



## Ecosystem under siege: Human activities and biodiversity in Munnar

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### Abstract

The hill atmosphere of Munnar, which lies inside India's Western Ghats, is well known for its abundant wildlife and ideal climate. Nevertheless, there are several environmental demands placed on this particular ecosystem. Using a network-based survey, this study seeks to understand the ecological consequences and social adaptation of the Munnar hill environment. Residents' opinions on government regulations, the effects of tourism, biodiversity initiatives, conservation activities, and overall environmental sustainability are gathered through the survey. In order to secure the long-term sustainability of the Munnar hill surroundings, the results indicate a complex relationship between human activities and ecological health, emphasizing the critical necessity for comprehensive conservation policies and active network involvement. These realizations highlight how urgent it is to promote a sensible approach that gives equal weight to social resilience and ecological preservation.

**Keywords:** Social adaptability, ecological implications, munnar hill habitat, western ghats, conservation initiatives, biodiversity, environmental sustainability

### Introduction

Hill stations are untamed formations in the terrain that are hard to distinguish. It is necessary to establish standards on what constitutes a mountainous area and what does not, as they are home to a disproportionate amount of species with significant ecological and conservational worth (Körner, Urbach, and Paulsen 2021) [8]. Hillside systems are crucial focal points of ecological and cultural diversity, spanning 24% of the Earth's land surface and accommodating 12% of the global population, thus offering essential resources and services to humanity. Additionally, these systems sustain 25% of terrestrial biodiversity and host nearly half of the planet's biodiversity hotspots (Lebuy *et al.* 2022) [9]. The primary characteristic of hill stations is their inclination, which allows gravity and geology to work together to shape the landscape. The resulting topography then interacts with the climate (solar radiation, wind, snow distribution, and substrate and water allocation) to produce a rich diversity of habitats (Körner, Urbach, and Paulsen 2021) [8]. Mountain life is severely temperature-limited, and mountain regions are especially vulnerable to climatic changes (Albrich, Rammer, and Seidl 2020) [2]. All the same, mountain systems are facing enormous ecological changes in this period with far-reaching consequences for the millions of people who directly depend on the ecosystem services provided by mountains. In addition, the expanding number of tourists is stressing out the delicate alpine ecosystems (Chakraborty 2020) [5].

One of the most pressing worldwide environmental issues causing greenhouse gas emissions and adverse effects on local health is land-use change and deforestation. The record-breaking occurrences or unusual climatic extremes (UCEs) had more tendency to increase plant death and impede ecosystem recovery, intense heatwaves and droughts have a significant impact on ecosystem stability and carbon cycling (Holm *et al.* 2023) [7]. In fact, by 2030, preserving

existing forests and reforesting deforested areas might provide one-sixth of the carbon mitigation needed to stop climate change from getting out of control (Abman *et al.* 2020) [1]. Outsiders perceive a disparity between nature and humanity, with mountains being deemed fragile due to deforestation leading to erosion. Additionally, indigenous communities are seen as lacking awareness of environmental issues in the region (Purohit 2021) [12]. The populations, species, and communities inhabiting high elevation mountainous areas located at or above the tree line are experiencing effects from the shifting climate (Seastedt and Oldfather 2021) [15].

Mountain communities have traditionally had a particular relationship with their surroundings, but they are currently going through a transformation that is rearranging how they utilize space, challenging dominant development paradigms, and creating new territorial initiatives (Bertolino and Corrado 2022) [4]. Numerous hill farming settings have seen a large-scale emigration of young, leaving farmlands abandoned (Rana and Bisht 2023) [14]. Moreover, global changes affect mountain regions, emphasizing the need to reconfigure community-based resource management to address biodiversity loss, climate crises, and social disparities while promoting sustainable development and thriving communities (Torre *et al.* 2022) [17]. These challenges underscore the importance of holistic approaches integrating economic, social, and cultural dimensions for the sustainable development of hill communities ("Tourism as An Unconventional Strategy Enriching Social and Economic Development at Hills Area in Bangladesh: A Study on Bandarban Hills Area" 2022) [18]. Community responses to environmental changes and disasters are crucial for resilience ("Bedyga - 2022 - A Review of Literature on Community Responses to E. Pdf," n.d.) [3]. Community engagement is proposed as a key intervention for achieving actual community resilience, with examples showcasing

technology transfer and knowledge co-production (Phillips, Nell, and Botsch 2021) <sup>[11]</sup>. It is imperative to utilize community-based initiatives and local understanding in order to improve sustainability and resilience in hill communities. Social activities, land management, and tourism projects have demonstrated the resilience of communities in places susceptible to landslides (Wyss *et al.* 2022) <sup>[19]</sup>. In mountainous locations, putting a focus on co-creation of solutions, local knowledge, and community engagement can help close knowledge gaps, improve livelihoods, and increase resilience (Shrestha 2019) <sup>[16]</sup>.

## Materials and Methods

### Study site

Munnar is one of the most popular tourist destinations and stunning hill stations in India's South Western Ghats. It lies over 557 square kilometers (Chandran and Bhattacharya 2021) <sup>[6]</sup>. Munnar has enormous potential to grow its tourist industry (Murugadoss and Nagarathinam 2007) <sup>[10]</sup>. The study area is located at latitudes 10°04'45"N–10°05'58"N and longitudes 77°02'40"E–77°03'45"E. Munnar's elevation is 1700 meters above mean sea level (Chandran and Bhattacharya 2021) <sup>[6]</sup>. Within the southern Western Ghats, it includes the greatest grassland-shola system. In addition to the town of Munnar and its extensive tea fields, it consists of four national parks, two animal sanctuaries, reserve forests, high altitude settlements, tribal hamlets, and Anamudi, the highest peak south of the Himalayas. The United Nations has designated four of the protected sites as World Heritage Sites. The protected areas total more than 40,000 hectares, whilst the tea gardens span 24,000 hectares. Many of the tea gardens, which offer essential habitats and stepping stone passages for numerous animal species, are situated inside a geophysical continuity with other protected areas (Rammohan, Soman, and Joseph 2015) <sup>[13]</sup>.

### Research design

The study took place in Munnar, a mountainous region in the Idukki district of Kerala, India. It went on from March to June. In this study information was gathered by using a questionnaire sent out through Google Forms. The survey had 22 questions, designed on a five-point scale ranging from strongly agree to strongly disagree. The main purpose of this survey was to understand people's views on environmental consequences and their attitudes towards community resilience. Responses were collected from hundred individuals in the Munnar district. Along with their responses, some basic demographic data like name, age, gender, and educational background were also collected. Random sampling method is used and received about 100 completed responses.

The survey questions were carefully crafted to get participants' opinions on different aspects of environmental impact and societal resilience. Some examples of the questions asked were: "Do you think human activities affect biodiversity?", "Are local communities involved in conservation efforts?", "Are there enough measures in place for wildlife conservation?", and "How do infrastructure development and tourism activities affect the ecosystem?"

To analyze the data, Microsoft Excel were used through a method of descriptive statistics like frequency, percentage, mean, and standard deviation. Throughout the investigation, ethical principles are followed. Also made sure that

participants were informed by providing them with detailed information about the survey's goals and confidentiality and informed that personal data is secured and only used it for research purposes

## Results and discussion

In the survey, most of the participants were female which is of 74%, whereas 26% are classified as male. This data shows that a greater level of female participants are actively interested compared to male respondents towards the research study. The segmentation of participants can be classified into four specific age brackets: 18-25, 26-35, 36-45, and 46-55. An analysis of the data illustrates a noteworthy clustering of survey takers within the younger age category, particularly the (18-25), constituting 76% of the total sample, with a count of 76 individuals. This substantial proportion shows that the younger population had a higher level of interest regarding the subject matter covered in the questionnaire. The main reason is the accessibility to digital channels through which the survey was likely disseminated, or their amplified awareness of environmental and societal issues impacting their future. In comparison, individuals aged 26-35 represent 18% of the respondents, totalling 18 participants. Even though this number is significantly lower than that of the younger generation, it nevertheless indicates a reasonable level of participation from young professionals who may be balancing early work obligations or academic pursuits. Through their active engagement, the survey's findings can be enhanced by their insightful comments on the transitional phases of their personal and professional lives. Surprisingly, the 36–45 and 46–55 age categories show a nominal and equivalent presence of 3% each, or just 3 people each category. The low participation of these age groups may be due to a number of things, including time restraints from work or family responsibilities, less engagement with online surveys, or perhaps a lower level of interest in the topic of the survey than their younger colleagues. The participants of age group 18–25 is the most prevalent, which highlights that this group is usually more active on social media where the surveys had been conducted. Also, it is an important matter to consider that they are in a stage of life where they are forming strong opinions about social and environmental issues, which probably contributes to their increased levels of participation. Figure 1 represents these percentages visually. On contrast, the low participation of older age groups suggests that specific outreach strategies are needed to reach a wider range of age groups. It is crucial to get opinions from these older populations since they have a variety of experiences and viewpoints that could significantly enhance the survey's overall findings.

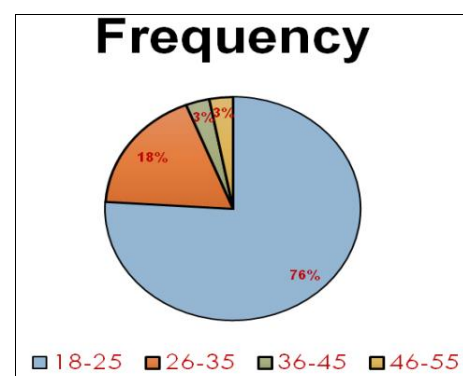


Fig 1: Age distribution

Subsequent to the age distribution study, the survey respondents' educational attainment is analyzed and classified into four categories: undergraduate, postgraduate, above postgraduate, and below undergraduate. Table 1 represents that the majority of respondents, have advanced degrees. More particular, twenty-five of the participants, or 43 percent, have earned their undergraduate degrees. Similarly, another 43% of the population—25 people—have earned postgraduate degrees. Higher education is significantly more prevalent among those in the survey sample, indicating that the majority of respondents are educated and may have greater interest in social and ecological issues.

Only a lesser portion of respondents that is 12% had less than an undergraduate degree ie 7 people in total. This group adds to the variety of perspectives in the poll despite their smaller numbers. Lastly, a very small percentage of respondents about 2% of them have degrees higher than a doctoral degree. This implies that the population surveyed does not include many people with very advanced educational backgrounds. The survey's target audience appears to be one that values education and also showed interest to participate in intellectual discussions about ecological and societal sustainability, which is mostly undergraduate and postgraduate degree holders. The respondents' high educational attainment may have influenced their perceptions of and opinions about the subjects of the study.

**Table 1:** Educational qualification

Educational Qualification	Frequency	Percentage (%)
Below undergraduate	7	12
Undergraduate	25	43
Postgraduate	25	43
Above postgraduate	1	2

**Survey responses on environmental issues and societal resilience**

According to the survey shown in table 2, the information gathered exhibits Munnar's local community perception on a number of environmental facts that comprises climate change, government laws, biodiversity and the impact of tourism. In this case, the main threat to the Munnar hill ecosystem, is identified as human activities. Some 72 percent of the participants concurred with the statement that they have a high level of concern regarding the impacts of human activities that led to effects on the biodiversity in the area. All the respondents together, which given the responses on the scale were positively skewed while still comes up to a positive mean of 2.014, as well as the standard deviation of 0.09 relating to the comparative binary outcomes. As a result, the views on conservation depend with the participation of the local community in conservation measures. All in all, the results of the survey identifies that the majority of the respondents agreed with or strongly endorsed the proposition that the local communities should participate more in global decisions, yet one third of respondents offered a neutral response, and the remaining 5% disagreed totally. There is clear evidence of variety seeking by buyers identifying broader range of perspectives with a greater standard deviation of 0.810. Also, the response mean was found to be 2.3. Different evaluation is possible concerning the governmental policy of Munnar concerning the environmental issues. Of all the respondents

only, few agree or strongly agree that these policies are sufficient with a 45% percentage, 39% were indecisive with a neutral response while 16% were negative with disagree or strongly disagree response. Concerns regarding Munnar's natural environment, 70% of the respondents agreed or strongly agreed with the assertion that Munnar's natural ecosystem has been affected due to tourism. The findings provide the impetus for arguing that there indeed exists a consensus on the detrimental impacts of tourism as evidenced by the average mean 2.11 and the standard deviation of 0.942 from the subject we can see the variation as to how much of environmentalist Munnar locals are. Yet only 41% of the sample agree or strongly agree with the statement but awareness is quite high as 18% disagreed and the same number as neutral. A moderate degree of agreement, or variation and dispersion, which is clearly indicative of the average, is indicated by the response of 2.7, and the standard deviation 0.948. To be more specific, 69% of the respondents said that climate change is a severe threat to natural balance of Munnar. On average the response shows an excellent level of consensus as the response summed up is 2.19 and the standard deviation 0.950. In turn, seventy two percent agreed that pollution is something that is of concern to the sustainability of the environment. The pollution levels in Munnar are a major concern as it shows average mean of about 2.15, and this is a very high degree of concern for action. The respondents focus on assessing the efficiency of government involvement as a functional part of making environmental policies. Although there is a general indifference on the part of the respondents in portraying the government as effective in its interface with local communities there is a general agreement that the government does interface the local people; 35% of the respondents agreed or strongly agreed with the statement, 47% were neutral while 18% of the respondents disagreed. Analyzing the data the author notes the respondents' skepticism in relation to governmental programs and services, according to which their experience was described as average, with the mean value of 2.8 and the standard deviation of 0.943. To the question regarding the infrastructure development strategy which can enhance the economic development while maintaining a sustainable environment only 42% of the respondents supported the statement. Notably, 38% of people said they were neutral on the issue, and 20% said they disagreed with the practice. These concerns are also seen in the 2.75 average response and from this it is clear that the responses to the question got a boost with the new designs adding three quarters to the average response and the 0.978 standard deviations. Views on the effectiveness of wildlife conservation initiatives show a range of viewpoints: Referring to the efforts made to integrate information literacy into the curriculum, 48% of respondents mildly or strongly believe that the efforts made are sufficient while 36% are in the middle and 16% do not believe that enough is being done in this area. Positive, negative or otherwise, none of them is conclusive as evidenced by an average response rate of 2.57 and the greater standard deviation of 1.075. Specific to question, average response was 2.3, an implication of respondents believing that 60% of the times, communities are likely to be resilient to any environmental challenge. At the end of the study, there was a mean score of 2.3 and the standard deviation of 0.823 which are physical which are general consensus. Topical perceptions of public educational and

awareness campaigns that promote the use of sustainable tourist behaviors in terms of opinion, 57% of the respondents have high positive evaluation of public education and awareness campaigns concerning tourists' sustainable behaviors, 33% offered a neutral response while 10% had a negative disposition. We also included it when using a standard deviation of 0.939. The overall mean response rate for the study was, 2.38. The following table highlights the response distribution among the participants; Table 2 – Response distribution among the participants. 2.38 can be regarded as rather close to accepted but also somewhat deviant from it to a certain extent. The respondents have demonstrated the following attitude towards the ability to conserve native biodiversity in Munnar: 40% assured, 15% are in vain. On this issue, there is some disagreement with the mean response rate being 2.6 as demonstrated in the study. It shows that the mean score of 2.6 and the standard deviation of 0.898. About the harm of tourism on the balance of the ecosystem, the majority of respondents are inclined towards the postulate (62%); 24% are neutral; 14% are against it. As indicated by the probability value, which is less than or equal to 0.992 and the mean response of 2.31 this means that there is consensus on the negative impact of library 32 and they conceive of it as being problematic. Specifically for the following statement: 'There are sustainable livelihood opportunities to support livelihoods', 56% of the respondents are in a supportive position, 36% are neutral and 8% of the respondents are in opposition. Standard deviation of two data sets has to be compared and with the data given above shows that the standard deviation of data is 0.857 and a mean response rate of 2.45 belongs to the set of relatively high values continuously accompanied by a unanimous opinion of the respondents. Majority response, 71% opined that climate change is a cause for concern while a minority 10% opined to the contrary and 19% employees were neutral. As showcased in the mean response of 2.22, this is an issue taken seriously by the respondent population and the standard deviation of 0.980. Differing opinions are

expressed in assessments of responsible land use methods intended to reduce soil erosion: There is a clear agreement of 49% of respondents in the statements made, while 34% are in a neutral perspective, and only 17% are in the disagreeing side. These differences range from one another represent the variability where the standard deviation is 0.977 and the average response rate varied with a mean response rate of 2.56, respectively. The respondents' attitudes towards the water resource management is considered important by 52% of the respondents, while 40% are not Certain, and 8% hold a disagree view. The results therefore seem to have a consensus basis with an average response rate of 2.48 and the standard deviation of 0.797. Only 4% of the respondents unequivocally disagree with the statement that deforestation is a threat, while 17% are indifferent to the given issue. This cognition hazard seems to have raised a lot of concern since the mean response is 1.92 to the standard deviation of 0.812. On the issue of infrastructure development, 53% of the respondents have a positive attitude toward development conservation ecological infrastructure development, 33% are indifferent while 14% have a negative attitude toward the same. We can also see the variation in the opinion of people as is evident by the mean of 2.5 to standard deviation of 1 the study revealed that out of the respondents, 39% approved of pollution control measures while 41% were indifferent and 20% disagreed. The standard deviation of 1.008 is usually considered to be set easy comparison and the mean response of 2.75 and it also shows that the standard deviation for the 1.008 condition was 2.75 suggest that pollution control strategies are a cause for concern. Sustainable development that can allow the growth of the tourism sector without harming the environment is supported by the 50% of the respondents, 38% of the respondents are not sure, and the last 12% of the respondents do not agree with the statement. A standard deviation of 0.937 and the average response was 2.52. As pointed out in this paper, there are not fully concordant opinions regarding this equilibrium

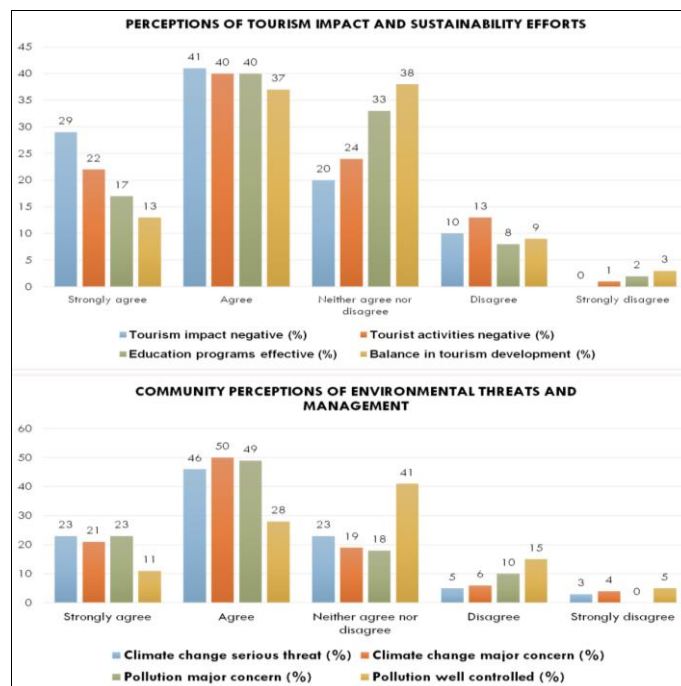
**Table 2:** Survey Responses on Environmental Issues and Societal Resilience

Questions	Response	Frequency	Percentage	Mean	Standard deviation
The biodiversity of Munnar hill ecosystems is under threat to human activities	Strongly agree	25	25	2.09	0.854
	Agree	50	50		
	Neutral	19	19		
	Disagree	5	5		
	Strongly disagree	1	1		
Local communities in Munnar actively involved in conservation efforts	Strongly agree	15	15	2.3	0.810
	Agree	46	46		
	Neutral	34	34		
	Disagree	4	4		
	Strongly disagree	1	1		
Government policies adequately address the ecological challenges faced by Munnar hill ecosystems	Strongly agree	10	10	2.64	0.937
	Agree	35	35		
	Neutral	39	39		
	Disagree	13	13		
	Strongly disagree	3	3		
Tourism development has a significant negative impact on the natural environment in Munnar	Strongly agree	29	29	2.11	0.942
	Agree	41	41		
	Neutral	20	20		
	Disagree	10	10		
	Strongly disagree	0	0		
The local population's awareness of environmental issues is high in Munnar	Strongly agree	10	10	2.7	0.948
	Agree	31	31		
	Neutral	41	41		
	Disagree	15	15		

	Strongly disagree	3	3		
Climate change poses a serious threat to the ecological balance of Munnar hill ecosystems.	Strongly agree	23	23	2.19	0.950
	Agree	46	46		
	Neutral	23	23		
	Disagree	5	5		
	Strongly disagree	3	3		
Pollution levels in Munnar are a major concern	Strongly agree	23	23	2.15	
for environmental sustainability.	Agree	49	49		0.892
	Neutral	18	18		
	Disagree	10	10		
	Strongly disagree	0	0		
The government effectively involves local communities in decision-making regarding environmental policies in Munnar	Strongly agree	8	8	2.8	0.943
	Agree	27	27		
	Neutral	47	47		
	Disagree	13	13		
Infrastructure development in Munnar balances economic growth with environmental conservation.	Strongly disagree	5	5	2.75	0.978
	Strongly agree	8	8		
	Agree	34	34		
	Neutral	38	38		
	Disagree	15	15		
Wildlife conservation efforts in Munnar are sufficient to protect endangered species	Strongly disagree	6	6	2.57	1.075
	Strongly agree	17	17		
	Agree	31	31		
	Neutral	36	36		
The community resilience of Munnar hill ecosystems is high in the face of environmental challenges.	Disagree	10	10	2.3	0.823
	Strongly disagree	1	1		
	Strongly agree	16	16		
	Agree	44	44		
Public education and awareness programs effectively promote sustainable practices among tourists visiting Munnar	Neutral	13	13	2.38	0.939
	Disagree	4	4		
	Strongly disagree	1	1		
	Strongly agree	17	17		
The local biodiversity in Munnar is being adequately protected.	Agree	40	40	2.6	0.898
	Neutral	33	33		
	Disagree	8	8		
	Strongly disagree	2	2		
Tourist activities have a negative impact on the ecological balance of Munnar	Strongly agree	11	11	2.31	0.992
	Agree	34	34		
	Neutral	40	40		
	Disagree	14	14		
Local communities have access to sustainable livelihood options in Munnar	Strongly disagree	1	1	2.45	0.857
	Strongly agree	10	10		
	Agree	46	46		
	Neutral	36	36		
Climate change is a major concern affecting the hill ecosystem in Munnar	Disagree	5	5	2.22	0.980
	Strongly disagree	3	3		
	Strongly agree	21	21		
	Agree	50	50		
Land use practices are managed responsibly to prevent soil erosion in Munnar	Neutral	19	19	2.56	0.977
	Disagree	6	6		
	Strongly disagree	4	4		
	Strongly agree	14	14		
Water resources in Munnar are managed effectively to meet local needs	Agree	35	35	2.48	0.797
	Neutral	34	34		
	Disagree	15	15		
	Strongly disagree	2	2		
Deforestation is a significant threat to the hill ecosystems of Munnar	Strongly agree	9	9	1.92	0.812
	Agree	43	43		
	Neutral	40	40		

	Disagree	4	4		
	Strongly disagree	0	0		
Infrastructure development projects prioritize ecological conservation in Munnar	Strongly agree	15	15	2.5	1
	Agree	38	38		
	Neutral	33	33		
	Disagree	10	10		
	Strongly disagree	4	4		
Pollution levels in Munnar are well controlled and monitored	Strongly agree	11	11	2.75	1.008
	Agree	28	28		
	Neutral	41	41		
	Disagree	15	15		
	Strongly disagree	5	5		
There is a balance between tourism development and ecological preservation in Munnar	Strongly agree	13	13	2.52	0.937
	Agree	37	37		
	Neutral	38	38		
	Disagree	9	9		
	Strongly disagree	3	3		

**Perceptions of tourism impact and sustainability efforts**



**Fig 2:** (a) Perceptions of tourism impact and sustainability efforts, (b) Community perceptions of environmental threats and management

The figure 2 (a), shows the analysis of viewpoints of the respondents regarding many aspects of tourism and how it is impacted on the Munnar hill ecosystem. The graph shows opinion about the negative effects of tourism, the negative repercussions of tourism-related activities, the effectiveness of public education campaigns, and the balance between tourism growth and environmental preservation. Significant insights were revealed from the opinions about how tourism affects the Munnar hill ecosystem and the effectiveness of related sustainability initiatives. Most of the responders strongly believe growth of tourism had been negatively impacted in the Munnar's natural surroundings. In particular, 41% agree and 29% strongly agree, indicating a general consensus that tourism poses a serious threat to the environment. The view of tourist activities, which is further supportive of this opinion, is that 62% of respondents (of whom 40% strongly agree and 22% agree) believe that tourism negatively impacts ecological stability. The indifferent replies, while significant, pale in contrast to the general agreement over the adverse effects of tourism. On the other hand, opinions on the success of public education and awareness efforts are noticeably more neutral but still

favorable. There is a difference in the perceived effectiveness of these ads, as seen by the fact that 33% of participants are indifferent, despite 57% of people (17% strongly agree and 40% agree) believing these campaigns to be beneficial. This neutrality shows how important it is in order to conduct public education campaigns to guarantee that tourists embrace sustainable practices more consistently. The balance between the growth of tourism and environmental conservation also shows a conflicting perspective. According to half of the respondents i.e., 13% strongly agree and 37% agree, while 38% of them neither agree nor disagree, indicating ambiguity. This ambivalence suggests that more work is needed to reach a more widely accepted equilibrium, even in the face of attempts to establish a balance between economic expansion and conservation. This ambiguity suggests that more effort is still needed to reach a more widely acknowledged equilibrium, even in the face of attempts to establish a balance between economic growth and conservation. In summary, the survey findings indicate that there is vast consensus regarding the harm that tourism causes to Munnar's environment and the need of more stringent

conservation measures. Different viewpoints on the harmony of tourism development and public education campaigns seeks attention to areas that require improvement. Moreover, addressing these issues and securing the future of the Munnar hill environment would require increased community involvement, better enforcement of policies, and focused educational initiatives.

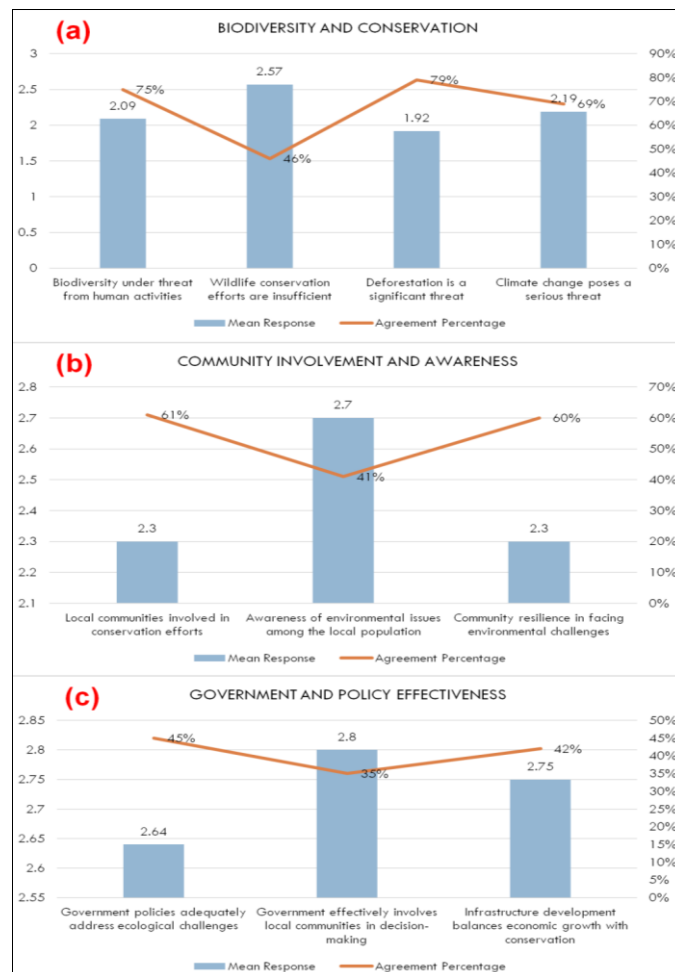
**Community perceptions of environmental threats and management**

A sizable portion of survey respondents believe that climate change poses a serious threat to the Munnar hill ecosystem. Figure 2 (b) shows that 23% strongly agree with this statement, and 46% agree, meaning that 69% of respondents recognize the seriousness of climate change implications. This large majority indicates a higher degree of consciousness and concern about effects on their environment due to climate change. On the other hand, 23% of respondents did not indicate whether they agreed or disagreed, this shows that they were not sure about this matter. A little of 5% of them disagrees, and 3% them strongly disagrees about the matter, this suggests that there is a minority that does not consider climate change as a major threat, possible cause is that they have little direct influence.

From the total of 71% of respondents 21% strongly agreeing and 50% agreeing seeing climate change as a significant issue that has to be considered. Although the immediate severity may vary, there is a general anxiety about climate change, as evidenced by the somewhat greater percentage when compared to those who perceive it as a significant

concern. A smaller percentage of them i.e. 19% of them are still undecided, indicating a percentage from the population is indecisive. The minority of 6% disagree and 4% strongly disagree, confirming the widespread recognition of how important climate change issues are. Another major worry raised by the attendees is pollution. Among 72% of respondents, 23% strongly agree and 49% agree thinking that pollution is a major concern in Munnar. This high degree of agreement highlights the general understanding how pollution effects to the community's environment and public health. Only 18% among the responses are indifferent, suggesting that there is a chance of some variation in people's experiences with or perceptions of pollution levels. The 10% disagree, and none strongly disagree—which emphasizes that majority of people feel that pollution is an urgent issue. Views on the effectiveness of pollution management strategies take a more polarized position. Only 11% strongly agree with this statement, but 28% do so as well. This means that 39% of respondents think pollution control measures are successful. This suggests a less confident view of the ongoing efforts to control pollution, as evidenced by the significant 41% who are undecided. This impartiality suggests a sense of incoherence or a lack of knowledge regarding pollution control programs. Furthermore, 15% disagree and 5% strongly disagree, suggesting that a significant portion of the community believes pollution management efforts are insufficient or inadequately carried out.

**Biodiversity and conservation in Munnar Hill ecosystem**



**Fig 3:** (a) Biodiversity and conservation in Munnar hill ecosystem, (b) Community involvement and awareness, and (c) Government and policy effectiveness

The study results shown in the figure 3 (a), indicate a noteworthy degree of apprehension concerning the impact of human activities on the biodiversity of the Munnar hill ecosystem. The majority of participants believe that biodiversity is in danger, as evidenced by the average rating of 2.09. The fact that 75% of respondents agrees or strongly agrees that human activity caused a negative impact on the area's biodiversity. This increased level of anxiety highlights that there is an urgent need to take effective measures to reduce human intervention, like sustainable tourism, reducing deforestation, and enforcing laws for environmental conservation. Activities such as deforestation, increased agricultural production, and infrastructure construction are common human endeavours in alpine environments such as Munnar, and they all lead to habitat loss and fragmentation. These activities could disrupt natural processes and reduce the diversity of animals. Given the critical role that biodiversity plays in maintaining the stability and flexibility of ecosystems, conservationists and policymakers must give the perceived hazards careful thought right away. The analysis from the figure 4, also sheds light on Munnar residents' perceptions of wildlife protection initiatives. The adequacy of these initiatives received an average grade of 2.57, suggesting a moderate level of dissatisfaction. Just 46% of respondents agreed or strongly agreed that current conservation efforts are adequate to protect endangered species. This feedback suggests that some efforts may not be sufficiently implemented or may not exist at all. Comprehensive strategies that consist of community involvement, habitat protection, anti-poaching measures, and ongoing monitoring are essential for the effective management of wildlife. The participants' moderate degree of satisfaction may be a sign of shortcomings in these areas. Increasing funding, strengthening to implement laws to protect in order to protect wildlife, and supporting community-based preservation initiatives are some ways to make conservation plans more effective. Implement transparency and communication between the public and conservation organizations may be necessary to foster confidence and guarantee community support. With a mean score of 1.92 and an astounding 79% of participants either agreeing or strongly agreeing with this assumption in the figure 4, deforestation is acknowledged as a severe threat to the Munnar hills' environment. This widespread agreement emphasizes how grave the issue of deforestation is. Deforestation causes habitat loss, soil erosion, and changes in microclimates, all of which can have detrimental effects on the local flora and wildlife. The level of concern that exists over deforestation is indicative of the ongoing challenges associated with efficiently overseeing land use and forest reserves. In order to address this problem, stricter land use regulations must be implemented, afforestation and reforestation projects must be supported, and sustainable farming practices must be encouraged. Another way to lessen the burden on forests is to provide other sources of income and include local communities in reforestation efforts. As shown in the figure 4, mean response of 2.19 and 69% agreement among respondents recognizing climate change's major threat indicate that it poses a significant challenge to Munnar's ecological equilibrium. The effects of climate change on alpine ecosystems include variations in temperature and precipitation patterns, which may result in

altered species distribution, disturbed breeding cycles, and increased vulnerability to invading species and diseases. Given the serious concerns about the effects of climate change, mitigation and adaptation plans are desperately needed. These tactics can involve putting climate-smart farming practices into place, encouraging sustainable tourism, and strengthening ecosystem resilience through conservation and restoration initiatives. Building a more resilient ecosystem can also be facilitated by increasing public understanding of the effects of climate change and including local populations in adaptation planning.

### **Community involvement and awareness**

The approach used to present these findings combines agreement percentages with average responses to provide a clear and comprehensive picture of the information as shown in the figure 3 (b). In this graphic representation, the statements are represented by the x-axis, the mean replies are displayed by the primary y-axis (left) in the form of grouped columns, and the agreement percentages are displayed by the secondary y-axis (right) in the form of a line graph. According to the data visualization, 61% of participants expressed strong or agreement with the statement addressing community engagement in conservation activities, with a mean score of 2.3. This link suggests that community perceptions of participation in conservation efforts are generally positive. With just 41% of respondents agrees with the statement on awareness of environmental issues, the higher mean score of 2.7 shows a more neutral or slightly disagreeing view. This disagreement emphasizes that there is a need for enhanced environmental awareness and education initiatives. Similar results are also found for the statement on community resilience, it has a mean score of 2.3 and agreement percentage of 60 for the conservation efforts. This consistency shows possible areas that can be benefited from improvements while also guiding to a reasonable assessment of community resilience. One way to promote this involvement can be achieved through rewards systems, recognition initiatives, and inclusive conservation tactics. A concentrated effort in environmental education is needed due to the decreased awareness of environmental issues. Community organizations, local schools, governmental entities, local schools, had a scope to work together in order to develop educational initiatives that increases the knowledge of public about Munnar's ecological significance. Along with these public campaigns, seminars, and educational materials can be an advantage. Resilient communities must be built through a variety of strategies. By making investments in social networks and community cohesiveness, building resilient infrastructure, and providing resources for adaptation makes the communities to become more resilient. Further this resilience can be strengthened through training courses about sustainable farming methods, alternative livelihoods, and catastrophe preparedness and response.

### **Government and policy effectiveness**

The figure 6 demonstrates the significant new insights into Munnar's views on public policies, community involvement in the decision-making process, and the coexistence of economic development and environmental preservation. These findings point to critical areas in need of

improvement as well as opportunities to enhance environmental governance and sustainability. The first area of the research represented in figure 3(c), is how well government actions handle environmental problems in the Munnar area. The statement "Government policies adequately tackle ecological challenges" had an average rating of 2.64 from participants, only 45% of whom indicated strong agreement or agreement. This narrow degree of agreement shows a general perception that the policies in place are insufficient. This adequately address that the unique environmental concerns found in Munnar may be a reasonable explanation for this dissatisfaction is the lack of comprehensive and enforceable directives. Hill ecosystems often face unique problems, such as degraded soil, shrinking forests, and declining biodiversity, which call for specialized policy responses. Inadequate execution and enforcement of governmental initiatives may also contribute to their perceived insufficiency. Well-crafted policies may not provide the desired effects if strict execution and attentive monitoring are not in place. Although, there can be a communication breakdown between locals and policymakers. Reduced support and compliance may result from the cause of inadequate communication with the local communities about policies and their benefits can be could be lack of support. The government might ensure the incorporation of local knowledge and concerns into policy development and execution by engaging in more transparent and participatory policy formulation procedures. One important factor that is being examined in the research is community involvement in decision-making processes shown in figure 6. In this just 35% of participants agreed or strongly agreed with the statement, "The government effectively engages local communities in decision-making," which has an average grade of 2.8. Communities mostly local peoples can contribute to more effective and sustainable policies since they have access to important indigenous knowledge and personal observations of the surrounding ecology because participatory governance is important for environmental management. But from the survey it clearly shows that the Munnar's current community participation mechanisms are inadequate. In order to overcome this problem authorities could implement stronger community engagement tools. Regular consultations, open discussions, and inclusive decision-making bodies that actively involve local representatives are a few examples of these activities. Increasing community involvement fosters a sense of accountability and ownership among community members in addition to improving the relevance and effectiveness of policies. Consequently, this may lead to a rise in adherence to environmental laws and a higher success rate for conservation projects. The third major element of the survey as shown in figure 6 focuses heavily on how infrastructure development strikes a balance between environmental preservation and economic growth. The statement "Infrastructure development balances economic growth with conservation" received an average rating of 2.75 from respondents, meaning that 42% of participants agreed or strongly agreed with it. Although attempts are made to balance these two characteristics, it appears that they are not generally seen as totally effective, given the moderate level of unanimity. Like many other hill stations, the construction of roads, hotels, and other infrastructure could lead to increased pollution, habitat loss, and other negative environmental effects, but Munnar must

balance it with both economic development and conservation. Therefore, it is crucial to achieve a lasting balance. The survey's results shows that opinions of the respondents on this equilibrium vary to some extent. Proponents may point to efforts to advance sustainable practices, including laws requiring environmental impact assessments for new projects or initiatives for eco-friendly infrastructure. Moreover, the significant percentage of neutral and opposed replies suggests that a sizable portion feel that conservation practices are inadequate. This equilibrium can be improved through giving policymakers of green infrastructure projects that lessen environmental damage top priority. By using renewable energy sources, incorporating sustainable materials, and creating building designs that blend in with the environment results in the decrease of ecological footprints The implementation of strict environmental impact assessments and the guarantee that projects pertaining to economic development meet strict environmental standards can contribute to the preservation of Munnar's natural charms while fostering economic growth.

### Conclusion

These results provide an insight into the major threats to the Munnar hill environment due to excessive anthropogenic pressures, inadequate government regulations and the occasional problems of deforestation and climate changes. According to the study, Munnar's biodiversity is hugely stressed. Hope for better wildlife conservation efforts from the community indicating human induced threats in the ecology. As we all know, deforestation is one of the main factors in the loss of balance of the ecosystem. In order to address this requires an overall approach which covers the social, ecological and economic aspects. Sustainable management is achieved only through public awareness, community involvement and good governance. Also, future research should focus on developing and implementing conservation strategies that address the root causes of degradation and promote development and resilience in the context of climate change. This study shows that an integrated approach that involves all stakeholders in conservation and management of Munnar hill ecosystem is necessary. Through a holistic response to these challenges, we can ensure Munnar's ecological health for future generations and socio-economic wellbeing of its people

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