Towards a climate-resilient future: Strategies for the Andaman and Nicobar Islands

Jointly prepared by PwC India and PwC India Foundation

March 2025

Foreword

The Andaman and Nicobar Islands (ANI) stand on the frontlines of climate change, where the impact is both immediate and significant. This unique region faces a myriad of challenges – rising sea levels, changing weather patterns, increasing temperatures and biodiversity threats – affecting the environment as well as the lives of the people in these regions.

Over the past few years, PwC India Foundation (PwCIF) has actively supported development efforts in the ANI, working closely with local communities, government bodies and think tanks to foster sustainable solutions and improve quality of life. In our latest study, a collaboration between PwC India and PwCIF, we have conducted extensive research and engaged with stakeholders to identify the socio-economic, biophysical and climate-related challenges in these islands. Tailored to the adaptation and mitigation needs of the ANI, we have prepared a comprehensive climate-resilient action plan comprising viable climate solutions and financing options.

We extend our gratitude to the many individuals whose invaluable insights have shaped this report. Their contribution has been crucial in understanding the complex dynamics at play and enabled us to curate effective solutions. As we move forward, our focus will be on implementing these solutions.

We remain committed to this mission, dedicated to making a measurable impact on the ground. We hope that this report will serve as a guiding document for policymakers, businesses and communities in the ANI, catalysing meaningful change towards a sustainable future.

Sanjeev Krishan

Chairperson, PwC in India

Jaivir Singh

Vice Chairman, PwC India Foundation

Leader of the Global Office for Humanitarian Affairs

Table of contents

1. **Setting the context** ... 9

   1.1. About the study ... 10

2. **Situational analysis** ... 12

   2.1. LULC analysis in the ANI ... 12

   2.2. Climate change impact assessment ... 19

3. **Identifying solutions for addressing vulnerabilities** ... 26

   3.1. Prioritisation of the vulnerable sub-districts ... 26

   3.2. Socio-economic and demographic profile of vulnerable sub-districts ... 33

   3.3. Proposed measures to address vulnerabilities ... 38

4. **Green finance options** ... 42

   4.1. Assessment of the feasible financing options ... 42

5. **Feasibility of carbon markets for pilot interventions** ... 44

   5.1. Assessing the applicability of carbon markets ... 44

   5.2. Estimated carbon credits for the proposed solutions in the pilot site(s) ... 46

   5.3. Final measures for implementation as a pilot ... 51

6. **The way forward** ... 56

7. **Annexures** ... 58

   Annexure A: Scale used for evaluating green financing options ... 58

   Annexure B: Indicative costs associated with carbon markets ... 60

List of tables

Table 1: LULC analysis for 2005-06, 2010-11, 2015-16, 2022-23 16

Table 2: Comparison of LULC changes from 2005 to 2023 in the ANI 17

Table 3: Climate change impacts on nature-based sectors 24

Table 4: SEVI 27

Table 5: BPVI 29

Table 6: CVI 32

Table 7: Socio-economic and demographic profiles of the selected sub-districts 33

Table 8: Proposed measures and their justification for selection 38

Table 9: Description of benefits from the proposed measure 40

Table 10: Evaluation of the green finance options 43

Table 11: VCS-registered ARR projects with estimated ERs/ha/annum 46

Table 12: VCS-registered clean cookstove projects with estimated ERs/IC/annum 47

Table 13: Indicative carbon credit revenue (USD/annum) through implementing clean cookstoves 48

Table 14: Percentage and number of HHs at the shortlisted sites by main source of lighting 48

Table 15: Indicative carbon credits for DRE 49

Table 16: VCS-registered mangrove restoration projects with estimated ERs/ha/annum 49

Table 17: Carbon market feasibility: Summary of the findings for the proposed measures 51

List of figures

Figure 1: Current land use patterns 13

Figure 2 (A, B, C, D): Historical land use patterns 14

Figure 3: Mangrove loss 18

Figure 4: Climate change impacts on the small islands 19

Figure 5: Rainfall recorded at Port Blair from 2011 to 2022 20

Figure 6: Annual precipitation (mm) 21

Figure 7: Maximum temperature (°C) 21

Figure 8: Minimum temperature (°C) 22

Figure 9: Projected sea level rise under different SSP scenarios 22

Figure 10: Cyclone tracks in the last 20 years 23

Figure 11: Map illustrating the SEVI of the ANI 28

Figure 12: Map illustrating the BPVI of the ANI 30

Figure 13: Comparison of SEVI and BPVI 31

Figure 14: Map illustrating the CVI of the ANI 32

Abbreviations

ANI	Andaman and Nicobar Islands	**LPG**	Liquefied petroleum gas
AR6	Sixth Assessment Report	**LULC**	Land use/land cover
ARR	Afforestation, reforestation and revegetation	**PDD**	Project design document
BPVI	Bio-Physical Vulnerability Index	**PNG**	Piped natural gas
CDM	Clean development mechanism	**SDG**	Sustainable Development Goal
CRD	Climate resilient development	**SEVI**	Socio-Economic Vulnerability Index
CSR	Corporate social responsibility	**SOP**	Share of proceeds
CVI	Composite Vulnerability Index	**SSC**	Small scale
DRE	Decentralised renewable energy	**SSP**	Shared socioeconomic pathway
ER	Emission reduction	**VCS**	Verified carbon standards
GHG	Greenhouse gas	**VCU**	Verified carbon units
HH	Household	**VCM**	Voluntary carbon market
ICS	Improved cookstoves	**WBG CCKP**	World Bank Group Climate Change Knowledge Portal
IPCC	Intergovernmental Panel on Climate Change		
IUCN	International Union for Conservation of Nature		

Executive summary

The ANI are strategically and ecologically significant for India; however, their development has been constrained by their geographic isolation. Recent government initiatives have aimed to transform the ANI into an economic hub, focusing on infrastructure, trade, commerce and tourism. However, given the islands' ecological sensitivity and vulnerability to climate change, a climate-resilient development approach is essential. This report, jointly developed by PwC India and the PwCIF, presents a comprehensive climate-resilient action plan that outlines viable climate solutions along with financing options for implementation in the most vulnerable regions of the ANI.

The report is divided into six chapters, which are summarised below:

Chapter 1: Setting the context

This chapter establishes the context of the study against the background of ongoing and planned development activities in the ANI, along with the ecological, climatic and social vulnerabilities of the islands. It also introduces the conceptual framework used to formulate the action plan, which is the IPCC's Climate-Resilient Development Framework from AR6. The action plan is derived from the identified needs in the ANI with the aim of fostering broader adaptation and mitigation benefits.

Chapter 2: Situational analysis

This chapter provides a comprehensive overview of the ANI's geographic, ecological and socio-economic profile, identifying key challenges and vulnerabilities. An LULC assessment was conducted to analyse changes in land use land cover patterns in the ANI over the past two decades.

The analysis indicated that the ANI has experienced an increase in agricultural activities, particularly plantations/orchards and annual crops, while traditional kharif cropping has declined. Evergreen and semi-evergreen woodlands have decreased, with a corresponding increase in degraded woodlands. Moreover, there has been a reduction in littoral, swamp/mangroves and an increase in the minimum spread of water bodies. The overall landscape has shifted towards more intensive land use, with significant changes in agricultural practices and forest cover. In addition to the LULC assessment, a climate change impact assessment was conducted using geospatial analysis of climate indicators such as temperature, precipitation, sea level rise and extreme weather events. The results indicated that the ANI's coastal, marine and forest ecosystems have been adversely affected by climate change. These impacts are manifested in various ways, such as degradation of soil quality, increased soil erosion, altered water availability, shifts in salinity distribution and nutrient leaching. These environmental changes lead to cascading physical, social and ecological repercussions that further degrade the ANI's natural ecosystems.

Chapter 3: Identifying solutions for addressing vulnerabilities

This chapter outlines measures to enhance the resilience of local communities and mitigation measures to reduce and sequester carbon emissions. A CVI was developed using bio-physical, socio-economic and demographic factors to identify the most vulnerable regions in the ANI. Diglipur, Mayabunder and Ferrargunj emerged as the most vulnerable sub-districts. Subsequently, the viability of several solutions to address the specific vulnerabilities in these sub-districts were assessed. **Agroforestry, clean cookstoves, decentralised renewable energy, coconut husk biochar and mangrove conservation** emerged as the most viable options that could be developed into pilot projects for implementation.

Chapter 4: Green finance options

This chapter examines the financial mechanisms to support the implementation of the climate solutions identified in the previous chapter. Green finance options, including impact investment, green bonds, green loans, climate finance and carbon markets, were evaluated based on key parameters such as accessibility, regulatory flexibility, volatility, returns and scalability. Among these options, carbon markets emerged as the most viable choice for financing the climate solutions in Diglipur, Mayabunder and Ferrargunj.

Chapter 5: Feasibility of carbon markets for pilot intervention

This chapter shortlists two to three climate solutions from those identified in Chapter 3 based on their feasibility for implementation through carbon market financing. The assessment considered factors such as the degree of alignment with existing carbon methodologies (e.g. Verra and Gold Standard), estimated emission reductions, indicative price/credit, and additionality through alignment with the SDGs.

Mangrove restoration, clean cookstoves and decentralised renewable energy emerged as the most promising solutions, with mangrove restoration standing out due to its significant carbon sequestration potential and additional co-benefits. As one of the three main blue carbon ecosystems in the ANI, mangroves present an untapped opportunity for the region, which have largely remained unexplored.

Chapter 6: The way forward

This chapter summarises the key findings of the report. Mangrove restoration, clean cookstoves and decentralised renewable energy were identified as the measures best suited for implementing as pilots in Diglipur, Mayabunder and Ferrargunj, with carbon markets as the preferred financing mechanism.

The next phase of the project will focus on implementing these measures in the identified areas. Key upcoming activities include developing detailed project plans for the pilots, securing funding and executing them on the ground.

1. Setting the context

Spread across 8,249 sq. km, with a long coastline of 1,962 km in the Bay of Bengal, the ANI represent a unique intersection of geopolitical importance and ecological sensitivity. Geographically closer to Southeast Asia than the Indian mainland, the ANI offer a significant locational advantage in the east to India. These islands are situated near the Malacca shipping lanes, which serve as key trade routes between Asia, Africa and the Pacific. To maximise this geographic advantage, the government has initiated a range of infrastructure projects aimed at transforming the ANI into an economic hub for trade, commerce and tourism while promoting socio-economic development.[1,2,3]

Simultaneously, these islands are characterised by a rich biodiversity and high levels of endemism due to their geographic location and isolation. The islands comprise fragile terrestrial, coastal and marine ecosystems that provide key ecosystem services and must be preserved. However, these natural resources face increasing threats from anthropogenic climate change, including rising sea levels, increasing temperatures and change in precipitation patterns. These changes are expected to negatively impact livelihoods, health and infrastructure in the ANI. For instance, changes in precipitation may lead to crop loss and reduced agricultural productivity and availability of drinking water as residents are primarily dependent on rainwater. Meanwhile, rising average temperatures may affect the ANI's key economic sectors (fisheries, agriculture and tourism) by altering fish habitats and spawning, reducing food production due to increased evapotranspiration, heat stress on crops, erratic weather and pest attacks. The tourism sector may also suffer as coral bleaching leads to the loss of natural attractions. Furthermore, rising sea levels may contribute to coastal erosion, increased storm surges, inundation of low-lying areas and saltwater intrusions, thus degrading water resources. The impacts of climate

1 The Economic Times, 2024 will be a transformational year for the Andaman and Nicobar Islands. Economic Times, 2023, https://infra.economictimes.indiatimes.com/news/urban-infrastructure/2024-will-be-transformational-year-for-andaman-and-nicobar-islands/106341740

2 The Economic Times, Modi Government's Rs 10,000 Crore Plan to Transform Andaman and Nicobar Islands, 2015, https://economictimes.indiatimes.com/news/economy/infrastructure/modi-governments-rs-10000-crore-plan-to-transform-andaman-and-nicobar-islands/articleshow/49111067.cms?from=mdr

3 The Hindu, Nicobar Triangle: On the ₹72,000-Crore Project on Great Nicobar Island, 2024, https://www.thehindu.com/opinion/editorial/%E2%80%8Bnicobar-triangle-on-the-72000-crore-project-on-great-nicobar-island/article68327922.ece

change not only threaten the ecological balance of the islands but also undermine their economic and social resilience, exacerbating existing vulnerabilities and creating new risks. For instance, people in the ANI are increasingly vulnerable to climate change-induced diseases such as malaria and dengue, as their prevalence is expected to increase with rising temperatures. This risk is further increased by limited healthcare facilities on the islands.[4]

Within this context of geopolitical and ecological significance and the growing threats posed by climate change, a balanced approach towards sustainable development is essential. This approach must incorporate climate-resilient strategies that protect and preserve the fragile ecosystem while addressing the region's economic and strategic needs. This study has been conducted within this framework with the aim of developing climate-resilient solutions that support sustainable development in the ANI.

1.1. About the study

Objective and conceptual underpinning

This study uses the lens of the IPCC CRD framework, with the aim of identifying solutions for the ANI that will build climate resilience and achieve sustainable development outcomes. CRD is defined as 'a process of implementing greenhouse gas mitigation and adaptation options to support sustainable development for all in ways that support human and planetary health and well-being, equity and justice'.[5] According to the CRD framework, climate action (adaptation and mitigation) and sustainable development are interlinked and cannot be effectively achieved in isolation. Adaptation actions enhance social, economic and ecological resilience to climate change, thereby supporting sustainable development outcomes. For example, climate-smart agricultural practices improve water management, increase water availability, and enhance livelihoods and food security. Simultaneously, without mitigation actions, global warming will continue to escalate, worsening climate impacts undermining development and limiting effective adaptation options that are available. CRD focuses on transforming five interconnected systems: Energy systems, industrial systems, urban and infrastructure systems, societal systems, and land, ocean and ecosystems. It also considers socio-economic inequities stemming from gender, race or ethnicity, geographic location and poverty to avoid compounding vulnerability to climate change and exacerbating injustice.

[4] Ministry of Health and Family Welfare, Andaman & Nicobar Islands: State Action Plan on Climate Change and Human Health. 2022-27, https://ncdc.mohfw.gov.in/wp-content/uploads/2025/01/34_SAPCCHH_Andaman-and-Nicobar_21-10-24.pdf

[5] IPCC, Sixth Assessment Report, Climate Change 2022: Impacts, Adaptation and Vulnerability, 2022, https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Chapter18.pdf

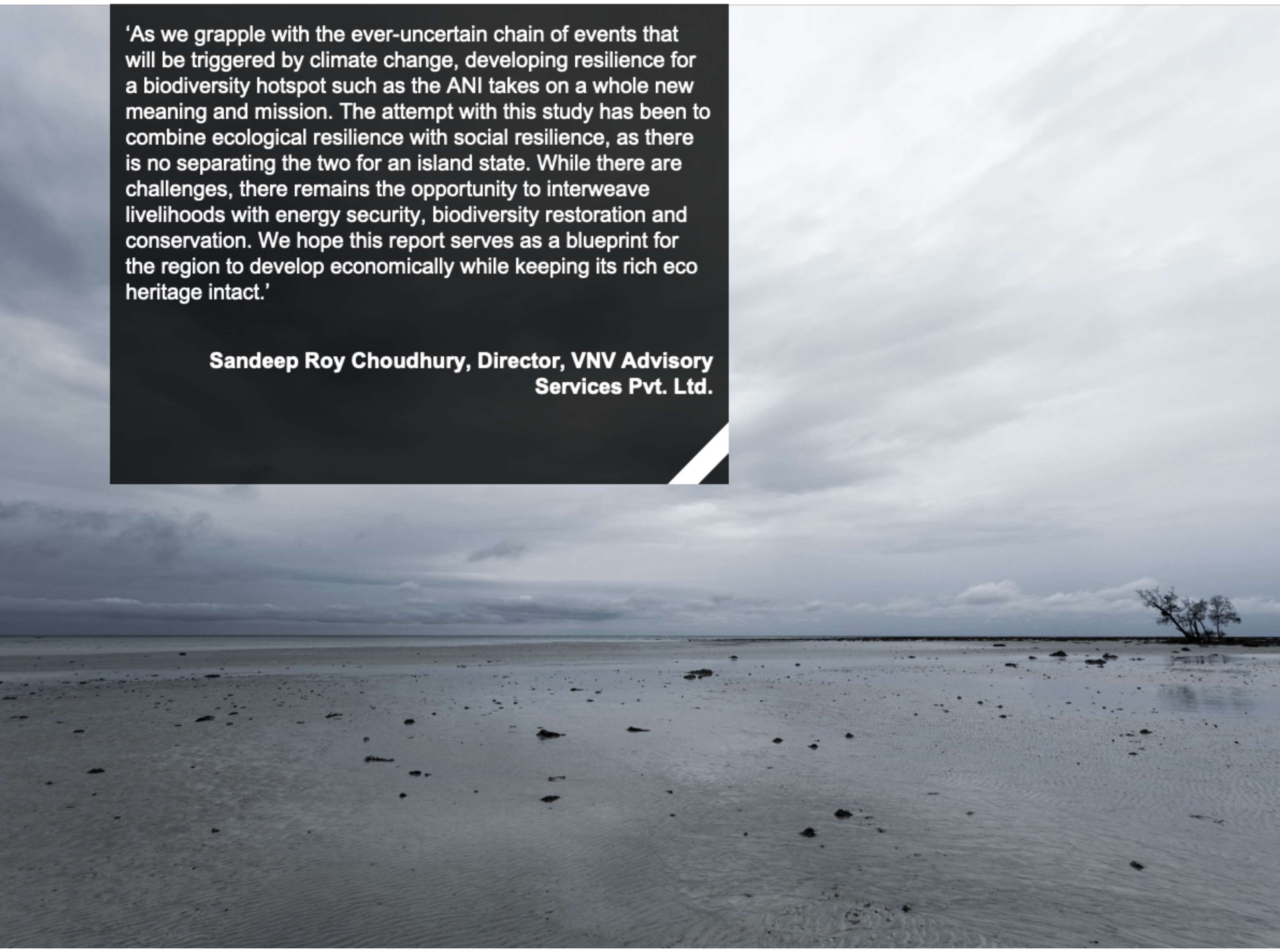
Methodology

The study used a comprehensive methodology comprising desk research, data collection, stakeholder consultations and data analysis. A literature review was conducted, examining research studies, articles and government reports, followed by the collection and analysis of quantitative and qualitative data to identify trends and assess the ANI's landscape. To strengthen the insights, extensive consultations were conducted with a range of stakeholders, including central and union-level government agencies, the private sector, development agencies and carbon market project developers. These consultations were conducted at different stages of the study to gather information and validate findings. In addition, an Advisory Committee (see Acknowledgements) consisting of four experts was established to provide critical reviews, direction and insights into the study's findings, enhancing the findings' robustness.

A situational analysis was conducted to assess the impacts of climate change and LULC changes. Subsequently, the three most vulnerable locations were prioritised using a CVI of socio-economic and bio-physical factors. Five feasible climate solutions were shortlisted based on two criteria: prior implementation in the ANI or presence in existing government policies and programmes in the ANI. Finally, several green financing options were assessed, with carbon markets emerging as the most feasible. The study concluded with an assessment of the carbon market's applicability to finance pilot projects, with mangrove restoration, clean cookstoves and decentralised renewable energy emerging as the most promising options.

'As we grapple with the ever-uncertain chain of events that will be triggered by climate change, developing resilience for a biodiversity hotspot such as the ANI takes on a whole new meaning and mission. The attempt with this study has been to combine ecological resilience with social resilience, as there is no separating the two for an island state. While there are challenges, there remains the opportunity to interweave livelihoods with energy security, biodiversity restoration and conservation. We hope this report serves as a blueprint for the region to develop economically while keeping its rich eco heritage intact.'

Sandeep Roy Choudhury, Director, VNV Advisory Services Pvt. Ltd.



2. Situational analysis

This chapter provides an in-depth analysis of the ANI's climate trends and shifts in LULC patterns. It offers a comprehensive understanding of the ANI's natural resource base, the threats to key economic sectors and anticipated climate risks. These findings, which form the foundation for the rest of the study, are detailed in the following sections.

2.1. LULC analysis in the ANI

LULC plays a critical role in the climate system, acting as a source and sink of GHGs.[6] Changes in LULC patterns modulate the incidence of heatwaves, cold waves, cloud formation and rainfall patterns. Such changes can directly and indirectly affect surface temperatures, leading to altered rainfall patterns and thereby droughts or floods.[7] Meanwhile, climate change, including the increasing frequency and intensity of extreme weather events, has negatively impacted food security and terrestrial ecosystems and contributed to land degradation and desertification. The land ecosystems in the ANI remain highly vulnerable to these ongoing changes and extreme weather events.

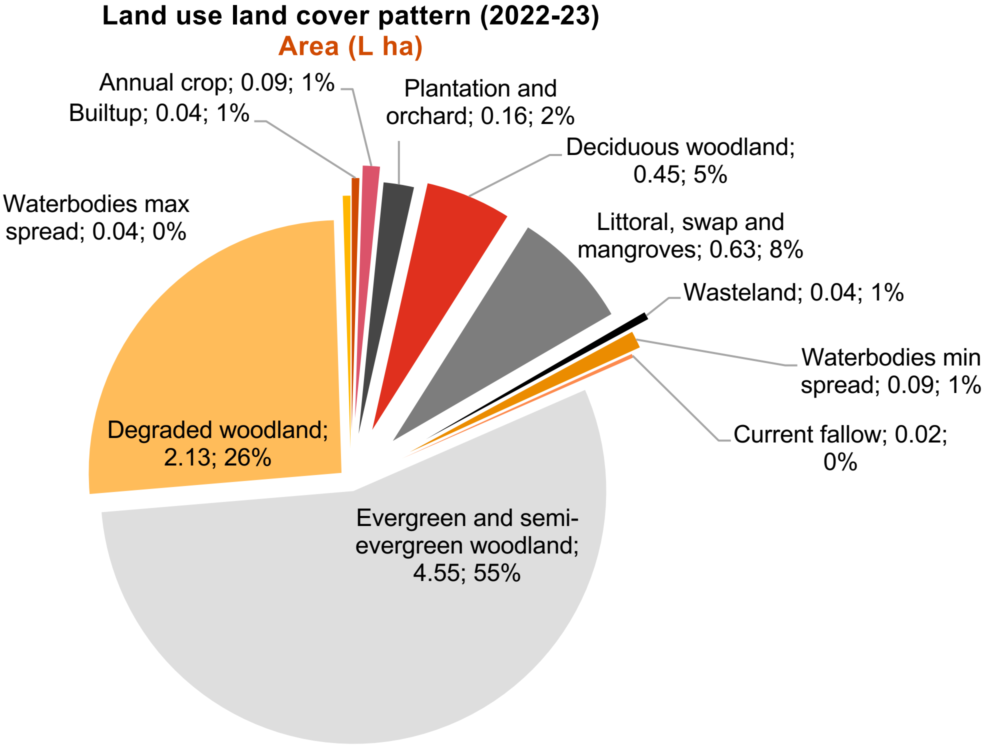
[6] U.S. Geological Survey, How do changes in climate and land use relate to one another? https://www.usgs.gov/faqs/how-do-changes-climate-and-land-use-relate-one-another-1?qt-news_science_products=0#qt-news_science_products

[7] U.S. Global Change Research Program, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II, 2018, https://nca2018.globalchange.gov/chapter/5/

2.1.1. Current land use patterns

The ANI have diverse LULC patterns, comprising dense tropical forests, mangroves, coastal wetlands, agricultural land and urban settlements. Approximately 86% of the total land area is covered by forests, which include tropical evergreen forests, tropical semi-evergreen forests, moist deciduous forests and mangroves.[8] The remaining land is used for agriculture, settlements and other purposes.

Figure 1: Current land use patterns



Source: Bhuvan; NRSC; Government of India

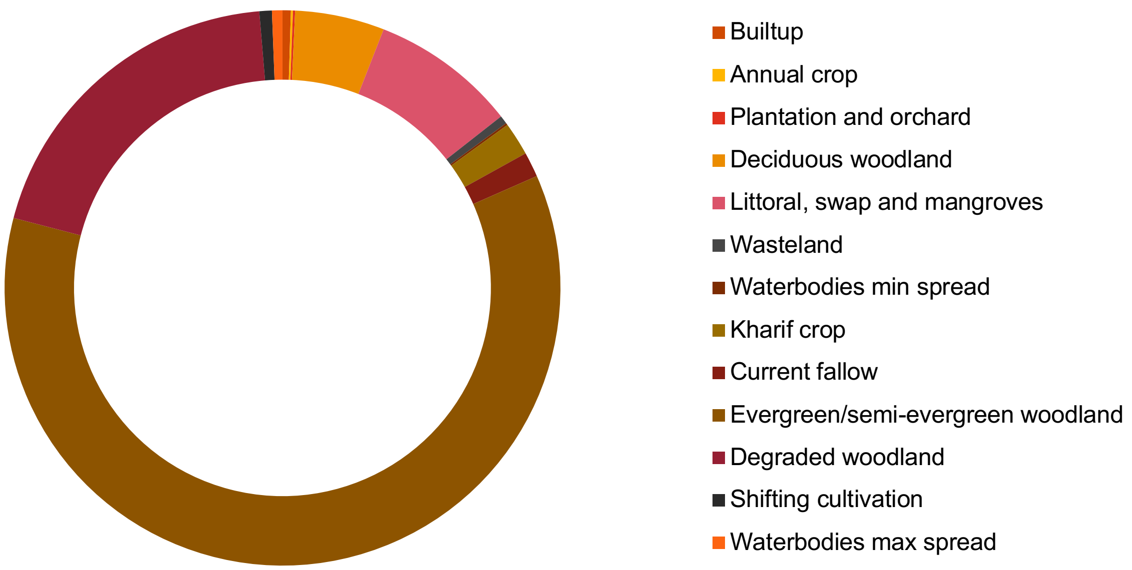
8 Government of India, Bhuvan; NRSC, 2023

2.1.2. Historical changes in land use

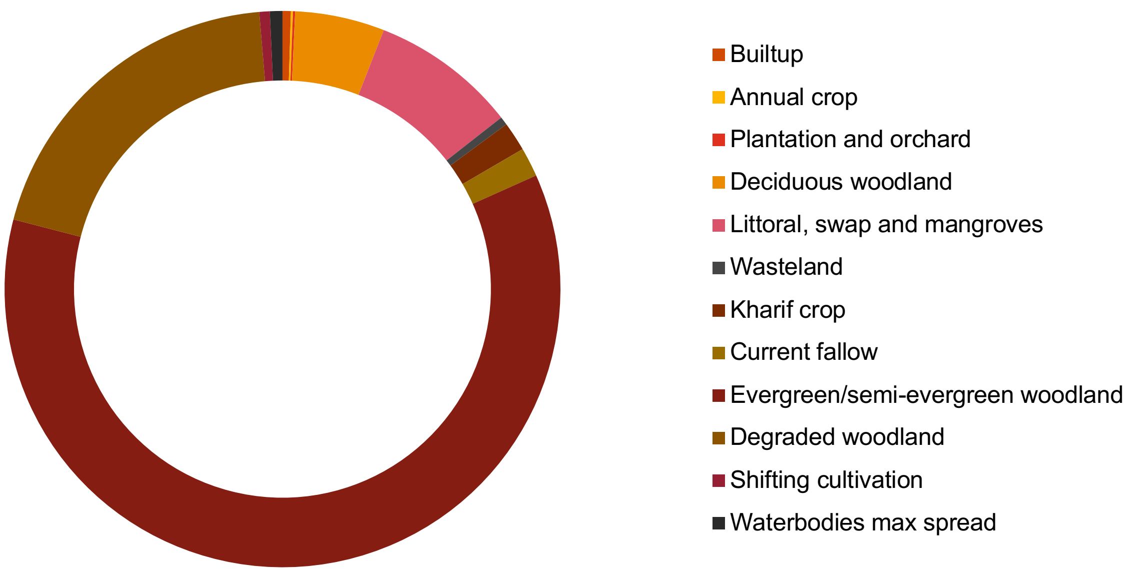
Historical changes in LULC patterns in the ANI have been shaped by natural events and human activities. The 2004 tsunami in the Indian Ocean significantly altered the coastal landscape, submerging several islands and causing substantial loss of mangrove forests. Meanwhile, post-tsunami reconstruction efforts and development projects have contributed to increased urbanisation and deforestation in certain areas.

Figure 2 (A, B, C, D): Historical land use patterns

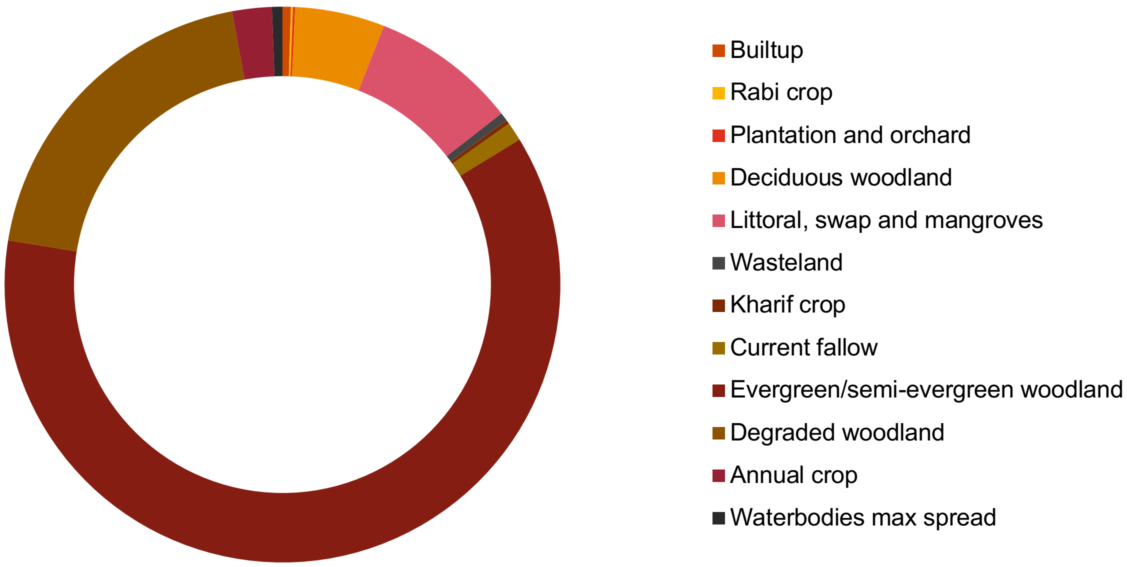
(A): LULC (2005–2006)



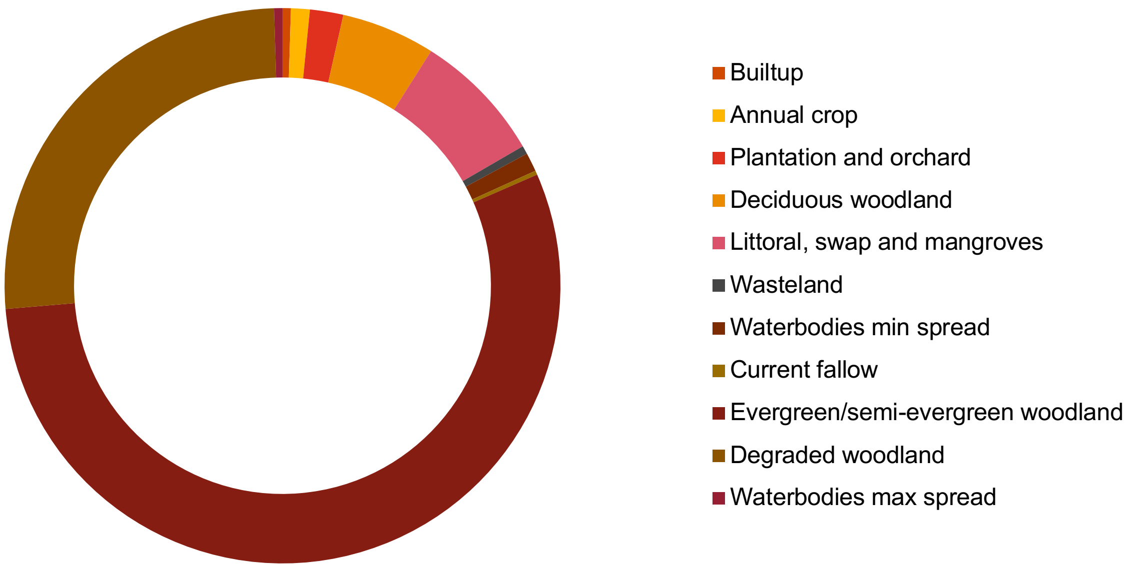
(B): LULC (2010–2011)



(C): LULC (2015–2016)



(D): LULC (2022–2023)



Source: Bhuvan

The findings of the LULC analysis are presented in Table 1.

Table 1: LULC analysis for 2005-06, 2010-11, 2015-16, 2022-23

Year	Description
2005-06	• The ANI were predominantly covered by forests, especially evergreen and semi-evergreen woodlands. • Significant degraded woodland and mangrove areas were also present. • Agricultural land use was minimal and human development was limited, with very little built-up areas and wasteland. • Water bodies that varied in size across the islands covered the landscape. • Overall, the data reflects a landscape with more natural vegetation than human development.
2010-11	• The ANI experienced minimal changes in land use and land cover. • The most notable changes include a slight decrease in kharif crops and shifting cultivation while a minor increase was observed in fallow land. • The maximum spread of water bodies increased. • Overall, the land cover remained mostly stable, with evergreen and semi-evergreen woodlands and degraded woodlands predominant.
2015-16	• The ANI experienced some notable changes in land use and land cover in 2015. • There was a significant reduction in kharif crop areas and a marked increase in annual crop areas by 2015. • Evergreen and semi-evergreen woodlands slightly increased, whereas degraded woodlands saw a marginal decrease. • The presence of rabi crops in 2015 indicates diversification in agricultural practices. • Overall, the landscape maintained a high degree of natural vegetation with minimal changes in built-up areas and wasteland.
2022-23	• The ANI experienced a mix of stability and changes in their land use and land cover patterns. • Built-up and plantation areas increased, showing signs of human development and agricultural intensification. • However, evergreen and semi-evergreen woodlands slightly decreased, suggesting some loss of forest cover. • Wetlands and water bodies showed notable increases, indicating positive changes in these ecosystems. • Overall, the islands maintained a significant amount of their natural vegetation, but there were signs of development and environmental changes.

Table 2: Comparison of LULC changes from 2005 to 2023 in the ANI[9]

LULC class	Area (L ha)				
	2005	2010	2015	2020	2023
Built-up	0.04	0.04	0.04	0.05	0.04
Annual crops	0.01	0.01	0.19	null	0.09
Plantation/orchards	0.01	0.01	0.01	0.21	0.16
Deciduous woodland	0.43	0.43	0.43	0.48	0.45
Littoral/swamp/mangroves	0.7	0.7	0.7	0.75	0.63
Wasteland	0.04	0.04	0.04	0.01	0.04
Waterbodies (min. spread)	0.01	null	null	0.11	0.09
Kharif crops	0.16	0.14	0.02	null	null
Current fallow	0.12	0.14	0.09	0.15	0.02
Evergreen/semi-evergreen woodland	5.01	5.01	5.05	4.76	4.55
Degraded woodland	1.62	1.62	1.16	1.69	2.13
Shifting cultivation	0.06	0.05	null	null	null
Waterbodies (max. spread)	0.05	0.06	0.05	0.04	0.04

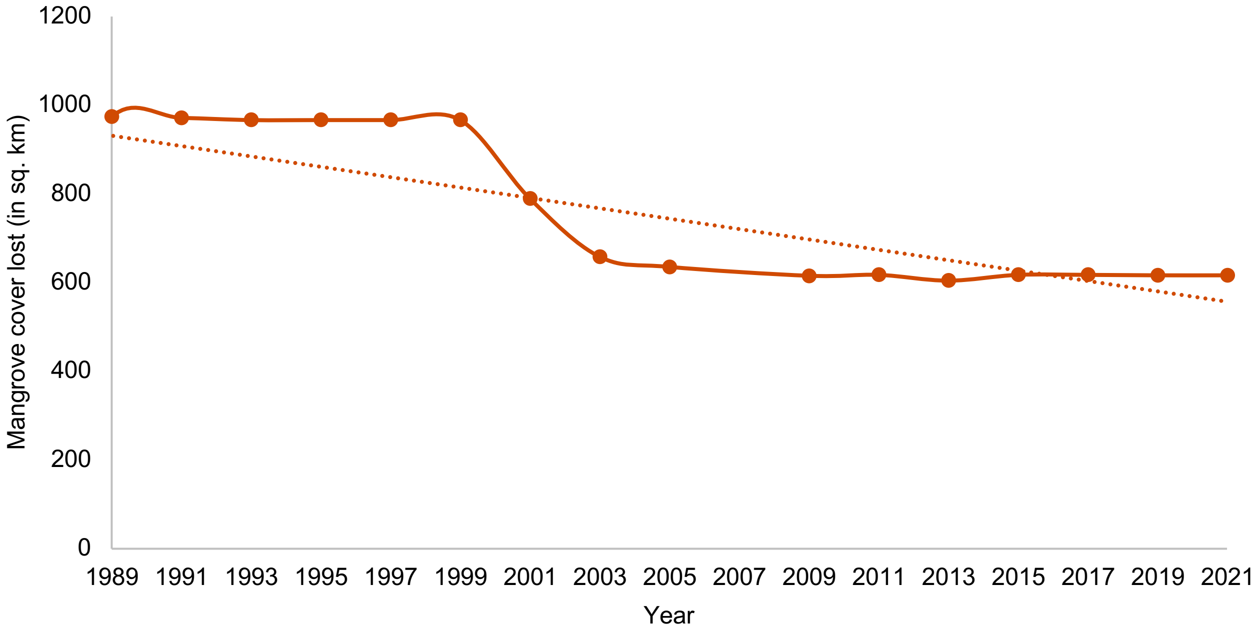
The LULC change analysis reveals several notable shifts in land use and cover across the ANI between 2005 and 2023. Agricultural activities have increased, particularly in plantation/orchard and annual crops, whereas traditional kharif crops have declined. Evergreen and semi-evergreen woodlands have decreased, with a corresponding rise in degraded woodlands. There has also been a reduction in littoral, swamp and mangrove areas, along with an increase in the minimum spread of water bodies. Overall, the landscape has shifted towards more intensive land use, with significant changes in agricultural practices and forest cover.

9 Government of India, Bhuvan-Thematic Service, ISRO, India - https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php

2.1.3. Deforestation and mangrove loss

Deforestation has been driven by logging, agricultural expansion and infrastructure development. Analysing satellite imagery and remote sensing data over the past few decades shows a gradual decline in forest cover, impacting the islands' biodiversity and ecological balance. The presence of mangroves has also rapidly declined, with approximately 357 sq. km lost between 1989 and 2021, representing nearly 15% of the total loss during this period.[10] Coastal development, aquaculture activities and natural disasters such as the 2004 tsunami have further contributed to mangrove degradation.[11,12] Significant changes in LULC patterns are observed in the ANI over recent decades, largely driven by natural disasters and human activities.[13,14,15] The compounded effects of these changes include ecological consequences such as species loss and reduced coastal protection, highlighting the urgent need for sustainable management practices in the region

Figure 3: Mangrove loss



Source: ISFR, 2021

The loss of these forests is linked to species loss, although quantifying the extent of this loss remains challenging due to data unavailability. These forests play a crucial role in coastal protection and biodiversity, and their degradation has significant ecological implications.

10 Forest Survey of India, State of Forest Report- Chapter 3: Mangrove Cover, 2021, https://fsi.nic.in/isfr-2021/chapter-3.pdf
11 Business Outlook, Is India's Mangrove Cover Shrinking? Here's All You Need To Know, 2024, https://www.outlookbusiness.com/planet/sustainability/is-indias-mangrove-cover-shrinking-heres-all-you-need-to-know
12 Down to Earth, Over half of world's mangroves face collapse due to human actions and climate change, 2024, http://downtoearth.org.in/wildlife-biodiversity/over-half-of-world-s-mangroves-face-collapse-due-to-human-actions-and-climate-change-96311
13 Down to Earth, NASA highlights loss of mangrove cover on Katchal island in the Nicobars, 2022, https://www.downtoearth.org.in/environment/nasa-highlights-loss-of-mangrove-cover-on-katchal-island-in-the-nicobars-84236
14 FAO, Rehabilitation of agriculture in tsunami affected areas in India: one and a half years later, 2006, https://www.fao.org/4/ag104e/ag104e08.htm
15 Frontline, On the brink: 10 endangered species of the Nicobar Islands, 2025, https://frontline.thehindu.com/environment/great-nicobar-project-endangered-species-saltwater-crocodile-species-wildlife/article69150433.ece

2.2. Climate change impact assessment

According to the IPCC's AR6, small islands, including the ANI, are increasingly affected by rising temperatures, frequent and intense tropical cyclones, storm surges, droughts, shifting precipitation patterns, sea level rise, coral bleaching and invasive species.[16] These climatic changes intensify impacts on natural and human systems. The ANI are particularly vulnerable as their population and economy rely heavily on climate-sensitive sectors such as agriculture, forests, fisheries, tourism and animal husbandry. The AR6 highlights several observed impacts and projected risks for small islands, emphasising the urgent need for adaptive measures to reduce climate change threats. These threats are detailed below:

Figure 4: Climate change impacts on the small islands

Natural systems	**Marine ecosystems**	• Submergence and flooding of islands and coastal areas, reef island destabilisation and coastal erosion • Coral bleaching due to elevated water temperatures • Loss of mangroves due to climate change • Loss of benefits such as provisioning services (e.g. timber and fisheries) and regulating services (e.g. coastal protection, carbon storage and pollutant filtering)
Natural systems	**Freshwater systems**	• Increased storm surges and inundation of low-lying areas • Saltwater intrusions, affecting ground and surface water
Natural systems	**Terrestrial biodiversity systems**	• Rising sea levels, causing habitat loss: - directly (e.g. submergence) - indirectly (e.g. salinity intrusion, salinisation of coastal wetlands and soil erosion), thereby affecting terrestrial biodiversity
Human systems	**Island settlements and infrastructure**	• Damage to major assets, loss of human lives due to flood events (caused by changes in rainfall), tropical cyclones and other extreme events.
Human systems	**Human health and well-being**	• The burden of climate-related health risks is projected to increase. This risk is heightened due to extreme weather and climate events such as heatwaves.
Human systems	**Water resources**	• Degradation of surface and ground water quality, posing a risk to water **security for drinking and irrigation**
Human systems	**Agriculture, fisheries and tourism**	• **Livelihoods dependent on nature (agriculture, fisheries and tourism)** face losses due to water scarcity, decrease in fish productivity and availability (as marine and coastal systems are impacted) and a decrease in tourists (increase in extreme events, rainfall, coral bleaching, etc.)

Source: IPCC AR6

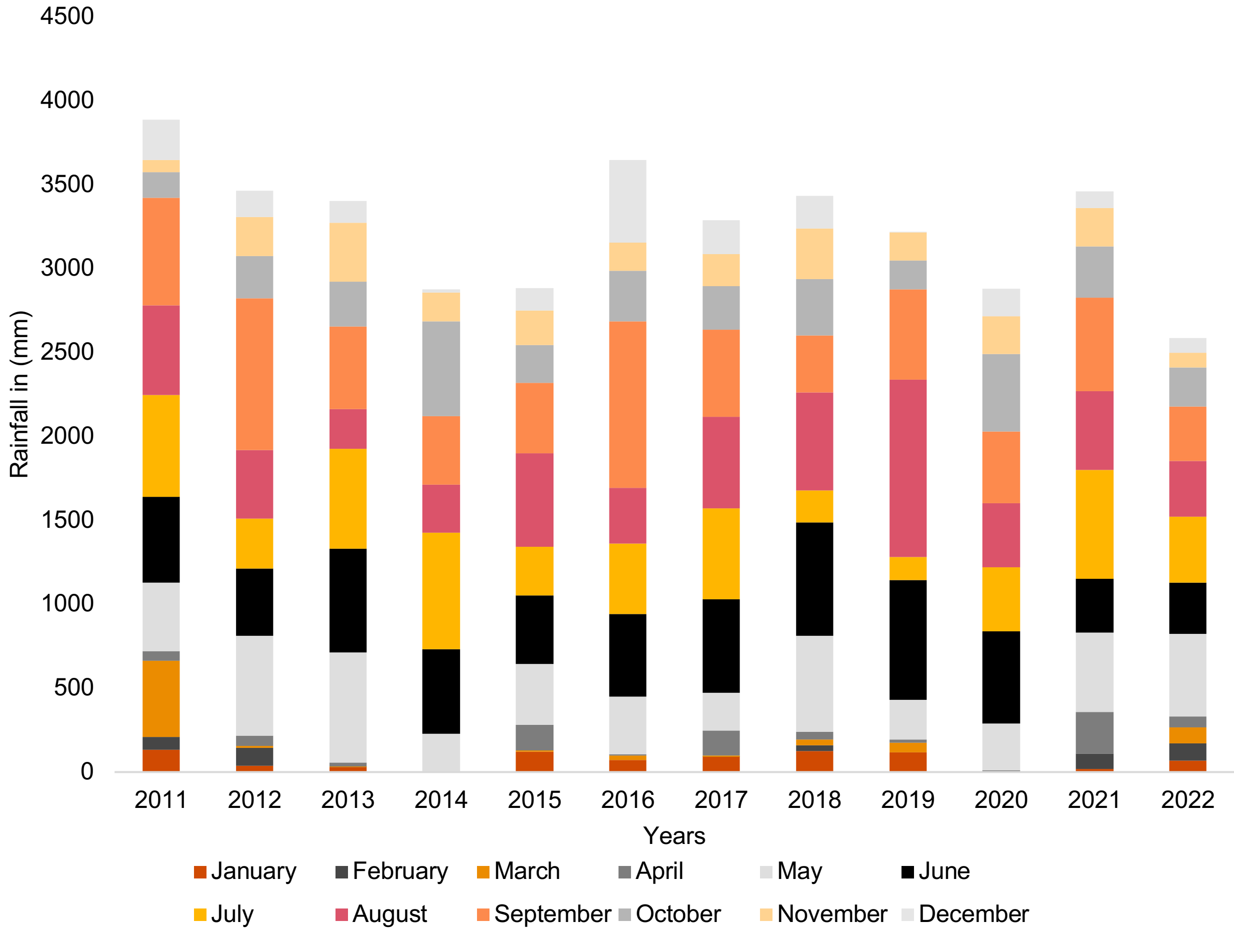
To assess global climate changes in the context of the ANI, a comprehensive geospatial analysis was conducted. The following sections outline the specific climate change impacts to the ANI.

[16] IPCC 2022, Small Islands. In Climate Change 2022: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, https://doi.org/10.1017/9781009325844.017

2.2.1. Climate baseline

The ANI has a tropical climate, warm, moist and equable climate due to its location near the equatorial belt and the temperatures ranges from 18°C to 35°C. These islands receive both Northeast and Southwest monsoons, with the Southwest monsoon bringing heavy rains from July to September and the Northeast monsoon from October to December. The islands receive an average yearly rainfall ranging from 3,000 to 3,500 mm, with humidity levels varying between 66% and 85%. Cyclones, accompanied by strong winds, commonly occur during the monsoon seasons, particularly in May and November.[17]

Figure 5: Rainfall recorded at Port Blair from 2011 to 2022



Source: Directorate of Economics and Statistics, Meteorological Analysis Andaman & Nicobar Islands 2022

The ANI receive rainfall from the south-west and north-east monsoons. Figure 5 illustrates the variability in annual rainfall, reflecting changes in weather patterns and monsoon intensity over the years. Typically, summer temperatures range from 28°C to 32°C, with variations from −1°C to +1°C. However, recent trends show that temperatures have consistently exceeded the normal range by more than 1°C, aligning with the IPCC projections of global warming for small islands. An analysis from 2011 to 2015 showed that minimum temperatures were notably above normal in January–February and even higher in March–April. In 2016, temperatures spiked sharply, reaching heat wave conditions. Since 2011, the number of very warm days has increased, while cold days have declined compared with historical averages.

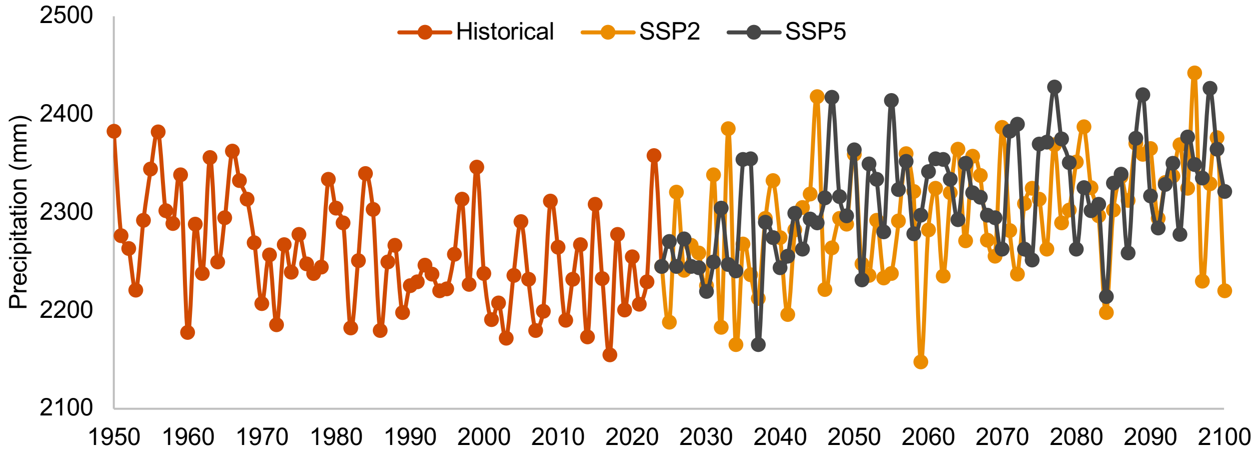
[17] Andaman and Nicobar Administration, Department of Environment and Forests, Andaman and Nicobar Islands Union Territory Biodiversity Strategy and Action Plan, 2005

2.2.2. Climate projections

Climate models indicate that surface air temperatures will continue to rise across small island regions over the next three 30-year period and significant changes in the climate over the coming decades.[18] The key projections are as follows:

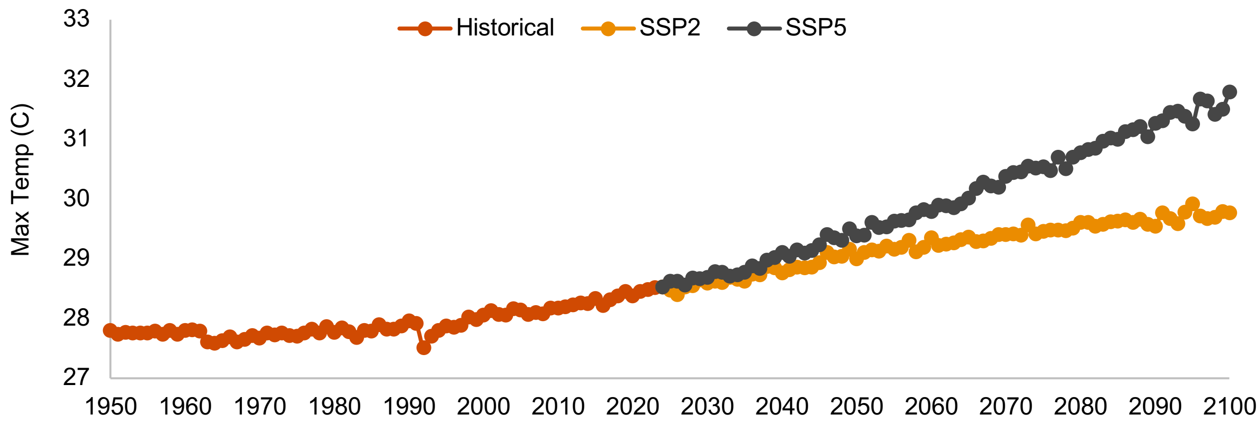
- **Temperature:** Average temperatures are expected to increase by 1.5°C–2.5°C by the end of the century, likely intensifying heat-related stresses on human and natural systems.
- **Precipitation:** Annual rainfall is projected to increase, but the distribution and intensity of rainfall events may become more erratic. The monsoon season is expected to bring heavier downpours, whereas the dry season may become even drier.
- **Sea levels:** Sea levels around the islands are projected to rise by 0.5 to 0.8 m by 2100, posing significant risks to coastal areas and low-lying islands.

Figure 6: Annual precipitation (mm)



Source: WBG CCKP

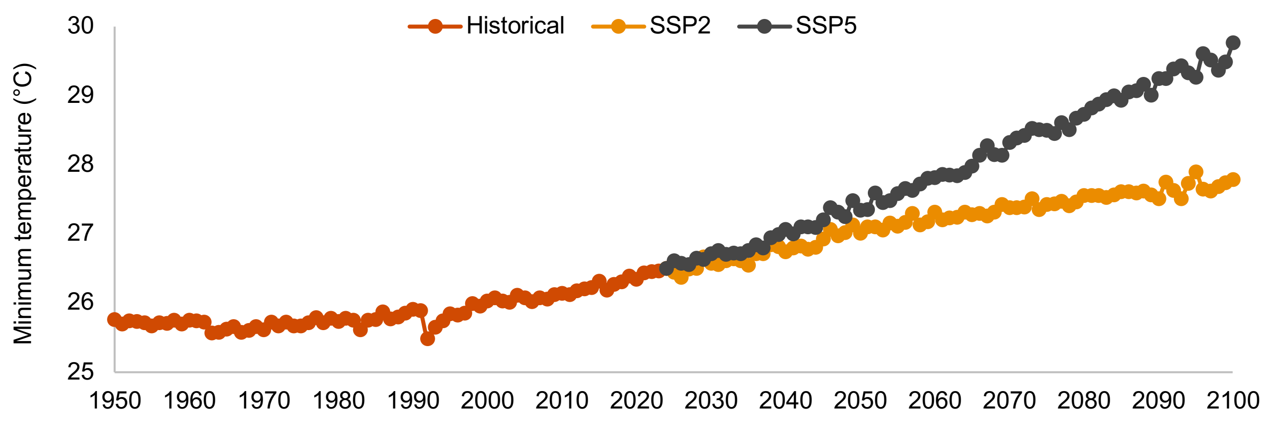
Figure 7: Maximum temperature (°C)



Source: WBG CCKP

[18] World Bank Group Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/

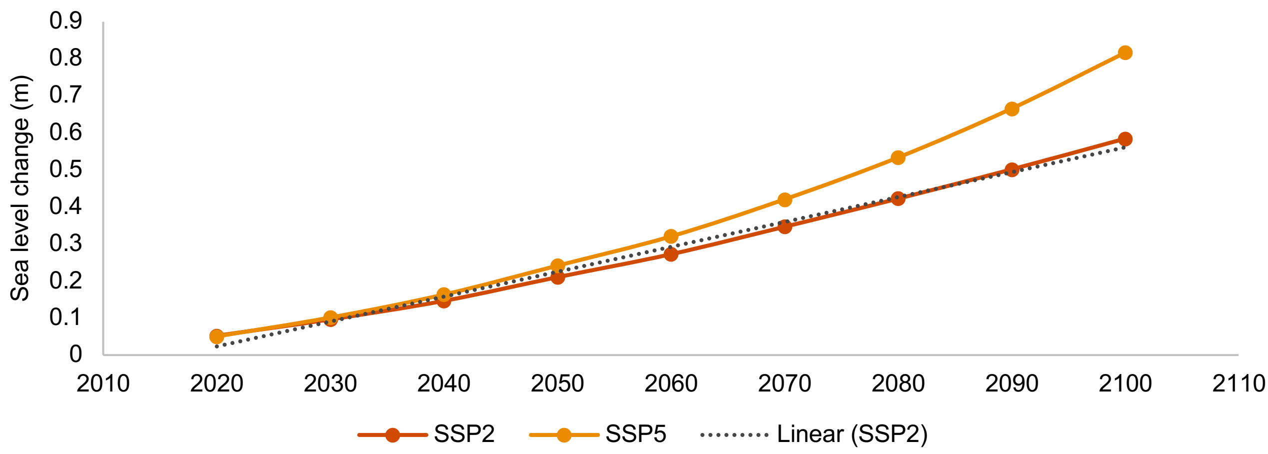
Figure 8: Minimum temperature (°C)



Source: WBG CCKP

Figures 6–8 present linear graphs depicting changes in annual rainfall and maximum and minimum temperature in the ANI for 2024–2100 under the SSP2 and SSP5 scenarios. Projections indicate that the ANI will experience the most significant increase in minimum temperature by 2100 under the SSP5 scenario.

Figure 9: Projected sea level rise under different SSP scenarios



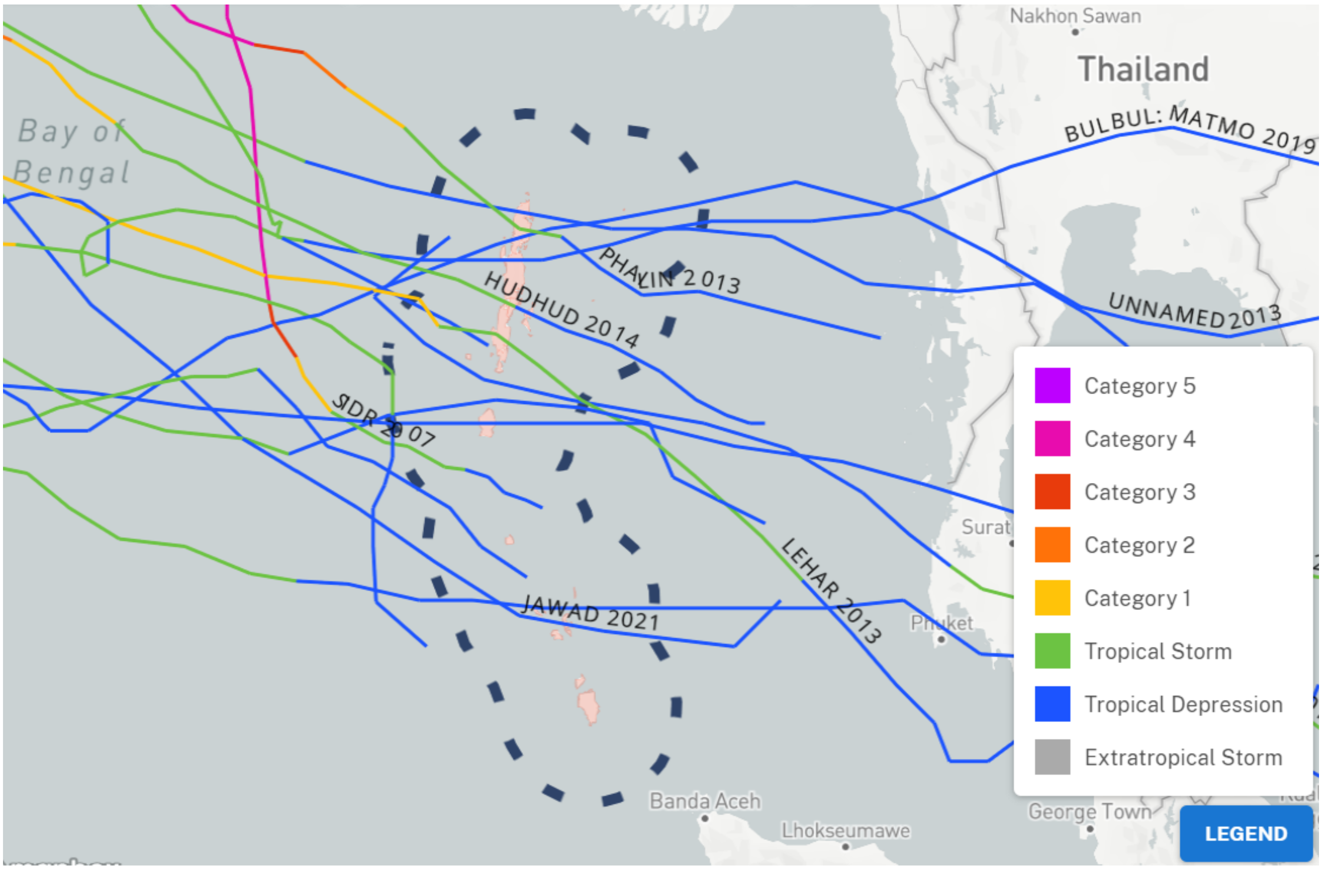
Source: NASA sea level projection tool

The graph in Figure 9 shows an increasing trend in sea level, with a linear trend line plotted alongside. These trends represents the rate of sea level change over time.

2.2.3. Climate hazards

The ANI are highly vulnerable to climate-related hazards. The frequency and intensity of tropical cyclones are projected to increase, heightening the risks of storm surges, flooding and wind damage. Rising sea levels, combined with intensified storm activity, contribute to accelerated coastal erosion, posing threats to infrastructure, settlements and natural habitats. Additionally, the rising sea levels can lead to saltwater intrusion into freshwater resources, impacting drinking water supplies and reducing agricultural productivity.

Figure 10: Cyclone tracks in the last 20 years



Source: NOAA Historical Hurricane Tracks

The lines on the map represent the cyclone pathways for each recorded year. An assessment of historical cyclone tracks over the past 20 years in the ANI indicates that all the islands are highly vulnerable to cyclone risk.

Coastal regions in India such as the ANI, face a risk of inundation due to rising sea levels and annual flooding. The National Centre for Coastal Research monitored shoreline changes along the Indian coastline from 1990 to 2018, revealing that 33.6%, 26.9% and 39.6% of the coastline was vulnerable to erosion, experienced accretion and remained stable, respectively.[19] The Shoreline Change Atlas indicates that between 1989-91 and 2004-06, 740.37 km of the Andaman Islands' shoreline experienced erosion, 944.84 km underwent accretion and 36.83 km remained stable. The eroded area totalled 17.93 sq. km, while the accreted area covered 27.09 sq. km. As for the Nicobar Islands, which have a shoreline length of 777.63 km (excluding the mouths of estuaries, rivers, and creeks), 690.10 km experienced erosion, 68.30 km saw accretion and 19.23 km remained stable over the same period. The eroded area amounted to 94.72 sq. km, and the accreted area was 0.77 sq. km.[20]

[19] Ministry of Environment, Forest and Climate Change, Government of India, 2023. Coastal Erosion.
[20] ISRO, Shore Line Change Atlas of the Indian Coast (Vol. 6), 2014, https://vedas.sac.gov.in/static/pdf/atlas/Seashore/Vol-6-Full.pdf

2.2.4. Sectoral impacts of climate change in the ANI

Climate change significantly impacts various nature-based sectors in the ANI. Key sectors such as biodiversity, agriculture, fisheries and water resources face significant threats from increased temperatures, sea level rise and altered precipitation patterns, affecting the ecological balance and livelihoods of local communities.

Table 3: Climate change impacts on nature-based sectors

Sectors	Climate change impacts
Forest and biodiversity	• **Coral reefs:** Rising sea temperatures and ocean acidification pose severe threats to coral reefs, leading to coral bleaching and the loss of marine biodiversity. • **Forests:** Changes in temperature and precipitation patterns can alter forest composition and health, affecting the habitat of numerous species. • **Mangroves:** Mangrove ecosystems are vulnerable to rising sea levels and changes in sedimentation patterns, which affect their ability to protect coastlines and support marine life.
Agriculture	• **Crop yields:** Altered rainfall patterns and increased temperatures can affect crop productivity, with potential declines in staple crops such as rice and coconut. • **Pest and disease:** Warmer temperatures and changing humidity levels can lead to the proliferation of pests and diseases, further threatening agricultural output.
Fisheries	• **Fish stocks:** Climate change can affect fish breeding and migration patterns, impacting local fisheries due to changes in fish stocks. • **Aquaculture:** Increased fluctuations in salinity and temperature can affect productivity and health, posing challenges for local communities that are reliant on this sector.
Water resources	• **Availability:** Changes in precipitation patterns can lead to variability in water availability, affecting drinking water supplies and irrigation. • **Quality:** Saltwater intrusion and pollution can degrade water quality, posing health risks and affecting agricultural practices.

The ANI are an ecologically sensitive region facing significant challenges due to land use and climate change. The geospatial analysis provides critical insights into current state of and historical changes in land use and land cover, and the potential effects of climate change. Effective management and conservation strategies are essential for protecting the islands' biodiversity and supporting sustainable development. Policymakers and stakeholders must prioritise measures to mitigate climate change impacts, promote sustainable land use practices, and enhance community resilience to environmental changes.

2.2.5. Summary of the climate change impacts in the ANI

The geospatial analysis indicates that the ANI's coastal, marine and forest ecosystems are being adversely affected by climate change. The impacts include soil degradation, increased erosion, altered water availability, changes in salinity distribution and nutrient leaching. These environmental shifts lead to a chain of physical, social and ecological consequences, which further degrade natural ecosystems in the region. To address these challenges, a comprehensive adaptation strategy is required to strengthen community resilience, along with mitigation measures to reduce and sequester carbon emissions. Implementing these actions will help address the root causes of climate change and protect the natural habitat in the region.

3. Identifying solutions for addressing vulnerabilities

Building on the situational analysis in the previous chapter regarding the changes in LULC, mangrove degradation and the heightened risk of climate-related hazards in the ANI, this section focuses on the adaptation and mitigation strategies that can be implemented in the most vulnerable areas in the islands, aiming to enhance their resilience. Aligned with the CRD framework, the study accounts for equity and justice by identifying the most vulnerable locations in the ANI based on socio-economic, demographic and bio-physical factors. Targeted solutions were shortlisted for these locations to address their specific challenges.

3.1. Prioritisation of the vulnerable sub-districts

Prioritising vulnerable locations is essential for effective climate adaptation planning, especially in an ecologically sensitive region such as the ANI. To systematically assess risk, the study developed the CVI, which integrates socio-economic and bio-physical vulnerability factors. Socio-economic vulnerability considers aspects such as livelihoods, population density and resource access, whereas bio-physical vulnerability includes environmental indicators such as LULC changes, biodiversity loss, mangrove degradation, and exposure to climate variability and extreme events. By combining these variables, the CVI helps identify the sub-districts that are most susceptible to climate impacts. Prioritising these locations is critical for the selection of pilot sites where climate resilience strategies can be tested and implemented, laying the groundwork for broader regional adaptation efforts.

3.1.1. Socio-Economic Vulnerability Index

Socio-economic vulnerability is determined by factors such as economic status (wealth, income and poverty), education level, housing quality, tenure type, built environment, family structure, age, gender, food insecurity and access to insurance.[21] These factors play a key role in determining vulnerability and correspond to sensitivity in the IPCC vulnerability framework in human systems.[22] A high-resolution spatial assessment of social vulnerability helps identify possible impact hotspots where adaptation measures are urgently needed.[23]

A detailed literature review and an assessment of secondary datasets from the Census of India and the Socio-Economic Caste Census were conducted. Key aspects of socio-economic vulnerability – household structure, gender, education, occupation, socio-economic status, housing and access to basic services – were considered during the selection. These variables helped identify socio-economically vulnerable communities exposed to multiple hazards. All variables were measured at the interval level. Normalisation of data was performed by removing units and converting values into dimensionless units (0–1) using the Human Development Index formula.[24] After normalisation, the indicators were averaged using simple arithmetic means to obtain values for major components, including socio-demographic profile, economic situation, amenities and assets. These components were then used to calculate the SEVI.

Table 4: SEVI

Category	Location	Nicobar			North and Middle Andaman			South Andaman		
	Variables	**Car Nicobar**	**Nancowry**	**Great Nicobar**	**Diglipur**	**Mayabunder**	**Rangat**	**Ferrargunj**	**Port Blair**	**Little Andaman**
Socio-demographic profile	HH size (5+)	0.71	0.41	0.00	0.86	0.64	0.52	1.00	0.09	0.06
	Female-headed HH	0.97	1.00	0.71	0.76	0.16	0.40	0.18	0.00	0.31
	SC/ST households	1.00	0.73	0.12	0.00	0.00	0.00	0.00	0.00	0.07
	Disability	0.92	0.58	0.67	1.00	0.08	0.00	0.46	0.42	0.75
	Illiteracy	0.60	1.00	0.61	0.27	0.53	0.37	0.17	0.00	0.42
	Average	**0.84**	**0.74**	**0.42**	**0.58**	**0.28**	**0.26**	**0.36**	**0.10**	**0.32**
Economic situation	Cultivation	1.00	0.76	0.04	0.41	0.30	0.10	0.00	0.05	0.36
	Marginal	1.00	0.64	0.08	0.24	0.25	0.18	0.24	0.00	0.24
	Landless	0.00	0.39	0.93	0.88	0.76	1.00	0.72	0.48	0.68
	Income<INR 5,000	1.00	0.91	0.67	0.92	0.74	0.42	0.48	0.00	0.66
	Average	**0.75**	**0.68**	**0.43**	**0.61**	**0.51**	**0.42**	**0.36**	**0.13**	**0.49**
Amenities and assets	Kutcha house	0.01	0.00	0.13	1.00	0.74	0.56	0.18	0.18	0.19
	Access to drinking water-Away	0.25	1.00	0.18	0.50	0.18	0.20	0.23	0.00	0.15
	No sanitation	0.00	0.24	0.36	1.00	1.00	0.85	0.56	0.08	0.40

21 IPCC, W. Neil Adger, 'Approaches to vulnerability to climate change', 2001, https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=6421

22 Adger, W. N., and Agnew, M., New indicators of vulnerability and adaptive capacity, 2004, https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=5463

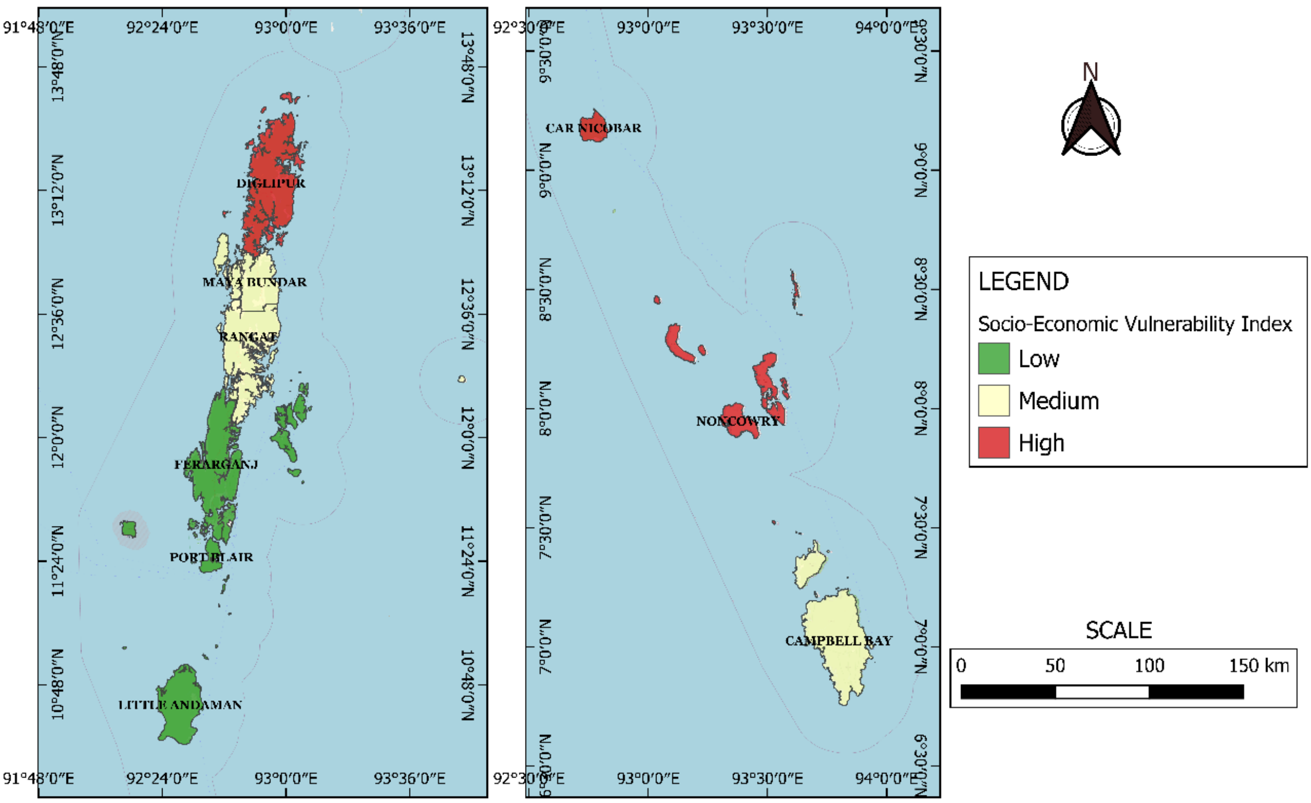
23 Das, S., Hazra, S., Haque, A., Rahman, M., Nicholls, R. J., Ghosh, A., and De Campos, R. S., 2021. Social Vulnerability to Environmental Hazards in the Ganges-Brahmaputra-Meghna Delta, India and Bangladesh, International Journal of Disaster Risk Reduction, Vol. 53, p. 101983

24 UNDP, Technical note 1. Human Development Index, 2022, https://hdr.undp.org/sites/default/files/2021-22_HDR/hdr2021-22_technical_notes.pdf

Cate-gory	Location	Nicobar			North and Middle Andaman			South Andaman		
	Variables	Car Nicobar	Nancowry	Great Nicobar	Diglipur	Mayabunder	Rangat	Ferrargunj	Port Blair	Little Andaman
	No assets	0.41	0.47	0.43	1.00	0.76	0.49	0.24	0.00	0.17
	No electricity	0.05	0.02	0.17	1.00	0.70	0.35	0.32	0.00	0.40
	Reliance on the fuel wood	0.80	0.75	0.24	1.00	0.84	0.74	0.44	0.00	0.57
	Average	**0.25**	**0.41**	**0.25**	**0.92**	**0.70**	**0.53**	**0.33**	**0.04**	**0.31**
SEVI		**0.61**	**0.61**	**0.37**	**0.70**	**0.50**	**0.40**	**0.35**	**0.09**	**0.37**

Based on the SEVI, Diglipur ranks the highest in vulnerability, with a score of 0.70, followed by Nancowry (0.61) and Car Nicobar (0.61). These locations face significant challenges related to limited access to amenities, economic instability and socio-demographic pressure. Specifically, in Diglipur, the high vulnerability is driven by inadequate sanitation, a high proportion of kutcha[25] houses and widespread economic hardship. In contrast, Port Blair and Ferrargunj record the lowest SEVI scores (0.09 and 0.35, respectively), indicating relatively lower socio-economic vulnerability due to better access to amenities, higher income levels and more stable household structures. However, even these sub-districts experience issues such as marginalisation and gaps in basic infrastructure.

Figure 11: Map illustrating the SEVI of the ANI



Source: PwC analysis

[25] Government of India defines kutcha houses as 'Houses made from mud, thatch, or other low-quality materials'- https://www.data.gov.in/catalog/distribution-households-pucca-and-kutcha-house

3.1.2. Bio-Physical Vulnerability Index

Bio-physical vulnerability refers to the susceptibility of natural systems and ecosystems to the adverse impacts of climate change and other environmental stressors. In the ANI, this vulnerability is driven by factors such as LULC changes, mangrove degradation, climate variability and exposure to extreme events such as cyclones and rising sea levels. These islands are ecologically sensitive and geographically isolated, making their bio-physical systems particularly vulnerable to changes in climate patterns and human activities. Assessing bio-physical vulnerability is essential for identifying priority areas for conservation and climate adaptation interventions, as these factors directly affect the resilience of ecosystems, biodiversity and local livelihoods.

To assess bio-physical vulnerability at the sub-district level, the study developed the BPVI, focusing on three key indicators: LULC changes, mangrove degradation and exposure to extreme events. Each indicator was scored on a scale of 0–1 based on secondary research and expert judgement, where 0 indicates low vulnerability and 1 represents high vulnerability. The scoring process was informed by secondary data from government reports; climate models; biodiversity assessments; and previous studies, with sources including the India Meteorological Department, the Indian National Centre for Ocean Information Services and peer-reviewed literature. A weighted average approach, with equal weights assigned to each indicator, was used to calculate the composite BPVI for each sub-district. This methodology enabled systematic comparisons of vulnerability levels across sub-districts, providing a robust, data-driven basis for identifying priority areas for climate resilience interventions.

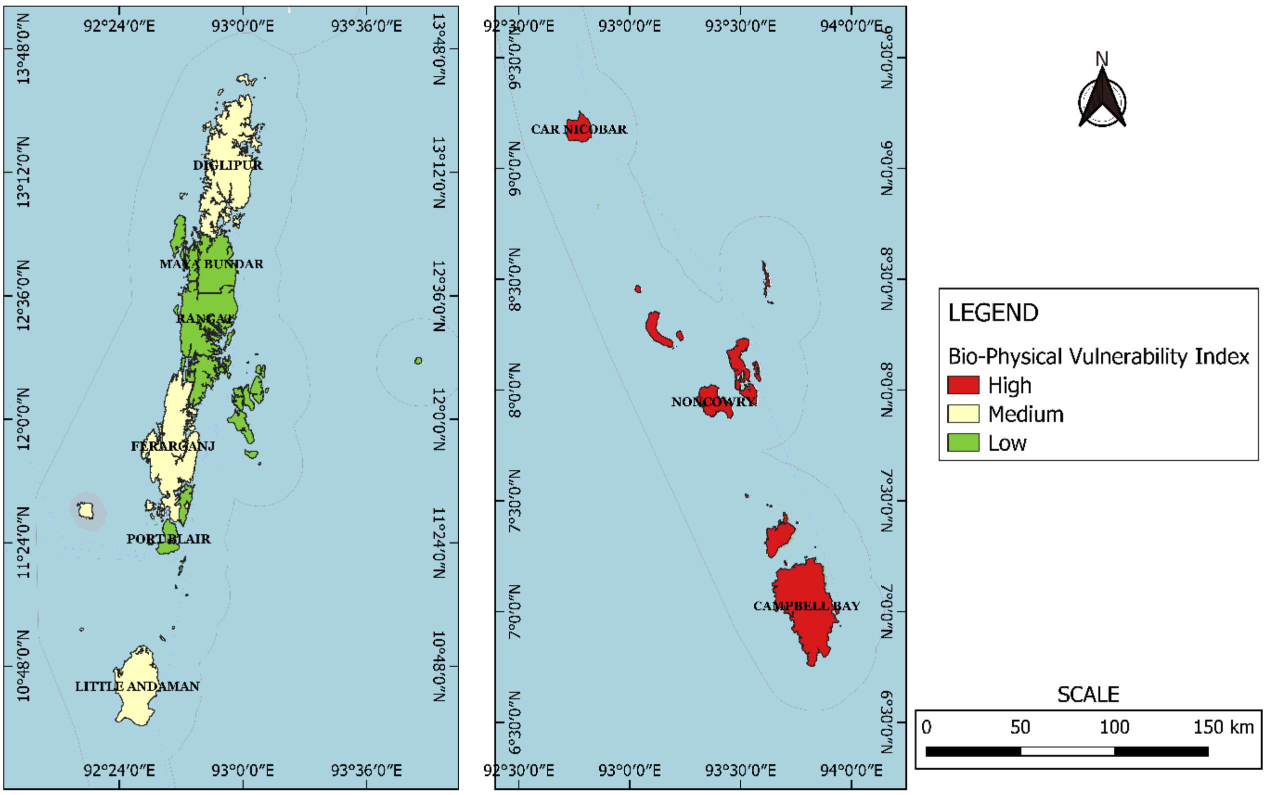
Table 5: BPVI

District	Sub-district	LULC change	Mangrove degradation	Extreme events	BPVI	Justification
Nicobar	Car Nicobar	0.80	0.90	0.90	**0.87**	High LULC changes due to rising sea levels; critical damage to biodiversity and mangroves; and severe exposure to extreme events such as cyclones and floods.[26]
	Nancowry	0.80	0.90	0.90	**0.87**	Severe LULC changes due to disasters; critical damage to biodiversity and mangroves; exposure to extreme weather and cyclones.[27]
	Great Nicobar	0.80	0.90	0.90	**0.87**	High LULC changes due to coastal erosion; critical damage to biodiversity and mangrove degradation; extreme exposure to cyclones and rising sea levels.[28]
North and Middle Andaman	Diglipur	0.50	0.60	0.70	**0.60**	Significant LULC changes from agriculture/tourism; high damage to biodiversity and mangrove degradation; frequent climate variability and extreme events.
	Mayabunder	0.40	0.50	0.60	**0.50**	Moderate LULC changes; moderate biodiversity loss; less severe mangrove damage than the southern islands; moderate exposure to variability and events.
	Rangat	0.50	0.50	0.60	**0.53**	Moderate LULC changes and biodiversity loss; mangroves under moderate pressure; exposed to moderate extreme events.[29,30,31]

26 NRDC, Sea Level Rise 101, 2024, https://www.nrdc.org/stories/sea-level-rise-101
27 The World Economic Forum, 'Sea level rise: Everything you need to know', 2024, https://www.weforum.org/stories/2024/09/rising-sea-levels-global-threat/
28 Directorate of Disaster Management, Andaman and Nicobar Administration, 2016, Andaman and Nicobar Islands Disaster Management Plan 2016. https://ddm.and.nic.in/Files/Disaster_Mgmt_Plan_2016_New.pdf
29 Ministry of Agriculture & Farmers Welfare, Land Use Statistics at a Glance: 2022-23, https://desagri.gov.in/wpcontent/uploads/2024/09/Final-file-of-LUS-2022-23-for-uploading.pdf
30 NRSC, National Land Use and Land Cover Mapping Using Multi-Temporal AWiFS Data, 2010, https://bhuvan-app1.nrsc.gov.in/2dresources/thematic/LULC250/0809.pdf
31 Forest Survey of India, 11.31 Andaman and Nicobar Islands, 2019, https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-andaman-nicobar-islands.pdf

District	Sub-district	LULC change	Mangrove degradation	Extreme events	BPVI	Justification
South Andaman	Ferrargunj	0.50	0.60	0.70	**0.60**	Significant LULC changes due to agriculture; moderate biodiversity and mangrove degradation; and moderate-to-high climate variability and cyclone exposure.[32]
	Port Blair	0.40	0.50	0.70	**0.53**	Moderate LULC changes due to urbanisation; biodiversity loss from habitat fragmentation; and mangroves under moderate pressure. Moderate climate variability and significant cyclone exposure.[33]
	Little Andaman	0.70	0.80	0.80	**0.77**	Extensive LULC changes from tourism/logging; high biodiversity loss; severe mangrove damage; and exposure to extreme events such as cyclones.[34,35]

Figure 12: Map illustrating the BPVI of the ANI



Source: PwC analysis

32 Intergovernmental Oceanographic Commission of UNESCO, UK. Department for International Development, IMM (UK), 2003, A Case Study from South Andaman Island, Poverty and Reefs, Vol. 2, pp. 147-186. https://unesdoc.unesco.org/ark:/48223/pf0000131839?posInSet=1&queryId=N-EXPLORE-c8ab7cff-2118-4ff7-9ac5-7cdc79b66853

33 Ministry of Environment, Forest and Climate Change, Government of India, New Delhi, Biodiversity and Climate Change: An Indian Perspective, 2018.

34 NRSC, Annual Landuse and Landcover Atlas of India, 2024, https://www.nrsc.gov.in/sites/default/files/pdf/Announcements/LULC_Atlas_NRSC.pdf

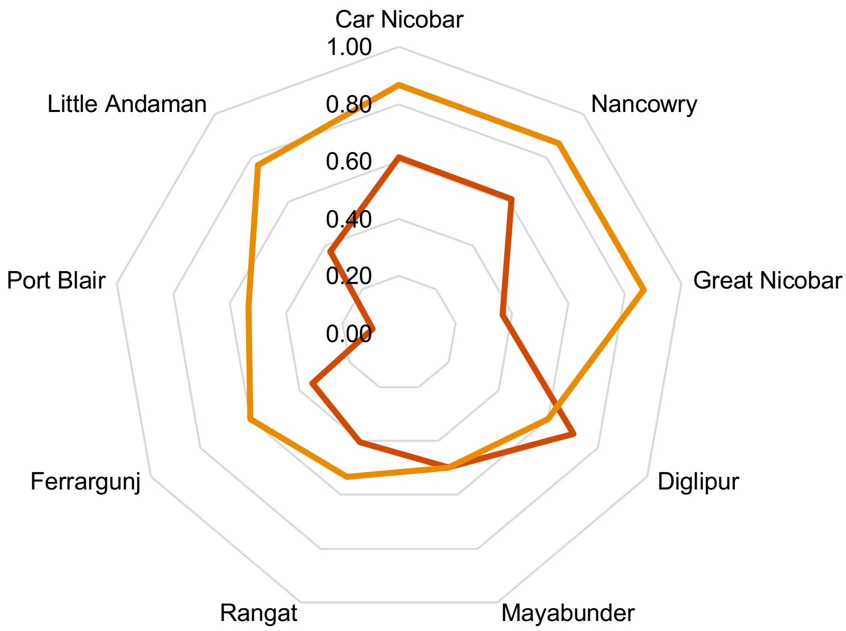
35 Earth Data NASA, ‘Decadal Land Use and Land Cover Classifications across India, 1985, 1995, 2005’, 2020, https://daac.ornl.gov/VEGETATION/guides/Decadal_LULC_India.html

The BPVI revealed significant variability in vulnerability levels across the ANI. Sub-districts such as Car Nicobar, Nancowry and Great Nicobar exhibited the highest levels of bio-physical vulnerability, with composite scores exceeding 0.80. These areas were identified as hotspots for extreme LULC changes, severe mangrove degradation, and high exposure to cyclones and rising sea levels. In contrast, sub-districts such as Port Blair and Mayabunder demonstrated moderate vulnerability, with index scores ranging from 0.50 to 0.60. The findings underscore the critical need for targeted climate adaptation and ecosystem restoration efforts in highly vulnerable areas, particularly in the southern regions of the ANI, where biodiversity loss and extreme event exposure are most severe. These results offer a clear framework for policymakers in terms of prioritising pilot sites for climate resilience and conservation projects.

3.1.3. Composite Vulnerability Index

The CVI is a key tool for assessing a region's overall vulnerability that integrates multiple dimensions, namely, socio-economic and bio-physical factors. It provides a comprehensive understanding of how susceptible specific locations are to external stressors such as climate change, natural disasters and socio-economic challenges. In addition, the CVI incorporates indicators related to socio-demographic profiles, economic conditions, infrastructure and environmental degradation, thereby offering a holistic assessment of the region's vulnerability. By integrating socio-economic vulnerability and bio-physical vulnerability, the CVI enables targeted decision-making. This index is essential for identifying high-priority areas that require intervention, helping policymakers allocate resources effectively and develop sustainable development strategies for vulnerable regions such as the ANI.

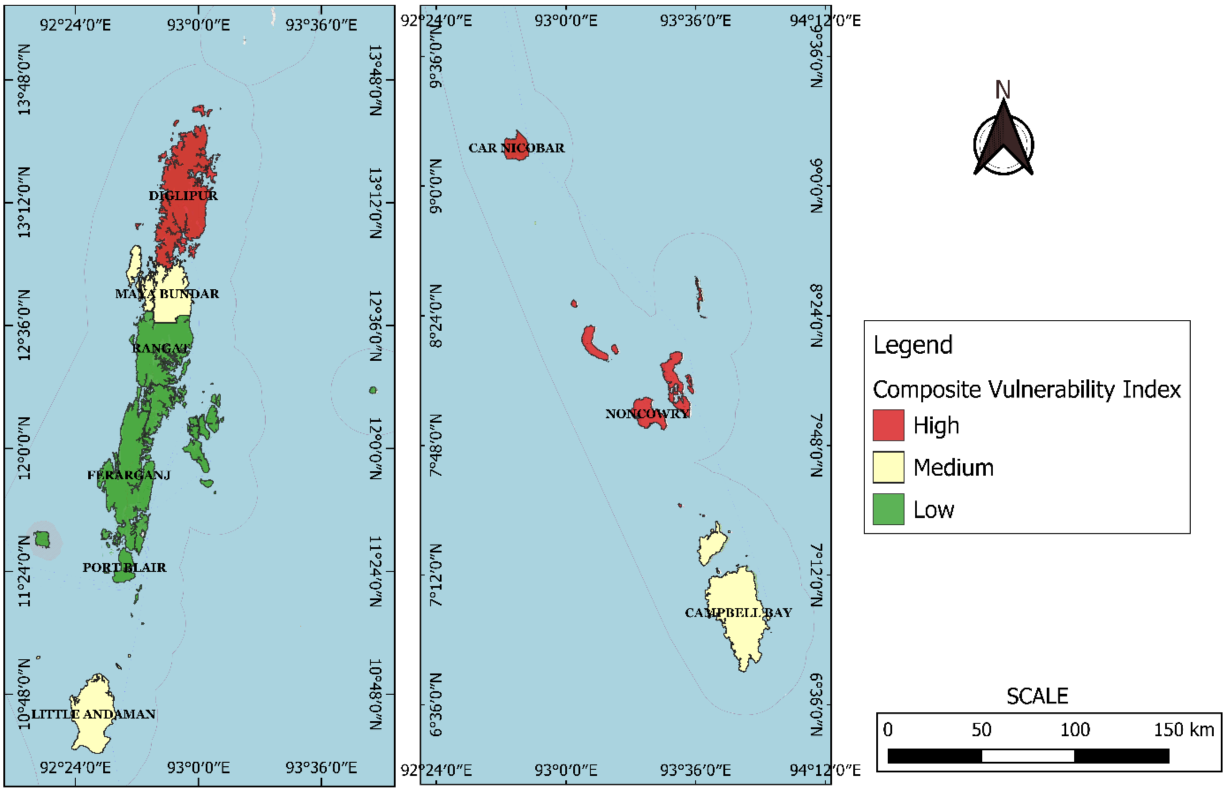
Figure 13: Comparison of SEVI and BPVI



Source: PwC analysis

This radar diagram illustrates the SEVI and BPVI scores for all sub-districts of the ANI. By comparing these indices, the diagram highlights areas where socio-economic and bio-physical vulnerabilities contribute significantly to the overall vulnerability. This visual representation provides a clearer understanding of regions that require increased attention and resources, helping prioritise targeted interventions for areas with particularly high SEVI and BPVI scores.

Figure 14: Map illustrating the CVI of the ANI



Source: PwC analysis

Table 6: CVI

District	Sub-district	SEVI	BPVI	CVI	Rank
Nicobar	Car Nicobar	0.61	0.87	0.74	2
	Nancowry	0.61	0.87	0.74	1
	Great Nicobar	0.37	0.87	0.62	4
North and Middle Andaman	Diglipur	0.70	0.60	0.65	3
	Mayabunder	0.50	0.50	0.50	6
	Rangat	0.40	0.53	0.469	8
South Andaman	Ferrargunj	0.35	0.60	0.475	7
	Port Blair	0.09	0.53	0.31	9
	Little Andaman	0.37	0.77	0.57	5

Source: PwC analysis

CVI results revealed distinct variations in vulnerability across the sub-districts of the ANI, highlighting the need for prioritised interventions. Nancowry and Car Nicobar, with the highest CVI score of 0.74, emerged as the most vulnerable sub-districts, followed by Diglipur (0.65). Nancowry and Car Nicobar exhibit a strong combination of socio-economic and bio-physical vulnerabilities, with high BPVI scores of 0.87, making them the top priority for climate adaptation and resilience-building efforts. Meanwhile, Great Nicobar shows significant bio-physical vulnerability but ranks fourth overall due to lower socio-economic challenges.

While Diglipur (0.65) also shows substantial vulnerability, it should be the next priority, given its balanced exposure in both dimensions. Port Blair (0.31) and Ferrargunj (0.475) exhibit lower socio-economic and bio-physical risks and may be considered low-priority regions but still require targeted interventions to address specific vulnerabilities.

3.2. Socio-economic and demographic profile of vulnerable sub-districts

Based on the SEVI, BPVI and CVI, developed using a range of vulnerability indicators, three sub-districts were selected in this study, representing high, medium and low vulnerability categories. The selection process involved consultations with experts, along with considerations of site accessibility and the feasibility of potential interventions. As a result, Diglipur, Mayabunder and Ferrargunj were chosen, each corresponding to a distinct vulnerability category. This approach ensures a representative and balanced sample.

Table 7: Socio-economic and demographic profiles of the selected sub-districts[36]

Category	Diglipur	Mayabunder	Ferrargunj
	High vulnerability	Moderate vulnerability	Low vulnerability
About	This sub-district consists of 72 inhabited and nine uninhabited villages over seven inhabited islands: Narcondam, East, Land Fall, North Andaman, Smith, Curlew and Stewart Islands. It is located at the northernmost part of this territory.	This sub-district comprises 47 inhabited and three uninhabited villages over three islands: Middle Andaman Island (Part), Aves and Interview Island.	This sub-district comprises 62 inhabited and 14 uninhabited villages over two islands: South Andaman (Part) and Flat Bay. It also consists of the Bamboofla area, which has been treated as a census town.

[36] District Census Handbook, Directorate of Census Operations, Andaman and Nicobar Islands, 2011, https://censusindia.gov.in/nada/index.php/catalog/1434

Category		Diglipur	Mayabunder	Ferrargunj
		High vulnerability	Moderate vulnerability	Low vulnerability
Demography	**Population**	Diglipur accounts for nearly 10% of the total population of ANI. The population of Diglipur stands at 40,873 persons (21,308 males and 19,565 females).	Mayabunder accounts for 7% of the total population of ANI. The population of the sub-district stands at 27,206 persons (14,094 males and 13,112 females).	Ferrargunj accounts for nearly 14% of the total population of ANI. The sub-district's population stands at 53,565 persons (27,908 males and 25,657 females).
	Illiteracy	23.52% of the population is illiterate, with illiteracy in females being close to 30% (compared with 18% in males).	Illiteracy in the sub-district was slightly higher at 27.92%, with illiteracy being marginally higher in females than in males.	Illiteracy stands at 21.81%, below the average of ANI. Illiteracy is more prevalent in females (close to 25%) than in males (19%).
	Scheduled castes (SC)/ scheduled tribes (ST) population	The sub-district has a low SC/ST population, with less than 1% of the households (HH) being SC/ST HHs.	The sub-district has a low SC/ST population, with less than 1% of the HHs being SC/ST HHs.	The sub-district has a low SC/ST population, with less than 1% of the HHs being SC/ST HHs.
Socio-economic	**Work participation rate**	The working population stands at 40.09%, of which nearly 20% are marginal workers.	The working population stands at 33.95%, of which nearly 20% are marginal workers.	The working population stands at 38.38%, of which nearly 20% are marginal workers.
	Income	Nearly 65% of the HHs fall in the lower-income bracket, which is higher than the district average of 57%. The majority of the households derive their income from cultivation or manual casual labour.	Nearly 57% of the households in the tehsil fall in the lower-income category, with a little over 25% of the households earning higher incomes. 41% of the households derive their income from cultivation or manual casual labour.	4.69% of the population is engaged in cultivation as their primary source of income, whereas 21.49% are engaged in manual casual labour.
	Household conditions	More than 4% of the HHs are single-room HHs, whereas 14% are landless deriving a major part of their income from manual casual labour.	Close to 13% of the households are landless and derive a major part of their income from manual casual labour.	Only 0.86% of the households are single-room households, and 11.9% of the households are landless households deriving a major part of their income from manual casual labour.

Category		Diglipur	Mayabunder	Ferrargunj
		High vulnerability	Moderate vulnerability	Low vulnerability
Access to basic amenities	**Kitchen facility**	Most households have a kitchen and cook inside the house. Fuelwood is most widely used for cooking.	Most households cook inside the house and have kitchens. A small number of households (including those who cook inside and outside) do not have kitchens. Fuelwood is most widely used for cooking.	The vast majority of the households have a kitchen and cook inside the house. LPG and fuelwood are most widely used for cooking.
	Source of the drinking water	Most HHs do not have a drinking water source within the premises; most have a source near the premises, and some have to travel long distances.	Most households have a source of drinking water either within or near the premises, whereas some have to travel long distances for the nearest source of water.	Most households have a source of drinking water either within or near the premises, whereas some have to travel long distances for the nearest source of water.
	Sanitation facilities	Most HHs do not have toilet facilities within the premises.	Most HHs do not have toilet facilities within the premises.	Most households have toilet facilities within the premises.
	Electricity	Most HHs have access to electricity as their primary source of lighting. Power generation is largely diesel-based. Some households are reliant on kerosene, and a very small number do not have access to lighting.	Most HHs have access to electricity as their primary source of lighting. Power generation is largely diesel-based. Some households are reliant on kerosene, and a very small number of households do not have access to lighting.	A vast majority of households have access to electricity as their primary source of lighting. Power generation is largely diesel-based. Some households are reliant on kerosene, and a very small number of households do not have access to lighting.
	Fuelwood	70.10% of the HHs rely on firewood to meet cooking needs. 10% use kerosene, and only 18.18% of households use LPG/piped natural gas (PNG).	60.40% of the HHs use firewood for cooking. Kerosene is used for cooking by 16.30%, and LPG/PNG is used among 22.26%.	35.72% of the households use firewood for cooking, 23.51% use kerosene and 39.11% use LPG/PNG.

Category		Diglipur	Mayabunder	Ferrargunj
		High vulnerability	Moderate vulnerability	Low vulnerability
Public infrastructure	**Road infrastructure**	Diglipur's road network is approximately 395 km long, with a road density much higher than the national average in terms of area and population.	Mayabunder's road network is approximately 199 km long, exceeding the national average road density in terms of area and population.	Ferrargunj's road network is approximately 341 km long, with high road density relative to the national average in terms of area and population.
	Schools	Most villages have public primary schools, although a few villages have schools located 5–10 km or 10 km+ away. Pre-primary schools are generally unavailable, whereas secondary and high schools are located 5–10 km or more away.	Most villages have public primary schools, although a few villages have schools located 5–10 km or 10 km+ away. Pre-primary schools are generally unavailable, whereas secondary and high schools are located 5–10 km or more away.	Most villages have public primary schools, although a few villages have schools located 5–10 km away. Pre-primary schools are generally unavailable, whereas secondary and high schools are located 5–10 km away.
	Healthcare	Public primary health centres are mostly unavailable at the village level, being available mostly 5–10 km away from villages and 10 km+ away in some cases. Public primary health sub-centres are relatively more available.	Public primary health centres are mostly unavailable at the village level, being available mostly 5–10 km away from villages and 10 km+ away in some cases. Public primary health sub-centres are relatively more available.	Public primary health centres are mostly unavailable at the village level, being available mostly 5–10 km away from the village and 10 km+ away in some cases. Public primary health sub-centres are relatively more available.

Category	Diglipur	Mayabunder	Ferrargunj
	High vulnerability	**Moderate vulnerability**	**Low vulnerability**
Environment	The annual average temperature is 26.9°C, with April as the warmest month and January the coldest. The average annual rainfall is 2,953 mm, with the highest precipitation (565 mm) occurring in June. This sub-district has undergone significant LULC changes due to agriculture and tourism, which have been accompanied by high levels of biodiversity loss and mangrove degradation. It is also frequently affected by climate variability and extreme events.	The annual average temperature is 26.9°C, with an average annual rainfall of 2,953 mm. The highest precipitation of 565 mm occurs in June. Regarding bio-physical factors, the sub-district has experienced moderate LULC changes, moderate biodiversity loss and less severe mangrove damage compared with the southern islands. It also faces moderate exposure to climate variability and extreme events.	South Andaman (Ferrargunj) has a tropical climate, with significant rainfall through most of the year. The annual average temperature is 26.4°C, and the average annual rainfall is 3,068 mm per year. The sub-district has undergone significant LULC changes due to agriculture, along with moderate biodiversity loss and mangrove degradation. It faces moderate-to-high exposure to climate variability and cyclones.

Based on the analysis, several adaptation and mitigation measures have been identified in the next part of the report to address specific vulnerabilities in Diglipur, Mayabunder and Ferrargunj.

3.3. Proposed measures to address vulnerabilities

Diglipur, Mayabunder and Ferrargunj face varying degrees of vulnerability, exacerbated by socio-economic, environmental and climate change factors, as reflected in their CVI scores. To effectively address these challenges and enhance resilience within these communities, implementing targeted adaptation and mitigation measures is necessary. Based on a literature review and existing government policies and programmes, specific measures have been identified to address key challenges in each sub-district. These include agroforestry, clean cookstoves, decentralised renewable energy and mangrove conservation and restoration.

The selected measures have been implemented in similar contexts, demonstrating their feasibility and effectiveness. Additionally, their alignment with government policies and programmes ensures they support broader strategic goals and national priorities. These measures aim to reduce vulnerabilities, enhance livelihoods and promote sustainable development in the three sub-districts.

Table 8: Proposed measures and their justification for selection

<table>
<tr><th>Summary of key challenges in Diglipur, Mayabunder and Ferrargunj</th><th>The proposed measures identified and their justification</th></tr>
<tr><td rowspan="3">Low household income

High climate vulnerability and exposure to extreme climate events

LULC changes due to agriculture

Significant biodiversity loss and mangrove degradation due to agriculture

High illiteracy rates, particularly among females

Diesel-powered electricity

High percentage of households relying on fuelwood for cooking</td><td>Agroforestry[37,38,39]

Agroforestry plays a vital role in addressing LULC changes due to agriculture. Integrating trees into farming systems enhances biodiversity, improves soil health and increases carbon sequestration, reducing climate vulnerability and exposure to extreme climate events. It also provides benefits that enhance livelihoods such as timber, fruits and other non-timber forest products. Additionally, the presence of trees acts as windbreaks, mitigating the impacts of extreme weather events.</td></tr>
<tr><td>Clean cookstoves[40]

Clean cookstoves can address the high percentage of households relying on fuelwood for cooking, reducing deforestation and biodiversity loss. They also improve indoor air quality, lowering health risks associated with smoke inhalation, particularly for women and children. This measure supports gender equality by reducing the time and effort women need to spend collecting fuelwood, providing more opportunities for education and other activities.</td></tr>
<tr><td>Decentralised renewable energy (DRE)[41]

DRE-based solutions can help supplement household energy needs, reducing dependence on diesel-generated grid electricity and kerosene. DRE solutions have been shown to improve quality of life and support local economic activities. This measure also contributes to reducing GHG emissions and aligns with national priorities for sustainable energy access.</td></tr>
</table>

37 Indian Council of Agricultural Research, 2011. A Modified Alley Cropping System of Agroforestry in South Andaman Islands: An Analysis of Production Potential and Economic Benefit, https://epubs.icar.org.in/index.php/IJAgS/article/view/7394

38 ICAR, Agroforestry Systems and prospects, 2014, https://krishi.icar.gov.in/jspui/bitstream/123456789/34941/1/Book%20Chapter_IFS_Agroforestry%20Systems%20and%20Prospects 2014.pdf

39 ICAR, Agroforestry Systems for Coastal and Island Regions, 2020, https://epubs.icar.org.in/index.php/IJA/article/view/102724

40 Venkataraman, C., Sagar, A. D., Habib, G., Lam, N., and Smith, K. R., 2010. The Indian National Initiative for Advanced Biomass Cookstoves: The Benefits of Clean Combustion, Energy for Sustainable Development, Vol. 14, No. 2, pp. 63-72, https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/1006571

41 Ministry of Power, Power for all Andaman and Nicobar, https://powermin.gov.in/sites/default/files/uploads/joint_initiative_of_govt_of_india_and_andman_nicobar.pdf

Summary of key challenges in Diglipur, Mayabunder and Ferrargunj	The proposed measures identified and their justification
	Mangrove conservation and restoration[42] The conservation and restoration of mangroves is crucial for coastal protection, biodiversity conservation and carbon sequestration. Conserving and restoring mangroves can mitigate the impacts of extreme climate events such as storms and tsunamis, reducing climate vulnerability. Mangroves also support fisheries and other livelihoods, enhancing food security and economic stability. This measure aligns with efforts to combat biodiversity loss and promote sustainable development in coastal areas.
	Coconut husk biochar[43] Coconut husk biochar projects offer socio-economic and environmental benefits, including job creation in rural areas, from the collection and processing of coconut husks to the distribution and sale of biochar. This initiative can transform agricultural waste into a value-added product that generates additional income for farmers and producers. Biochar also serves as an alternative to firewood while sequestering carbon, contributing to climate change mitigation.

42 Kumar, R., Conservation and management of mangroves in India, with special reference to the State of Goa and the Middle Andaman Islands, https://www.fao.org/4/x8080e/x8080e07.htm

43 Ajien, A., Idris, J., Md Sofwan, N., Husen, R., and Seli, H., 2023. Coconut Shell and Husk Biochar: A Review of Production and Activation Technology, Economic, Financial Aspect, and Application, Waste Management & Research, 2023, https://pmc.ncbi.nlm.nih.gov/articles/PMC9925910/

A summary of the key challenges and expected outcomes from implementing these measures is elaborated in the table below.

Table 9: Description of benefits from the proposed measure

Benefits from the measures	Description of the measure-wise benefits				
	Agroforestry	Clean cookstoves	DRE	Mangrove conservation and restoration	Coconut husk biochar
Economic	• Diversified and additional income sources • Improved productivity	• Savings on fuel and health expenses	• Lowered energy costs as dependence on kerosene, diesel and other fuel reduce • Support for local economic development and improvements in quality of life	• Provision of livelihood opportunities such as fishing and tourism	• Potential for job creation from the collection and processing of coconut husks to the distribution and sale of biochar • Value-added products from agricultural waste, potentially generating additional income for farmers and producers
Social	• Improved livelihoods	• Improvements in indoor air quality and health, especially for women and children • Reduced cooking-related time for women	• Energy security by provisioning reliable electricity access and reduced dependence on kerosene/diesel • Potential educational outcomes	• Disaster resilience • Improved livelihoods	• Reduced indoor air pollution compared with traditional biomass fuels

Benefits from the measures	Description of the measure-wise benefits				
	Agroforestry	Clean cookstoves	DRE	Mangrove conservation and restoration	Coconut husk biochar
Biodiversity	• Mitigation of LULC changes and biodiversity loss	• Reduction in reliance on fuelwood, helping to forest preservation		• Carbon sequestration • Habitat protection • Provisioning of ecosystem services	• Enhance soil health • Alternative to fuelwood • Biochar production sequesters carbon, helping mitigate climate change
Environment	• Improvements in soil health • Protection against extreme climate events	• Lowered GHG emissions • Improved air quality	• Reduced GHG emissions • Reduced pollution	• Protection against coastal erosion, rising sea levels and natural disasters	• Biochar production sequesters carbon, helping mitigate climate change

'Empowering local communities and integrating traditional knowledge with modern solutions are critical for achieving climate resilience in fragile ecosystems like the ANI.'

Somya Bhatt, Project Specialist, UNDP India

4. Green finance options

Green finance has emerged as a crucial mechanism for mobilising financial resources for climate action. It encompasses a range of financial instruments and strategies designed to support projects that deliver environmental benefits. These instruments facilitate the transition to a low-carbon economy while attracting investments aligned with the SDGs. Green financing can enhance access to environmentally friendly goods and services, particularly for vulnerable communities, promoting socially equitable growth. Consequently, increased investments in businesses through green finance helps them adopt more sustainable practices, leading to job creation and economic growth as well as reduced carbon emissions.

Projects funded through green finance typically include renewable energy and energy efficiency, pollution prevention and control, biodiversity conservation, circular economy initiatives, and the sustainable use of natural resources and land.[44]

4.1. Assessment of the feasible financing options

Green finance options are diverse, with each offering distinct mechanisms to support environmentally beneficial projects. These instruments, which include green bonds and loans and investment and climate funds, collectively drive the transition towards sustainability. While each option presents unique advantages and challenges, all of them play vital roles in mobilising financial resources to combat climate change and promote sustainable development.

[44] United Nations Environment Programme, n.d. Green Financing. https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-financing

A comprehensive evaluation was conducted to assess the feasibility of available green financing measures. The results are presented below:

Table 10: Evaluation of the green finance options

Parameter	Green finance instrument				
	Impact investment	Green bonds	Green loans	Climate finance	Carbon markets
Ease of Access	Medium accessibility	Medium accessibility	Medium accessibility	Low accessibility	Medium accessibility
Degree of flexibility due to regulations	High flexibility due to minimal regulations	Low flexibility due to extensive regulations	Low flexibility due to extensive regulations	Low flexibility due to extensive regulations	Medium flexibility due to medium regulations
Volatility	High stability	High stability	High stability	High stability	Medium stability
Returns/Value	Potential for medium returns	Potential for medium returns	Potential for medium returns	Potential for medium returns	Potential for high returns
Scalability	Moderate capacity to expand in size and impact	Moderate capacity to expand in size and impact	Moderate capacity to expand in size and impact	Moderate capacity to expand in size and impact	Significant capacity to expand in size and impact

Among the green finance mechanisms analysed, carbon markets stand out as a dynamic and scalable solution, offering direct financial incentives for emission reduction while fostering innovation across industries. Carbon markets mobilise larger volumes of capital compared with the other finance instruments. As the global focus on sustainability intensifies, strategically deploying green finance mechanisms will be critical in achieving long-term environmental and economic goals. The next chapter explores the feasibility of using carbon markets to finance the five measures identified for the three most vulnerable sub-districts in the ANI.

5. Feasibility of carbon markets for pilot interventions

Building on the potential of carbon markets, as discussed in the previous chapter, this chapter examines their practical application in the ANI. It assesses the feasibility of leveraging carbon markets to finance proposed measures in Diglipur, Mayabunder and Ferrargunj. The analysis aims to identify the most suitable measures for carbon market financing and their implementation as pilot projects.

5.1. Assessing the applicability of carbon markets

To determine the suitability of the proposed measures for carbon markets, project activities were evaluated against the eligibility criteria of relevant methodologies, additionality and baseline conditions. The key findings from this assessment are summarised below.

5.1.1. Agroforestry

The proposed project activity was assessed against Verra's VM0047 Afforestation, Reforestation and Revegetation[45] as well as Gold Standard's Methodology for Afforestation/Reforestation (A/R) GHG Emission Reduction and Sequestration,[46] as these methodologies are the most relevant for agroforestry/afforestation, reforestation and revegetation (ARR) activities. The assessment indicates that most applicability conditions are expected to be met or can be ensured during the project design stage. However, as Diglipur, Mayabunder and Ferrargunj are coastal regions, project activities must carefully account for tidal wetlands (including mangroves) and organic soils in wetlands. If these conditions apply, the activities may not be eligible under these methodologies.

45 Verra, 2023, VM0047: Afforestation, Reforestation and Revegetation, https://verra.org/wpcontent/uploads/2023/09/VM0047_ARR_v1.0-1.pdf

46 Gold Standard for the Global Goals, 2024, Methodology for Afforestation/Reforestation (A/R) GHGs Emission Reduction & Sequestration, https://globalgoals.goldstandard.org/403-luf-ar-methodology-ghgs-emission-reduction-and-sequestration-methodology/

5.1.2. Clean cookstoves

The proposed project activity was assessed against Verra's VM0050 Energy Efficiency and Fuel-Switch Measures in Cookstoves,[47] as well as Gold Standard's Methodology on Reduced Emissions from Cooking and Heating: Technologies and Practices to Displace Decentralized Thermal Energy Consumption (TPDDTEC)[48] as these methodologies are the most relevant for activities involving the distribution of improved cookstoves in communities. The assessment indicates that applicability conditions are expected to be fulfilled or can be ensured during project design. No specific barriers have been identified for the three shortlisted sites at this stage.

5.1.3. DRE

The proposed project activity was assessed against the Verra-approved CDM AMS-I.L. Electrification of rural communities using renewable energy.[49] This small-scale methodology is well-suited to activities that may involve the implementation of renewable energy projects such as rooftop solar photovoltaic systems in rural communities to reduce fossil fuel use. An assessment of the proposed measure against this methodology indicates that the applicability conditions are expected to be fulfilled or can be ensured during the project design stage.

However, the grid-connected status of households in the baseline scenario must be carefully considered, as this methodology applies to cases where consumers were previously unconnected to the national or regional grids and are now supplied with electricity from the project activity. It also covers situations where a fraction of consumers previously powered by a fossil fuel mini-grid are now supplied with electricity from the project.

5.1.4. Mangrove restoration

The proposed project activity was assessed against Verra's VM0033 Methodology for Tidal Wetland and Seagrass Restoration as well as Gold Standard's Methodology on Sustainable Management of Mangroves as these methodologies[50] are typically used for mangrove restoration projects. The former replaced the CDM methodologies AR-AM0014 (Afforestation and reforestation of degraded mangrove habitats) and AR-AMS0003 (Afforestation and reforestation project activities implemented on wetlands) in 2022. An assessment against these methodologies indicated that that the applicability conditions are expected to be fulfilled or can be ensured during the project design stage. No specific barriers are expected for the three shortlisted sites.

5.1.5. Coconut husk biochar

The proposed project activity was assessed against Verra's VM0044 Methodology for Biochar Utilization in Soil and Non-Soil Applications[51] as well as Puro Earth's Biochar Methodology[52] as these are typically used for biochar projects. An assessment against the aforementioned methodologies indicated that that the applicability conditions are expected to be fulfilled or can be ensured during the project design stage.

---

47 Verra, 2024, VM0050: Energy Efficiency and Fuel-Switch Measures in Cookstoves, https://verra.org/wp-content/uploads/2024/10/VM0050-EE-and-Fuel-Switch-Measures-in-Cookstoves-v1.0.pdf

48 Gold Standard for the Global Goals, 2021, Reduced Emissions from Cooking and Heating: Technologies and Practices to Displace Decentralized Thermal Energy Consumption (TPDDTEC), https://globalgoals.goldstandard.org/407-ee-ics-technologies-and-practices-to-displace-decentrilized-thermal-energy-tpddtec-consumption/

49 Gold Standard for the Global Goals, 2021, Reduced Emissions from Cooking and Heating: Technologies and Practices to Displace Decentralized Thermal Energy Consumption (TP DDTEC), https://globalgoals.goldstandard.org/407-ee-ics-technologies-and-practices-to-displace-decentrilized-thermal-energy-tpddtec-consumption/

50 Gold Standard for the Global Goals, 2024, Sustainable Management of Mangroves, https://globalgoals.goldstandard.org/standards/443_V1.0_BCFW_Sustainable-Management-of-Mangroves.pdf

51 Verra, 2023, VM0044: Methodology for Biochar Utilization in Soil and Non-Soil Applications, https://verra.org/wp-content/uploads/2023/07/VM0044-Methodology-for-Biochar-Utilization-in-Soil-and-Non-Soil-Applications-v1.1.pdf

52 Puro Earth, 2022, Biochar Methodology V3, https://7518557.fs1.hubspotusercontent-na1.net/hubfs/7518557/Supplier%20Documents/Puro.earth%20Biochar%20Methodology.pdf

However, local use of biochar for agricultural productivity may be limited, as croplands and plantations cover only 3% of the ANI's total area. Additionally, the transportation of biochar over long distances may not comply with the applicability conditions of the two methodologies.

5.2. Estimated carbon credits for the proposed solutions in the pilot site(s)

This section presents the estimated ERs and indicative carbon credit revenue expected from each proposed measure. Where sub-district-level data are available, ERs and revenue calculations have been conducted for the shortlisted sites.

5.2.1. Agroforestry

An assessment of Indian agroforestry/ARR projects registered on Verra was conducted to provide an indicative range of ERs per hectare per year. Table 11 presents the list of projects along with their associated ERs:

Table 11: VCS-registered ARR projects with estimated ERs/ha/annum[53]

Country	Project ID	Estimated annual ERs (tCO2e)	Project area (ha)	Estimated ERs/ ha/annum
India	2552	22,051	4,255	5.2
	2555	24,074	4,073	5.9
	2404	146,998	14,969	9.8
	994	11,047	672	16.4
	689	5,007	282	17.8
	2833	10,673	502	21.3
	3892	222,923	8,860	25.2

This analysis yielded an average value of **16 ERs per ha per annum**. Given that Verified Carbon Standard (VCS) ARR projects are priced at approximately **USD 10.85 per credit**,[54] this translates to an indicative revenue of **USD 173 per ha per annum.**

The specific area (in ha) for the project activity at the three shortlisted sites is yet to be determined using primary data on land and satellite imagery. Therefore, the total expected credits per site have not been calculated at this stage.

53 Verra, 2024, VCS Registry, https://registry.verra.org/app/search/VCS
54 Based on consultations with stakeholders/advisory committee

5.2.2. Clean cookstoves

An assessment of clean cookstove projects listed on Verra was conducted to estimate an indicative range of ERs per ICS per year. The table below presents a list of VCS-registered clean cookstove projects along with their estimated ERs:

Table 12: VCS-registered clean cookstove projects with estimated ERs/IC/annum[55]

Country	Project ID	Estimated annual ERs (tCO2e)	Proposed number of ICS	Estimated ERs/IC/annum
India	2942	1,350,340	1,000,000	1.4
	3109	13,806	5,839	2.4
	2908	44,163	18,299	2.4
	4980	53,191	20,000	2.7
	4457	1,310,160	400,000	3.3
	3007	333,938	75,000	4.5
	2922	449,956	100,000	4.5
	2944	714,973	151,154	4.7
	4250	94,759	20,000	4.7

This analysis yielded an average value of **3.6 ERs per ICS per annum**. Given that cookstove projects are priced at approximately **USD 3.45 per credit,[56]** this translates to an indicative revenue of **USD 12 per ICS per annum**.

Based on 2011 Census data,[57] firewood remains a significant source of fuel for cooking across Diglipur, Mayabunder and Ferrargunj. Assuming the project activity involves deploying ICS across 5% of the households dependent on firewood, Table 13 presents the expected ERs per annum and indicative revenue may be expected from the shortlisted sites.

55 Verra, 2024, VCS Registry, https://registry.verra.org/app/search/VCS
56 Based on consultations with stakeholders/advisory committee
57 Office of the Registrar General & Census Commissioner, India, n.d., Census Tables: HH-10 Households (excluding institutional households) by availability of separate kitchen and type of fuel used for cooking, 2011 https://censusindia.gov.in/census.website/data/census-tables

Table 13: Indicative carbon credit revenue (USD/annum) through implementing clean cookstoves[58]

Site	Use of firewood as the cooking fuel		Target ICS deployment (~5% of total HHs)	Estimated ERs/annum	Indicative revenue (USD/annum)
	% of HHs	Number of HHs			
Diglipur	70%	7,520	380	1,368	4,720
Mayabunder	60%	3,817	200	720	2,484
Ferrargunj	36%	4,550	230	828	2,857

5.2.3. DRE

Based on the 2011 Census, grid-connected electricity and kerosene are significant energy sources for lighting needs across the three shortlisted sites (Table 14). While these households may be connected to the grid, continuity of electricity access remains a likely issue. Additionally, most grid-connected power generation in these areas relies on diesel, which is not a sustainable source of electricity. Therefore, DRE presents a viable alternative, offering a more reliable and sustainable power source.

Table 14: Percentage and number of HHs at the shortlisted sites by main source of lighting[59]

Site	Electricity		Kerosene	
	% of HH	Number of HH	% of HH	Number of HH
Diglipur	60%	6,426	38%	4,121
Mayabunder	71%	4,492	28%	1,761
Ferrargunj	85%	10,783	15%	1,868

Due to the lack of baseline data on fuel consumption, the below ER calculations were performed after replacing 1,000 L of diesel and kerosene with DRE solutions.

[58] Office of the Registrar General & Census Commissioner, India, n.d., Census Tables: HH-10 Households (excluding institutional households) by availability of separate kitchen and type of fuel used for cooking, 2011 https://censusindia.gov.in/census.website/data/census-tables

[59] Office of the Registrar General & Census Commissioner, India, n.d., Census Tables: HH-07: Households (excluding institutional households) by main source of lighting, 2011. https://censusindia.gov.in/census.website/data/census-tables

Table 15: Indicative carbon credits for DRE

Fuel type	Volume replaced by DRE (L)	Emission factor (kg CO_2/L)	Emissions avoided (kg CO_2)	Carbon credits (mtCO_2)
Diesel	1,000	2.68 [60]	2,680	2.68
Kerosene	1,000	2.50[61]	2,500	2.50

5.2.4. Mangrove restoration

Mangroves are widely known for their high carbon stocks per hectare, with these coastal ecosystems sequestering carbon at a rate 10 times greater than mature tropical forests.[62] Mangroves globally store around 8.5 Gt of carbon, highlighting their significance as key carbon sinks or potential sources of emissions if not properly conserved.[63]

An assessment of mangrove restoration projects listed on Verra was conducted to estimate ERs per hectare per year. Given the limited number of projects registered in India, the scope was expanded to include global projects. Table 16 presents the list of projects along with their estimated ERs.

Table 16: VCS-registered mangrove restoration projects with estimated ERs/ha/annum

Project ID	Country	Estimated annual ERs (tCO2e)	Project area (ha)	Estimated ERs/ha/annum
1318	Senegal	48,598	10,415	4.7
2343	China	2,554	380	6.7
1463	India	51,249	4,403	11.6
1493	Indonesia	124,706	5,000	24.9
3155	Nigeria	23,851	600	39.8
2088	Myanmar	353,871	5,174	68.4
2792	Myanmar	70,285	1,003	70.1
1764	Myanmar	184,006	2,146	85.7

60 Ministry of New Zealand, 2024. Measuring Emissions: A Guide for Organizations

61 United for Efficiency Initiatives, 2017. Establishing the Foundations of a Partnership to Accelerate the Global Market Transformation for Efficient Appliances and Equipment. Reducing Black Carbon Emissions by Transitioning to Clean and Sustainable Lightning (Nigeria). https://www.ccacoalition.org/sites/default/files/resources//2017_Country%2C%20Risk%20and%20Regulatory%20Framework%20Assesment%20Summary.pdf

62 National Ocean Service, National Oceanic and Atmospheric Administration. n.d. What is Blue Carbon. https://oceanservice.noaa.gov/facts/bluecarbon.html

63 World Bank, 2024. The Changing Wealth of Nations - Estimating Global Carbon Storage of Mangrove Ecosystems. Washington, D.C.: World Bank Group. https://thedocs.worldbank.org/en/doc/6ddb5b7d3adb1684b84a388a2784bcd9-0320052024/original/WorldBank-CWON-MangroveCarbonStocks-14Nov2024-Final.pdf

This yielded an average value of **39 ERs per ha per annum**. Given that mangrove restoration projects are priced at an average of **USD 24 per credit**,[64] this translates to an indicative revenue of **USD 936 per ha per annum.** Notably, the specific project area (in ha) at the three shortlisted sites is currently unavailable through secondary research; therefore, the total expected credits per site have not been calculated. The variation in estimates between the projects may be due to differences in species and geographic conditions. Based on the above-registered projects in India, mangrove restoration activities may generate an indicative revenue of USD 278 per ha per annum.

5.2.5. Coconut husk biochar

The use of biochar can generate carbon credits in the range of **1.5–3 tCO2e per tonne** of biochar depending on feedstock type.[65] Other influencing factors include biochar composition (carbon percentage, bulk density and dry weight) and fossil fuel consumption during biomass processing or biochar production.[66] Based on this range, indicative revenues fall between **USD 245–495 per tonne**, according to Puro Earth's Biochar Price Index, which estimated a result of EUR 158 per tonne as of November 2024 (approximately USD 165).[67]

64 Based on consultations with stakeholders/advisory committee
65 Based on consultations with stakeholders/advisory committee
66 Based on consultations with stakeholders/advisory committee
67 Puro Earth, n.d. CORC Carbon Removal Price Indexes. https://puro.earth/corc-carbon-removal-indexes

5.3. Final measures for implementation as a pilot

The assessment of the proposed activities, namely, agroforestry, clean cookstoves, DRE, mangrove restoration and coconut husk biochar, against relevant methodologies, indicated that applicability conditions are expected to be fulfilled or can be ensured during the project design stage. **Therefore, from a methodological point of view, no major feasibility challenges are anticipated across these five measures.**

An indicative carbon credit assessment was conducted for each proposed measure; however, site-specific data were only available for the clean cookstove project. As part of the pilot projects, the collection of primary data is necessary to accurately determine the carbon market potential of the proposed activities.

As summarised in Table 17, **mangrove restoration, clean cookstoves and DRE emerge as particularly promising options among the five proposed measures, considering credit price and SDG alignment.** Mangroves in India have declined by almost 15% between 1989 and 2021.[68] Carbon financing can play a key role in reversing this trend by providing funding and incentives for large-scale mangrove restoration projects, supporting carbon sequestration, coastal resilience and biodiversity. Additionally, the ANI's dependence on the mainland for energy security, along with its reliance on diesel-based power, highlights the need for sustainable energy solutions. DRE systems could reduce this dependence, providing more stable, sustainable and secure energy for the shortlisted sites. Finally, the reliance on firewood for cooking means that clean cookstoves can be a viable solution in the shortlisted sites, and their inclusion in India's Article 6.2 whitelist of 14 technologies offers an additional advantage in attracting international finance to enhance climate mitigation efforts in India.

Table 17: Carbon market feasibility: Summary of the findings for the proposed measures

Proposed measure	Methodology alignment	Estimated ERs	Indicative price/credit	Additionality (SDG alignment)	Additional observations
Agroforestry	• Generally aligned with applicability conditions. • However, the presence of tidal wetland and organic soils must be checked in the project area.	16 tCO_2e/ha/annum	USD 10.85	• **SDG 1:** No poverty: By enhancing agricultural productivity and income through integrated tree and crop farming • **SDG 2:** Zero hunger: By improving food security and nutrition through diversified farming systems	**Pros:** • Tested methodology • High credit-generation capacity

68 Forest Survey of India, State of Forest Report - Chapter 3: Mangrove Cover, 2021, https://fsi.nic.in/isfr-2021/chapter-3.pdf

Proposed measure	Methodology alignment	Estimated ERs	Indicative price/credit	Additionality (SDG alignment)	Additional observations
				• **SDG 13:** Climate action: By sequestering carbon and mitigating climate change • **SDG 15:** Life on land: By promoting sustainable use of terrestrial ecosystems and preventing deforestation	**Cons:** • Agroforestry may not be applicable in the ANI due to the predominance of monocropping compared with mixed farming practices.[69]
Clean cookstoves	• Generally aligned with applicability conditions.	3.6 tCO_2e/ICS/annum • Estimated ERs/annum for the project sites: Diglipur: 1,368 Mayabunder: 720 Ferrargunj: 828	USD 3.45	• **SDG 3:** Good health and wellbeing: By reducing indoor air pollution and associated health risks • **SDG 7:** Affordable and clean energy: By providing access to clean and efficient energy for cooking • **SDG 13:** Climate action: By reducing emissions from traditional cooking methods • **SDG 5:** Gender equality: By decreasing the time women and girls spend collecting firewood, empowering them with more time for education and other activities	**Pros:** • Tested methodology • Inclusion in India's A6.2 whitelist **Cons:** • Elements like baselining and additionality would have to be carefully considered.

69 Ministry of Statistics and Programme Implementation, n.d. Methods of Estimating Area under Mixed Crops

Proposed measure	Methodology alignment	Estimated ERs	Indicative price/credit	Additionality (SDG alignment)	Additional observations
DRE	• Generally aligned with applicability conditions • However, the grid-connectedness of the HHs must be confirmed to check if the baseline scenario is suitable.	• Diesel: 2.68 tCO_2 per 1,000 L • Kerosene: 2.50 tCO_2 per 1,000 L	Prices for RE projects range from USD 1.8/credit to 2.8/credit.[70] However, community-based RE projects may fetch higher prices, averaging around USD 5/credit.	• **SDG 7:** Affordable and clean energy: By increasing access to renewable and sustainable energy sources • **SDG 1:** No poverty: By reducing energy costs and fostering economic development • **SDG 13:** Climate action: By reducing reliance on fossil fuels and lowering GHG emissions • **SDG 9:** Industry, Innovation and Infrastructure: By promoting resilient infrastructure and fostering innovation	**Pros:** High potential to address the ANI's fossil fuel dependency and energy security issues **Cons:** The level of grid-connectedness of HHs in the shortlisted sites must be confirmed before determining alignment with the methodology.

70 Based on consultations with stakeholders and advisory committee

Proposed measure	Methodology alignment	Estimated ERs	Indicative price/credit	Additionality (SDG alignment)	Additional observations
Mangrove restoration	• Generally aligned with applicability conditions	39 tCO2e/ha/annum	USD 24	• **SDG 13:** Climate action: By sequestering carbon and protecting coastal areas from storm surges • **SDG 14:** Life below water: By preserving marine ecosystems and biodiversity • **SDG 15:** Life on land: By promoting the conservation and restoration of terrestrial ecosystems • **SDG 6:** Clean water and sanitation: By improving water quality and preventing soil erosion	**Pros:** • Potential to fetch premium prices in the VCM • Strong linkage with economic, social and biodiversity-related benefits **Cons:** • Potential challenges with community engagement due to trade-offs with higher market-value activities such as aquaculture
Coconut husk biochar	• Generally aligned with applicability conditions	1.5–3 tCO_2e per tonne	USD 245–495 per tonne	• **SDG 13:** Climate action: By sequestering carbon and enhancing soil resilience to climate impacts • **SDG 12:** Responsible consumption and production: By utilising agricultural waste efficiently, reducing waste and promoting sustainable practices	**Pros:** • Coconuts are the predominant plantation crops in the ANI, with coconut husks having high potential for use as biochar feedstock.[71] • Potential to fetch premium prices in the VCM

[71] Coconut Development Board, 2022. ICJ Report on Coconut-Based Products. https://coconutboard.gov.in/docs/icj/icj-2022-01.pdf

Proposed measure	Methodology alignment	Estimated ERs	Indicative price/credit	Additionality (SDG alignment)	Additional observations
				• **SDG 15:** Life on land: By enhancing soil health and promoting sustainable land use, contributing to ecosystem conservation and restoration	• Strong linkages with economic, social and environmental benefits **Cons:** • The local use of biochar to boost agricultural productivity may be restricted because croplands and plantations occupy approximately 3% of the ANI's total area. • There is a risk that the transportation of biochar over long distances may not comply with the applicability conditions of Verra and Puro Earth. • Some businesses in the ANI currently purchase and supply coconut husk to the coir industry. Consequently, project developers may need to offer farmers higher prices to compensate for their income from selling the coconut husk to these enterprises to allocate the husk for biochar production instead.

6. The way forward

This study presents a climate-resilient development model for the ANI, integrating adaptation and mitigation actions. The broad aim is to foster socio-economic development while addressing the pressing challenges posed by climate change. Based on the regions that faced the most significant socio-economic, climatic and biodiversity-related challenges, we identified the most vulnerable locations in the ANI and finalised three measures – **mangrove restoration, clean cookstoves and DRE** – for pilot project development. Finally, we narrowed down on carbon markets as a key financing mechanism for implementing the proposed measures. Among these solutions, mangrove restoration stands out due to its high carbon sequestration potential and additional co-benefits. As one of the three main blue carbon ecosystems in the ANI, mangroves offer largely unexplored opportunities in the region. In this regard, carbon markets can serve as a key financing tool, leveraging the high sequestration potential of mangroves while addressing the high costs associated with such a restoration project.

Our interactions with experts led to the emergence of several key points, clarifying the criticality of financing measures for implementing carbon market projects. Indian corporates have shown interest in investing in carbon market-related projects, particularly in mangrove conservation and restoration due to their niche credit nature. However, concerns about credit quality have made them hesitant to invest heavily. While CSR funding is a potential avenue for funding, it is often limited and insufficient for high-cost initiatives such as mangrove restoration and agroforestry. Additionally, companies in India prefer directing CSR funds towards geographies where they have an operational presence or footprint, unlike international companies, which are investing significantly in carbon- and nature-based solutions.

To attract investors, it is essential to develop a strong business case that clearly defines the project scope, funding schemes and revenue projections to provide a clear understanding of the project and the timeline for returns on investment. Baseline condition assessments are crucial for determining the projects' economic viability. Clear implementation structures, such as involving non-governmental and farmer producer organisations in addressing on-ground challenges, along with digital monitoring systems to maintain carbon credit quality and value, are necessary. Large-scale implementation is critical for maximising carbon credits and ensuring the projects' viability. Challenges such as land ownership, particularly in mangrove restoration and agroforestry, require site-based, micro-level assessments as a key next step.

In the next phase, this study's findings will guide the implementation of pilot initiatives in vulnerable locations in the ANI and the development of a carbon market project covering mitigation and adaptation. It will also explore private and public funding sources. It will involve two strategic components: Implementing measures through pilot projects and developing the carbon market project. Key activities in the implementation phase of the pilot projects will include identifying implementation partners, selecting sites, engaging with communities and other stakeholders, conducting site-specific assessments and exploring the feasibility of technical and financial assistance from development agencies. Likewise, for the carbon market project, the next steps will include developing a comprehensive PDD, securing third-party validation of the PDD to ensure compliance with carbon standards, registering the project and issuing carbon credits.

7. Annexures

Annexure A: Scale used for evaluating green financing options

Parameter and description	Scoring and interpretation		
	Low	**Medium**	**High**
Ease of access How easily investors and stakeholders can access each type of green finance instrument. It considers factors such as market availability, entry barriers and the complexity of the investment process.	Limited accessibility with significant entry barriers and/or specialised expertise needed.	Accessible with some entry barriers or specialised knowledge required.	Widely accessible with low entry barriers and established market presence.
Degree of flexibility due to regulations The extent to which entities face policies and institutional frameworks regulating each type of green finance instrument. This parameter considers level of oversight and compliance requirements.	Low flexibility due to extensive regulations with detailed compliance obligations and stringent regulatory requirements.	Medium flexibility due to moderate regulations allowing entities some freedom to operate while adhering to necessary regulatory requirements.	High flexibility due to minimal regulation, allowing entities to enjoy significant degree of freedom in their operations and decision-making processes.
Volatility The stability and predictability of returns associated with each type of green finance instrument. This parameter considers potential price fluctuations and market instability.	Low stability with significant potential for price fluctuations and market volatility.	Moderate stability with some potential for price fluctuations and market variability.	High stability with predictable returns and minimal price fluctuations.

Parameter and description	Scoring and interpretation		
	Low	Medium	High
Returns/value The financial returns and overall value generated by each type of green finance instrument. This parameter considers monetary returns and nonfinancial benefits such as social and environmental impact.	Limited potential for financial returns and/or minimal social or environmental impact.	Potential for moderate financial returns with notable social or environmental impact.	Potential for significant financial returns along with substantial social or environmental impact.
Scalability The financial instrument's ability to grow and expand in scope, size and impact without compromising on performance or efficiency.	Investments are limited in their capacity to grow in size and impact, and expansion may lead to decreased performance or efficiency.	Investments can moderately expand in size and impact but may encounter limitations or diminishing returns.	Investments can significantly increase in size and impact, accommodating large volumes or an extensive geographic spread.

Annexure B: Indicative costs associated with carbon markets

Verra

Table B1: Costs applicable during the VCS project cycle

Fee	Rate
Validation fee (one-time fee levied by validation and verification bodies or designated operational entity)	USD 17,000–40,000 (depending on project type and size)
Verification fee (recurring cost during each verification)	USD 14,000–30,000 (depending on project type)
Consultancy fee (for PDD preparation, other documentation and advisory services during the project cycle)	USD 11,000–35,000 (depending on services provided)

Table B2: Fees payable as per VCS schedule

Fee	Rate
Account opening fee	USD 500 for each account opened with the Verra Registry, payable in full at account approval
Account maintenance fee	USD 500 per year for each account, payable in full at account approval and subsequently in January of each year
Pipeline listing request fee	USD 1,000 for each pipeline listing request, payable at the time of the request
Project registration request review fee	USD 2,500 for each project registration request, payable at the time of the request

Fee	Rate
VCU issuance levy, including conversion of GHG credits from approved GHG programmes	USD 0.20 per VCU, payable at the time of the issuance request.

Gold Standard

Table B3: Fees payable as per the Gold Standard schedule

Certification stage	Preliminary review fee	Project design review	Performance review	Issuance (first year, i.e. 365 days)		Subsequent issuance (second year onwards)		Crediting period renewal	Issuance (first year after CP renewal, i.e. 365 days)		Subsequent issuance (sixth year onwards)	
				CASH	SOP*	CASH	SOP		CASH	SOP*	CASH	SOP*
GS voluntary emission reduction	Charged by third-party certification body (currently, SustainCERT)	USD 0.15 per credit (ex-ante estimation for the first year) minus USD 900 credited from the preliminary review fee	Charged by third-party certification body (currently, SustainCERT)	USD 0.15 per credit (ex-post requested) minus USD 1,000 credited from the performance review fee	USD 0.30 per credit (ex-post requested) minus USD 1,000 credited from the performance review fee	USD 0.10 per credit + 2% credits (ex-post requested) minus USD 1,000 credited from the performance review fee		USD 0.15 per credit (ex-ante estimation for the first year of the subsequent crediting period)	USD 0.15 per credit (ex-post requested) minus USD 1,000 credited from the performance review fee	USD 0.30 per credit (ex-post requested) minus USD 1,000 credited from the performance review fee	USD 0.10 per credit + 2% credits (ex-post requested) minus USD 1,000 credited from the performance review fee	
Land use and forestry carbon				USD 0.30 per credit	USD 0.30 per credit	N/A		Charged by third-party certification body	USD 0.30 per credit	USD 0.30 per credit	N/A	

*SOP- Share of Proceed

Acknowledgements

This white paper was jointly developed by PwC India and the PwC India Foundation, drawing upon inputs from a diverse range of stakeholders including businesses, government entities, multilateral agencies and INGOs/NGOs. We thank our stakeholders for participating in the consultations and sharing their valuable insights.

Advisory committee

- Ankit Todi, CSO, Mahindra Group
- Dr Nilanjan Ghosh, Vice President – Development Studies and Senior Director- Kolkata Centre, ORF
- Sandeep Roy Choudhury, Director, Value Network Ventures Advisory Services Pvt. Ltd.
- Somya Bhatt, Project Specialist, UNDP India

About PwC

At PwC, our purpose is to build trust in society and solve important problems. We're a network of firms in 151 countries with over 360,000 people who are committed to delivering quality in assurance, advisory and tax services. Find out more and tell us what matters to you by visiting us at www.pwc.com.

PwC refers to the PwC network and/or one or more of its member firms, each of which is a separate legal entity. Please see www.pwc.com/structure for further details.

Contributors

PwC India

Madhura Mitra, Managing Director,
One Consulting – Climate and Energy

Syed A A Farhan, Associate Director,
One Consulting – Climate and Energy

Dr Anjan Katna, Associate Director,
One Consulting – Climate and Energy

Dr Shouvik Das, Manager,
One Consulting – Climate and Energy

Kaveri Gogoi, Senior Associate,
One Consulting – Climate and Energy

Ritika Sowda, Associate,
One Consulting – Climate and Energy

Shiv Bhatia, Specialist,
One Consulting – Climate and Energy

PwC India Foundation

Jaivir Singh, Vice Chairman,
PwC India Foundation, and Leader of the Global Office for Humanitarian Affairs

Punyasil Yonzon, Senior Associate,
PwC India Foundation

Abhiir Bhalla, Specialist,
PwC India Foundation

Editorial support

Rashi Gupta

Design support

G Gnanaraj

Download the report using the QR code below:

Data Classification: DC0 (Public)

GG/March 2025 – M&C 44207