, income opportunities, and food sources drive NTFP collection. It also highlighted that dependency ratios and employment from NTFPs significantly impact household income, suggesting that socioeconomic factors play a crucial role in NTFP sustainability.

Table 11 presents a comprehensive overview of the ecologically vulnerable species that were collected from Nagaland based on their vulnerability index score. Among these species, the Asian honey bee exhibited a vulnerability index score of 3.57, the betel leaf vine scored 3.40, and the wild black pepper scored 3.13, indicating that these species are classified as ecologically very vulnerable. The reason behind their vulnerability lies in their high market demand and price, coupled with their low regenerative potential. Furthermore, several other Non-Timber Forest Products (NTFPs) were identified as moderately vulnerable. These included bamboo with a vulnerability index score of 2.43, jungle fowl scoring 2.38, Indian gooseberry scoring 2.35, myrobalan scoring 2.19, Chinese sumac and *ketibu* both scoring 2.16, broom grass with a score of 2.09, wild pig scoring 2.05, and *tsumangai* scoring 2.01. These moderately vulnerable NTFPs were characterized by relatively lower vulnerability compared to the highly vulnerable species. The remaining species listed in the table were deemed as less vulnerable based on their vulnerability index scores.Pervez and Manzoor (2021) highlighted that excessive pesticide use in Asian agriculture threatens pollinators like the Asian honey bee by disrupting their physiology, behavior, and cognition, leading to higher mortality and reduced pollination. High honey demand and low regenerative potential worsen the decline. Pandey *et al.* (2022) highlighted

that wild pigs are integral to the diet, medicine, and spiritual practices of indigenous people in Nagaland. A combination of high market demand, low regenerative potential, environmental threats, and unsustainable harvesting practices influences the ecological vulnerability of these species in Nagaland. Conservation strategies should focus on sustainable management, habitat conservation, and community involvement to preserve these valuable species.

Conclusion

The sustainability assessment on using Non-Timber Forest Products (NTFPs) in the Eastern Himalayan Region indicated that it boasts a rich diversity of NTFPs, including medicinal herbs, wild fruits, wild vegetables, bamboo etc. This diversity presents both opportunities and challenges for sustainable management. The sustainable harvesting of NTFPs positively impacts the local ecosystem and can contribute to biodiversity conservation and the overall health of forests. NTFPs play a vital role in the livelihoods of local communities, providing a source of income, particularly for marginalized and indigenous populations, contributing to poverty reduction and food security. Unsustainable harvesting practices pose a significant threat to NTFPs and the ecosystems they rely on, leading to overexploitation, habitat destruction, and improper harvesting techniques, which can lead to resource depletion. Regulatory Framework with effective regulation and governance are critical for the sustainable management of NTFPs. The study highlights the importance of implementing and enforcing policies that promote sustainable harvesting practices. Engaging local communities in NTFP management is essential to empower communities with knowledge and skills for sustainable harvesting, leading to better conservation outcomes. There is a growing demand for NTFPs locally and globally; therefore, developing sustainable value chains and market linkages can create economic opportunities for communities while encouraging responsible harvesting. The empirical analysis of NTFPs in the Eastern Himalayan Region underscores their multifaceted importance. While NTFPs offer significant benefits in terms of livelihoods, biodiversity conservation, and economic opportunities, they are also vulnerable to overexploitation and habitat degradation. While sustainable harvesting supports ecosystem health and poverty reduction, unsustainable practices threaten resource depletion and habitat degradation. Effective governance, community engagement, and sustainable value chains are essential for long-term management. Balancing Conservation and utilization through holistic strategies can ensure the viability of NTFPs, providing valuable guidance for policymakers and stakeholders in the region.

Conflict of interest

The authors declare that they have no conflict of interest.

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