Contents

PAPERS

THE INTERNATIONAL FORESTRY REVIEW

Vol. 25 (4), 2023

The International Forestry Review

EDITOR: A.J. POTTINGER

International Forestry Review (print) ISSN 1465-5489
International Forestry Review (online) ISSN 2053-7778

Vol.**25**(4), 2023

PUBLISHED BY THE COMMONWEALTH FORESTRY ASSOCIATION

www.cfa-international.org

Measurable impacts of climate change on biodiversity and livelihoods in the tropical dry deciduous forest of Sheopur, Madhya Pradesh, India

R. PRASAD, R. TIMOTHY, S. MALAKAR and V. DAYMA

Society for Resource Planning, Development and Research (SRPDR), 06, Aranya Vihar, Chunabhatti, Kolar Road, Bhopal, India

Email: srpdr.bhopal@gmail.com

HIGHLIGHTS

- Climate change has had a direct and measurable impact on the livelihoods of local communities in Sheopur.
- There has been an observable trend in declining plant species within the forest due to changing climate patterns.
- A significant alteration in precipitation patterns, including a decrease in overall rainfall and an increase in the frequency of extreme weather conditions, such as droughts and unseasonal rainfall, are affecting the agricultural crops more frequently.
- Over the past two decades, the productivity or availability of NTFP has decreased by more than 30%.
- The identified forest landscape restoration interventions have brought positive results reflected in all three sample plots of Sheopur.

SUMMARY

This study investigates the measurable impacts of climate change on biodiversity and livelihoods within the tropical dry deciduous forest of Sheopur, Madhya Pradesh, India. With climate change emerging as a significant global concern, its effects on delicate ecosystems like the tropical dry deciduous forest are of paramount importance. Through a combination of field surveys, data analysis, and community engagement, an evaluation was conducted on the changes in vegetation and the impact on local livelihoods resulting from shifting climatic patterns. The findings underscore the critical need for adaptive strategies to mitigate the adverse consequences of climate change on both biodiversity and the well-being of local communities in this region.

Keywords: non-timber forest product (NTFP), biodiversity, climate extremes, vulnerability, adaptation, mitigation

Impacts mesurables du changement climatique sur la biodiversité et les revenus dans la forêt tropicale sèche de feuillus de Sheopur au Madhya Pradesh, en Inde

R. PRASAD, R. TIMOTHY, S. MALAKAR et V. DAYMA

Cette étude recherche les impacts mesurables du changement climatique sur la biodiversité et les revenus des ménages dans la forêt tropicale sèche de feuillus de Sheopur au Madhya Pradesh, en Inde. Alors que le changement climatique se révèle être un souci global d'envergure, ses effets sur les écosystèmes délicats comme la forêt tropicale sèche de feuillus revêtent une importance majeure. Avec l'aide d'un éventail d'études sur le terrain, d'analyse de données, et d'engagement avec les communautés, une évaluation a été menée sur les changements dans la végétation et l'impact sur les revenus des ménages locaux résultant des schémas climatiques en évolution. Les résultats soulignent le besoin critique de trouver des stratégies d'adaptation pour atténuer les conséquences néfastes du changement climatique sur la biodiversité et le bien-être des communautés locales de cette région.

Impactos cuantificables del cambio climático sobre la biodiversidad y los medios de vida en el bosque seco tropical caducifolio de Sheopur en el estado de Madhya Pradesh de la India

R. PRASAD, R. TIMOTHY, S. MALAKAR y V. DAYMA

Este estudio investiga los impactos cuantificables del cambio climático en la biodiversidad y los medios de vida dentro del bosque seco tropical caducifolio de Sheopur en el estado de Madhya Pradesh de la India. Debido a la aparición del cambio climático como una preocupación global significativa, sus efectos en ecosistemas delicados como el bosque seco tropical caducifolio son de importancia primordial. Mediante una combinación de encuestas sobre el terreno, análisis de datos y conversaciones con la comunidad, se llevó a cabo una evaluación de los cambios en la vegetación y el impacto en los medios de vida locales como resultado de los cambios en los patrones climáticos. Los resultados subrayan la necesidad crítica de estrategias de adaptación para mitigar las consecuencias adversas del cambio climático tanto en la biodiversidad como en el bienestar de las comunidades locales de esta región.

INTRODUCTION

The negative impact on biodiversity due to climate change and human intervention is becoming significantly more severe and its impact diminishes forest health and functionality of ecosystems. Furthermore, it undermines their capacity to withstand and rebound from climate-related threats, such as droughts, floods or storms. Consequently, a decline in biodiversity results in an elevation of the climate vulnerability of landscapes. Climate change is expected to exert various impacts on biodiversity, from ecosystems to the species level. The most evident impact is the influence of temperature and precipitation on the ranges of species and the boundaries of ecosystems (Kumar *et al.* 2009).

Impacts are visible on forest landscapes both directly and indirectly. Drying of the landscape due to erratic rainfall, heatwaves and frequent forest fires are directly limiting the benefits expected to flow from ecosystem services. Failure to promptly address the current challenges faced by impoverished farmers are exacerbated as a consequence of climate change resulting from global warming (Ninan *et al.* 2012). Frequent crop failures require the local population, especially the traditional forest gatherers, to resort to unsustainable and often destructive non-timber forest products (NTFPs) collection in excess of the regenerative capacity of forests. This trend of unsustainable extraction and use has been causing forest degradation and the gradual decline of many NTFP species.

This research study is focused on measuring the impact of climate change on biodiversity and livelihoods of local NTFP gatherers of Sheopur Forest division of Madhya Pradesh, India. The study employed three methodologies to assess the likely correlation between climatic parameters such as rainfall, temperature and heatwaves and the integrity of biodiversity, mostly plant species, which are routinely collected by forest gatherers to sustain their livelihoods. The first methodology was the assessment of the global and local status of biodiversity consisting of the most collected and traded species, through a CAMP (Conservation Assessment and Management Plan) workshop. The second method was to employ timeline data on biodiversity enumeration in sample plots of different sizes. The third method was based on questionnaire-based data collection and income in the past 4–5 years.

CLIMATE CHANGE IMPACT ON BIODIVERSITY AND LIVELIHOODS

The ability of species to adapt and track shifting climate conditions is crucial in mitigating the heightened risk of extinction posed by climate change (Davis MB 2001). Fluctuations in temperature and climate have a significant impact on both plants and animals, in some cases leading to mass extinctions (Srivastava 2019). Anticipating the effects of climate change on biodiversity is challenging due to the uncertainty surrounding the capacity of numerous species or ecosystems to adapt to alterations in climatic extremes, as well as changes in the intensity and frequency of extreme weather events (Freeman *et al*. 2008).

In the context of India, forests hold immense importance, having been historically utilized throughout the densely populated subcontinent and continue to play a direct and crucial role in supporting the livelihoods of at least 275 million rural people (World Bank 2006). Forest-dependent livelihoods face escalating vulnerability as forest cover diminishes and the incidence of both natural and human-induced fires increases. Notably, the forests in proximity to protected areas are projected to experience heightened susceptibility due to the growing pressures of climate change (CIWWF 2008).

Variations in climate can impact the physiology, phenology and interactions among species, potentially resulting in alterations to their geographic distributions (Maarten Kappelle 1999). Forest ecosystems, being sensitive to climate change, manifest discernible effects on the growth of trees and saplings in natural forests (Nigatu 2019). Climate is a powerful factor determining global vegetation patterns and wields a substantial impact on the arrangement, composition and dynamics of forests. Numerous studies that have focused on the relationship between climate and vegetation have demonstrated that specific climate conditions are linked to distinct plant communities or functional types. Consequently, it is reasonable to infer that shifts in climate would inevitably reshape the structure of forest ecosystems (Ravindranath 2013), the relevance of which is heightened by their importance to forest-dependent communities.

Heatwaves impact the regeneration of plant species, particularly during the vulnerable seedling stage, as they lead to lower soil moisture levels and increased competition with other species. The variability and changes in climate contribute to the degradation of forest resources and the release of carbon dioxide into the atmosphere which, in turn, affects the overall health of forest resources and their capacity to provide essential ecosystem services (Hirpo 2019). Climate change diminishes the effectiveness of various natural carbon sinks and weakens the processes that drive these sinks, thereby amplifying the cycle of climate change through positive feedback (Shin *et al.* 2022). Climate change can also expedite vegetation growth due to a warmer climate, extended growth seasons and increased concentrations of atmospheric CO_2 (Kirilenko *et al.* 2008). Research in the field of ecosystem dynamics underscores that 'phenology,' 'growth rates/productivity,' and 'alterations in the geographical distribution of species and biomes' stand out as the primary indicators of forest ecosystem transformations in reaction to climate change (Chaturvedi *et al*. 2011).

The impacts of climate change on forest landscapes in general and tropical dry deciduous forests in particular is known to delay establishment of natural regeneration and phytosociological functions. Forest degradation is often associated with decline of NTFP resources and subsequent reduction in households' income of forest dependent communities. Until the 1990s, NTFP resources supported about 30% of household (hh) requirements of the tribal population, which was almost equal to the hh income from agriculture. Climate change coupled with other anthropogenic pressure led to perceptible reduction in hh income from NTFPs by

10–92% (Prasad 2014). The erratic rainfall pattern and subsequent crop failures have compelled tribal communities to extract NTFPs in a destructive manner, leading to biodiversity loss and disruption of ecosystem functioning.

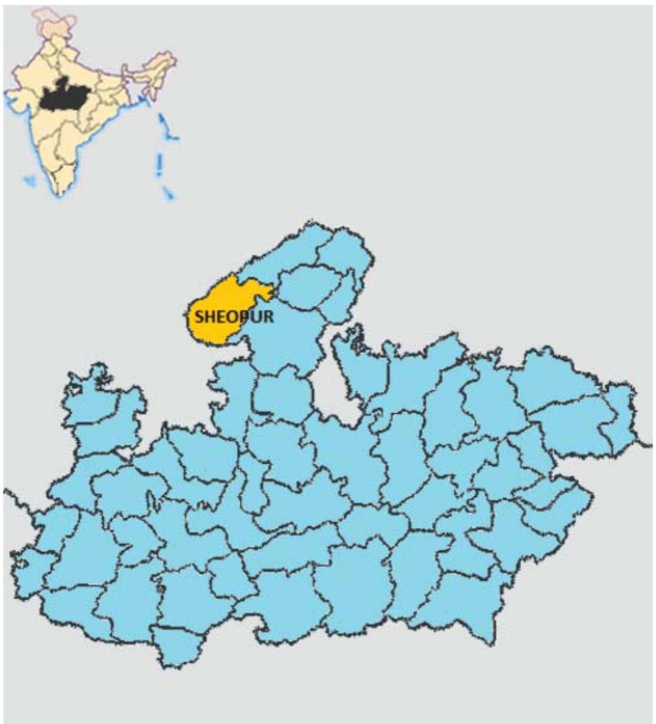
Climate change and the consequent poor return from agricultural harvests (erratic rainfall and heatwaves) increase the pressure on NTFP collections. However, governments are often less concerned with the adverse impacts of unsustainable NTFP collection as these impacts may be less visible to the general public compared to poverty and hunger resulting from crop failure. Socio-economic impacts would not only hinge on the disruptions in the established relationships between forests and climates but also on how human beings adapt to the resulting consequences (Sedjo *et al.* 1998)

There has been a notable tendency within society for climate change to be cited as the cause of a wide range of problems. As such, this paper has focused on available field data (quantitative and qualitative) in an attempt to examine the link between biodiversity and livelihood with climate change in Sheopur forest areas of Madhya Pradesh.

RESEARCH AREA

The Sheopur Forest Division lies between 25.6728°N and 76.6961°E towards the northern part of the state (Figure 1). According to the 2019 India State of Forest Report, Sheopur District encompasses an area of 6606 km^2. Within this expanse, there are specific forest classifications: 6 km^2 comprise dense forest, 1395.23 km^2 are categorized as moderately dense forest, and 2028.77 km^2 are classified as open forest. Overall,

FIGURE 1 *Sheopur district location in Madhya Pradesh*



the district boasts a green cover of 52.38%. Out of total open/degraded forest in the state, 0.2 M ha of open and degraded forest land is in Northern district of Sheopur, the Chambal catchment area.

In the southeastern part of Sheopur district, near the Chambal River, lies a plateau region which gradually transforms into a series of forested hills in the eastern part of the district, where the Kuno Wildlife Sanctuary is situated (District Environmental Plan Sheopur – District 2021). The most important river Chambal, which is also known for its deep gorges and ravines, drains on the northern side of Sheopur. As a result of overflow of the Chambal River course, alluvial deposits enrich the forest ecosystem.

Sheopur District is one of the prominent tropical dry forests in Madhya Pradesh, having rich biodiversity (The forest of Sheopur contain thorny and deciduous species that are declining (Chaturvedi *et al*. 2011)). These forest apart from being known for valuable timber species are also known to harbor a rich variety of useful NTFPs. It also accounts for about 20% of the tribal population of the country.

The rationale behind choosing this particular region as a forest area is due to its unique characteristic of being covered with ravines. Moreover, over the past two decades, the discernible effects of climate change have become increasingly evident in this area.

Fluctuating temperatures in Sheopur have led to deteriorating weather conditions, exacerbating numerous natural disasters and weather-related events. As temperatures have increased, the soil moisture content has decreased, leading to the drying out of trees and vegetation, making them more prone to combustion, a phenomenon which further delays the establishment of natural regeneration. During the dry season, an increasing prevalence of droughts leads to a heightened incidence of wildfires, a scarcity of clean drinking water, dust storms, and a greater frequency of heatwaves which affects phenological behavior. Livelihoods have been adversely affected due to the unpredictability of current rainfall patterns (Obeng *et al.* 2011). The anticipated rise in temperature and the heightened occurrence of extremely dry and wet years are expected to impede advancements in crop productivity, livestock systems, and the enhancement of food security (Fadairo *et al.* 2021).

Consecutive years of crop failures and low productivity have placed immense pressure on forest ecosystems due to the practice of unsustainable extraction of NTFPs. Due to a lack of resources and infrastructure (such as agriculture inputs and limited irrigation facilities, with less than 2% of land being irrigated), tribal communities invariably turned to the NTFP resources as a safety net from year to year, but the absence of responsible management protocols contributed to the decline of NTFP biodiversity.

The marginalized Saharia (Tribal) community is now confronted with the dire possibility of their resources being wiped out entirely, leading them to migrate to the adjoining Sawai Madhopur areas of Rajasthan state in search of newer resources. Biodiversity decline in the range of 10–90% can be attributed to factors driven by climate change (Prasad 2021).

Biodiversity richness, current collection practices and resource sustainability

Sheopur district was once abundant in numerous medicinal plants and NTFPs. The primary tree species that dominate the area are Khair (*Acacia catechu*), Salai (*Boswellia serrata*), Tendu (*Diospyros melanoxylon*), Palash (*Butea monosperma*), Dhok (*Anogeissus latifolia*), Safed Babul (*Acacia leucophloea*), Indian jujube (*Ziziphus mauritiana*), and Katber (*Ziziphus xylopyrus*). Noteworthy shrub species present include Falsa (*Grewia flavescens*), Marorphali (*Helicteres isora*), Hopbush (*Hopbush viscosa*), and Nirgundi (*Vitex negundo*). The grass species in the region consist of *Heteropogon contortus*, *Apluda mutica*, *Aristida hystrix*, *Themeda quadrivalvis*, *Cenchrus ciliaris*, and *Desmostachya bipinnata*. Additionally, *Senna tora* and *Argemone mexicana* are commonly found in the area (Kuno National Park 2023).

The Salai gum is one of the most important medicinal plant products and has high commercial use. Salai (*Boswellia serrata*) forests are found on the plateau with shallow and poor soils. Within these forests, Salai forms a nearly pure crop. The Salai tree growth is robust, resulting in a dense cover. Kardhai (*Anogeissus pendula*) forests occur on ridges and slopes associated with rocky and infertile soils. The site quality for these forests is high, and they exhibit a dense cover. Khair (*Acacia catechu*) forests, found on plains generally characterized by sandy soils, are more open and often border human habitation.

The upper canopy of Sheopur forests is primarily dominated by robust growth of Kardhai (*Anogeissus pendula*), Khair (*Acacia catechu*), Salai (*Boswellia serrata*), and other companions such as Gurjan (*Lannea coromandelica*), Dhaora (*Anogeissus latifolia*), Ber (*Zizyphus spp*.), and Tendu (*Diospyros melanoxylon*). A considerable expanse comprises three primary forest types: *Boswellia serrata* forest, *Anogeissus pendula* forest, and *Acacia catechu* forest. These forests are almost exclusively dominated by a single species, *Boswellia serrata* which is an important resin yielding tree species.

Currently, a substantial variety of NTFPs and medicinal plants with significant market value, are being harvested from forests without due consideration for their sustainability within the forest ecosystem. Despite various government initiatives aimed at promoting private cultivation of medicinal plants, the inclination remains towards utilizing wild resources, attributed to their perceived lower cost, organic nature and greater effectiveness. Surprisingly, over 85% of the industry's demand is still met by sourcing from forested areas. The industry reluctantly admits to excessive extraction without any commensurate efforts to promote *in-situ* conservation while the Forest Department has generally emphasized forest management with focus on timber species (Prasad 2021).

The story of Bael is equally disheartening due to unsustainable and damaging collection practices where the extensive requirement for fuelwood in processing Bael has resulted in the excessive collection of fuelwood from forests. When examining gender distinctions in forest resource utilization, the research found that 70 percent of women source their firewood from the forest. The primary reason for this substantial proportion of women engaged in gathering firewood from the forest stems from their societal role, wherein they are tasked with ensuring a consistent supply of cooking fuel for their families (Saalu *et al.* 2019).

Research methodology

In order to undertake measurable impacts of climate change on forest biodiversity and the livelihoods of communities reliant on forest resources, it is crucial to assess the changes in biodiversity over the past few decades through field surveys involving stakeholders. The research was been carried out using three different approaches to determine the current state of biodiversity: (i) the identification of species within sample plots, and (ii) species identification through transect walks, (iii) to evaluate global and local status of species by a CAMP (Conservation Assessment and Management Plan) Workshop.

Furthermore, in order to anticipate potential changes in biodiversity over the coming decades, a Focus Group Discussion (FGD) was conducted, engaging various stakeholders along the NTFP supply chain, including gatherers (community members), forest officials, and traders (who purchase from gatherers for further distribution).

Subsequently, following a one-year intervention involving protection, conservation and plantation efforts in the degraded site, the growth of plant species was quantified. This measurement aimed at assessing natural growth in the absence of external disturbances.

Identification of species within sample plots

Sample plots measuring 20x20m were chosen using random sampling in regions where the practice of NTFP collection had been ongoing for the past several decades (Table 2). This selection was determined in consultation with the gatherer community. Enumeration of species was accomplished by establishing sample plots of different dimensions (10x10m, 15x15m, and 20x20m) to test the optimum size representative of the area. It was found that the size from 10X10 and 20X20 had similar counts. These sample plots were set up using a stratified random sampling methodology, with the forest divided into strata based on tree density, coverage, and the presence of minor disturbances (Tables 1 and 2). Following this, the sample plots were placed randomly within each stratum. Any saplings in the sample plots with a diameter at breast height (DBH) exceeding 3 cm and a height exceeding 100 cm were recorded as established regeneration.

Identification of species through transect walks

Routes for transect walks were chosen along pathways that the gatherer community traditionally utilized for NTFP collection. These routes were identified during the focus group discussion with community members, aided by maps and on-site guidance. During the transact walks, 100 meters was covered, and plants situated within 10 meters on both sides of the walking path were taillied and recorded at each 10 meter interval along the walking path, plant species were identified,

TABLE 1 *Geolocation of Sample plots in Sheopur Forest Division*

Sample plot Details								
S. No.	Forest Division	Physical Location	Compartment No.	Geo-location		Sample plot size	Enumerated NTFP Species No.	Date
				Latitude	Longitude			
1	Sheopur	Karahal North Range	378	25.51537	77.09139	10x10	7	14-01-2022
2	Sheopur	Karahal North Range	378	25.51537	77.09139	15x15	6	14-01-2022
3	Sheopur	Nichli & Uprikhori	382	25.50994	77.14798	20x20	7	15-01-2022
4	Sheopur	Piprani	404	25.63842	76.95587	15x15	7	15-01-2022
5	Sheopur	Piprani	405	25.63842	76.95587	10x10	5	16-01-2022

TABLE 2 *shows average number of some of commercial NTFP plant species found in sample plots of size 20X20 m^2*

S. No.	Species Name	Scientific Name	Average no of plants	
			Plot 20x20	Per ha (m^2 to ha)
1	Satawar	*Asparagus recemosus*	-	-
2	Safed Musli	*Chlrophytum borivilianum*	1.3	32.5
3	Baheda	*Terminalia bellerica*	2	50
4	Kullu	*Sterculia urens*	-	-
5	Chironji	*Buchnania lanzan*	-	-
6	Salai	*Boswellia serrata*	2	50
7	Mahua	*Madhuca latifolia*	0.3	7.5
8	Bael	*Aegle marmelos*	-	-
9	Gudmaar	*Gymnema sylvestris*	-	-
10	Aonla	*Emblica officinalis*	1	25

encompassing an area 10 meters deep on both sides of the line, as depicted in the figure. The Table titled "Transect Walk" presents the species types and their respective quantities observed within each 10x10 m^2 sample plot on both the left-hand side (LHS) and the right-hand side (RHS). The total count of plants across all species during the transect walk amounted to 291. Among these, the count of plants on the LHS and RHS of the walking path were 200 and 91, respectively (Figure 2).

The dominant species encountered during the transect walk were Siris (*Albizia procera*), followed by Van Tulsi (*Ocimum tenuiflorum*), Palas (*Butea Monosperma*), and Kureta (*Holarrhena flribunda*). These three species together constituted almost 78% of the total biodiversity observed during the walk (Table 3).

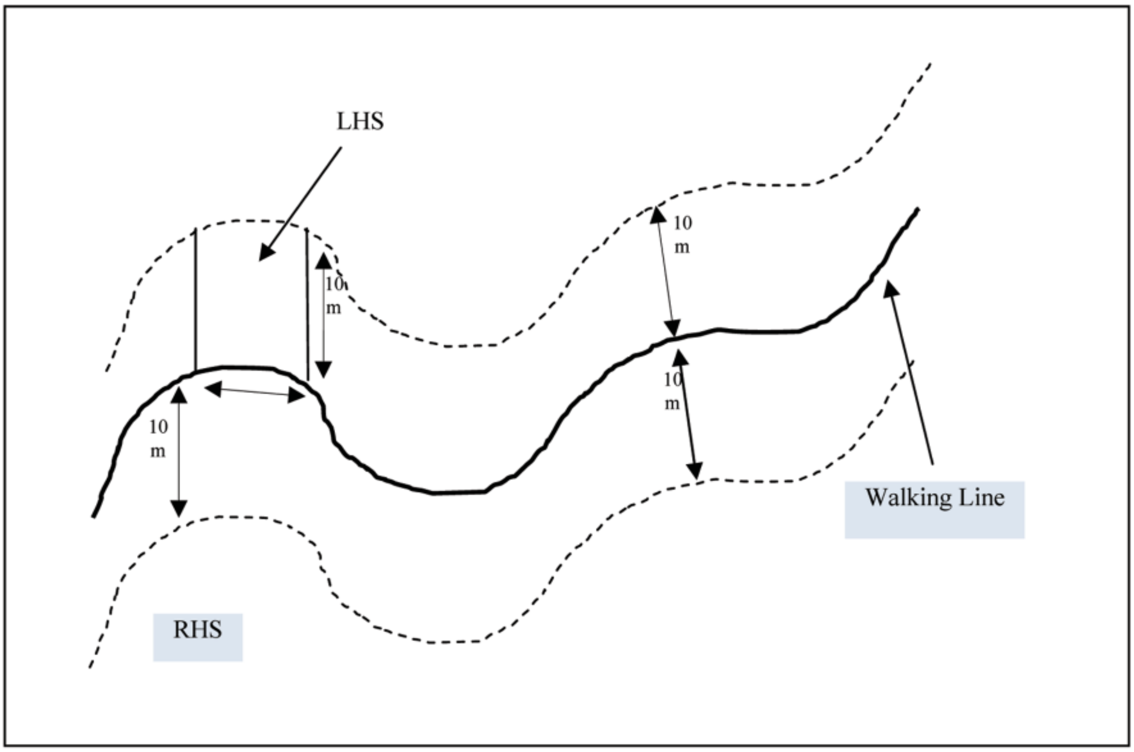
In contrast, commercially valuable NTFP species such as Anola (*Emblica officinalis*), Bael (*Aegle marmelos*), Baheda (*Terminalia bellirica*), and Chirol (*Holoptelea integrifolia*) collectively comprised only 9.8% of the total record. To obtain a comprehensive understanding of the annual NTFP availability changes in the study area, separate Focus Group Discussions (FGDs) were organized with each stakeholder group with the objective to gain insights into the decline or growth of NTFPs. A questionnaire was specifically developed to assess the extent of degradation for 24 indigenous NTFP species. This assessment was made by comparing their current availability with that of two decades ago.

Responses to the questionnaire varied based on a scale from 0 to 5, where '0' indicated 'No Decline' in NTFP availability over the past two decades, and '5' indicated 'Extinction' of the NTFP within the same timeframe. Each value within the 0–5 scale represented a different level of degradation, ordered in increasing severity. The collected responses from all stakeholders were compiled and averaged to determine the degradation level for each of the 24 NTFP species.

Stakeholders tend to hold distinct viewpoints regarding the extent of degradation for each species:

- According to the NTFP gatherer community of the region, Safed Musli, Kali Musli, and Baheda are categorized as experiencing 'High-Extreme High' levels of degradation. In contrast, species like Arjun, Harsingar, Pilu, and Van Tulsi are either exhibiting extremely low levels of degradation or have shown no degradation at all over the last two decades.
- On the traders' perspective, the most degraded species based on their marketplace availability are Safed Musli, Baheda, and Guggul. These species are categorized as experiencing 'High-Extreme High' levels of degradation.

FIGURE 2 *Transact Walk*



- Conversely, foresters assert that a relatively greater number of species have undergone severe degradation. According to their assessment, species such as Aonla, Chironji, Safed Musli, Baheda, Guggul, Arjun, and Varuna fall into the category of 'High-Extreme High' degraded species. However, species such as Harsingar, Pilu, Vidari Kand, and Van Tulsi either display extremely low levels of degradation or no degradation at all over the same period.

Assessment of global and local status of species determined through a CAMP Workshop

There are 15–20 widely collected and traded NTFP species which are considered important to provide safety net to the population of Saharia in Sheopur against poverty and hunger. As the potential cost of losing these species is significant there is an urgent need to proactively consider and fully embrace partnerships, with the support of Corporate Social and Environmental Responsibility (CSER) initiatives, designed to collaborate on the production of goods and services through conservation and wise use. This approach involves engaging communities to assist in the protection and production efforts in exchange for benefits such as usufructs, forest product sharing and employment opportunities.

Various local stakeholders, including gatherers, foresters, village aggregators and traders, have expressed their concerns regarding the degradation and decline of biodiversity because of climate change, both directly and indirectly. Directly because the temperature extremes and deficient rains affect the natural regeneration, and indirectly through the loss of crops affected by erratic rains and temperature extremes which drive villagers to destructive forest gathering. To validate these concerns scientifically, there is a need to employ established scientific methodologies which aim to assess the current status of the most frequently collected and economically crucial NTFP species, thereby offering scientific credibility to the concerns raised by the stakeholders.

The CAMP Workshop (Conservation Assessment and Management Plan), which includes methods of stakeholder consultation, serves as a widely used tool for biodiversity assessment. It is a prominent on-site facilitation approach designed to assess both the local and global status of indigenous biodiversity through comparing the biodiversity status of locally occurring species with their global counterparts.

The Workshop itself follows a participatory approach, encompassing various stakeholders who contribute their expertise in the technical, social and economic aspects of these local resources. This collaborative effort is geared towards a comprehensive understanding of the species and their conservation needs.

Two workshops, one in Sheopur and another in Karhal, were organized between 5th and 7th May 2023, technically facilitated by the IUCN-India (Delhi), along with a resource person from TERI-SAS University Delhi. The culmination of the assessment exercise is summarized in Table 4 which outlines the comprehensive overview of stakeholders' perspectives on the ecological status of the most frequently collected and traded species.

The prominent commercial NTFP species within the study region included Aonla, Bael, Salai, Shatavar and Safed

TABLE 3 *Transact walk*

Transect Walk														
S. No.	**Side**	**Range Goras**	**Compartment No. RF 259**	**Number of Species**										**Total**
		Species Name	**Scientific Name**	**10X10**	**10X10**	**10X10**	**10X10**	**10X10**	**10X10**	**10X10**	**10X10**	**10X10**	**10X10**	
1	LHS	Kureta	*Holarrhena flribunda*		7	2	4				7		2	22
2		Baheda	*Terminalia bellirica*	7	1									8
3		Salai	*Boswellia serrata*		1		2	1				4		8
4		Siris	*Albizia procera*	1	8	17	20	16	12					74
5		Sisham	*Dalbergia sissoo*	3	4	2						1		10
6		Van Tulsi	*Ocimum tenuiflorum*	15	20		1		8			6	2	52
7		Chirol	*Holoptelea integrifolia*			2			3					5
8		Nilgiri	*Eucalyptus*							3				3
9		Palas	*Butea Monosperma*				3	5	6			3	1	18
													Total (A)	**200**
1	RHS	Bael	*Aegle marmelos*	1				3				1		5
2		Khair	*Senegalia catechu*	2	1		1				1			5
3		Kureta	Holarrhena flribunda			5		8	1		2		4	20
4		Neem	*Azadirachta indica*		1				1				1	3
5		Baheda	*Terminalia bellirica*		1	1			4	1				7
6		Dhawda	*Anogeissus latifolia*				1					1		2
7		Aonla	Emblica officinalis	1					1					2
8		Siris	*Albizia procera*			9	4			7	2			22
9		Palas	*Butea monosperma*	5	1	1		7	1			4		19
													Total (B)	**91**

TABLE 4 *Shows the results obtained after examining the responses of all the stakeholders together*

S. No.	Species Name	Scientific Name	Level of Degradation
1	Aonla	*Emblica officinalis*	High-Extreme High
2	Baheda	*Terminalia belllerica*	High-Extreme High
3	Chironji	*Buchnania lanzan*	High-Extreme High
4	Guggul	*Commiphora wightii*	High-Extreme High
5	Harra	*Terminalia chebula*	High-Extreme High
6	Kali Musli	*Curculigo orchioides Gaertn*	High-Extreme High
7	Safed Musli	*Chlorophytum borivilianum*	High-Extreme High
8	Bael	*Aegle marmelos*	Moderate-High
9	Bhringraj	*Eclipta prostrata*	Moderate-High
10	Bhumi Aonla	*Phyllanthus niruri)*	Moderate-High
11	Dhawda	*Anogessus latifolia*	Moderate-High
12	Gudmaar	*Gymnema sylvestre*	Moderate-High
13	Kullu	*Sterculia urens*	Moderate-High
14	Mahua	*Madhuca longifolia*	Moderate-High
15	Nagarmotha	*Cyprus rotundus*	Moderate-High
16	Salai	*Boswellia serrata*	Moderate-High
17	Satavar	*Asparagus racemosus*	Moderate-High
18	Arjun	*Terminalia Arjuna*	Low-Moderate
19	Beeja	*Paterocarpus marsupium*	Low-Moderate
20	Harsingar	*Nyctanthes arbor-tristis*	Low-Moderate
21	Varun (Verna)	*Crateva religiosa*	Low-Moderate
22	Vidari Kand	*Pueraria tuberosa*	Low-Moderate
23	Pilu	*Salvadora persica*	Extreme Low-Low
24	Van Tulsi	*Ocimum tenuiflorum*	No Decline

Musli, which substantially contribute to the annual income of households. The degradation levels of these species range from Moderate to High for Bael, Salai, and Shatavar, while Aonla and Safed Musli experience High to Extreme High degradation. The deterioration of these commercial NTFP species directly affects the livelihoods of tribal households within the region.

Figure 3 illustrates the proportion of the total number of NTFP species falling into each category of degradation. The collective responses from all stakeholders are evident in the figure, revealing that 70.9% of the total species belong to degradation level exceeding moderate degradation. This implies that over the past two decades, the productivity or availability of these species have been decreased by more than 30%.

Changes observed during past two decades

According to the India State Forest Reports, over the past two decades (2001–2022), the forest cover in Sheopur district has diminished by more than 30 000 hectares, which accounts for 8.1% of the total forest area in the district. The combined effects of climate change, including subsequent heatwaves, consecutive years of insufficient rainfall, and unsustainable harvesting practices, have led to a nearly one-third reduction in the density of the forest since 2001.

Table 5 presents the changes in dense forest, open forest and total forest cover in Sheopur from 2001 to 2021. The significant decrease in dense forest and the corresponding increase in open forest cover within the district can be attributed to the reasons mentioned previously. The notable 21.72% rise in open forest cover serves as an indicator of the district's forest degradation rate. Based on these data, the annual rate of conversion from dense to open forest is approximately 1.61%, while the annual rate of open forest loss is 0.40%. Consequently, the cumulative annual rate of forest degradation in the district has reached 2.02% since 2001.

Prevailing climatic conditions

In Sheopur, the wet season is oppressive and mostly cloudy, the dry season is mostly clear, and it is hot year-round. Over the course of the year, the temperature typically varies from 11°C to 42°C and is rarely below 8°C or above 45°C. shown in Table 6 and 7.

FIGURE 3 *CAMP Workshop*

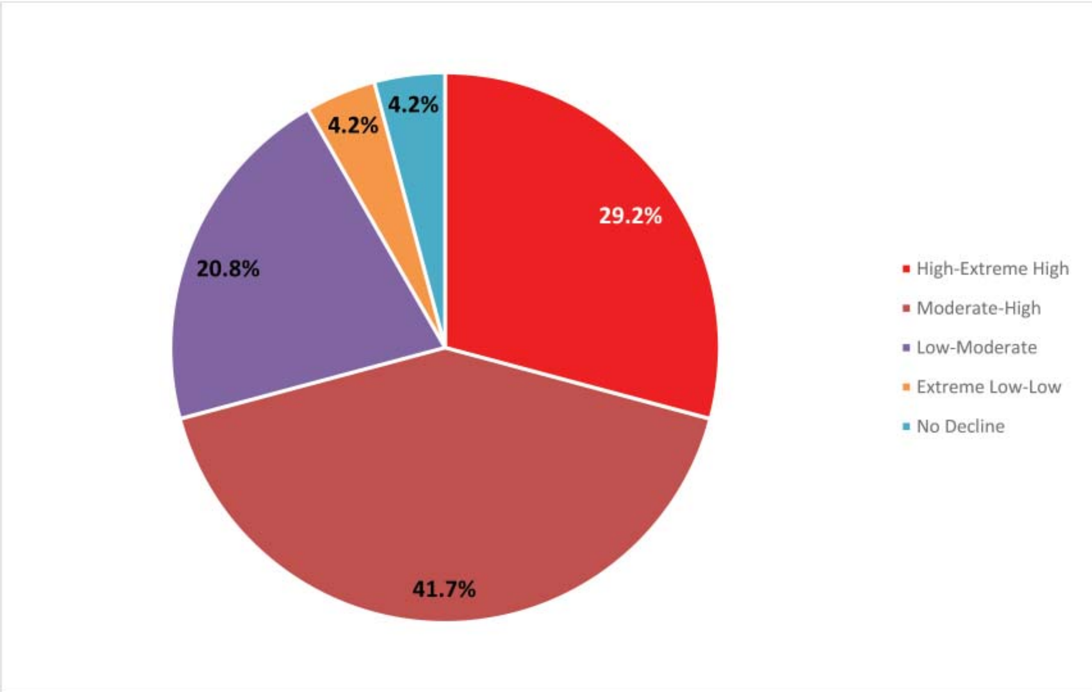


TABLE 5 *Biannual report*

Year	Dense Forest	Change	Open Forest	Change	Total Forest	Change
2001	2,07,000	-32.36%	1,67,900	21.72%	3,74,900	-8.14%
2021	1,40,025		2,04,366		3,44,391	

Source: Biennial reports of ISFR 2001–2021.

TABLE 6 *Climatic data for Sheopur for the years between 1981–2010*

Climate data for Sheopur (1981–2010, extremes 1951–2010) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	32.0 (89.6)	37.2 (99.0)	41.6 (106.9)	46.0 (114.8)	48.8 (119.8)	48.0 (118.4)	46.4 (115.5)	41.8 (107.2)	41.2 (106.2)	40.8 (105.4)	37.3 (99.1)	32.6 (90.7)	48.8 (119.8)
Average high °C (°F)	24.3 (75.7)	28.0 (82.4)	33.6 (92.5)	39.0 (102.2)	42.7 (108.9)	41.9 (107.4)	35.0 (95.0)	33.2 (91.8)	34.6 (94.3)	34.8 (94.6)	30.6 (87.1)	25.7 (78.3)	33.6 (92.5)
Average low °C (°F)	7.2 (45.0)	9.8 (49.6)	15.0 (59.0)	21.1 (70.0)	25.3 (77.5)	26.2 (79.2)	24.2 (75.6)	23.1 (73.6)	22.8 (73.0)	18.2 (64.8)	13.0 (55.4)	8.4 (47.1)	17.8 (64.0)
Record low °C (°F)	−2.2 (28.0)	1.1 (34.0)	4.6 (40.3)	8.8 (47.8)	16.2 (61.2)	17.4 (63.3)	15.8 (60.4)	15.2 (59.4)	15.1 (59.2)	8.8 (47.8)	4.4 (39.9)	0.0 (32.0)	−2.2 (28.0)
Average rainfall mm (inches)	8.0 (0.31)	6.1 (0.24)	3.7 (0.15)	4.8 (0.19)	8.4 (0.33)	69.6 (2.74)	248.6 (9.79)	190.3 (7.49)	85.3 (3.36)	24.6 (0.97)	9.4 (0.37)	2.8 (0.11)	681.6 (26.83)
Average rainy days	0.8	0.6	0.5	0.6	0.8	3.8	10.2	6.9	4.1	1.0	0.7	0.2	32.1
Average relative humidity (%) (at 17:30 IST)	48	72	31	25	23	39	67	72	61	48	45	53	47

Source: India Meteorological Department[3][4]

Potential changes in the growth of NTFPs

The evaluation of alterations in the productivity and availability of NTFP species, coupled with the present conditions, facilitates an estimation of potential biodiversity changes achievable via plantation, protection, and conservation strategies. After the assessment of the site's existing state, an initiative for landscape restoration encompassing plantation, protection, and conservation was developed. Following a year's completion, the site underwent re-evaluation to gauge the natural growth of NTFP species in order to assess the impact of sustainable harvesting practices in the conservation of NTFP species.

TABLE 7 *Show climatic profile of Sheopur for the recent year 2011–2023*

Climatic Profile of Sheopur district									
Year	Temperature			Humidity			Pressure		
	High	Low	Average	High	Low	Average	High (mbar)	Low	Average
2023	32°C	20°C	27°C	100%	57%	85%	1007	996	1002
2022	28°C	9°C	18°C	88%	19%	59%	1020	1007	1014
2021	27°C	4°C	17°C	97%	19%	66%	1024	1009	1017
2020	34°C	6°C	18°C	98%	15%	61%	1022	1008	1015
2019	27°C	3°C	16°C	100%	24%	70%	1023	1007	1017
2018	27°C	6°C	17°C	88%	15%	53%	1023	1002	1016
2017	28°C	9°C	18°C	93%	17%	55%	1023	1008	1016
2016	30°C	10°C	19°C	95%	21%	57%	1022	1002	1015
2015	32°C	7°C	18°C	90%	20%	54%	1024	1008	1016
2014	31°C	6°C	17°C	97%	20%	61%	1023	916	1015
2013	29°C	8°C	18°C	97%	27%	64%	1022	1008	1015
2012	31°C	6°C	19°C	86%	16%	52%	1020	1006	1014
2011	31°C	8°C	19°C	95%	21%	58%	1019	1006	1014

(wheather of sheopur, n.d.)

After one year in the landscape restoration program and concurrent plantation efforts, a spontaneous rejuvenation of numerous Non-Timber Forest Product (NTFP) species was observed. Throughout the intervention, the site remained protected, and the harvesting of accessible NTFPs was carried out using sustainable methods. Examination revealed the natural growth of nine species, previously threatened by unsustainable harvesting practices, had been successfully restored. The Table 8 presented the average count of naturally regenerated plants per hectare for these species at the project site.

Only two NTFP species, Pilu and Van Tulsi, exhibited either extremely low levels of degradation or no decline at all. Figure 3 also highlights that the degradation rate of numerous other commercial and medicinal NTFP species, such as Mahua, Bhringraj, Gudmar, Nagarmotha, and others, has reached an alarming level.

TABLE 8 *Average number of naturally regenerated plants per hectare*

S. No.	Species Name	*Scientific Name*	*Saplings Adopted*
1	Safed Musli	*Chlorophytum borivilianum*	18
2	Satavar	*Asparagus racemosus*	15
3	Aonla	*Emblica officinalis*	8
4	Salai	*Boswellia serrata*	7
5	Mahua	*Madhuca longifolia*	6
6	Baheda	*Terminalia belllerica*	4
7	Chironji	*Buchnania lanzan*	4
8	Kullu	*Sterculia urens*	4
9	Guggul	*Commiphora wightii*	2

Table 8 illustrates the regeneration potential of the region and underscores the influence of unsustainable harvesting practices on the regeneration of NTFP species. Among the species that regenerated naturally, Safed Musli (*Chlorophytum borivilianum*) and Satavar (*Asparagus racemosus*) exhibited the highest dominance. Conversely, Guggul (*Commiphora wightii*) was observed to be among the least naturally regenerating species at the site.

RESULTS AND DISCUSSION

This study has revealed several impacts of climate change on the status of forest biodiversity and the livelihoods of the community and highlights the issue that biodiversity faces an ongoing and intensifying danger due to the effects of climate change. The scenarios identified in the Sheopur division are as follows

i. Ecological impact

The two CAMP workshops conducted in Sheopur and Karhal revealed that 70.9% of the total species belonged to a degradation level exceeding moderate degradation. This implies that over the past two decades, the productivity or availability of these species has decreased by more than 30%.

ii. Economic Impact

Livelihood options are becoming limited due to fast changing climatic conditions. The failure of agriculture crops is transferring unsustainable pressure on the collection of NTFPs as the only alternative livelihood options available to the communities. This problem is becoming more serious due to low profits from collected NTFPs caused by inefficient and unsustainable harvesting and post-harvesting practices. Excessive carbon emissions are being observed due to biomass burning in the post-harvesting practices (e g. boiling of bael fruits- *Aegle marmelose).* The economic status of the tribal community has significantly deteriorated due to biodiversity decline attributed to the impact of climate change (Figure 4).

In 2012–13, the economic status of forest gatherers of Sheopur stood at $618.69 per household from NTFP collection, which dropped to $316.48 five years later (2018–20), $213.82 in 2021, and $136.31 in 2023.

To address this situation and improve the economic status of Sheopur, it may be essential to implement targeted policies and initiatives that focus on economic development, job creation, education and healthcare access. Additionally, it would be valuable to conduct a comprehensive analysis of the specific challenges facing the community to determine the most effective strategies for improvement. It is important to note that economic development is a complex and long-term process, and addressing such challenges often requires collaboration between government agencies, NGOs, and the community itself to bring about positive change.

iii. Social Impact

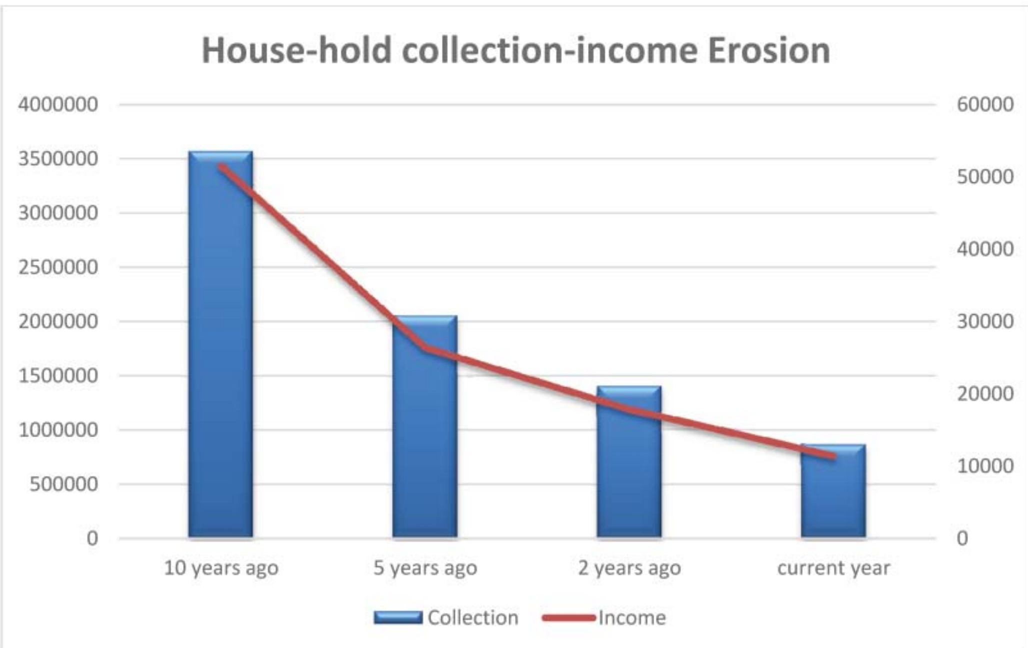
This study supported by the findings of Obeng *et al*. (2011) who reported that livelihoods are adversely affected by the unpredictability of current rainfall patterns compared to the past. A similar situation is being observed in many NTFP rich forest areas of central India (Prasad 2021).

1. The impact of erratic rainfall patterns, heatwaves, crop failure, poverty, diseases, commodity price escalation, and irrational social and economic behaviors, is supported by the observation of Sedjo *et al*. (1998).
2. Employment that was earlier available through silvicultural practices, like harvesting in forest coupes, is presently not available as normal silvicultural felling has been discontinued owing to conservation concerns. That has resulted in a loss of forest harvesting related income
3. The main reason for leaving the villages is the lack of opportunity to gain employment in the village, which means that people are migrating from Sheopur to Rajasthan and Gujarat for one or two months. In this situation, all the members of the family migrate for two or three months to harvest paddy or mustard or wheat from the village of Sheopur district. Such social migration can be very difficult for the village as the productive workforce move out leaving only the oldest people behind.

Climate change mitigation strategy can be built-in through proper planning

Forest landscape restoration interventions have brought positive results reflected in all three demo plots of Sheopur. The community were included through participatory planning and implementation strategy in the project and the interventions of the project were planned in such a way that the community benefitted in the first year of intervention itself. The observations on greenery, survival and growth after one rainy season (three months after planting) showed over 95% survival and signs of establishment of regeneration. After three months the roots and rhizomes of medicinal plants such

FIGURE 4 *Overall Economic status of Sheopur Tribal community from NTFP collection*



as *Chlorophytum borivilianum*, *Randia dumetorum*, *Curcuma longa*, *Curculigo orchioides*, *Curcuma angustifolia Roxb* etc. whose upper parts face dying back post rains appeared carpeting the forest floor. These plants are valuable medicinal plants, which contribute $240.05–300.07 to each hh and cn be sustained through sustainable harvesting practices. Furthermore, grass seeding in the blank patches contributed green fodder for the cattle. The palatable grass sowing and access to villagers for sustainable grass removal contributed $240.05–300.07 per hh because of higher milk yield sampled from 60 villagers who owned milch cattle.

The restoration involved to bring back the biological productivity of an area in order to achieve benefits for people and the state is long-term endeavor because it requires a multifacated vision of the ecological functions and benefits to human well-being that restoration will produce, even though tangible deliverables such as jobs and income can begin to flow right away.

The measurable impacts of climate change on biodiversity and livelihood in the tropical dry deciduous forest of Sheopur, Madhya Pradesh, are of significant concern and have far-reaching consequences. Over the years, this region has experienced noticeable changes in its climate patterns, resulting in the following adverse effects on both the environment and the local communities:

- Biodiversity loss: Climate change has disrupted the delicate balance of ecosystems within the Sheopur forest. Rising temperatures, erratic rainfall patterns and increased frequency of extreme weather events have led to habitat degradation and loss. This has resulted in the decline and migration of several plant and animal species, affecting the region's biodiversity.
- Retarded vegetation growth: Climate change hinders vegetation growth resulting from the hotter climate and erratic rainfall.
- Altered plant composition: Changes in temperature and precipitation have led to shifts in the types and distribution of plant species within the forest. Some species that were once abundant are struggling to survive, while invasive species may become more prevalent. This can impact the availability of food and resources for both wildlife and local communities.
- Impact on livelihoods: The local communities in Sheopur often rely on the forest for their livelihoods, including agriculture, livestock grazing, and collection of non-timber forest products (NTFPs). Climate change-induced alterations in rainfall patterns can lead to water scarcity, affecting crop yields and the availability of fodder for livestock. Additionally, shifts in NTFP availability can disrupt income sources for many households.
- Increased vulnerability: The already vulnerable communities in the Sheopur region are further exposed to risks due to climate change impacts. They may face food insecurity, water scarcity and reduced income opportunities, which can exacerbate poverty and socio-economic inequalities.
- Adaptation and mitigation: Efforts to address these challenges require a combination of adaptation and mitigation strategies. These may include sustainable forest management practices, the promotion of drought-resistant crops, water harvesting techniques, and community-based conservation efforts. Additionally, raising awareness and building local capacity to adapt to changing conditions is crucial.

In conclusion, the measurable impacts of climate change on biodiversity and livelihood in the tropical dry deciduous forest of Sheopur, Madhya Pradesh, highlight the urgency of addressing climate-related challenges at both local and global levels. Mitigation efforts to reduce greenhouse gas emissions must be complemented by adaptation strategies that empower local communities to cope with changing conditions and protect their livelihoods. Collaborative efforts involving government agencies, NGOs, researchers, and local residents are essential to mitigate the adverse effects of climate change in this critical ecosystem and ensure the sustainability of both biodiversity and livelihoods.

ACKNOWLEDGEMENTS

We would like to express our heartfelt gratitude to all the referees for valuable suggestions and those who have contributed to the successful completion of this manuscript.

First and foremost. We extend our sincere thanks to the people of Sheopur, Panwada, Goras under Karhal whose unwavering support, cooperation, and willingness to share their knowledge and experiences played a pivotal role in the execution of this study. Their insights and perspectives have enriched our understanding of the complex interplay between climate change, biodiversity, and livelihoods in the region.

We are deeply indebted to the local communities, forest officials, and various stakeholders who generously shared their time and expertise during our field visits and interviews. Their invaluable contributions enabled us to gather crucial data and firsthand information essential for this report.

Finally, we extend our gratitude to the local NGOs and environmental organizations for their support in organizing community engagement activities and helping us establish a network of collaboration within the region.

REFERENCES

BAIG, S.E. 2015. Synergies between climate mitigation and adaptation in forest landscaperestora tion. *IUCN*, *India.* Doi:chromeextension https://portals.iucn.org/library/efiles/documents/2015-013.pdf

CHATURVEDI, D.R. 2013. Impact of climate change on forests and biodiversity of madhya pradesh. *Environmental Planning and Coordination Organisation*. doi: chromeextension://efaidnb mnnnibp cajpcglclefindmkaj/https://www.devalt.org/images/L2_ProjectPdfs/(15)ForestsDiversity.pdf?Oid=150