BIODIVERSITY & CLIMATE CHANGE

Ecosystem-based Adaptation for Enhancing Climate Resilience of Coastal Vulnerable Communities In India

Research Report

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PREFACE

Climate Change is a global hazard to the environment and communities. It has been observed to have an inordinate impact on marine and coastal ecosystems. Current climate solutions in coastal zones are primarily focused on technical investigations. The opinions of fishing communities have garnered little attention, further marginalizing coastal populations who rely directly on coastal resources for a living, with incomes further declining.

The Aga Khan Agency for Habitat (AKAH) India conducted a study to better understand the challenges associated with changes in lives and livelihoods of the coastal communities. The report emphasizes the perspectives of fishing communities and farmers on the effects of climate variability, as well as the importance of developing and implementing nature-based adaptation and mitigation solutions through consultative processes to address their vulnerability. The study's primary purpose is to use an ecosystem-centred and community-based strategy to improve the resilience of the most vulnerable people's lives and livelihoods, particularly women, in India's coastal areas to climate change and extreme events.

The study takes an innovative approach by emphasizing the interconnections between biodiversity and the environment, and it offers a comprehensive understanding of solutions to improve Porbandar, Gujarat's resilience to climate change.

I am optimistic that the research findings will be valuable to policymakers, practitioners, and communities working to build a more sustainable and resilient future for cities like Porbandar and beyond.

Prerana Langra
Chief Executive Officer

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Aga Khan Agency for Habitat
India

ACKNOWLEDGEMENT

The completion of this report would not have been possible without the cooperation and support of the Climate Change Department and the Forest Department, Government of Gujarat. We would also like to thank the Panchayati Raj Institutions in Porbandar for their guidance in this research. Special appreciation to the local communities and stakeholders in Porbandar who shared their knowledge and experiences, making this research possible. Their unrivalled contributions, as well as their participation, were critical to the specificity and relevance of this research.

We would like to extend our thanks to the research team. Their expertise in climate change, disaster management and environmental science merits special mention for their relentless efforts and dedication to this project. We are happy to be a part of this important initiative and are committed to continuing our efforts towards a more sustainable future at the Aga Khan Agency for Habitat India.

Aga Khan Agency for Habitat India

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~ INTRODUCTION ~

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INTRODUCTION

Climate change has been attracting growing attention for potential adverse impacts upon the environment and human populations in the immediate and long term. Marine and coastal ecosystems have been observed to be extremely vulnerable to climate-change processes. For instance, ocean warming and sea-level rise have a direct impact on the lives and livelihoods of local communities that are dependent upon fishing and agriculture. A major limitation in the current initiatives related to climate change and its impacts on fisheries and fishing communities is that it is based mainly on technical studies. The perceptions and suggestions of fishing communities themselves have received scant attention. A similar situation is prevalent with agriculture and plantation-based households in the coastal areas being affected severely by sudden-onset and slow-onset disasters induced by climate change.

The interventions taken and planned under the national and state action plans on climate change are yet to focus on the specific issued faced by the coastal communities. The coastal communities are increasingly finding themselves further marginalized and more vulnerable to the impacts of, and the responses to, climate change.

This study was designed to understand the perceptions of such coastal communities of Porbandar district in Gujarat as well as to identify any indigenous or possible resilience measures especially those utilizing biodiversity.

Porbandar is a coastal district with many communities who are directly dependent upon the coastal resources for their livelihood. The welfare of such communities is often sidelined by the industrial development of certain part. While there are indicators showing an overall development in the district, such communities fail to receive the benefits of developmental activities.

Being dependent upon coastal resources, the households of such communities have seen incomes from fishing fluctuating widely. Although the modernization process contributed to improving small-scale fishers' access to technologies, resources, markets, and incomes in the beginning, the inherent contradictions in the process led not only to a failure to bring the small-scale fishers out of their poverty, but actually made them more vulnerable to emerging threats such as climate change.

This report is the outcome of a study undertaken by Aga Khan Agency for Habitat (AKAH) India, which aimed to

- highlight the perspectives of fishing communities on the implications of climate variability and change on their lives and livelihoods, and
- highlight the importance of developing and implementing nature-based solutions for adaptation and mitigation through consultative processes to address their vulnerability.

Through this research, AKAH India team unearths the most urgent issues and the most appropriate solutions and supports the local and state governments to make suitable plans. We

believe a multi-stakeholder approach and collaborative consultative processes involving the affected community can lead to finding and implementing the most appropriate solutions.

Aims and Objectives

The overarching goal of the study was to develop a pathway to enhance the resilience of the lives and livelihoods of the most vulnerable populations, particularly women, in the coastal areas of India to climate change and extreme events, using an ecosystem-centred and community-based approach.

To come up with a holistic approach for resilience building in the coastal communities of Porbandar, the following parameters were assessed.

- Understand the current socio-economic condition of the coastal communities with a special focus on women.
- Conduct a perception analysis on the impact of climate change on the daily activities of the coastal communities and understand climate change from the vulnerable community's point of view.
- Identify the indicators of climate change impact on the source of livelihood and overall well-being of the coastal communities.
- Develop an inclusive plan of action for resilience building, which is based on nature-based solutions.

~ PROJECT AREA ~

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PROJECT AREA

The study was conducted for the coastal communities in the selected villages of Porbandar district in Gujarat. Porbandar district, in Gujarat state, has a geographical area of about 2316 sq. km (Census 2011). It lies between Latitude 20°45" and 22°05" North and Longitude 69°20" and 70°10" east. It is bounded by Jamnagar district in the north, Junagadh district in the east and south-east, Arabian Sea in the south. Porbandar city is the birthplace of Mahatma Gandhi, the father of the nation.

Figure 1. Project area: Porbandar district

Socio-economic Status of Porbandar

The economy of Porbandar is largely dependent on the fishing industry. As the name suggests, it is a port and its proximity with the Arabian Sea is advantageous. Porbandar carries on its trade and commerce through sea and road routes.

Apart from the fishing industry in Porbandar, there exists other industries like the cotton garment manufacturing industry, mineral producing industry, and the fertilizers and petrochemical industries. The Gujarat Industrial Development Corporation has recognized Porbandar as one of the mega industrial areas due to the following reasons.

- Porbandar is a base for cement, chemicals, metallurgical, ports and ship-building, and fishing industries.
- Presence of large reserves of important minerals such as limestone, chalk, and bauxite in the district has given rise to several mineral-based and cement industries. Companies such as Saurashtra Cement Ltd and Birla VXL Ltd have set up their manufacturing facilities in Porbandar.

- Presence of a port centre has offered a cutting edge to the district to catalyze the growth of industries, making it a terminal for export and import of goods.
- Some of the major activities at this port include import of fertilizers, coal, LPG, export of oil cakes, cement, chemicals, and raw cotton.
- Over 100 small-scale industry (SSI) units are currently functioning in Porbandar with an investment to the tune of INR 10 crore.
- As far as agriculture is concerned, major crops produced in Porbandar are groundnut, bajra, wheat, jowar, gram, cotton, castor, onion, brinjal, and tomato.
- Coconut yield is also a good source of income in the coastal region of Porbandar. It was affected during the pandemic as a new pest had ruined the crop.
- The district grows onion, accounting for about 70,000 Metric Tonnes (MT) (average of last three years – 2020-2019, 2019-2018, and 2018-2017)[1].

Even though Porbandar has a diverse portfolio of industries, fisheries stand as a major source of livelihood for many communities that are living near the coastal region of Porbandar. Porbandar has an all-weather port and boasts of a magnificent 106 km coastline on the Arabian Sea. The port makes it suitable for fishing and accounts for 8.53% of Gujarat's total fish catch. Marine fishing is the primary source of fish. The 'Kharva' community of Porbandar is mostly engaged in sea-farming.

The variety of catch in Porbandar (in local language) are Vichuda, Halwa, Boomla, Dara, Dhol, Palla, Tanti, Madra, Khaga, Gandiya, Vam, Sag, Surmai, Chappari, Ravas, Baga, Dai, Perch, Dhoma, Shrimp-Prawns, Crab, Squid, Katal, Tuna, Mackerel, Ranidish, and Sol Fish.

Human-induced climate change has adversely impacted the fishing communities in many ways, the prominent being the ever-fluctuating quality and quantity of their catchment. Adding to the issues, the recent pandemic led to a total shutdown of the fishery industry along with most fishery dependent allied industries for some time. Further, closure of restaurants and lack of transportation facilities resulted in a decline of domestic buyers. Overall, a sharp decline in demand resulted in price drop. As fish is a perishable item, such lockdowns and temporary suspension of the supply and demand chains affect the fishing community to a large extent.

Climate-change-related sea level rise (SLR) increases the vulnerability of coastal ecosystem by posing threat to many coastal cities, urban centres and coastal population in developed as well as in developing countries. SLR has a number of biophysical and socio-economic impacts. These include loss of property and coastal habitats, damages to infrastructure, increased flood risks and potential loss of life, loss of tourism recreation and transportation functions, impacts on agriculture and aquaculture through decline in soil and water quality and inundation (Nicholls and Lowe, 2004). Degradation of coastal ecosystem, especially wetlands and coral reefs, also has serious implications on the well-being of the societies dependent on them for goods and services.

[1] *https://dag.gujarat.gov.in/images/directorofagriculture/pdf/APY-2019-20-final.pdf*

Climate of Porbandar

Porbandar has a hot semi-arid climate (Köppen BSh) with three distinct seasons: the 'cool' from October to March, the 'hot' in April, May, and early June, and the monsoonal 'wet' from mid-June to September. Almost no rain falls outside the monsoon season, except for a few late-season tropical cyclones. The most powerful one occurred on 22 October 1975 and produced a storm surge of 4 metres or 13 feet. During the monsoon season, rainfall is exceedingly erratic. Annual rainfall has been as low as 32.2 mm or 1.27 inches in 1918 and 34.3 mm or 1.35 inches in 1939, but as high as 1850.60 mm or 72.86 inches in 1983—when a cyclone caused over 1100 mm (43.3 in) to fall over four days and 1251.7 mm or 49.28 inches in 1878 (Patel, Patil, Desai, & Mankad, 2019).

During the 'wet' season, especially during the few but intense periods of heavy rainfall, very high humidity makes for extremely dangerous conditions; in the 'hot' season, temperatures reach 40 °C or 104.0 °F on occasions (Ray, Mohanty, & Chincholikar, 2009).

A study published by Koya et al., 2017 provides necessary inputs to understand the vulnerability and impacts on fishing communities due to the climate change. The study revealed that the economic performance of the sector is going to be impacted substantially, which will compromise the adaptive capacity of the fishermen. This adverse impact could aggrandize and pose serious threats because of higher sensitivity of the community due to inadequate social performance, which ranked as the second most impacted parameter. The study clearly reveals that there is an urgent need for awareness building among the coastal fisher folk on the climate change and related threats to the livelihood. It further concludes that the developmental and welfare activities in the coastal areas need to be planned from a climate change perspective equipping the coastal population to adapt to changes. Similarly, mitigation strategies should be made by providing adequate infrastructure in the working areas and by creating opportunities for alternative vocations.

To address this scenario, the study focused on selected 10 villages in Porbandar district, which are most vulnerable to effects of climate change. Details of selected villages are given below.

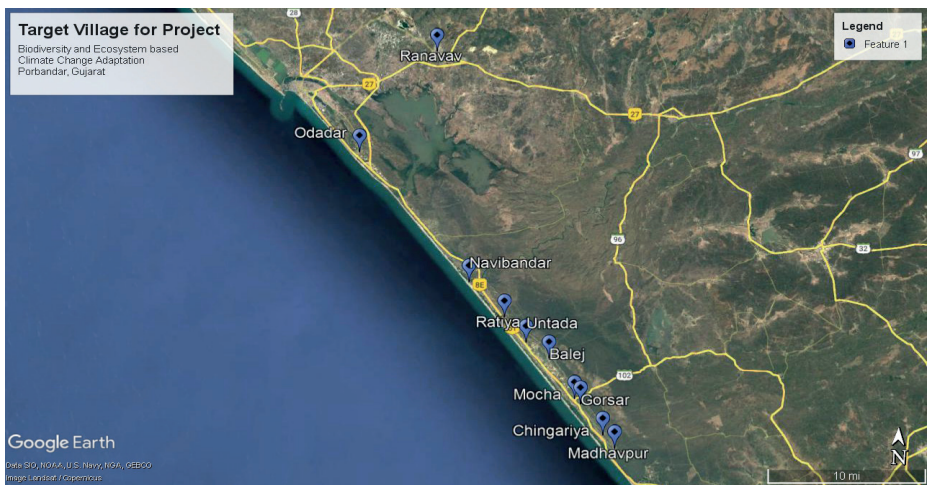

Figure 2. Location of selected villages

S. No.	Villages	Taluka	Approx. population	Approx. households
1	Mocha	Porbandar	1,219	244
2	Gorsar	Porbandar	1,366	273
3	Untada	Porbandar	1,398	280
4	Navi Bandar	Porbandar	1,432	286
5	Chingariya	Porbandar	1,835	367
6	Ratiya	Porbandar	4,415	883
7	Odadar	Porbandar	6,455	1291
8	Balage	Porbandar	7,670	1534
9	Ranavav	Ranavav	20,556	4111
10	Madhavpur	Porbandar	24,289	4858
Total			**70,634**	**14,127**

~ RATIONALE BEHIND THE STUDY ~

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RATIONALE BEHIND THE STUDY

Climate change, the highly debated global phenomenon, is an important area of research in the recent days. The increased incidences of loss of crops due to unprecedented droughts or increase in SLR due to excessive rainfall are a few of the impacts believed to be generated from climate change (Nelson et al., 2009). Similarly, the fisheries sector is also prone to the deleterious effects of climate changeThe assessment of climate variability studies has reported changes in the migration pattern of pelagic fishes such as tuna, anchovy and sardine fishery in the Pacific Ocean (Chavez et al., 2003), shift in recruitment regimes in tuna (Lehodey et al., 2003), *Nemipterus japonicus* (Vivekanandan et al., 2009) and expansion of inhabitant boundaries as shown by Indian mackerel and Oil sardine in tropical waters (Vivekanandan et al., 2009a). Climate change not only influences the fisheries sector directly by affecting various physiological processes such as developmental rates, reproduction, behaviour, and survival of individuals but also affects indirectly by altering the ecosystem, food availability, prey–predator relationship (Brander, 2010) . Some studies have also pointed out that the capture fisheries will get severely affected by climate change, affecting the national economies (Allison et al., 2009).

Porbandar is highly prone to frequent storm surges, flooding, and extreme weather events. Climate change is expected to further increase the variability of rainfall patterns along the Gujarat coastal plain, with more intense rainfall events causing more frequent flooding and reduced groundwater infiltration, and longer dry spells affecting planting seasons. Coastal villages within 100 m of the high tide line are at risk to climate change impacts such as SLR and flooding from storm surges.

Sometimes, tropical cyclones produce a storm surge of 4 metres or 13 feet height. As mentioned earlier, rainfall during the monsoon is highly erratic. With a coefficient of variation exceeding fifty percent and an expectation of only 41 percent of mean annual rainfall in the driest year in ten, the Porbandar region is among the most variable in the world – comparable to northern Australia, the Brazilian sertão, and the Kiribatese Line Islands (Van Etten, 2009).

The communities that depend on fisheries are more vulnerable to climate impacts such as cyclone, flood, droughts, SLR, and temperature and rainfall variability. These impacts increase the vulnerability of fishery-based livelihood. Assessment has been made regionally and globally to delineate the impacts of climate change on a country level (Koya et al., 2017).

Examining the vulnerability of fishing communities will help in identifying and characterizing timely actions to be taken in order to combat the negative impacts of climate change, and will help in successful implementation of various climate-resilient policy initiatives through awareness, mitigation, and adaptation options.

CASE STUDY: Vulnerability of Women in Coastal Communities of Porbandar

Parvati was born in the family of fishermen and was married at an early age. 'All women in our community are married between ages 17 and 20, so that's not new for us. We are daughters of fishermen and are married to fishermen. So, we are used to the hardships of managing a family while men are away at sea.

A fisherman earns anything between Rs 10,000 to Rs 12,000 if he makes at least two trips a month. During monsoon they stay back home for a month or two," says Parvati.

Eight or ten years earlier, men would go fishing along the coastline and would come back in four or five days. But due to pollution, there are no fish now along the coastline and men venture far into the sea for a good catch. At times they go so deep that a trip could last 15 days.

Source: Dhar, 2018

~ METHODOLOGY ~

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METHODOLOGY

The chapter details out the adopted methodology for the proposed study. Keeping in mind the aims and objective of the study, the approach and methodology adopted is consultative and field-based.

Approach of the Research

Focus areas of the study

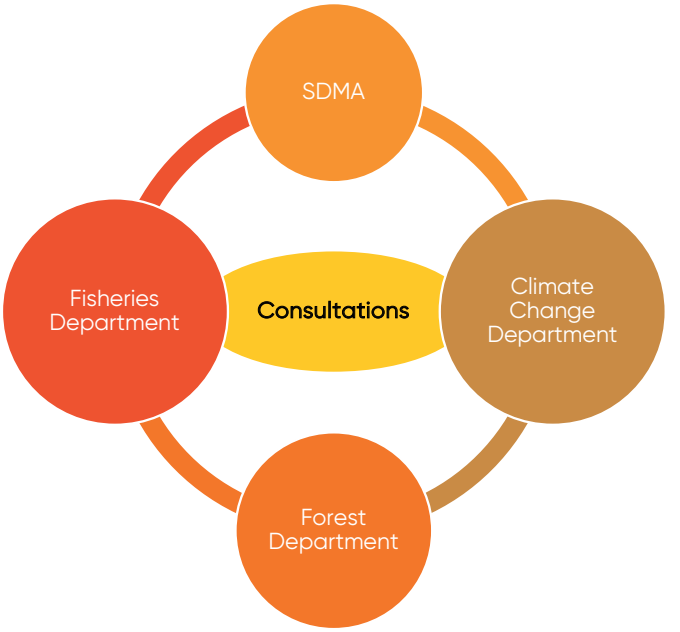
Socio-economic Evaluation	Understanding the current socio-economic condition of the local communities, village dynamics, and major sources of livelihood
Climate Change Perception	Assess the perception of local communities on climate change and build a better understanding on how they perceive climate change and changes in weather parameters
Indicators of Climate Change Impacts	Identify the climatic parameter, which has caused or can cause a negative impact on the overall well-being of the local communities.

Finding Linkages	Establish linkages between the changes in climatic parameters and the resulting vulnerable impact on the local communities
Suggestions and Recommendations	Provide nature-based solutions to build resilience in the communities towards climate change and its impacts on their day-to-day activities.

Stakeholder Consultations

Senior project team from AKAH met the following departments to understand the current scenario and the challenges faced:

- Fisheries Department
- Forest Department
- Climate Change Department
- State Disaster Management Authority (SDMA)



All the departments shared relevant information and documents with the AKAH team, which helped the team understand the threats posed by climate change on important sectors like forests/ biodiversity, agriculture, and fisheries.

Based on the baseline information of projected climate change and anticipated challenges on the communities, flora and fauna, and infrastructure within Porbandar, the AKAH team designed a study to assess and understand the key challenges faced and identify the most appropriate solutions, including any indigenous practices.

Fisheries Department

- In Porbandar district, the below-mentioned nine villages are engaged in fishing activity for living. The percentage of population dependent on fishing activity is as listed below.
    1. Porbandar City – 40%
    2. Subhash Nagar – 70%
    3. Kuchdi – 10%
    4. Visavada – 10%
    5. Miyani – 50%
    6. Tukda Gosa – 10%
    7. Chikasa – 10%
    8. Navibandar – 95%
    9. Madhavpur – 30%
- More than 50% population of these villages is involved in fishing.
- Climate change and climate-induced disasters impact fishermen. Due to climate change, the quality and quantity of fish are degraded.
- Frequency of climate-induced disasters, i.e., cyclone, low pressure area, and storm surge has been increasing. There have been instances of fishermen being lost in the seas due to bad weather conditions.
- Small fishes are declining due to over-fishing as there are only a few sites where fish catch is possible now.
- Indian Meteorological Department (IMD) publishes weather forecast and that is helpful on several occasions.
- Fisheries department also publishes warnings for fishermen.
- Alternative practices that have been adopted include fish culture method and fishing in brackish water.
- Fishing community/coastal communities have planted species like *Saru*, *Pilu*, and other coastal native species to get natural defense against saline winds.

Forest Department

- Farmers have been requested to plant fruit-bearing trees such as Kharek, Badam, Jamphal, Jamun, Coconut, and Mango in their farmland. Some of the other species rccommended by the Forest department are as listed below.

S. No.	Sapling Name
1.	Anar (Pomegranate)
2.	Chiku (Sapodilla)
3.	Jamun black (Java plum)

4. Jamun white (Java Apple)
5. Nimbu (Lemon)
6. Moringa (Drumstick)
7. Sitafal (Sugar-apple)
8. Jamphal (Guava)
9. Gunda (Indian cherry/ Glue berry)
10. Bore (Indian date)

- Forest department agreed to give grafted sapling to the beneficiaries of the village.
- Plantation of mangroves and other plants: *Avicennia marina* (Mangrove), *Casuarina equisetifolia* (*Saru*), *Salvadora persica* (*Pilu*), and *Ravan tad*. Suggested to use these species as multi-layer natural defence against saline wind.
- Plan district-level workshops for stakeholders highlighting the importance and revival of Biodiversity Management Committee (BMC), and discussion of CCA and DRR projects. (please spell out CCA and DRR?)
- Revival of BMC with the help of Forest department is required.
- Training on plantation techniques for CAG (spell out CAG) members is required.
- Mentioned the decrease in the number of some fauna species like Lion. About100 years back there were large numbers of Lions in Gujarat.
- Decrease in the forest cover has been happening over the past few years (Any data to strengthen this statement?).
- There has been an increase in the level of salinity in soil, water, and wind, which affect production.
- Some species of Grass are extinct because of encroachment of other exotic plants like *Cassiatora* species, Maldhari Nes in Barda Hills.
- Due to overgrazing of grass in the Barda Hills, the local people have to take their animals outside the Barda area to feed animals.
- To overcome this problem of overgrazing, the Forest department developed 25 hectares of grassland for feeding animals of the local population.
- Due to excessive mining activity, natural sand dunes in Porbandar are on a decline.
- Extinction of some species of fauna including Jackal (Siyar), Fox (Lomdi), Hayana (Jarak), Badger (Vinj), Porcupine (Sedhadi), Khera Vulture, Parrot, Crow

Primary Data Collection

In this study, we adopted 'Cross-sectional Survey Methodology' as it focuses on collecting insights from a target audience at a particular time interval. This survey research method was implemented in various sectors such as household, retail, education, healthcare, and SME businesses.

The advantage of cross-sectional survey research is that it can either be descriptive or analytical. It is quick and helps researchers collect information in a brief period. Researchers rely on the cross-sectional survey research method in situations where descriptive analysis of a subject is required. The steps involved in the research are as listed below.

- Deciding survey questions:
  The survey questions were a mix of close-ended and open-ended questions to capture the understanding and perceptions of the target respondents.
- Finalizing the samples:
  - The sampling will be done using the random sampling method.
  - Total number of samples: Given in Table 5
- Collecting information through personal interviews

The survey was conducted via personal interviews with the help of KoBo Collect App.

- Generating the data

Plan of Survey

- Questionnaire formulation: Guiding questions were listed and structured to form a questionnaire.
- Team formation: Five teams were formed consisting of a junior and a middle-level staff from AKAH Field Office in Porbandar.
- Training of the team: Training session on the questionnaire and data collection objectives and methodology was conducted.
- Pilot study: Three teams were sent to one village and other two teams to another village for pilot testing of the survey methodology. The teams were then brought together, results generated by each team were discussed, anomalies and inconsistencies were discussed, and recommendations for coherence in methodology was established.
- Village allocation and survey plan: Every team was assigned villages for every week. A plan was shared with all survey team members.
- Evidence: Photography and videography were done for every HH survey. Additionally, general village photography and videography were also undertaken to give the team a sense of the location and susceptibility.
- Data review: Project senior team at AKAH reviewed the results and shared feedback and suggestions with data collection team on a weekly bases
- Data cleaning and compilation: Teams were required to check data and clean any erroneous details before sharing data with AKAH senior team.
- Data analysis: Further, AKAH senior team conducted analysis of the data and conducted weekly sessions with the field team to discuss the results of every village.

Survey Questionnaire

The survey questionnaire was designed with the aim to understand the current status of the local communities and the impact of climate change as experienced by the communities.

The questionnaire focused on the following six points to better understand the local conditions. A detailed survey questionnaire is attached as an annexure.

1. Demographic and farm characteristics of the respondents
2. Community perceptions of meteorological change over the past 25 years and those on flood, cyclone, drought, and other hydro meteorological hazards
3. Community perceptions about climate change risks, impacts, and level of severity
4. Perceived impacts of climate change on crops production
5. Farmers' perception on adaptation responses towards climate change
6. Constraints to climate change adaptation

Details of the Sample Size

S. No.	Villages	Taluka	Approx. Population	Approx. House holds (HHs)	HHs Surveyed
1	Mocha	Porbandar	1,219	244	22
2	Gorsar	Porbandar	1,366	273	29
3	Untada	Porbandar	1,398	280	22
4	Navi Bandar	Porbandar	1,432	286	30
5	Chingariya	Porbandar	1,835	367	39
6	Ratiya	Porbandar	4,415	883	91
7	Odadar	Porbandar	6,455	1291	127
8	Balej	Porbandar	7,670	1534	150
9	Ranavav (4 vulnerable wards of Nagar Palika)	Ranavav	20,556	4111	413
10	Madhavpur	Porbandar	24,289	4858	481
Total			70,634	14,127	1404

Snaps from the Field

Figure 3:
Government stakeholder consultation

Figure 4:
Community stakeholder consultation

Figure 5:
Stakeholder consultation with panchayat and village elders

Figure 6:
A participatory rural appraisal (PRA)exercise with community

Figure 7:
Street play for awareness in a village

Figure 8:
Wall painting for awareness in a village

Figure 9:
Distribution of saplings to promote tree plantation

Figure 10:
Tree plantation by villagers with AKAH support

Figure 11:
Primary survey to assess perceptions about impacts of climate change

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MAJOR FINDINGS OF THE STUDY

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MAJOR FINDINGS OF THE STUDY

This section presents the major findings of the study that was conducted through household survey in the selected 10 villages of Porbandar. The findings are presented with an aim to create a link between the overall well-being of the local communities and the negative impact of climatic changes happening due to global warming.

One of the most important parameters for ensuring resilience of the vulnerable communities to the onset and sudden shocks is to establish a sustainable source of livelihood. Livelihoods are both complex and dynamic (Allison and Ellis 2001); people respond to both and cause many ecological changes due to excessive resource consumption by a growing population and their ever-growing desires. Perceptions of well-being are shaped by material conditions, history, and culture. For these reasons, the study focused on the major sources of livelihood and identified indicators that are dependent on climate, which can lead to negative outcomes.

The survey results showed that the average number of members in a family is 5. More than 60% respondents were either illiterate or only attended primary school. Only 8% of the respondents were either graduate or post-graduate (**Figure 12**).

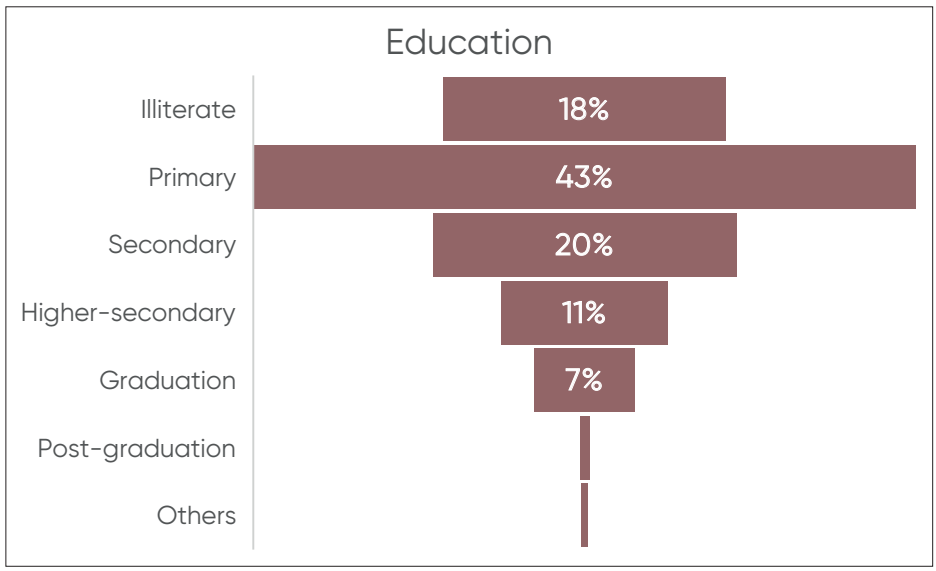


Figure 12: Educational status of the respondents

The study found that almost 30% of the households are directly associated with agriculture and fisheries as their primary source of livelihood (**Figure 13**). In addition, most of the respondents working as labour also have farms as their major sources of livelihood working as farm-labour. These findings suggest that majority of the households living in the coastal areas are vulnerable to climate change.

The data collected from households suggest that majority of the population is engaged in agriculture, farm, labour and related activities like land preparation, tilling, sowing, weeding

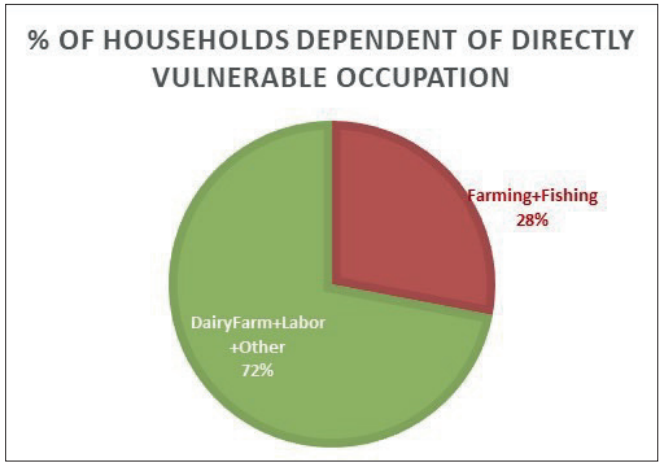


Figure 13: Percentage of households dependent on directly vulnerable occupation in the study area

and harvesting, dairy and cattle rearing or fishing. As most of these sources of income are dependent on climatic parameters, it can be assumed that their sustainability is in question with the increasing threat of climate change and the related changing weather pattern.

In fact, most of the jobs reported under 'Others' are also climate-dependent. For instance, shops and driving will get affected by unexpected extreme weather events.

It can be said that agriculture and allied sectors, including dairy, form the most important sector as they provide livelihood to almost 73% of the total population.

A village-wise breakup of households associated with climate-dependent occupation is given in (**Figure 14**).

Major sources of livelihood for the local communities

Untada (**Figure 15**) is a coastal village having a population of 1,392 and 280 households. The major sources of livelihood for the locals are agriculture and associated activities. About 81% of the population was directly or indirectly dependent upon local agriculture for their livelihood. About 18% of the population were engaged in industry jobs or some other trade or skill-based occupation.

There are 286 families living in Navibandar (**Figure 16**) with a population of about 1432 people. The name 'bandar' signifies its affinity to port-related activities and as the name suggests fishing is the most dominant occupation for the locals in this village with around 90% of the population dependent on it for livelihood. The remaining population either work as farm labour in the nearby village or take up some jobs for livelihood.

Mocha (**Figure 17**) is a village with 244 families and a population of 1219. The locals are totally dependent on agriculture and allied sector for their livelihood. 82% of the locals are directly engaged in farming and related labour activities, while the remaining 18% is engaged in dairy farms for their main source of livelihood. Although a coastal village, no one is engaged in fisheries-related activity for livelihood.

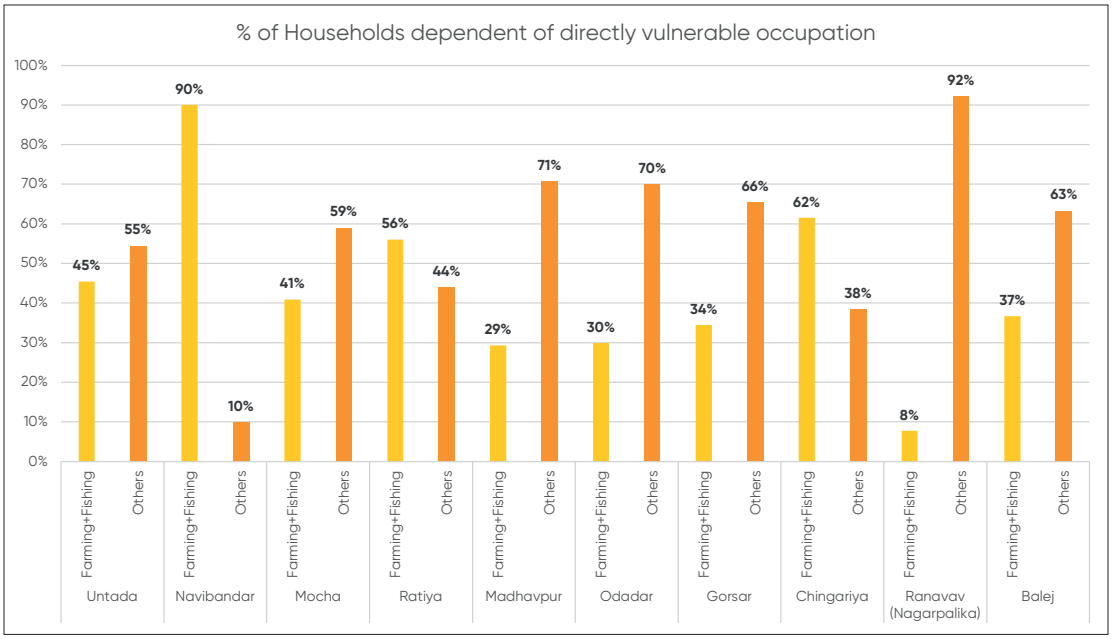


Figure 14: Percentage of households dependent on directly vulnerable occupation – village-wise data

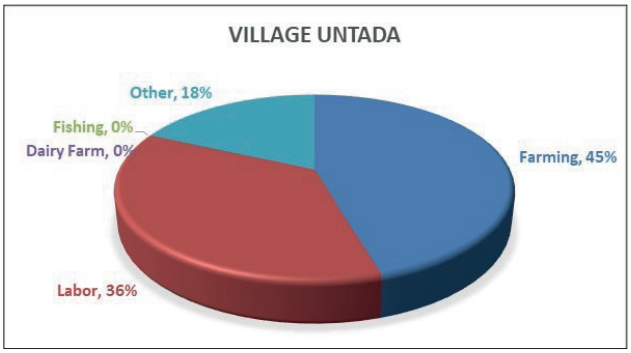


Figure 15: Major Sources of Livelihood in Untada

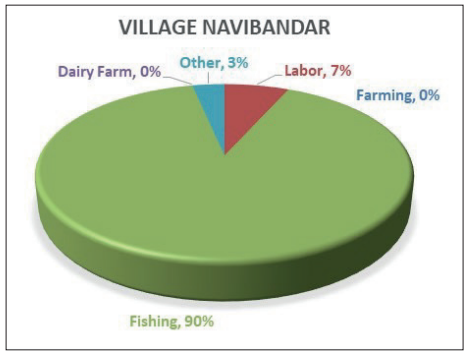


Figure 16: Major sources of livelihood in Navibandar

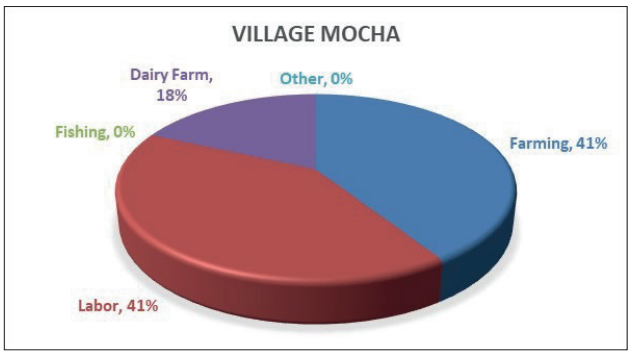


Figure 17: Major sources of livelihood in Mocha

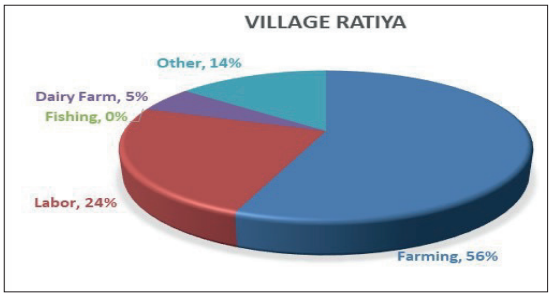


Figure 18: Major sources of livelihood in Ratiya

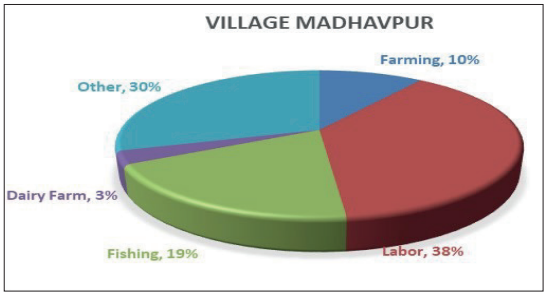


Figure 19: Major sources of livelihood in Madhavpur

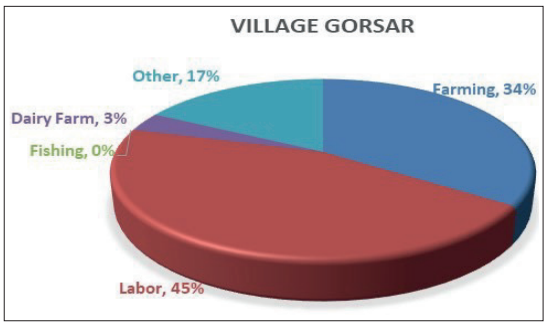


Figure 21: Major sources of livelihood in Gorsar

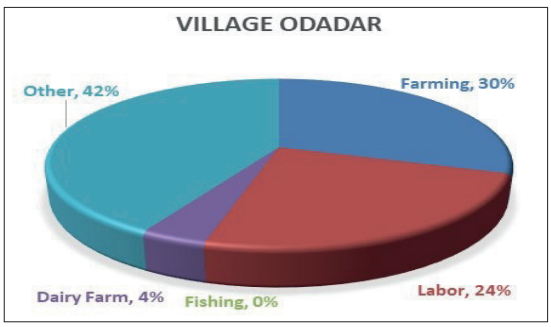


Figure 20: Major sources of livelihood in Odadar

Ratiya (**Figure 18**) has 883 families and a total population of 4415. The major sources of livelihood are farming and farming-related activities, with about 80% of the population being dependent on it. Besides farming, the locals are also engaged in dairy related activities and other forms of livelihood. There are no families that are engaged in fishing or ocean-related activities as a source of livelihood in Ratiya village.

Madhavpur (**Figure 19**) is the biggest rural settlement among the selected villages for the study. It has around 4858 families comprising a population of 24,289. Farming as a primary source of livelihood share a minor percentage as most of the people are mainly associated with labour work (38%) or other jobs (30%). About 19% of the population is directly associated with fishing-related activities while a small portion of population (3%) is associated with dairy related activities for livelihood.

Odadar (**Figure 20**) is another coastal community with a population of 6455. Almost half of the population (54%) is directly dependent upon the agriculture-related activities for their livelihood. While 42% of the people are engaged in other odd jobs or skill-related sources of livelihood. Only 4% of the people are engaged in dairy farm while no one is practicing fisheries-related activities as a source of livelihood in Odadar village.

Gorsar (**Figure 21**) is a small village with a population of 1366 living in 273 families. The village is mostly dependent on agriculture and allied activities like farm labour and dairy as a source of livelihood. About 83% of the population is engaged in either farming, farm labour work or dairy and cattle raising. Remaining 17% of the people are engaged in other jobs while no one is engaged in fishing or related activities for livelihood

Chingariya (**Figure 22**) has a population of 1835 living in 367 families. The village is mostly dependent upon agriculture and allied activities like farm labour and dairy as a source of livelihood. Almost 77% of the population is engaged in either farming, farm labour work or

dairy and cattle raising. Remaining 23% of the people are engaged in other jobs while no one is engaged in fishing or related activities for livelihood.

Ranavav (**Figure 23**) is a major coastal town with a Nagarpalika. Only 4 wards with vulnerable communities were covered under the study. While only 4% of the people are engaged in dairy farm, 89% are engaged in other jobs including farm labour or other skill related sources of livelihood. Only about 8% are engaged in farming directly and no household is practising fisheries related activities as a source of livelihood.

Balej (**Figure 24**) is a relatively larger village with a population of 7670 and a 1534 families living in it. About 60% of the population is dependent upon agriculture and related labour activities as a main source of livelihood. 32% of the population is dependent on other jobs and skilled activities as primary source of livelihood while 8% of the population survive through dairy-related activities.

The survey revealed that agriculture was the most important source of livelihood for most people in the villages. **Figure 25** reveals that around 57% of the population is directly or indirectly (as a farm labourer) dependent upon agriculture for their livelihood. 31% of the total population is dependent upon other jobs and skill-based activities for income generation.

Even though the selected villages were coastal villages, only 9% of the population is engaged in fishing related activities for their livelihood while the remaining 4% of the population is engaged in dairy farming and related activities.

However, in Village Navibandar, about 90% households depend on fishing as their primary source of income.

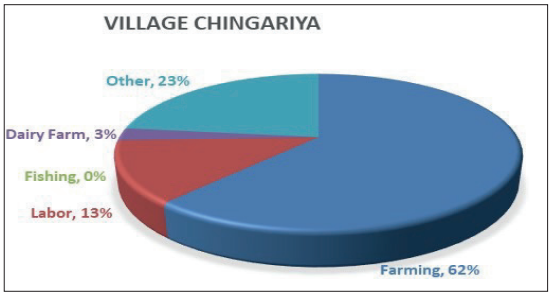


Figure 22: Major sources of livelihood in Chingariya

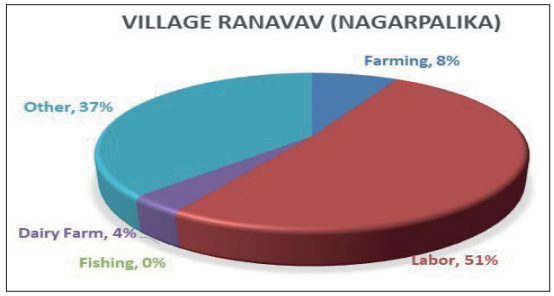


Figure 23: Major sources of livelihood in Ranavav

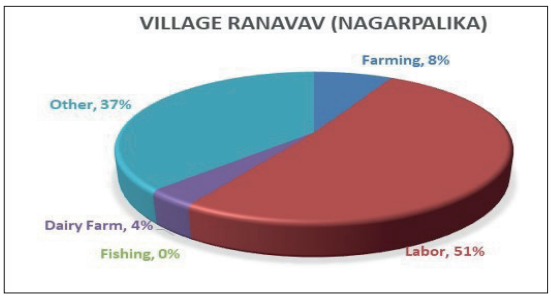


Figure 24: Major sources of livelihood in Balej

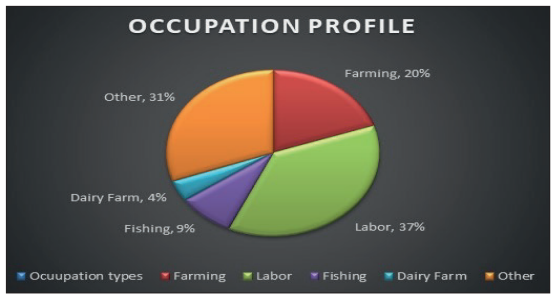


Figure 25: Percentage distribution of major sources of livelihood

Income Strata in the Villages

Based on the average annual incomes, the respondent households were categorized as high income, upper-middle income, lower-middle income, and low-income groups. More than half the households fall within the lower-middle income group of about INR 70 thousand to INR 1 lakh in a year. About 85% of households fall within the low and lower-middle income groups ranging from an income of INR 40 thousand and INR 1 lakh in a year (**Figure 26**).

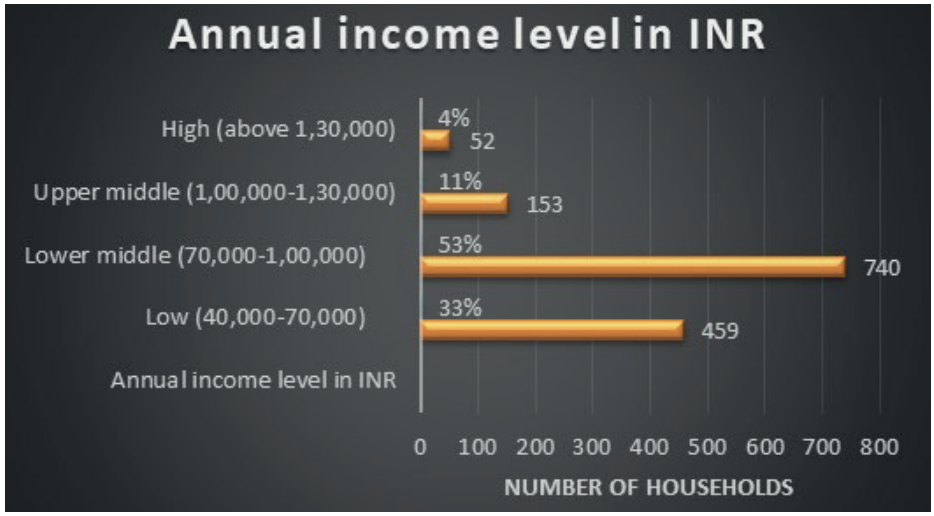


Figure 26: Annual income level of the respondents in INR

Dependence on Rain and Irrigation

Agriculture in the study area is heavily dependent upon artificial source of irrigation (**Figure 27**). As shown in (**Figure 28**), 37% of the respondents said that they are dependent on rainfall for their irrigation requirement.

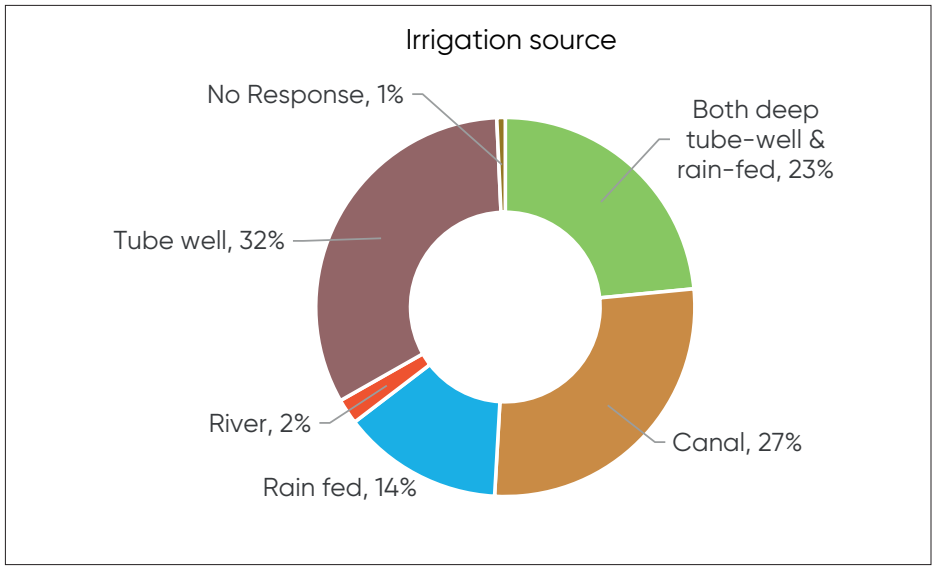


Figure 27: Different sources of irrigation for agriculture

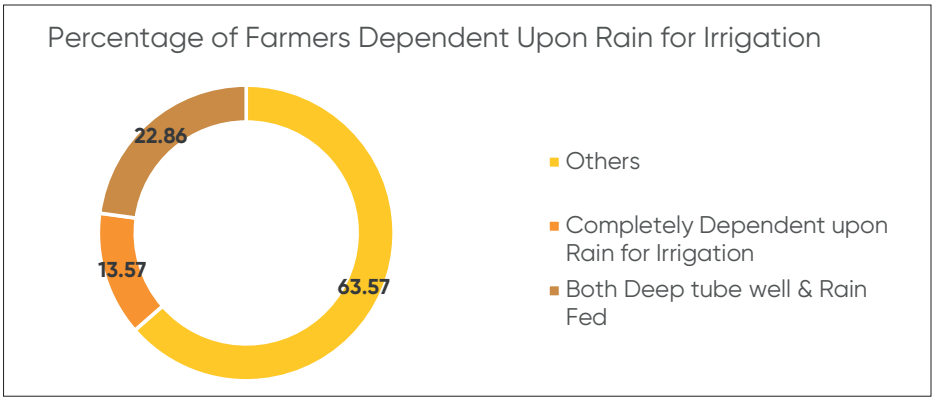


Figure 28: Percentage of farmers dependent upon rain for irrigation

280 respondents were directly associated with farming as their main source of livelihood. Out of those, 38 (14%) respondents said that they were completely dependent upon rain for irrigating their farm, while 64 (23%) respondents said that they were dependent upon rain but they also had access to deep tube well.

Access to Weather-related Information

Upon asking whether or not they receive information about weather updates regularly, about 87% of the respondents said that they regularly receive weather updates. It is crucial for fishermen who go for weeks in the deep sea to have a weather forecast before going into the deep sea. Likewise, farmers need accurate weather information to decide on the time of sowing new crops as it is generally associated with the first rain of the season. Hence weather updates were crucial for the local communities.

For most respondents, the major source of weather updates is news channels and other forms of media. Other major sources of information are village elders, friends, and family members who use their wisdom and experience to forecast the weather pattern.

Out of 120 respondents who have fishing as their primary source of livelihoods, about 70% agreed to receiving weather information. Similarly, out of 277 respondents who have farm-

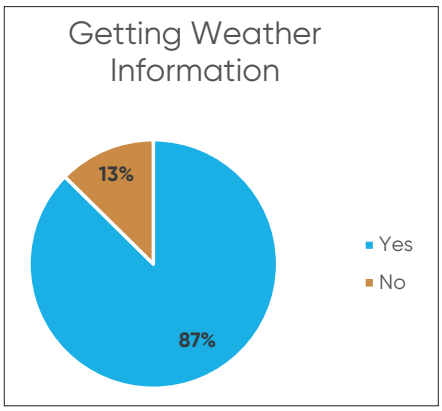


Figure 29: Access to weather information

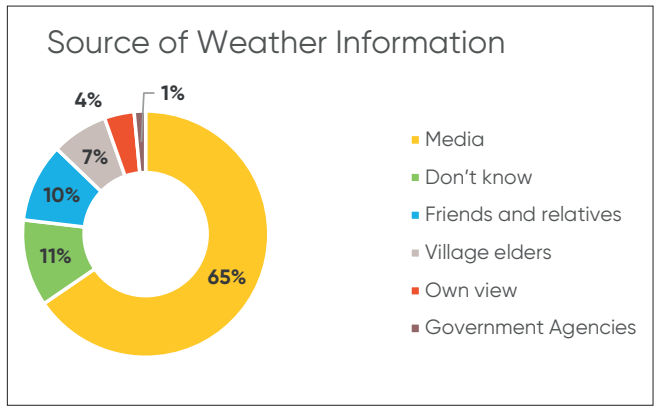
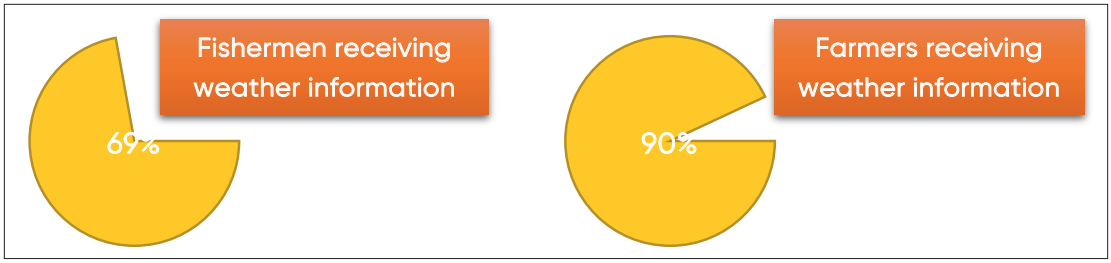


Figure 30: Major sources of weather related information



ing as their primary source of livelihoods, about 90% reported receiving weather information regularly.

Disposal of agri-waste

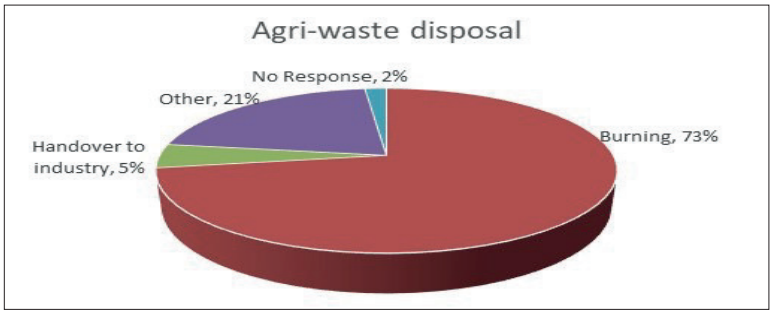


Figure 31: Status of agri-waste disposal

Most respondents (73%) agreed that the disposal of crop residue or agri-waste was done through crop burning. Only 5% of the respondents used the residue for alternative use and handed them over to industries. 21% of the respondents reported that they use the residue for other unspecified purposes depending upon the need of the situation.

Community perceptions of meteorological change

Local communities engaged in farming and fishing have a good understanding of the climatic parameters and the observant changes as their activities were based on weather patterns. During the study, the respondents were asked about their observations and perceptions of experienced meteorological changes to establish an understanding on climate change from the vulnerable community's point of view.

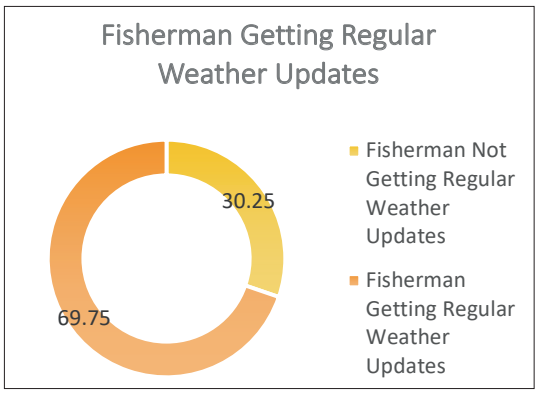


Figure 32: People having fishing as primary source of income getting weather information

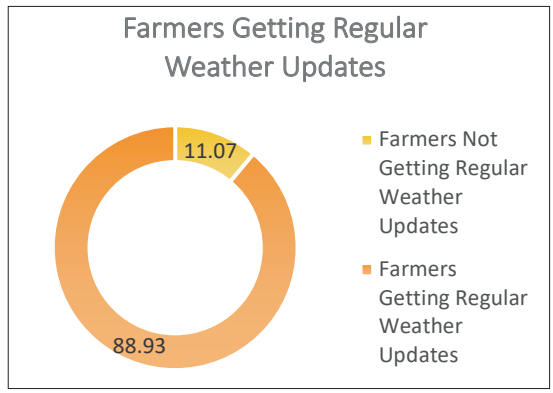


Figure 33: People having farming as primary source of income getting weather information

Community perceptions of meteorological change over the past 25 years and perception on flood, cyclone, drought, and other hydro-meteorological hazards

Climatic variability refers to long-term changes in the weather pattern. This section reports on the observation of the local communities on various parameters such as temperature, rainfall, floods, droughts, cyclone, storm surges, and salinity ingress over the last few decades. Most respondents to the survey mentioned that there is an increasing trend in temperature over the past decade. 99% of respondents agreed with the statement while 91% of the respondents sais that there was increase in rainfall.

Majority of the respondents have noted that there is an increase in the occurrence of cyclone and storm surges along with increased rainfall. Although 78% of the respondents have reported an increase in flooding events, 38% of the respondents felt no change in drought-like situation in the region. Moreover, 24% of the respondents felt that drought events have increased in the past 25 years.

Salinity ingress is a major problem in the Saurashtra region of Gujarat, especially near the coastal regions. Around 55% of the respondents have suggested that there is an increase in the salinity of water, while 52% of the respondents suggested that the salinity in soil has increased.

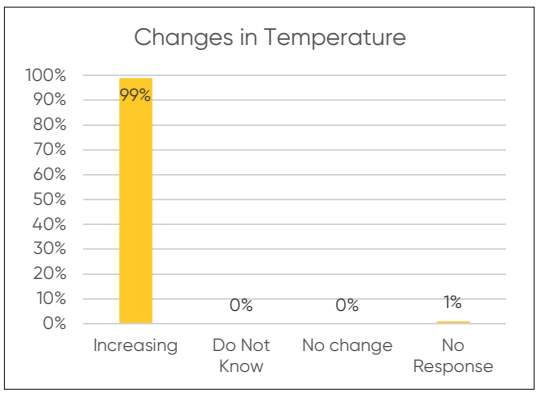


Figure 34: Perception on temperature changes

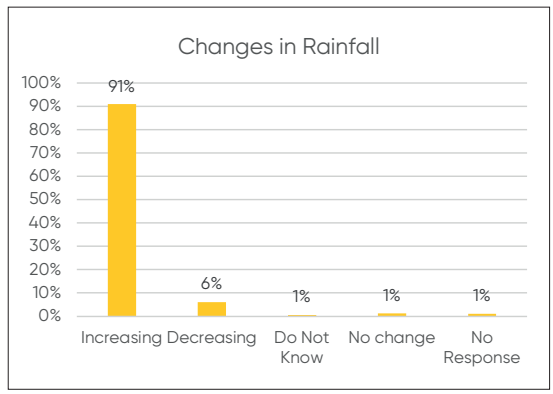


Figure 35: Perception on rainfall change

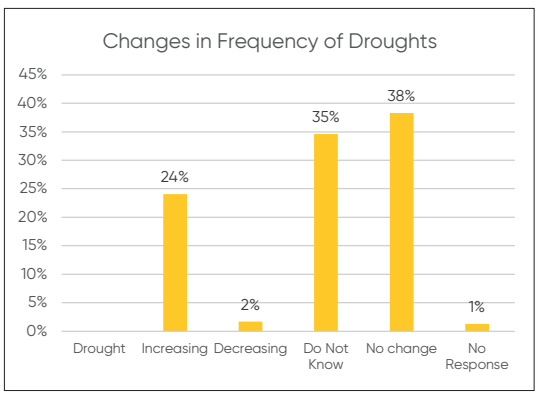


Figure 36: Perception on frequency of droughts

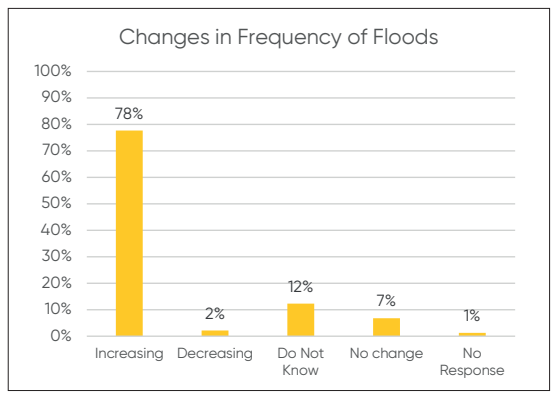


Figure 37: Perception on frequency of floods

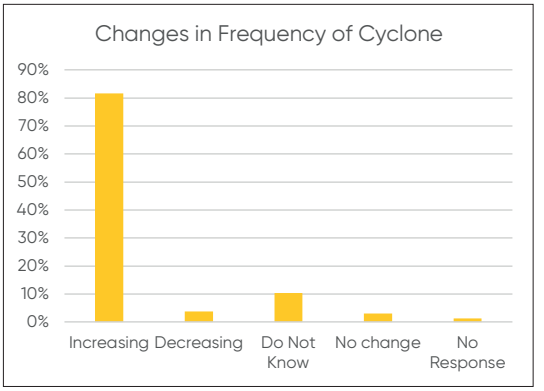


Figure 38: Perception on frequency of cyclone

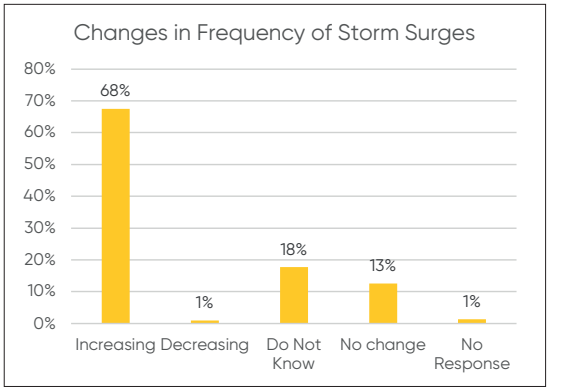


Figure 39: Perception on frequency of storm surges

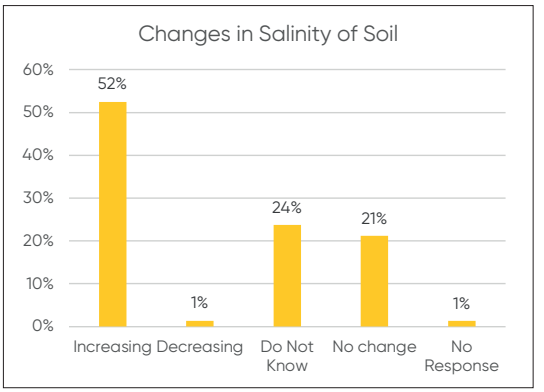


Figure 40: Changes in salinity of soil

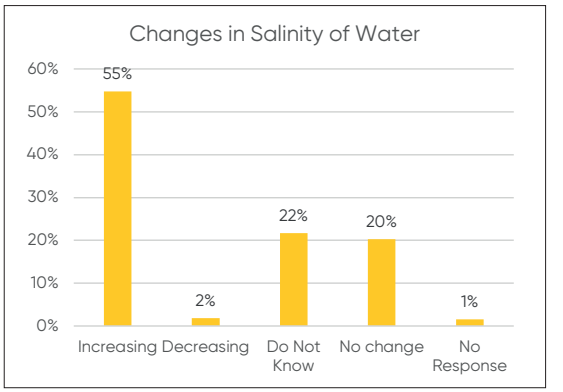


Figure 41: Changes in salinity of water

How frequently below-mentioned climatic hazards are occurring in the area?

This section provides the observations of the respondents on the negative impact of climatic parameters that they have experienced in their village or in the nearby areas.

When asked whether they have experienced any drought-like situation, 44% of the respondents responded with a 'no' in their area, while 21% of the respondents reported a few cases of drought-like situation in their area (**Figure 43**).

About 46% of the respondents have said that there are high cases of flood-like situation in their area while 14% of the respondents said such situations are very high in the region (**Figure 42**).

Almost 77% of the respondents believed that there is an increase in heatwave experiences in the region. 41% of the respondents replied with high occurrence while 37% of the respondents said that the occurrence is very high in the region.

Lightning strikes are reported to be increasing due to climate change and when the respondents were asked about the same, 38% replied with medium increase in the occurrence of lightning. 25% believed that such occurrences are high while 8% said that it is very high.

42% of the respondents have reported high occurrence of heavy storms while 12% said that such incidents are very high.

The response of respondents on soil-related problems was divided; 30% believed that there is an increase in soil-related problems while 35% reported no such problems in their area. 25% of the respondents indicated a medium increase in soil-related problems. There was mixed response when it came to changes in pest infestation and problems in irrigation over the past 25 years. Many respondents believed that there was no change in such parameters.

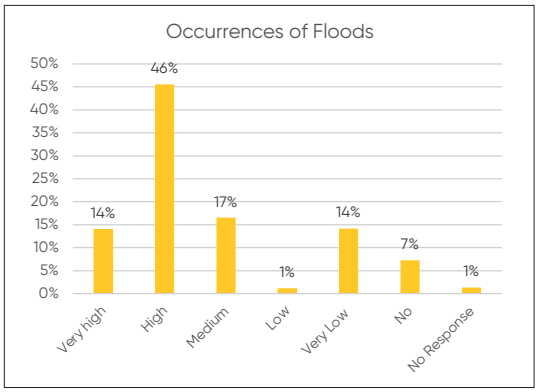


Figure 42: Occurrences of floods

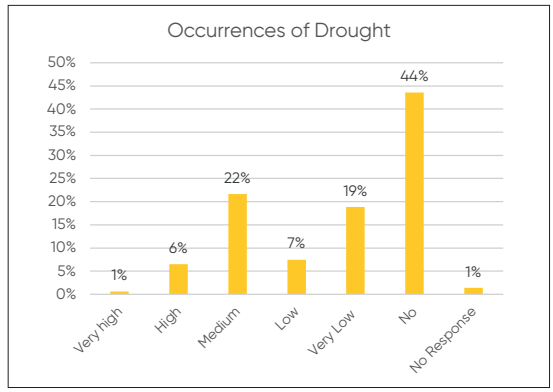


Figure 43: Occurrences of droughts

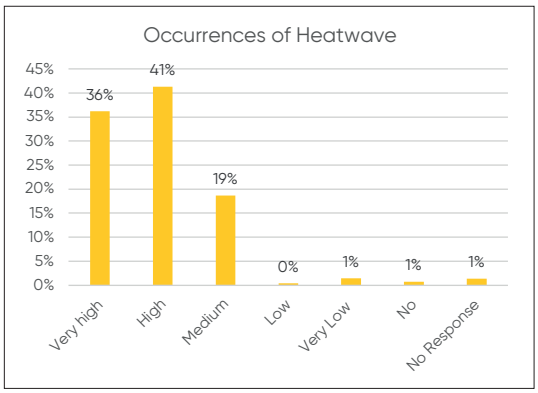


Figure 44: Occurrences of heatwaves

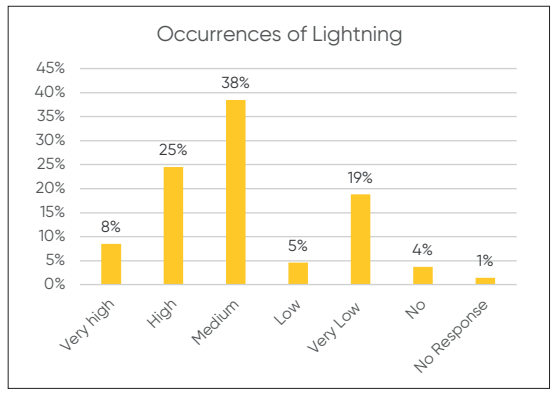


Figure 45: Occurrences of lightening

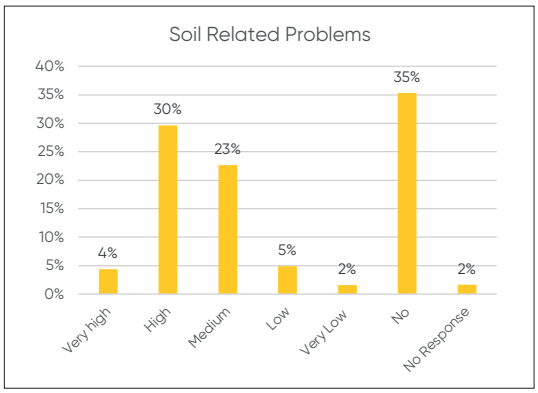


Figure 46: Soil-related problems

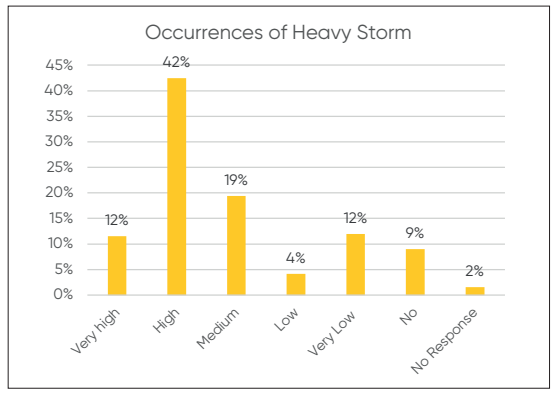


Figure 47: Occurrences of heavy storm

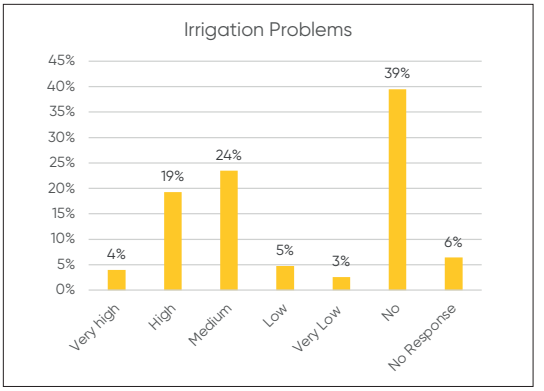


Figure 48: Irrigation problems

As far as coastal erosion is concerned, 31% responded with no occurrences, 25% agreed on high cases of coastal erosion, and 11% responded with very high occurrences of coastal erosion.

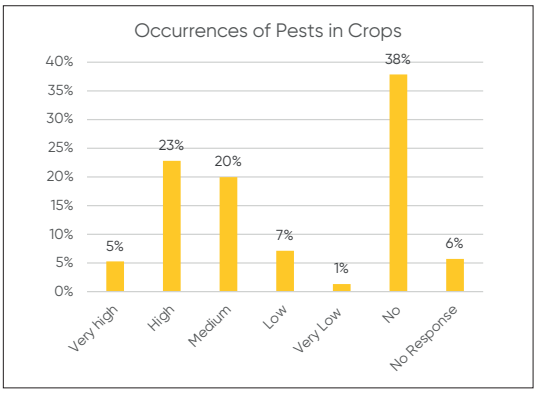


Figure 49: Occurrences of pest in crops

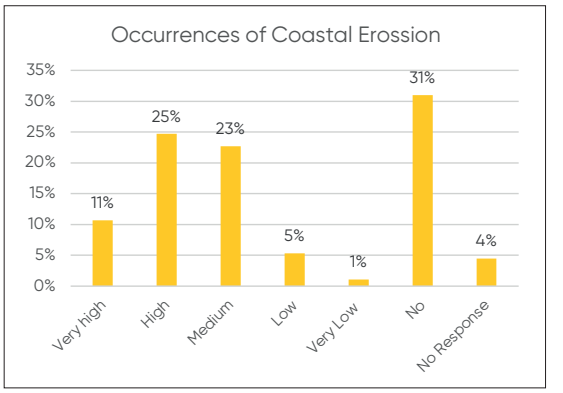
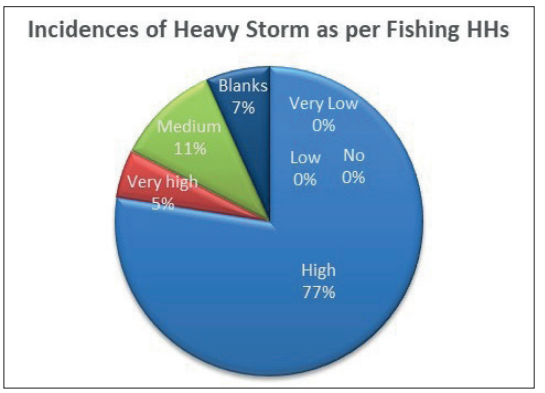


Figure 50: Occurrences of coastal erosion

Perception of Households practicing Farming and Fisheries

It was observed that people perceive climate change in their unique manner, which is largely dependent on their inherent and livelihood-related vulnerabilities. The team specifically assessed the perceptions of the farming and fishing households as their livelihoods are directly dependent on any weather and climate change.

About 80% of fishing households reported high number of incidences of heavy storms that affect their work and lifestyle. Interestingly, none of the respondents reported to receiving 'No', 'Low' or 'Very Low' heavy storms. When asked 'How frequently below-mentioned climatic hazards are occurring in your area?', most of the households expressed concerns over the rising storms.



About 56% of farming households reported high and very high number of incidences of floods that affect their crop. When asked 'How frequently below-mentioned climatic hazards are occurring in your area?', most of the households expressed concerns over the rising floods.

The findings suggest that there are increasing cases of flood, heavy storms, and other extreme weather events. The temperature is getting warmer and there are increased cases of heat waves experienced by the local population along with increased number of days with extreme winds and heavy storms.

Perception of Local Farming Communities on the Impact of Climate Change

The analysis of response given by the respondents on various questions regarding the impacts of climate change are discussed here.

Impact of climate change on water availability is a major concern across the globe. However, this survey results suggest that the impact of climate change on water availability is low. 36% of the respondents said that there is no impact while 28% said that there is a little impact on water availability for irrigation.

When asked about whether the respondents have experienced an increase in the cases of crop diseases due to climate change, majority of the respondents suggested that there is an increase in crop diseases due to climate change. 28% of the respondents suggested that there is a great increase while 50% of the respondents suggested that there is an increase of some level due to climate change.

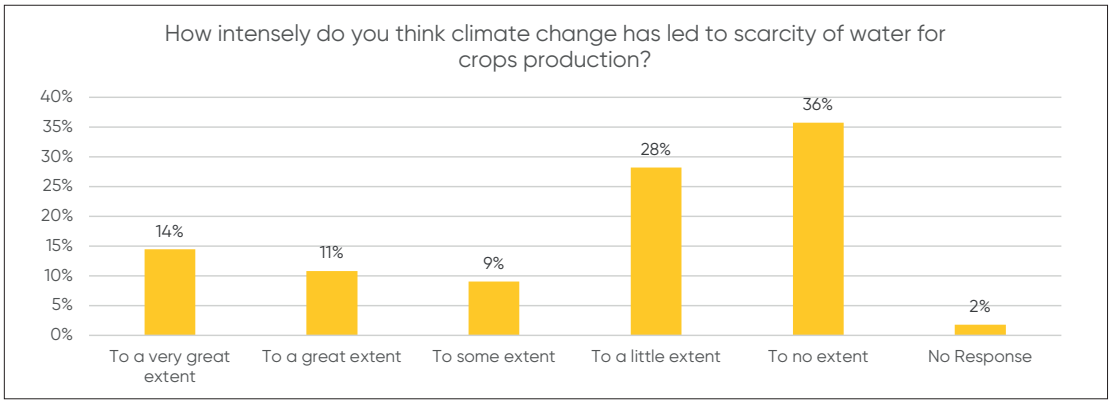


Figure 51: Impact of climate change on irrigation water

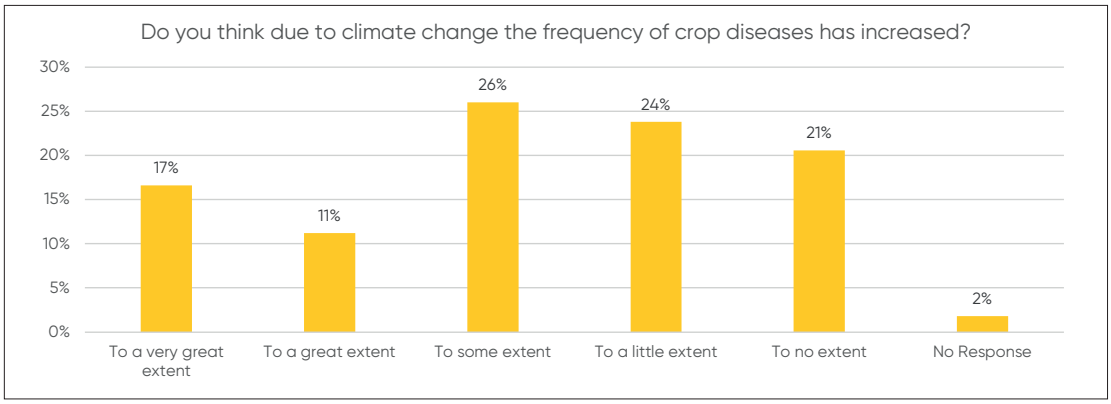


Figure 52: Impact of climate change on crop-related diseases

A large portion of the respondents replied positively for the connection between drought occurrence and increased stress on crops. 79% of the respondents felt that the crops are stressed due to drought-like conditions with varying degree of emphasis.

There is an established correlation between climate change and increased pest infestation, which was discussed with the local communities. The response suggests that there is an increase in pest infestation. 15% of the respondents believed that pest infestation has very greatly increased due to climate change while 22% believed that there is no increase in pest infestation. Overall, 75% of the respondents agreed that pest infestation has increased due to climate change.

The timing of crop plantation plays an important role in getting a good produce, which is affected by climate change. The respondents were asked whether they believed that such changes are happening in their villages or not. The overall response suggests that irregularity in crops plantation has increased in the recent times due to erratic rainfall and seasonal changes.

Due to various impacts of climate change on the agriculture sector, it has been observed that the income generation has been affected in regions that are facing climate change related issues. A similar case was found with the locals in the study area; 85% of the respondents believed that their farm income has suffered due to climate change with varying degree

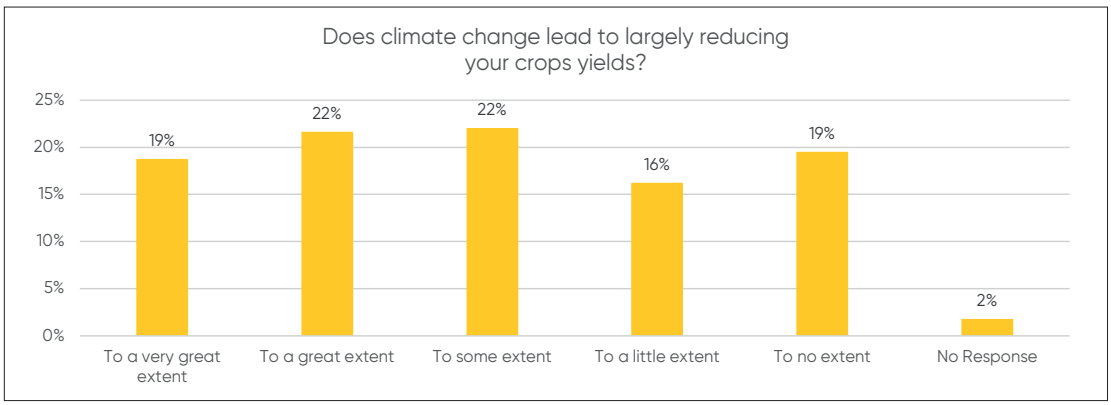


Figure 53: Impact of climate change on crop yields

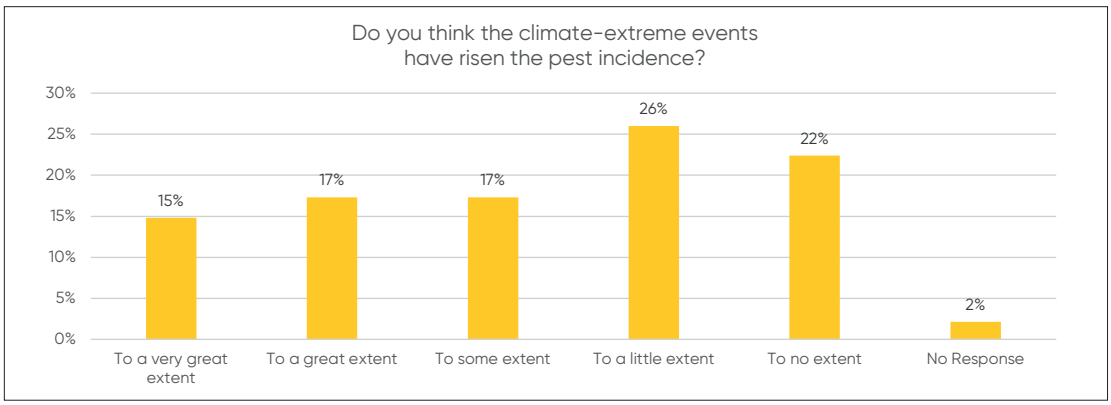


Figure 54: Impact of climate change on pest incidences

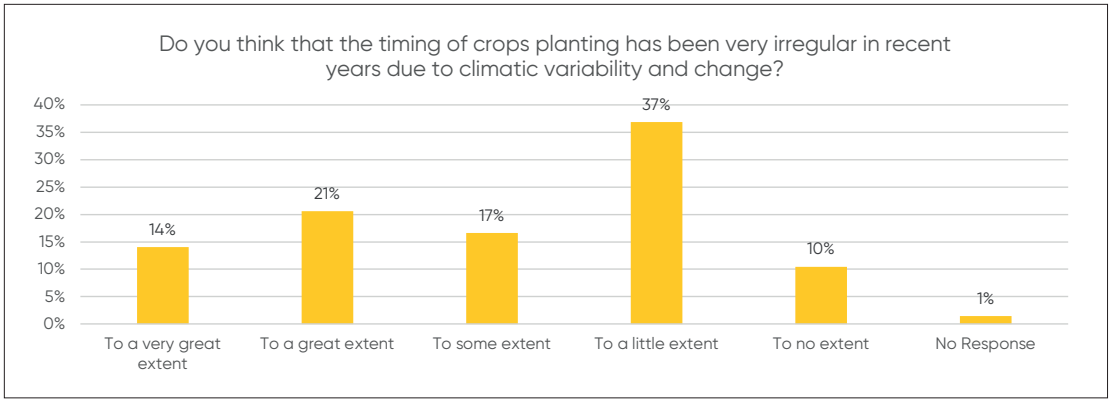


Figure 55: Impact of climate change on timing of crop plantation

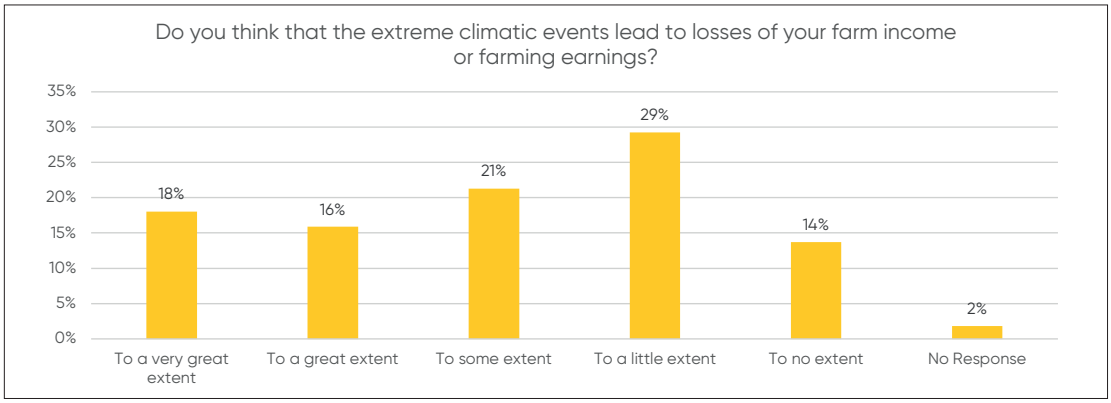


Figure 56: Impact of climate change on farm income

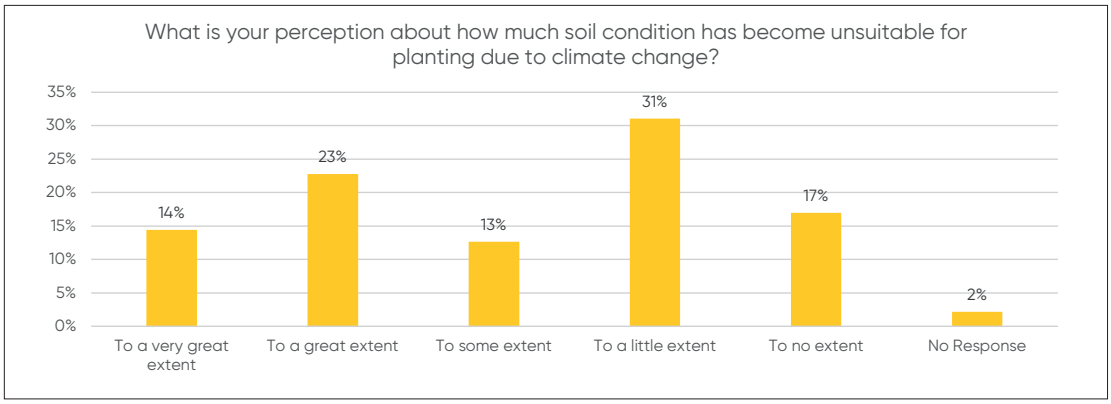


Figure 57: Impact of climate change on soil condition

of emphasis. 29% believed that there is a little impact while 18% responded that the farm income has suffered a very great loss due to climate change.

The impact of climate change on soil health was also assessed during the study. It was found that 31% of the respondent believed that their soil has been affected to some extent due to climate change, while 23% of the respondents believed that it has greatly affected the soil health in their field.

Because of the erratic nature of rainfall and the delays in the onset of monsoon, the process of harvesting is also affected. 24% of the respondents suggested climate change has prolonged the harvesting period to a great extent. Overall, 84% of the respondents agreed that the harvesting of crops has been prolonged due to climate change.

A major issue that was recorded during the study was decreasing quality of the crops. 22% of the respondents believe that due to climate change, the difficulty to produce high quality of crops has increased to a very great extent.

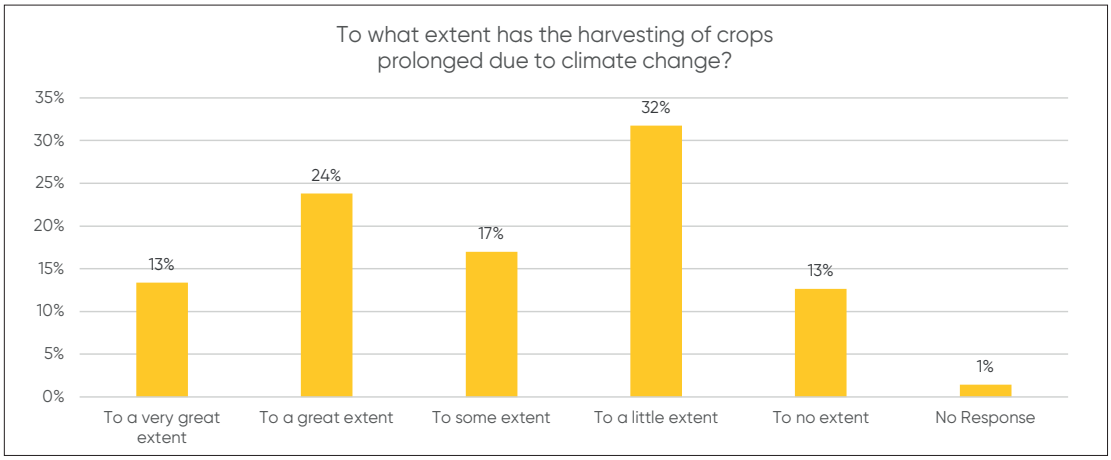


Figure 58: Impact of climate change on delays in harvesting

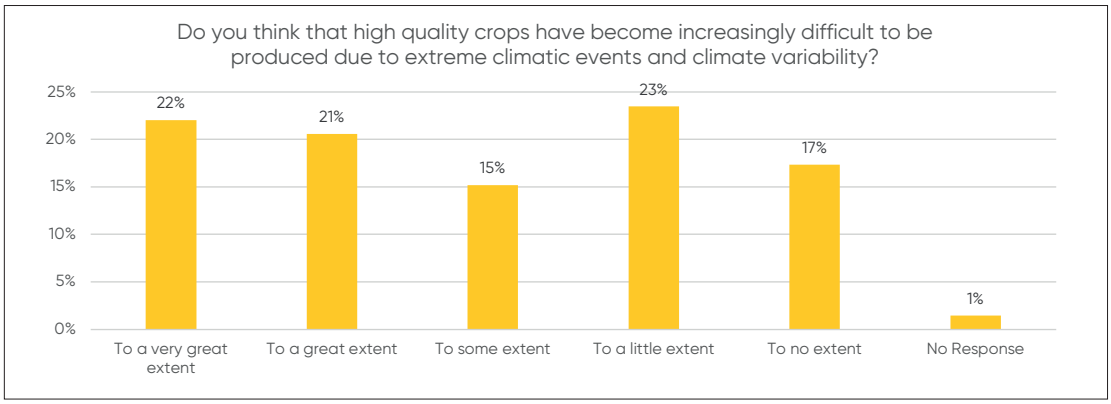


Figure 59: Impact of climate change on quality of crops

Key Reasons for Reduced Crop Production and Farm Income

Questions	Response
Does drought damage your crops production and agricultural income? If yes, then how	The general consensus was that unexpected extreme weather events like drought were one of the factors that led to reduced yield, which resulted in significant reduction in farm income. As many farmers are dependent upon rainfall and tube well for water, increased number of days without precipitation causes problems for irrigation, thus reducing the overall productivity.

Questions	Response
Does flood and sea erosion damage your livelihoods and agricultural sector? If yes, then how does it affect?	The rainfall pattern has changed significantly; the number of rainy days has decreased but the amount of rain has increased. This results in higher quantum of water reaching the fields in a quick succession causing water logging and flood-like situation. This has led to increased diseases in crops. Many farmers have registered that due to excess water, plants are catching diseases easily, causing crop damage. Heavy water logging is also a reason for poor soil quality, as mentioned by some of the respondents.
Do extreme temperatures and heat waves influence your agriculture field? If yes, then how it affects production?	Heat waves were reported to be particularly damaging to the crops. The number of days with extreme temperature has increased significantly leading to crop failure as most of the crops do not flourish in such high temperature and extreme conditions.
Has the soughing or harvest timing changed over the past 10 years due to weather and climate changes?	>200 respondents from 277 farming households (73%) reported change in the timing of farming. The time for soughing and harvesting has seen a delay due to erratic rainfall in the recent years.
Have you changed the crop type over the past few years due to reduced production and/or degrading quality of produce?	Some farmers have changed the crops to cope up with the climatic changes. 180 respondents out of 277 farming households (65%) reported that they had to change the crop in order to increase the farm production and income. They specifically reported the declining quality of crops and crop failure as one of the reasons for changing the crop type.

Farmers perception on adaptation responses towards climate change

Local communities have been affected with various climatic and natural changes eventually resulting in decline in the socioeconomic status of the communities. This section presents the finds of various adaptive measures taken by local communities, barriers, and their perception about climate change adaptation.

Adaptation measures applied by the local communities	Taking up crop insurance for when the crops fails. Make use of Government subsidies for reducing the cost of farming. Changes were made in the crops selection by selecting resilient crops, which can withstand the climatic changes. To protect the crops from saline winds, the locals plant coconut tree barriers and cover the crops with clothes like saree. Some try to change the crops to more resilient species, which can withstand the climatic changes. Implement agroforestry and intercropping to address the declining production. Use traditional techniques for soil and pest management and organic farming to reduce the cost of production.
Details of financial assistance taken by the locals	Major financial assistance came in the form of • Crop insurances • Government subsidies

Suggestion on additional initiatives to build resilience to climate change within the livelihoods of the village	Major problems are flooding, water logging, heatwaves, a greater number of dry days and salinity ingress. There is a need for implementing watershed management strategies, building bio-barriers from mangroves and Sharu trees to check salinity ingress and implementing flood control measures. Training and capacity building of the locals on latest technology, natural farming methods, and resilience. Awareness on schemes and other financial instruments. Adopting natural farming to reduce input cost and increase farm income. Provide local alternative sustainable livelihood options to diversify income sources for the local communities.

Constraints to climate change adaptation

Responses were recorded on the major constraints faced by the local communities in implementing adaptation measures. There is a lack of information regarding adaptation techniques and how to implement them. About 86% of the respondents felt that there is a need for more knowledge sharing and capacity building to better implement the adaptation measures.

As agriculture is the main source of livelihood for most of the respondents, agriculture insurance played an important part in their adaptation strategies. 63% of the respondents felt that better accessibility to agriculture insurance and ease in process will highly influence their adaptive capacity.

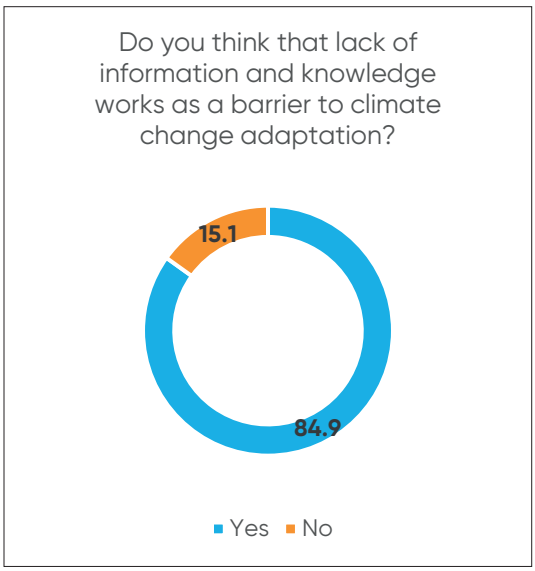


Figure 60: Lack of information a barrier to climate change adaptation

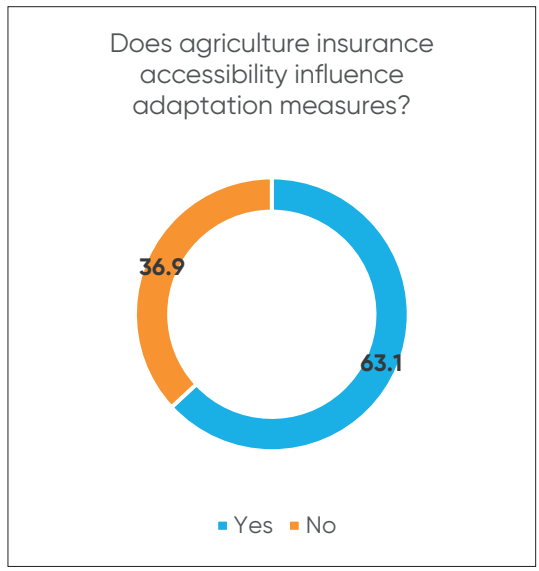


Figure 61: Does agriculture insurance accessibility influence adaptation measures?

Locals have been using various tools of information like mobile, TV, radio for knowledge building and believes that it plays a major role in capacity building towards climate change. Such IT-based devices are often used for finding about new technologies and government

schemes, which are then implemented by the locals. Over 81% of the respondents said that the information received through such devices highly influence their decision making regarding adaptation strategies.

There was a mixed response regarding the availability of support from local authorities, government agencies, and other organizations for adaptation support. While many believed that suitable support is available (54.7% of the respondents), about 45% of the respondents said that there is a lack of support from such organizations.

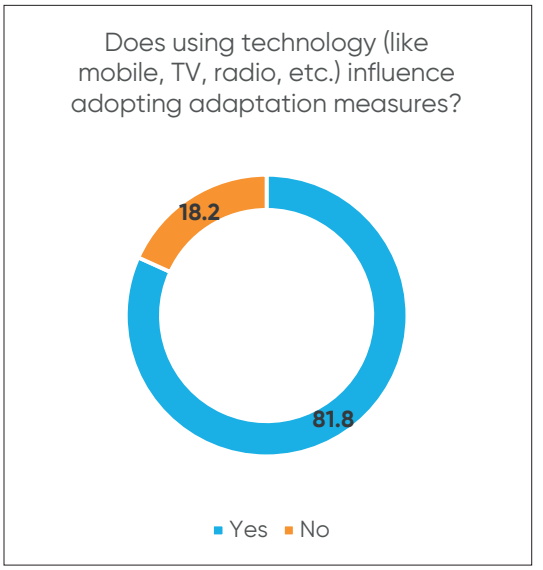


Figure 62: Is suitable support available from the Government/ NGO/others for adopting adaptation

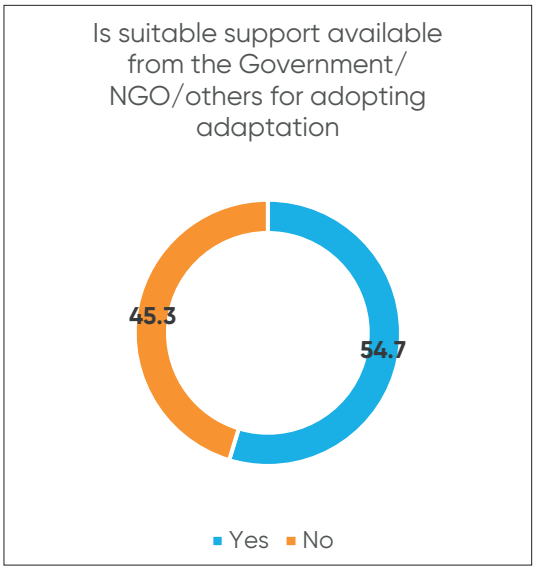


Figure 63: Does using technology (like mobile, TV, and radio) influence adopting adaptation measures?

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OBSERVATIONS AND INTERPRETATION

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OBSERVATIONS AND INTERPRETATION

Interaction with the local communities has given some interesting insights on the vulnerability of the people living in the coastal villages of Porbandar district. The most important characteristic of the rural settlement is its affinity towards natural parameters such as ecosystem and climate, as most people living in rural areas are predominantly dependent on agriculture and allied sector as their primary source of livelihood.

Driver	Changing climate patterns
Pressure	Increasing salinity in soil and water
	Extreme heat
	Strong winds
	Erratic rainfall
Status	Reduced soil fertility
	Reduced crop produce
	Increased crop–pest incidence
	Reduced fish quantity and low quality
	Increased instances of flood, drought, and storm surge
Impact	Reduced farm income
	Reduced fisheries income
	Damage to life and infrastructure during disasters

The table above summarizes and lists some of the drivers, pressures, status, and impact. This study focused to understand these parameters and recommend the most appropriate response mechanisms.

Agriculture is a sector that needs healthy environmental conditions to flourish and it is completely dependent upon the climatic parameters for efficient production. Climatic parameters are a few such variables that are not under the control of human beings, hence the human system needs to make adjustments according to the climatic behaviour and changes.

Additionally, biodiversity is impacted by climate and weather conditions, both in the long term and in day-to-day functioning. Life perpetuates in suitable climatic conditions. Climatic variability, a natural phenomenon, has played a significant role in shaping current ecosystems through species redistributions, extinctions, and originations. Climate change has led to habitat alteration and thus has threatened key species due to amplified extreme weather events such as floods, heatwaves, and wildfires.

Some of the inferences that we draw from the primary and secondary data collected during this study are enlisted here.

A large percentage of community members are dependent on climate-dependent occupation in agriculture and allied sector

The study revealed that 73% of the respondents are engaged in agriculture and allied sector like farm labour, dairy, and cattle raising as their primary source of income. This means that most of the population is directly or indirectly exposed to the negative effects of climate change. The study further reveals that 32% of the respondents were directly engaged in farming, 30% of the respondents were working in the farm as cultivator, harvester or other farm-related labour work, and 11% of the respondents were engaged in dairy-related activities for their main source of income.

Only two villages, Navibandar and Madhavpur, are engaged in fisheries-related activities as their primary source of income. 90% of the respondents from Navibandar and 13% of the respondents are engaged in fisheries as their main occupation. The study area being a coastal region, it is an interesting finding that 8 out of 10 villages have zero respondents who are engaged in fisheries or other coastal resources for livelihood.

Most of the respondents (73%) have mentioned that they use some form of artificial irrigation sources such as bore well or canal water for irrigation. This indicates that the rainfall pattern in the area is suitable for taking a rain-fed crop forcing them to be dependent upon artificial irrigation sources. This also gives an insight into the soil condition; for instance, increasing need for irrigation is an indicator of poor soil health. The reason for this can be the practice of crop residue burning.

72% of the respondents have said that they practise crop residue burning. This is a very destructive practice when soil health is considered. Conserving soil health is the most important part of sustainable farming practice, which is ignored in the villages. This may be one of the most important indicators for the financial difficulties that are faced by the local communities.

Overall impact is a decline in the net production of the farm produce. Irregularities have been found in the cropping pattern due to extreme conditions of climatic changes and degrading soil condition due to salinity ingress. This has resulted in the decline of economic conditions of the local residents.

Majority of the respondents were from lower-income household, suggesting an inefficient set-up for income generation. 32% of the respondents were from lower-income households with an annual income of INR 40,000–70,000 and 53% of the respondents were from lower- middle-income households with an annual income of INR 1,00,000–1,30,000.

Locals are impacted by climate change and climate-induced disaster collectively

The local conditions were heavily dependent upon the natural resources for their sustenance. With degrading environmental conditions and added pressure of climate change, the locals are facing major problems..

Observations of past 25 years suggest that there is an increase in rainfall, temperature, floods, cyclone, storm surges, and salinity ingress. These are the main parameters that have caused major problems for the local communities. Some of the major impacts are discussed below.

- Due to high heat, problems have arisen for people working in mines, due to which the incidence of skin and lung diseases has increased.
- Animal disease, crop disease, etc. are seen in the village due to heat.
- Floods cause massive loss of life and livestock. Villagers demand construction of dam for agriculture.
- Fields remain waterlogged due to heavy rains so that farmers can grow only one crop throughout the year.
- People living in low-lying areas have a lot of difficulty in commuting and going to school in monsoon. People living in *kachcha* houses demand *pakka* houses. In such a situation, there is a negative effect on business and employment.
- Animals also suffer in monsoons. As there is no safe place to keep animals, they die due to lightning. When it rains heavily, animals get stressed. They die of electric shock due to exposed electrical wires.

Fish catch and healthy fish out of the extracted lot have declined – fisheries

Local fishing communities are observing a steep decline in the quality and quantity of fishes in the ocean.

The main occupation of the people of Navibandar village is fishing and small industries run on it. For 7 months, the fishermen find it difficult to take their boats to the sea due to sand dunes. At Navibandar village, Bhadar River forms delta with Arabian sea. During monsoon, water of Bhadar River brings heavy mud that gets collected near seashore of the village.

Meteorological information is an important parameter as most locals regularly need weather updates

Almost 87% of the respondents have said that they regularly need weather updates. Mobile phone, TV, and Radio are the most important tools that are used for taking weather information.

The study also revealed that the use of such IT-based devices is crucial for any adaptation strategy.

Communities are coming up with local solutions to address the issue of climate change

Crop insurance and Government subsidies remain the most important mechanisms, which give the safety net for the locals with respect to ensuring proper returns from the farm.

Changes like organic farming, traditional techniques for soil conservation and pest control, intercropping and selection of resilient species were implemented by locals.

To protect the crops from saline winds, the locals plant barriers of Sharu and Pilu trees and cover the crops with clothes like saree.

Alternative livelihood methods are also used by the locals to compensate the income loss due to climate change

People earn by making plates and bowls from the leaves and making broom, mats, and other items from coconut leaves.

Some species of flora and fauna have disappeared from the area

Some species of flora and fauna are not found in the area anymore. These include:

- Jackal (*Siyar*)
- Fox (*Lomdi*)
- Hyena (*Jarak*)
- Badger (*Vinj*)
- Porcupine (*Sedhadi*)
- Vulture
- Parrot
- Crow
- Khera

Biodiversity can be used to build resilience of communities

Through secondary and primary research, it has come to the fore that biodiversity can be used for building resilience of communities to climate change in two ways: (i) Physical defence to climate-change-induced disasters like storms and (ii) Biodiversity-based livelihood including fruit-bearing trees.

Coastal ecosystems are especially good at storing carbon because of the thick, rich layers of soil they build up. In most forests, when trees die, they release their carbon back into the atmosphere. However, in many coastal ecosystems, when plants die, they do not fully break down, and their carbon can stay trapped in water-logged soils for thousands of years. In fact, mangroves store three to five times as much carbon per acre as other tropical forests. Coastal wetlands can also store carbon that comes from other ecosystems, by filtering out carbon-rich sediments suspended in river water as it flows out to sea. As coastal ecosystems are such potent 'carbon sinks', the loss of these habitats is an important driver of climate change (Donato et al., 2011).

Unlike terrestrial soils, the sediments of marine ecosystems are largely anaerobic (without oxygen). This means that the carbon incorporated into the sediments decomposes slowly and it takes a long time until it is eventually released back to the water as carbon dioxide.

If sediment continuously accumulates, organic matter can be sequestered over geological timescales. The carbon found in coastal sediments is often thousands of years old.

In fact, these coastal habitats are actually one of our best ways to protect coastal communities from climate change. During hurricanes and other storms, high winds can push walls of water towards shore. Coastal habitats absorb energy from incoming waves and slow down these storm surges. As sea levels rise and hurricanes become stronger, we will need this protection more than ever (Duarte, Losada, Hendriks, Mazarrasa, & Marbà, 2013).

The forest department suggested plantation of the following species of plants: *Avicennia marina* (Mangrove), *Casuarina equisetifolia* (Saru), *Salvadora persica* (Pilu), and *Ravan tad*. The department suggested to use these species as multi-layer natural defence against saline wind.

CO-BENEFITS OF COASTAL PROTECTION AND RESTORATION

- Biodiversity: Healthy coastlines host biodiverse ecosystems.
- Water quality: Wetlands and coastal vegetation can filter water, take up nutrients, enhance the water quality, and produce oxygen.
- Ocean acidification: Coastal vegetation can locally alleviate low pH conditions, thereby representing a possible tool to mitigate the consequences of ocean acidification.
- Food security: Coastal ecosystems are breeding grounds for commercially important fish species.
- Recreation and tourism: Coasts provide attractive settings for outdoor activities.

Source: (Baltic Sea Centre, 2021)

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~ RECOMMENDATIONS ~

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RECOMMENDATIONS

The study has brought the issues being faced by the coastal communities in Porbandar to the fore. There are some emerging risks in addition to the already realized impacts of climate change and climate-induced disasters. The adverse impacts on fisheries, agriculture, biodiversity, soil quality, ground water quality and quantity have triggered impacts on life and livelihoods. Though the situation seems grim, and risks are aggravating every year, there are certain indigenous measures that have been practised by communities to build resilience to such risks. This chapter highlights such indigenous practices that can be replicated and scaled up with suitable technical and financial support. At the same time, the chapter also discusses good practices implemented elsewhere in coastal areas that can be tested and adopted in Porbandar and adjoining areas.

Indigenous practices in Gujarat

This section highlights the community-based resilience building strategies employed in Gujarat.

Water Availability

Problem Statement

- Major barrier for water sustainability in the community are the increasing occurrences of floods or excessive water accumulation in a short time due to erratic rainfall pattern.
- The number of days with maximum temperature is increasing along with the increasing events of heatwaves. The number of dry days has increased. This has resulted in inadequate water availability.
- Water scarcity for irrigation is especially affected and as agriculture is the most important source of livelihood, the communities are very much vulnerable to the impact of climate change.

Strategies

Watershed Management: Watershed management is a concept that recognizes the judicious management of soil, water and vegetation (the three basic resources) on watershed basis, for achieving particular objective for the well-being of the people. It includes treatment of land through most suitable biological and engineering measures. Through systematic land work and terrain management, the rain water can be controlled and channelized for intended purpose. Watershed management will help solve the problem of floods and water storage.

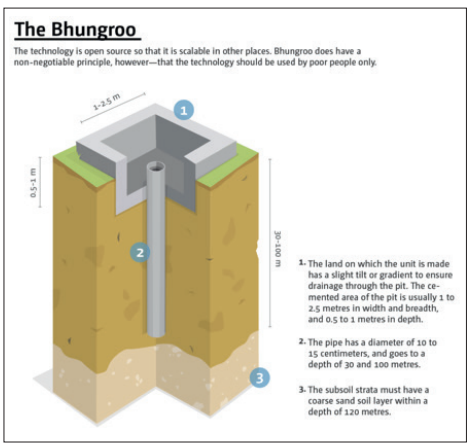

Figure 64: Vertical Section of Bhungroo Design

Bhungroo: Bhungroo is a traditional technique used for restoring ground water during monsoon. Bhungroo means 'Straw', which is traditionally used to draw excess of water from water logging into the depth of the grounds. This tech-

nique not only provides solution to water logging but also restores ground water levels. (Source: Naireeta Services, n.d.).

Mulching: The practice of crop residue burning is a major cause for decline in soil health. Air pollution and carbon emissions add to the problems. It reduces the water-holding capacity of soil and increases the water loss. A simple practice of mulching will significantly reduce the water demand in the field. Mulching will also solve many of the soil nutrition problems.

Figure 65: Mulching from crop residue

Holiya Technique for Controlling Water Logging and Salinity: The Holiya technique is widely used in Patan and Banaskantha regions, where issues of salinity and flooding are prevalent due to clayey soil. By diverting flood water for aquifer recharge, holiya helps prevent damage to the crops and enhances water availability during the Rabi season. Farmers have reported about 20–25 percent increase in production due to enhanced drought resilience with this method. In the current climate context, holiya can provide a simple solution to farmers in the region, to simultaneously address the challenges of salinity, flooding, and drought.

Under this technique, a recharge well of about 9–12 metres deep is installed in a lower part of the farm. A pipe with perforations at one end is inserted into this well through which water can flow down recharging the groundwater. The upper end of the pipe is housed in a square-shaped concrete collection pit with sides of one metre or less (Climate Change Department, 2022).

Figure 66: Holiya structure built by locals

Salinity Ingress

Problem Statement

The problem of salinity has been observed across the coastal belt of Gujarat. There are many ways the salt travels through air and water to the mainland from the coastal areas, causing conditions that are not suitable for growing crops and often damaging the standing crops.

Strategies

Bio-shield made of a combination of Mangroves and Sharu (*Casuarina equisetifolia*) is the best strategy for the local conditions. Mangroves can provide a barrier to salinity ingress from tides and storm surges during cyclone. Creating a mangrove ecosystem can also provide a source of income.

Dense plantation of Sharu adjoining the Mangrove will create a shield against saline wind. Plantation of Sharu can also be done on the borders of the field. Casuarina is a type of pine tree, which grows easily in saline conditions (Orwa, et. al, 2009).

Agriculture

Problem Statement

Climatic stress is resulting in the decline of crop yield and the quality of production.

The cost of agriculture is increasing, which is adversely affecting the farm income.

Strategies

Strengthening the Agro-ecosystem through Natural Farming: The natural farming techniques by famous Mr Subhas Palikar is a proven way to amplify the organic cycles, which

Figure 67: Border made of Sharu trees

are essential for nutrition management and providing a suitable growing environment. This holistic approach will not only reduce the cost of farming significantly but also build resilience towards climate change (CEEW, 2018).

Changes in Crop Selection: To address the decline in traditional crops, new crops can be introduced. Such interventions have been fruitful in many regions. For example, farmers have started growing Dragon Fruit, an exotic fruit, in the Kutch region.

Green Hedge: The hedge is made up of shady trees, along with creepers, shrubs, and bushes, with or without thorns. They seem to naturally form a green wall, which protects the farm from raiding animals or free grazing livestock. Several wildly growing creepers or

Figure 68: Green hedge in a traditional farm

vines occur naturally in the hedges, such as Kharkhodi, Samardudheli, Kankodi, Fanj, and Kanska. It prevents soil erosion and protects the dikes. It provides dry wood for fuel at home, fodder for animals, and edible fruits and vegetables for the family. Besides, the trees provide wood, which can be used for many purposes including handles of small agricultural tools like axe, spade, and fork. The leaves, fruit, root and even bark of some trees have medicinal properties and, thus economic value. With value addition, they can become a secondary source of income. The green hedge also helps maintain the temperature levels in the field by becoming a barrier to hot winds. It attracts birds who act as natural pest controllers and pollinators, which help in increasing the farm productivity (Climate Change Department, 2022).

Mixed Cropping: Mixed cropping helps farmers fight the uncertainty of drought or floods and heavy rains. It keeps the soil healthy and the crops pest-free without using chemical pesticides. Besides, when different crops are grown together, the nutrients are shared and the plants thrive well. Mixed farming also gives farmers access to a rich variety of food to fulfil their nutritional requirements. Usually, a mix of cereals and pulses and sometimes millets and vegetables is grown. Crop diversity prevents farmers from going hungry and serves as a risk-mitigating measure in the context of excessive dependence on rainfall for agriculture. Groundnut and cotton, wheat and chickpea or cumin and castor are a few examples of mixed crop systems seen in Gujarat.

Cultivation of Babapuri Bajro: Babapuri bajro is a tall, mature plant that grows to about 8 –12 feet in height and its biomass is a highly palatable cattle feed. Being a millet, it grows on very less inputs and gives grains for human consumption and high biomass production can be used for mulching the field and cattle feed.

Figure 69: Babapur bajro crop

Cultivation of Bhalia Wheat: Bhalia wheat is long-grained and is around one and a half times longer in length than the other varieties. It is rich in protein and gluten (a type of amino acid) and has a high amount of carotene. Its water absorption is low. This has been cultivated in the black soil of Bhal and some coastal areas for centuries without irrigation, using only conserved soil moisture. The farmers construct a bund of 45–60 cm in height around the field to store the rain water received during the monsoon. After the monsoon, the land is furrowed using bullocks to maintain soil compaction. This process is repeated to form a fine layer of soil called penh, which acts as a soil mulch. The sowing takes place during October and November. The crop does not receive either rain water or irrigation after sowing but sustains itself on the moisture present in the soil and winter dew.

Vadoliya (Kitchen Garden): Farmers have a tradition of setting aside a small area of their field for cultivating plants other than the main crop, such as vegetables, flowers, medicinal plants, and fruits. How much area would be spared for this depends on such factors as family size, availability of land, and inclination. Plants in Vadoliya, besides fulfilling the

Figure 70: Vadoliya (Kitchen Garden) in traditional rural set-up

needs of vegetables, fruits, flowers, and medicinal plants, enhances the farm's aesthetics. Organic waste, dung and waste water can be put to use in this cultivation. As the produce from vadoliya is mainly for self-consumption, farmers prefer to grow native species, which are sturdier and require little or no pesticides. This also helps conserve native seed varieties that are slowly disappearing in the market-dominated cultivation system.

Livelihood

Problem Statement

Most people are engaged in livelihood activities that are directly affected by climate change. Hence there is a need for diversification in livelihoods, which will provide increased sustainable returns to the locals.

Strategies

Value Added Products: By introducing processing in farm products, the farmers can increase the return on their produce. This can be as simple as grading and packaging. Establish set-ups for value addition like mini oil mills, pickle-making unit, jam, grading and packing, etc. for higher returns.

Nutraceuticals: Nutraceuticals is an emerging area of market with great potential for small-scale enterprise. Powder made from Moringa and Spirulina (blue-green algae) are consumed by many for their health and nutrient benefits.

Eco-friendly Products: Making products like dishes, bowls, carpets, bags from local tree and plants is a great source of livelihood. Such products can fetch good price in urban markets, especially during exhibitions and fairs.

Setting up Enterprise: By developing a cooperative or a small unit, farmers can act as a big unit and take part in commercial trade giving them a better position in market. Operating as an enterprise will also help them with many other forms of financial assistance.

Fishing

Problem Statement

Quantity of fish along the shore is decreasing due to climatic variations and ecological degradation due to pollution and over fishing.

This has increased the number of days fishermen have to explore the sea to catch the required quantity of fish.

Strategies

Malam ni Pothi - Pre-Modern Kutchi Navigation Techniques and Voyages: The captain or the navigator of a ship was called Malam. Malams mapped and coded their knowledge of the sea, wind, current patterns and swells, and also documented the sea route charts in Gujarati manuscripts called Pothis. These Pothis were a record of knowledge gathered during the voyages and were closely guarded, and passed on from one Malam to another, each adding to the spectrum of this knowledge (Climate Change Department, 2022).

Pagadiya – A Traditional Fishing Technique: Over the last 400 years, a group of migrants called Pagadiyas have been practising a unique technique of fishing barefoot (pag means foot) in the intertidal areas without the use of boats. The Pagadiya fishers venture into the intertidal area during the low tide and place their nets on sticks planted into the mud. During high tide, the incoming water covers their nets and brings a variety of fish, prawns, and crabs from the gulf to this intertidal zone. When the water recedes during the next low tide, these fish get caught in the nets. The Pagadiyas wade into the water and collect the fish thus caught. The mesh size of the net is such that the small fish and fingerlings pass through, thus leaving some of the reproductive stock for the next season. Other techniques are also used like placing the net in a 'V' shape, with the mouth of the 'V' towards the landward side, to ensure that only large fish are caught.

This fishing activity is carried out for about eight to nine months in a year. Men, women, and even children are involved in fisheries activities ranging from capturing, transporting, sorting, sun drying, salting, packing, marketing, and sales. They use donkeys and mules for the transportation.

The Pagadiya traditional fishing method is a case of the sustainable use of marine resources in the intertidal region and the application of the people's knowledge of tides and intertidal shelf, without the use of any technology or modern fishing tools (Climate Change Department, 2022).

Best Practice Recommendations for Resilience building

Overview

Traditionally, engineered structures have been considered to be the only defence mechanism against hazards prevalent in coastal areas such as cyclones, flooding, landslides, droughts, storm surges, and sea-level rise. However, it has now been realized that engineered structures have certain limitations such as the ones listed below.

1. Conventional, concrete-based coastal defence structures are not able to adapt to and compensate for sea-level rise and, therefore, need to be regularly maintained and reinforced.
2. Such structures tend to cause unwanted erosion in other locations.

Coastal dynamics can be rapidly altered through inappropriate coastal engineering projects, for example, the damming of rivers, which create new hazards elsewhere. Shore structures need to be designed so that they allow longshore sediment transport, and dams on rivers should be carefully planned to reduce their impact on sediment flows to coastal mangrove areas (see Spalding et al., 2014, for more information).

On the other hand, nature-based solutions like mangroves are better able to keep up with sea-level rise in areas with high rates of sediment flows, provide vital habitat for species and store carbon. We can achieve better climate and environmental resilience through ecological engineering. Any kind of solutions planned should aim to improve all three aspects – Life and livelihoods, natural environment, and reduction in climate change.

Figure 71: Seawall on a beach in Kerala, India
Source: Sundar & Murli, 2007

Unintended Consequences of Hydraulic Infrastructures

The Mahanadi delta in Odisha, India, is home to millions of farmers and fishers who used to benefit from the dynamic and nutrient-rich floods within the landscape. The wetlands in the delta formerly served the important function of buffering excess flood waters and acted as water reservoirs during dry periods. However, many of these areas have been degraded or reclaimed for agriculture and settlements, thus interrupting and fragmenting the natural water flows and putting additional pressure on the ecosystem. This, alongside a changing climate, has resulted in increased floods downstream and more droughts upstream.

Hard infrastructure that was built as a short-term solution for flood defence has disrupted the natural linkages between wetlands and water. The delta is now marked with persistent water logging, low agricultural productivity, loss of migratory fisheries, declining incomes, social conflicts, migration, and health hazards due to limited availability of safe drinking water and sanitation. Due to climate change, rainfall patterns have altered, and extreme hydrological events are more frequent. This makes the life and livelihoods of communities even more vulnerable to flooding.

For more please visit: https://www.wetlands.org/casestudy/towards-vibrant-wetlands-maha-nadi-delta-kosi-gandak-floodplains-indian/ (accessed on date??)

In coastal areas, 'hard' infrastructure solutions alone are not successful in achieving results for resilience. Due to unplanned urbanization, coastal soils are eroding and subsiding, while sea levels rise and salt water intrudes onto agricultural lands. In many developed countries, previous grey infrastructural solutions to DRR are being combined with or changed for blue and green solutions. For example, many rivers that were canalized to reduce flooding in the last century are now being restored to their natural form, and in other cases, dams and levees are being taken down and floodplains revived to improve flood management (Département du territoire, 2009; Partners of the Restore Project, 2013; Logar et al., 2019; see case study 2.8 'Building with nature').

Figure 72:
Three-pronged target of resilience approaches

Land subsidence in north coast Java, Indonesia

Land subsidence occurs when water is extracted from the earth's crust, lowering the land surface potentially to even below river or sea level, leading to increased risks of disasters, like flooding. Indonesian coastal lowlands – estimated to cover a total of 30 million hectares with mangroves, peatlands, river estuaries and lagoons, which are – are mostly situated at around 30 metres above sea level. Drainage and conversion of these wetlands for housing, fishponds, plantations, and industrial development, along with the massive extraction of ground water, are among the main causes of land subsidence in Indonesian coastal lowlands.

In Demak, in north-central Indonesia, the root causes of coastal erosion problems were addressed by rehabilitating a mangrove greenbelt. First, the sediment balance was restored by using temporary permeable structures to create sheltered zones, thereby facilitating accretion of suspended sediments. The permeable structures stopped the erosion, which is a big gain for the villagers and promising for other villages along northern Java's shorelines, where millions of people face similar coastal erosion problems.

For more information, please visit: https://www.wetlands.org/news/first-national-workshop-held-indonesia-address-land-subsidence-problems/

As the World Bank states in its 2019 report **Putting Nature to Work: Integrating Green and Gray Infrastructure for Water Security and Climate Resilience:** '21st century challenges require innovative solutions and utilizing all the tools at our disposal. Integrating 'green' natural systems, like forests, wetlands and flood plains, into 'grey' infrastructure systems shows how nature can lie at the heart of sustainable development.' (Browder et al., 2019).

IUCN defines **Nature-based Solutions (NbS)** as: 'Actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (Cohen-Shacham et al., 2016; IUCN Resolution WCC2016-Res-069). The EC, in turn, defines NbS as: 'Solutions that aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or borrowed from nature, using and enhancing existing solutions to challenges as well as exploring more novel solutions. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, in order to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth" (EC, 2015).

NBS
Landscape restoration
Wetland restoration
Climate smart agriculture/ agroforestry
Urban greening
Sustainable land management
Integrated water resource management
Integrated coastal zone management
Blue-Green Infrastructure (BGI)
Protecting People & Livelihoods

Ecosystem-based approaches are encompassed within the NbS umbrella concept. These approaches aim to manage land, water, sea and living resources in a way that promotes conservation and sustainable use in a holistic and equitable way. The NbS concept is based on a scientific understanding of the interconnectedness of

nature and people, and prizes biodiversity and functioning ecosystems and their services (supporting, regulating, provisioning and cultural) within the landscape/seascape. Thus, management that goes contrary to biodiversity and natural processes, such as planting monocultures or intensive farming, is not considered an ecosystem-based approach, and thus does not qualify as sound/effective NbS.

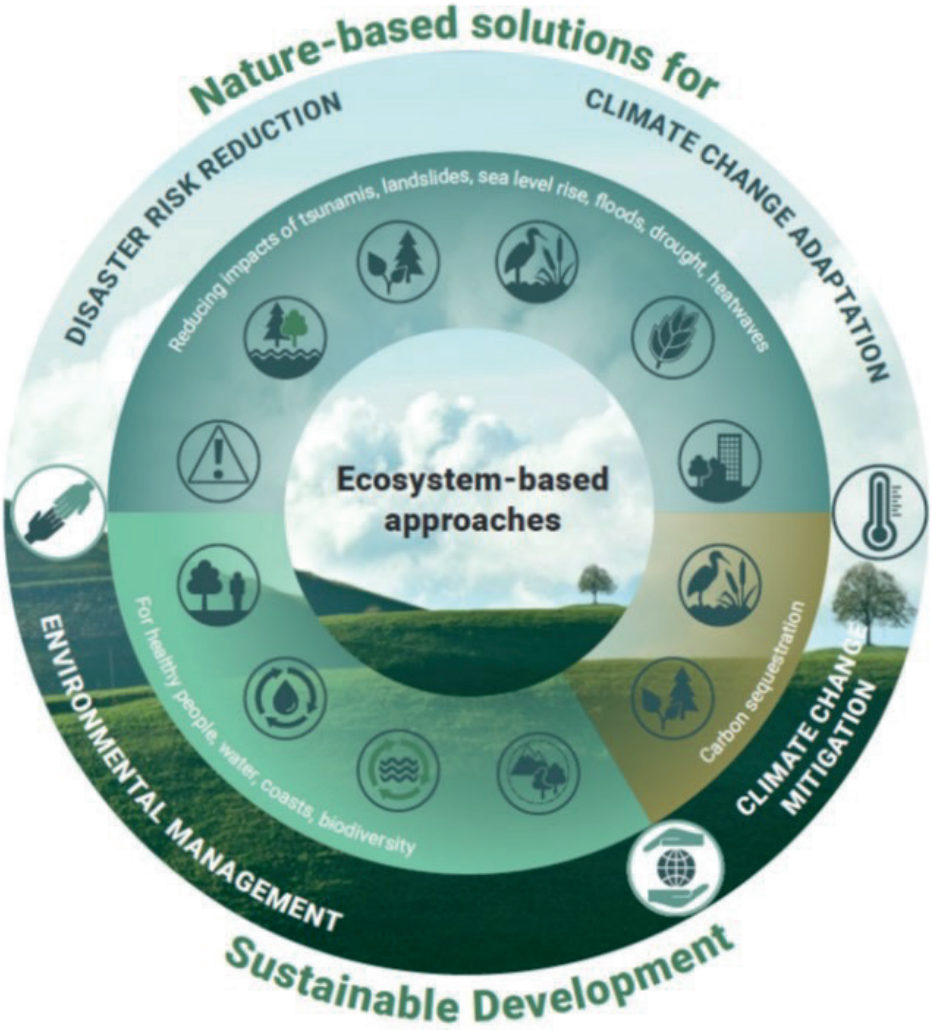

Figure 73: Ecosystem-based approach for climate risk resilience

Sustainable Land Management (SLM)

SLM was defined by the UN 1992 Rio Earth Summit as 'the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions.'[2] It includes management practices in agriculture and forestry aiming at sustaining ecosystem services and livelihoods. SLM

[2] https://knowledge.unccd.int/topics/sustainable-land-management-slm

practices have already been adapted, tried and tested to reduce the expansion of dryland areas and erosion on slopes. For example, the World Overview of Conservation Approaches and Technologies (WOCAT), a global network on SLM, has developed a global database on sustainable land management practices that are currently practised around the world.[3]

Target 15.3 of the SDGs bears on sustainable land management with its aim to achieve 'land degradation neutrality' (LDN)[4] worldwide by 2030.

Integrated Water Resources Management (IWRM)

IWRM is a cross-disciplinary coordination and governance process to manage water, land, and related resources to maximize economic and social welfare while ensuring ecosystem sustainability (Renaud et al., 2013; Sudmeier-Rieux, 2013). Ensuring stakeholder participation in this process is crucial and is often undertaken in water committees. IWRM is also one of the most common approaches to dealing with climate change adaptation and disaster risk reduction because it is often used to control flood peaks and ensure a water reserve for drought periods (Sudmeier-Rieux et al., 2019).

Mainstreaming Eco-DRR into IWRM is particularly relevant (Sebesvari et al., 2017), including the use of ecosystems to improve catchment and watershed management and their sustainable management (Renaud et al., 2013). Conserving and enhancing the natural characteristics of water-dependent ecosystems increase their ability to retain water. This, in turn, minimizes water-related risks, such as floods or droughts (Taramelli et al., 2019).

Making use of institutional frameworks for IWRM implementation (such as the UN Economic Commission for Europe's (UNECE) 'model provision on transboundary flood management'15) is a quick way of operationalizing parts of DRR strategies (UNDRR, 2018). The case study of the Lukaya Basin, Democratic Republic of the Congo (DRC) illustrates how Eco-DRR can be applied in IWRM.

Integrated Coastal Zone Management (ICZM)

ICZM is a multi-disciplinary approach to manage coastal zones. It includes land use planning, marine spatial planning, resource management and, often, community involvement. Coastal zones are among the most productive areas in the world and often host a high concentration of people, economic assets and biodiversity (Renaud et al., 2013; EC, 2019). **Under increasing coastal disaster risk (Duxbury and Dickinson, 2007; Renaud et al., 2013), it is important to maintain the environmental status and biodiversity of areas upon which the viability of coastal zones depend.**

ICZM provides a framework for the sustainable management and development of coastal zones and resources, which ensures the continued functions and services of the eco-

[3] https://www.wocat.net/en/global-slm-database

[4] *The United Nations Convention to Combat Desertification (UNCCD) adopted LDN as the principle target of the Convention at COP12, in October 2015*

Applying Eco-DRR in IWRM in the Lukaya Basin, DRC – UNEP

In the Lukaya river basin of the Democratic Republic of Congo, UNEP worked with government and community partners to promote ecosystem-based measures, such as revegetation on degraded slopes, to mitigate hazards, namely gully erosion and floods, and address ecosystem degradation, which is a driver of disaster risk in the basin. It also ensured more diversified local livelihoods and augmented household incomes and established local risk monitoring systems. Central to the work was bringing different stakeholders together in a planning process (IWRM), which openly recognized the multiple and conflicting priorities for water and land use and to work towards a shared development vision for the Lukaya basin. This process generated an action plan implemented by the Association of the Users of the Lukaya River Basin. Women, as community leaders, farmers, and income earners, demonstrated high interest and showed strong engagement throughout the project. Several women in local leadership positions played an influential role in Eco-DRR activities.

system (Renaud et al., 2013; Sudmeier-Rieux, 2013). ICZM is a process and instrument which allows addressing coastal risks in a holistic manner by using a multi-stakeholder and multi-sectoral approach (Schernewski, 2002; PEDRR, 2010). It is an effective way to strengthen coastal resilience and strongly encouraged by the Global Platform for Disaster Risk Reduction.[5]

The main goals of ICZM, as identified by Thia-Eng (1993), are to:

- maintain functional integrity of coastal resource systems;
- reduce conflicts on resource use;
- maintain a healthy environment; and
- facilitate multi-sectoral development (Whelchel et al., 2018).

This is achieved using a range of instruments, such as **ecosystem-based measures** (sand dunes, coastal wetlands, coastal forests, coral reefs, etc.) and non-structural measures (regulatory frameworks, plans, economic instruments, awareness raising, etc.), making ICZM an integrated approach to addressing risk (Renaud et al., 2013).

ICZM covers the full cycle of information collection, planning, decision-making, management and monitoring of implementation (EC, 2019b), with proper considerations of spatial and temporal scales (Ruppercht Consult, 2006). Combining ICZM and IWRM is a powerful integrated approach that has also been labelled 'ridge-to-reef' (mountain to sea) which has been used as a technique for Eco-DRR.

Disaster risk reduction and climate change adaptation

Ecosystem-based disaster risk reduction (Eco-DRR) and ecosystem-based adaptation (EbA) are related approaches (see Doswald and Estrella, 2015) and can also be thought of

[5] https://www.preventionweb.net/files/53439_thecancunhighlevelcommuniquof24may2.pdf

Water as Leverage: multi-stakeholder and holistic approaches to address coastal flooding in Semarang – Wetlands International

Like many coastal cities across Southeast Asia, Semarang (Java, Indonesia) faces an uncertain future. The city has experienced coastal flooding and will soon reach a tipping point: unsustainable water extraction is leading to aquifer depletion and land subsidence, increasing the city's vulnerability to flooding in lowland and upland areas.

As part of 'Water as Leverage for Asian Resilient Cities: Asia' (https://waterasleverage.org/), led by the Netherlands' Special Envoy for International Water Affairs, Henk Ovink, the two design teams of ONE Resilient Semarang design team, including Wetlands International, and Cascading Semarang brought their knowledge and expertise of other coastal regions worldwide together. In order to leverage existing and planned developments for coastal resilience and utilize the abundance of water, the teams embarked on developing innovative concepts to restore the city's coastal mangrove 'green belt' and other blue and green infrastructure (BGI) measures, such as 'spongy' mountain terraces, a Green Port and natural water reservoirs. These were developed through a series of local and regional workshops, where all stakeholders were involved from local communities to multilateral development banks.

In the next phase, 'Water as Leverage for Asian Resilient Cities: Asia' is developing the concepts into bankable projects for implementation in Semarang, as well as Chennai (India) and Khulna (Bangladesh).

For more information: https://www.wetlands.org/casestudy/future-proofing-cities-asia-water-leverage-resilient-cities/

as a continuum, from mitigating large-scale disasters, such as tsunamis and landslides, to adapting to different climatic conditions.

Both these techniques involve sustainable land management and conservation and restoration of ecosystems. Eco-DRR addresses climatic and non-climatic hazards, while EbA addresses climatic hazards and adaptation to long-term climatic change and its impacts.

Despite their differences, EbA and Eco-DRR have many similarities because of their shared focus on ecosystem management, restoration, and conservation to increase resilience of

EbA: The use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (CBD, 2009).

Eco-DRR: The sustainable management, conservation & restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable & resilient development (Estrella and Saalismaa, 2013).

people (or to reduce risk or reduce vulnerability). At the project/operational level, they are often indistinguishable.

Eco-DRR and EbA can mitigate the risks of negative external impacts or provide buffers against shocks through using appropriate nature-based solutions.

NbS can reduce the frequency of hazard occurrence. For example, forests can prevent landslides, which often occur due to environmental degradation in conjunction with other factors, such as heavy rainfall.

NbS can also reduce the magnitude of hazard impacts. For example, sand dunes can offer a buffer against large waves. Mangrove ecosystems stabilize coastal system protecting against coastal hazards and erosion, and adding to carbon sequestration.

NbS can help reduce animal–human conflict. Coastal ecosystems provide natural habitats for wildlife so they do not encroach on urban areas, potentially reducing the risk of diseases and pandemics in urban areas.

NbS can decrease GHG emissions and mitigate climate change as well. For example, sustainable management and restoration of tropical peatlands can prevent emissions from drainage. Healthy natural ecosystems can sequester and store greenhouse gases through conservation, restoration and sustainable management

Specific targeted ecosystem-based approaches can also be adopted such as measures for flood protection including creation of retention areas or coastal protection by artificial dunes. Hence, the paradigm for development is shifting to the notion that NbS are indispensable for ecologically and socially inclusive sustainable development that supports people to be resilient to all types of disasters. The table below shows the growing evidence base of NbS.

Author	Topic	Findings
Sudmeier et al. (accepted)	The role of ecosystems to reduce disaster risk (Eco-DRR)	There is good evidence that forest and vegetation management can reduce a variety of hazards, notably wildfires, erosion and flooding. There is good evidence that urban ecosystems and green infrastructure design (e.g. green rooftops, permeable sidewalks, constructed wetlands) are effective for attenuating urban flooding, pollution and heat waves. There is good evidence that mountain ecosystems can reduce landslides. There is medium evidence that coastal ecosystems can reduce hazards but relatively good evidence that they can stabilize shorelines and protect against storm surges. There is medium evidence of inland wetland ecosystem's role in reducing flooding. The main gaps in the literature relate to the role of ecosystems for earthquake hazards, as well as the role of dryland and agro-ecosystems in disaster risk reduction.
Sierra-Correa & Kintz (2015)	EbA for sea level rise	Actions involve integrated river basin and coastal zone management, mangrove management planning.

Author	Topic	Findings
Spalding et al. (2014)	NbS for coastal defence and DRR	Mangroves for coastal defence against waves, storm surges, tsunamis, erosion, and sea level rise. Wind and swell waves are rapidly reduced as they pass through mangroves. Wide mangrove belts can be effective in reducing the flooding impacts of storm surges occurring during major storms (cyclones, typhoons). Wide areas of mangroves can reduce tsunami heights. Mangroves can actively build up soils, which may be critical as sea level rise accelerates. If they are integrated appropriately, mangroves can contribute to risk reduction in almost every coastal setting, ranging from rural to urban and from natural to heavily degraded landscapes. Mangroves, and their coastal risk reduction function, can recover in most places where appropriate ecological and social conditions are present or restored.
Ruangpan et al. (2020)	NbS for hydro-meteorological risk reduction	Small-scale NbS (green roofs, rain gardens, rainwater harvesting, dry detention ponds, permeable pavements, bio-retention, vegetated swales and trees) can be very effective at reducing peak flows, depending on the magnitude and frequency of rainfall events. Large-scale NbS (river restoration, floodplain lowering, flood storage basins, green floodway, wetlands, sand dunes, forest preservation and restoration, mountain forestation) can reduce flood risk and provide co-benefits (biodiversity, recreation, livelihoods), but more research is needed.
Hutchinson et al. (2014)	NbS for fisheries enhancement (co-benefits of NbS)	Fish productivity from mangroves will be highest where mangrove productivity is high, where there is high freshwater input from rivers and rainfall and where mangroves are in good condition. Mangrove conservation and restoration in areas close to human populations will render the greatest return on investment with respect to enhancing fisheries.
Shepard et al. (2011)	Protective role of coastal marshes	Salt marsh vegetation reduces wave power and stabilizes the shore.

Landscape Restoration

Landscape restoration includes afforestation and revegetating land with grasses, shrubs or trees. Doing so in the context of EbA and Eco-DRR aims to curb erosion and landslides through the stabilizing effect of roots, as well as improve water filtration and water resources. Species choice is extremely important and is dependent on climatic, geological, and ecological conditions, as well as purpose (i.e., is the species needed to stabilize the slope? does it need to be a food source?). Protected areas can also be a useful tool, along with sustainable land management. Forest landscape restoration plays an important role in adaptation and mitigation by increasing climate change resilience, reducing disaster risk, and combating desertification (IUCN, 2017).

Landscape restoration can promote carbon storage and sequestration. Protecting areas and using sustainable management can also help avoid release of carbon through ecosystem loss and degradation.

Forest landscape restoration and the Bonn Challenge – A global effort

The Bonn Challenge is a global effort to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020, and 350 million hectares by 2030. The forest restoration landscape approach is the means leveraged by the Bonn Challenge to restore ecological integrity at the same time as improving human well-being through multifunctional landscapes.

Source: https://www.bonnchallenge.org/content/challenge

Wetland Restoration

This covers management activities in a very wide range of ecosystems – from freshwater to marine. In the context of EbA and Eco-DRR, the aim is to prevent or reduce the impact of flooding and drought, as well as land subsidence because of unsustainable development. **It also covers restoration and management of coastal ecosystems, such as mangroves or lagoons, to reduce the impacts of sea level rise, wave surges, cyclones, coastal erosion, saltwater intrusion and coastal flooding.**

Wetland restoration can be undertaken in different ways and can contribute to climate change mitigation. Examples of wetland restoration include, but are not limited to, increasing interconnectivity of water flows, seagrass or weed/grass coverage, mangroves or peatlands restoration, etc.

Mangroves, as coastal habitats, account for 14% of carbon sequestration by oceans. If mangrove carbon stocks are disturbed, resultant GHG emissions are very high. Studies indicate that mangroves can sequester four times more carbon than rainforests. Most of this carbon is stored in the soil beneath mangrove trees (Sanderman et al., 2018).

Mangroves for coastal defense in Viet Nam: double dividend

The Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project in Viet Nam, supported by the World Bank Group (WBG), World Resources Institute (WRI), Global Facility for DRR (GFDRR) and Global Water Security and Sanitation Partnership (GWSP), embedded nature-based solutions in its design to shift away from traditional 'hard' infrastructure towards solutions adapted to natural conditions in the Mekong Delta. The government of Viet Nam is moving strongly towards initiating climate-resilient projects that involve combinations of green and grey infrastructure, with corresponding benefits in local livelihoods. The project has restored and expanded mangroves and rehabilitated sea dikes. This has a double dividend for local communities. Firstly, it helps protect them from flooding and coastal erosion. Secondly, it offers new and innovative economic opportunities, better aligned with the subregion's natural soil and water conditions. These include promoting mangrove shrimp systems, which are less intensive, more organic, and can help farmers become internationally certified as sustainable seafood operations. This means they can fetch a premium price in the market, therefore increasing their revenues.

Source: Bowder et al. 2019.

Ecosystem Services Shared-Values Assessment (ESSVA), Odisha, India

Wetlands International South Asia used the ecosystem services shared-values assessment (ESSVA) tool in 2018 to engage with communities living around the upstream and downstream reaches of the Tampara wetland, a freshwater lake on the east coast of Odisha State, India, prone to floods, droughts, heatwaves, and cyclones. The use of the tool has led to including the community in drafting the wetland strategy and resulted in a community-led management plan.

Some examples of how the ESSVA results are used:

- To develop stakeholder-differentiated messages for participation in wetland management.
- As a monitoring tool to assess changes in preferences for ecosystem services over a period of time.
- To address disaster threats through ecosystem services within DRR plans, e.g., to include:
  (i) Provisioning services and cultural services as resilience-building measures;
  (ii) Regulating services as DRR mitigation measures.

Gaining a nuanced understanding using tools such as ESSVA is crucial to engage communities systematically in management for wise use of wetlands to reduce disaster risks for enhanced resilience.

See for more information p. 26-28 of: https://south-asia.wetlands.org/wp-content/uploads/sites/8/dlm_uploads/2019/02/Sarovar-Vol-4.pdf (accessed on date?)

Peatlands are the world's largest terrestrial organic carbon stock. GHG emissions from drained or burned peatlands are estimated to amount 5% of global carbon emissions – in the range of two billion tonnes of CO2 per year. These emissions can be reduced by preventing drainage for alternative land usages (such as oil palm plantations) and by rewetting drained peatlands and implementing alternative forms of use, such as paludiculture (Günther et al., 2020).

Conserving peatlands intact and restoring degraded peatlands will prevent the release of vast amounts of methane and nitrous-oxides and effectively result in reducing GHG emissions.

Climate Smart Agriculture/Agroforestry

According to the Food and Agriculture Organization of the United Nations (FAO), climate-smart agriculture is 'an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate.'[6] It aims at increasing productivity and incomes, building resilience, and reducing GHG emissions. One strategy to reach these goals is 'the use of trees and shrubs as part of agricultural systems', which is called agroforestry (FAO, 2013).

[6] https://www.fao.org/climate-smart-agriculture/en/

Urban Greening

Urban greening covers adding 'green' and 'blue' elements, such as trees, parks and wetlands, into the urban landscape, as well as many hybrid approaches – a combination of green/blue and grey (human engineered) infrastructure, such as green roofs, bioswales, permeable pavements and sustainable drainage systems. Urban greening helps combat urban heat island effects, in which metropolitan areas can be significantly warmer than surrounding rural areas, as a result of human activities, by cooling temperatures. It is also effective in reducing impacts from flooding.

Blue-Green Infrastructure (BGI)

UNDRR defines **green infrastructure** (GI) as a 'strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services, such as water purification, air quality, space for recreation and climate mitigation and adaptation, and management of wet weather impacts that provides many community benefits' (UNISDR, 2017). GI refers to land-based elements, such as forests and parks, some of which might be hybrid (partially engineered), such as green roofs or facades. Blue infrastructure (BI) is a relatively new concept and aims to highlight the water-based elements in the landscape. BI includes coastal areas, rivers, and lakes but also hybrid elements, such as artificial channels and urban wastewater networks (Nesshöver et al., 2017).

Blue and green infrastructure (BGI) can complement, be a substitute for engineered structures or safeguard infrastructural assets (Browder et al., 2019). A complement would be, for example, a protection forest or gabion walls to help stabilize a slope, or an urban wetland complementing a storm water system. These approaches reduce the need for engineered infrastructure. For example, having a healthy forest filtering water can substitute the need for a filtration plant (Browder et al., 2019). Safeguards protect people and assets, such as coral reefs, seagrasses and mangroves, protect the coastline.

Combining engineered structures with BGI can sometimes be an optimal mix. In addition, BGI and hybrid measures need to be implemented alongside other measures of risk reduction, including avoidance of high-risk zones and implementation of building codes and

early warning and evacuation procedures. **BGI can be used to close infrastructure access and quality gaps in a climate-resilient manner and contribute to increased environmental and climate resiliency** (IDB, 2020).

Hybrid infrastructure is blue and/or green infrastructure (BGI) combined with grey infrastructure or – ecologically engineered infrastructure made to reduce disaster risk and help develop climate resilience (Browder et al., 2019). For instance, the strategy of ecosystem restoration to reduce risk may be combined with an engineered structure to protect the natural infrastructure at its early stages when the restored ecosystem still needs to take hold (Sudmeier-Rieux et al., 2019). Similarly, natural infrastructure can protect built infrastructure and reduce the impact of hazards on grey infrastructure (Sutton-Grier et al., 2015), thereby reducing maintenance costs, supporting lifespans and enhancing the sustainability of grey infrastructure (Sebesvari et al., 2019).

Hybrid infrastructure designs require engineers to work with other disciplines, such as ecologists, to develop artificial, human-made ecosystems (see Browder et al., 2019). Many urban NbS are hybrid solutions, such as green roofs and permeable pavements.

Summary

Ecosystem-based approaches using NbS offer win-win situations by countering environmental degradation, biodiversity loss, and climate change (through mitigation and adaptation) and helping to reduce the risk and impact of disasters. This can also be the case when they are combined – when appropriate – with grey infrastructure. NbS may not always be silver bullets, but they are an important part of a strategy for long-term sustainable development.

Coastal development should be avoided in low-lying areas due to risk of flooding, inundation, and retreat should have top priority in development planning. Zoning of low-lying areas as no development areas (similar to the No Development Zones prescribed in the CRZ) will reduce the number of problems due to climate change impacts in the future. Once people build close to the shore, either legally or not, the responsibility to protect them normally comes back to the government. It may be difficult to deal with millions of climate change coastal refugees in the future and so planning now may reduce that problem. Strict implementation of the CRZ along with the hazard line being demarcated and utilization of the Coastal Hazard Vulnerability Atlas of the Ministry of Earth Sciences, Government of India, are convenient tools for reducing the climate change impacts on the low-lying areas of the coast.

It is also important that existing sand on the island beaches should be preserved as it is a scarce resource in the islands. The coral islands are different to the mainland, with fringing coral reefs already protecting the coast. The reefs produce coarse coral sand, which is protecting the beaches, but coral growth is slow and the corals are threatened by global warming. If the reefs are damaged, then the beaches will start to erode. Thus, it is essential to nurture the existing sands (with no removal) in preparation for global warming and climate change.

Coral reef preservation / enhancement should be adopted on the islands. The offshore natural reefs on tropical coral islands already provide substantial protection to the beaches. Reefs may grow naturally to catch up with SLR. However, due to coral bleaching and man-made damage the coral growth is stunted. In such areas, SLR will allow larger waves to reach the shore. In any circumstance, the best approach is to copy nature's systems. Thus, offshore reefs could be reinforced biologically by introducing 'modern biotechnology'. If that fails, then artificial reefs can be placed shoreward of the reef crest, which allows the natural reef to break the waves while the smaller man-made reef behind the natural reef can compensate for SLR, while avoiding damage to corals.

Ecological engineering is used to "design [...] sustainable ecosystems consistent with ecological principles which integrate human society with its natural environment for the benefit of both". Bergen Bolton & Fridley 2001; Mitsch 2012).

The following table showcases some of the options that can be adopted for ecosystem-based adaptation using nature-based solutions:

Ecosystem Type	Nbs Category	Nbs Measure	Specific Interventions
COASTAL	Blue Infrastructure	Mangrove, salt marsh, wetland restoration	❖ Nurseries ❖ Planting ❖ Protection zones ❖ Hydrology amelioration
	Wetland restoration	Restoration of reefs	❖ Coral nurseries ❖ Coral transplant ❖ Artificial reef creation
		Managed realignment	❖ Hydrology amelioration ❖ Replacing defence further away from the coast
	Integrated Coastal Zone Management	Sustainable resource use/fisheries	❖ No-take areas; ❖ Zoning ❖ Education/awareness raising
		Integrated coastal zone management	❖ Use of a combination of approaches ideally in partnership with local communities
	Protected Areas	Conservation	❖ Creation and management of protected area(s)
	Sustainable Land Management	Alternative livelihoods	❖ Ecotourism, honey production, etc.
	Blue Infrastructure	Sand management	❖ Beach nourishment ❖ Dune rehabilitation ❖ Artificial dune construction
	Integrated water resource management	Watershed management	❖ Upstream management to protect water quality (see Forest/Agriculture/Slopes)

Ecosystem Type	Nbs Category	Nbs Measure	Specific Interventions
FOREST	Landscape restoration	Reforestation	✣ Nurseries ✣ Planting
	Sustainable Land Management	Alternative livelihoods	✣ Use of manure instead of firewood, ecotourism, etc
	Climate smart agriculture/ agroforestry	Agroforestry	✣ Intercropping ✣ Alley or strip cropping ✣ Shade systems ✣ Crop diversification ✣ Soil and water management
		Sustainable management	✣ Zoning ✣ Use of a combination of approaches ideally in partnership with local communities
	Protected Areas	Conservation	✣ Creation and management of protected area(s)
RIVER	Blue Infrastructure	Living weirs	✣ Bamboo or log grids across river with biodegradable sacks containing elements for soil ✣ Planting and natural regeneration of stabilizing plants on the river bank whose roots will also colonize the bamboo/ log grid.
	Integrated water resource management	Watershed management	✣ Use of a combination of approaches at the watershed scale through integrated water resource management, ideally in partnership with local communities
	Wetland restoration	Renaturation	✣ Recreating natural river forms ✣ Planting vegetation
		Removal invasive species	✣ Removal of species
	Protected Areas	Conservation	✣ Creation and management of protected area(s)
WETLAND	Protected Areas	Conservation	✣ Creation and management of protected area(s)
	Wetland restoration	Restoration	✣ Hydrological landscape shaping ✣ Planting
		Removal invasive species	✣ Removal of species
	Integrated water resource management	Sustainable resource management	✣ Use of a combination of approaches, ideally in partnership with local communities

Ecosystem Type	Nbs Category	Nbs Measure	Specific Interventions
AGRICULTURAL	Climate smart agriculture/ agroforestry	Agrobiodiversity	✣ Seed banks ✣ Nurseries ✣ Mixed farming ✣ Intercropping
	Integrated water resource management	Integrated nutrient management	✣ For example, using nitrogen-fixing species
	Integrated water resource management	Rainwater harvesting	✣ Collect rainwater
		Community gardens	✣ Creation of community gardens and bio manure
		Agroforestry	✣ See Forests
	Green Infrastructure	Ecological pest management	✣ Use local species to manage pests (e.g., ducks in vineyards)
	Climate-smart agriculture/ agroforestry Green infrastructure	Soil practices	✣ Terracing ✣ Conservation tillage ✣ Indigenous practices ✣ Irrigation
	Sustainable Land Management	Sustainable agriculture/ husbandry	✣ Creation of protected zones ✣ Rotation
		Alternative livelihoods	✣ Ecotourism, etc.
	Landscape restoration	Revegetation	✣ Planting of areas on degraded land
GRASSLAND PASTURE		Revegetation	✣ Nurseries ✣ Planting and natural regeneration
	Integrated coastal zone management	Conservation	✣ Creation of protected zones
	Green infrastructure	Bush control	✣ Fire management regimes
	Green infrastructure	Sustainable grazing management	✣ Use of a combination of approaches, ideally in partnership with local communities ✣ Zoning
	Integrated coastal zone management	Removal invasive species	✣ Removal of species
SLOPES (mountain, river banks, etc.)	Landscape restoration	Revegetation	✣ Planting and natural regeneration
	Protected areas	Bio-engineering (e.g., brush attressing)	✣ Nurseries ✣ Planting of deep-rooted plants
		Conservation	✣ Creation of protected zones
	Sustainable land management	Sustainable use of resources	✣ Use of a combination of approaches, ideally in partnership with locals ✣ Zoning

Ecosystem Type	Nbs Category	Nbs Measure	Specific Interventions
URBAN AREA	Urban greening	Urban green areas	❖ Tree planting ❖ Park creation and management ❖ Community gardens ❖ Green roofs and facades
	Green infrastructure	Urban wetlands	❖ Pond creation ❖ River renaturation
	Integrated water resource management	Sustainable drainage systems	❖ Bioswales ❖ Permeable pavements ❖ Retention basins
	Protected areas	Urban nature reserves	❖ Conservation and management ❖ Educational areas

As interest in the role of NbS for climate change adaptation and mitigation, disaster risk reduction and sustainable land management grows, a more systemic approach and understanding is required. Indonesia has emerged as a frontrunner in coastline restoration, leveraging natural sediment flows, and mangroves. Such solutions hold much promise for other countries but require innovative collaborations and integrated approaches to change the current way nature is planned and utilized in development.

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