Srushti Conservation Foundation
Nurture Nature

Final Report

Comparative study of impact caused by Nisarga cyclone along coast of Maharashtra in mangrove and non-mangrove areas with special focus on Raigad & Ratnagiri Districts

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Dr. Qamar Qureshi peer reviewed the report for its scientific correctness.

Ms. M.R. Maithreyi did excellent editorial work.

CONTENTS

INTRODUCTION

A super cyclone, Nisarga, hit the western coast of Maharashtra on June 3, 2020, causing enormous destruction to infrastructure, agriculture and the coastal habitats predominantly in Raigad and Ratnagiri districts. According to reports, the wind speed was up to 120 km/hr, and the centre of this cyclone was Harihareshwar–Kalinje, Raigad district, leading to severe damages between the coastal areas of Raigad district, including Harnai, Dapoli (south) and Diveagar, Shrivardhan (north). Some damages were also reported in the southern part of Ratnagiri and Sindhudurg districts as well as in Thane and Palghar districts.

Cyclone Nisarga was followed by an extremely severe cyclonic storm, Tauktae (May 12–19, 2021), at 180 km away from the coastline running parallel towards the north. Tauktae began parallel to the west coast of India and, in Maharashtra, it became a severe cyclonic storm. It was one of the strongest tropical cyclones to ever affect the west coast of India. Tauktae did not make landfall in Maharashtra, but it battered the coast with heavy rain and winds. The cyclone also caused widespread infrastructure and agricultural damage to the western coast of India. The wind speed along Maharashtra ranged between 80–114 km/h, but its major impact was on the sea.

Tauktae wreaked havoc in Raigad district. As per administration records, it caused damage to 11,144 houses and 15,00 hectares of farmland, mainly mango, coconut and paddy.[1] The cyclone also damaged 2,542 structures partially, while a few were destroyed completely in Sindhudurg, Ratnagiri, Raigad, Thane, Palghar, Pune, Kolhapur and Satara.[2]

These two consecutive cyclones within a year's gap left a trail of destruction along their path. The major affected areas were the districts of Raigad and Ratnagiri.

ROLE OF MANGROVES

Mangroves provide shelter against tidal surges, tsunami and cyclones, besides performing key ecological functions. The west coast of India has not witnessed many cyclones and so the role of mangroves in protecting the coastal infrastructure has remained unknown. Study compared mangrove and non-mangrove areas of the affected districts.

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[1] Sanjana Bhalerao, "Tauktae impact in Raigad: More than 11,000 houses, 1500 hectares of farmland damaged," *Indian Express*, May 20, 2021. https://indianexpress.com/article/cities/mumbai/tauktae-impact-in-raigad-more-than-11000-houses-1500-hectares-of-farmland-damaged-7323530/

[2] https://www.news18.com/news/india/maharashtra-cm-uddhav-thackeray-assesses-damage-caused-by-cyclone-tauktae-3747677.html

CYCLONE NISARGA

Nisarga, the severe cyclonic storm, originated from a low-pressure area that formed over the southeast. It intensified into a deep depression over the east central Arabian Sea in the early morning. Continuing to move north-eastwards, it crossed the Maharashtra coast close to south of Alibag.

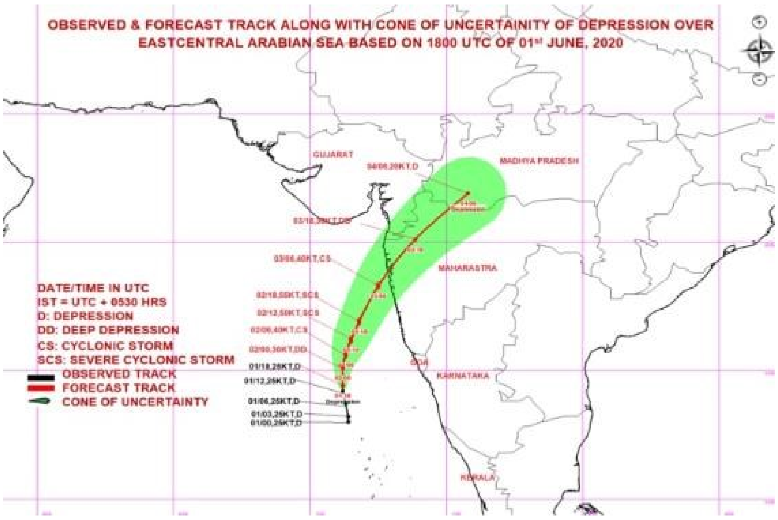

Figure 1: Cyclone Nisarga and its track along coastline (Source: IMD)

CYCLONE TAUKTAE

Tauktae originated from an area of low pressure in the Arabian Sea on May 13, 2021. It intensified into a severe cyclonic storm on May 17, making landfall soon afterward. The cyclone made landfall in Gujarat on the night of May 17 after passing along the western coast of the country.

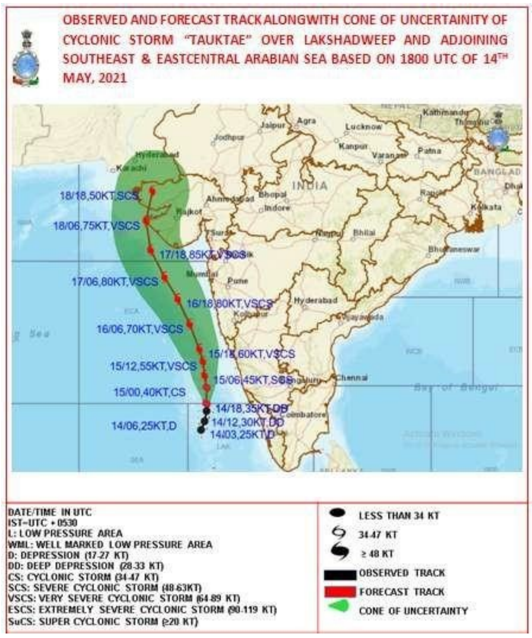

Figure 2: Cyclone Tauktae and its track along the coastline (IMD)

OBJECTIVES

- Assess impacts of cyclone 'Nisarga' in mangrove and non-mangrove coastal habitats of Raigad and Ratnagiri districts:
    - Extent of damage along shoreline
    - Noticeable changes that took place in the coastal habitat
    - Changes in water level
- To check effectiveness of Mangroves during cyclone preventing salt water inundation and wind-related damage to coastal property.
- To give further recommendations for development of ecological restoration of coastal areas and habitats in cyclone hit areas.

MATERIALS AND METHODS

STUDY AREA

The cyclone Nisarga severely impacted the coastal parts of Raigad and Ratnagiri districts that lay in close proximity to its landfall area in Raigad. The cyclone track was extracted from International Best Track Archive for Climate Stewardship (IBTrACS) dataset (Knapp et al., 2010 & 2018). This study focuses on the impact of the cyclone Nisarga in detail.

RAIGAD

Raigad is one of the districts in the Konkan Division of Maharashtra. It has an average annual precipitation of 3,884 mm and population density of 370/km^2. The Raigad coastline extends up to 122 km.

RATNAGIRI

Ratnagiri is a coastal district of Maharashtra, having a north-south length of about 180 km and an average east-west extension of about 64 km. The district falls within 16.30 to 18.04 north latitudes and 73.02 to 73.53 east longitudes. Ratnagiri has 237 km coastline extending from Raigad to Sindhudurg district and it receives about 2500 mm rainfall. The population density is 196/km^2.

The study area was kept limited to 30–km grid from Nisarga's landfall area (north and south) and within 3 km from the coastline. This area includes the northern taluks of Ratnagiri viz. Dapoli and Mandangad and the southern taluks of Raigad viz. Dighi, Shrivardhan.

METHODOLOGY

Detailed methodology is outlined in the final report. A graphic representation of the same is as below.

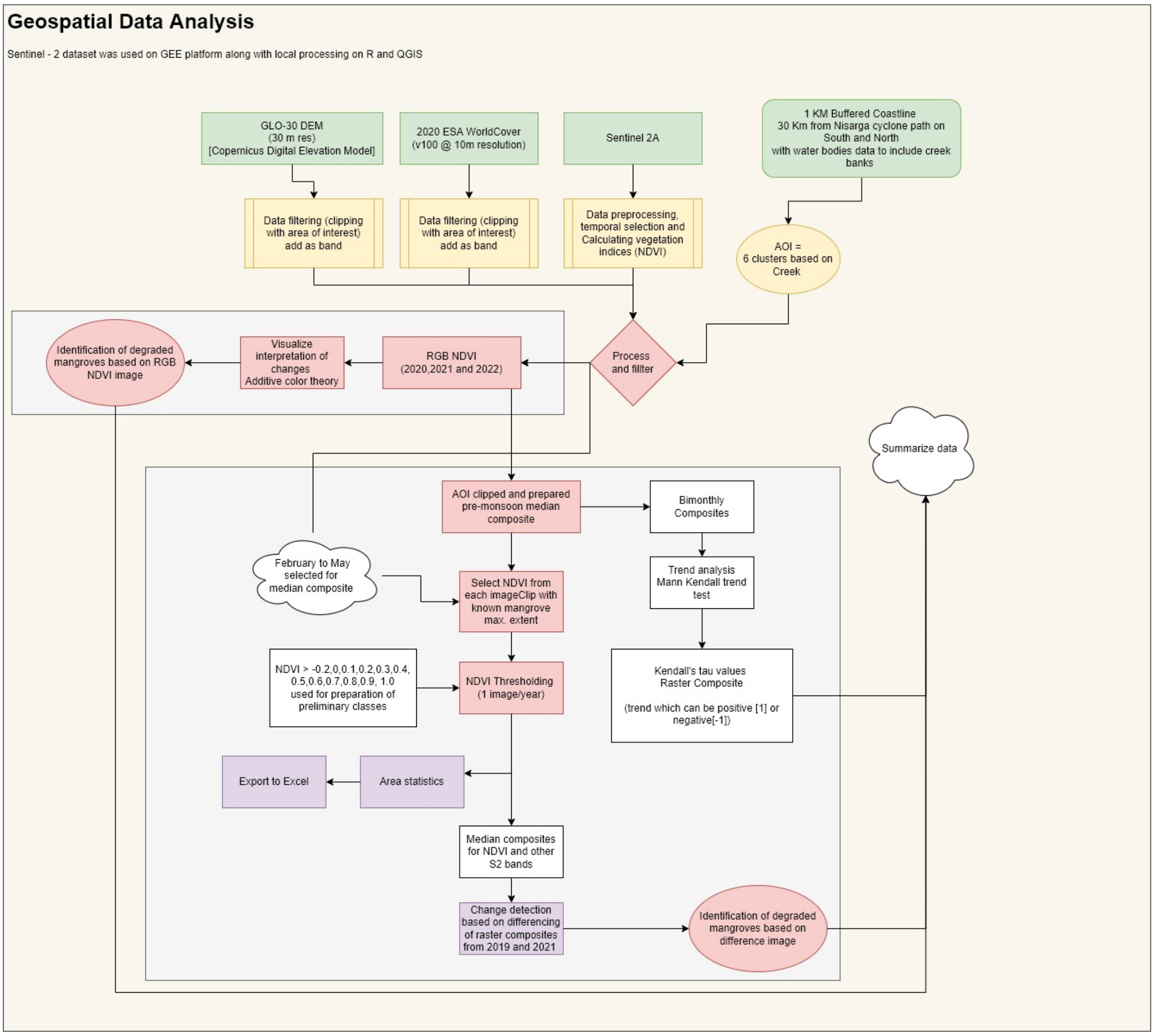

Figure 3 Flowchart showing methodology for remote sensing/ GIS data analysis

To establish baseline pattern we chose 2017–2019 as pre-cyclone years (baseline) and 2021 and 2022 post-cyclone rasters to asses damage done by the cyclonic event.

LIMITATIONS AND ASSUMPTIONS

- The remote sensing approach taken in the present study to measure canopy damage (i.e., changes in NDVI-based classes) did not translate into the precise measurement of the types of damage; hence, a similar change in NDVI could be observed from defoliation or structural canopy damage (e.g., branch and stem breakage) or death of tree (which could be reflected from prolonged lower values). Thus, other approaches such as RGB NDVI and the long-term trend analysis MK Trend were performed to support the results.

- In some of the patches of Bankot Creek, physical sampling was not possible due to the presence and active movement of Marsh Crocodiles (especially upstream areas of the Creek).
- The mangrove community structure is based on the fieldwork undertaken in 2021 and 2022. Field studies for the year 2020 and parts of 2021 were not possible due to COVID-19 pandemic and related travel restrictions.
- Entry-level drone limitations (DJI Mini 2):
    - Flying beyond VLOS (visual line of sight) is prohibited by law.
    - 15 m relative flying altitude limit (as locked by DJI flying app – DGCA restriction) is time consuming considering higher GSD / accuracy but limited area captured per flight (considering 20 minutes of battery life for actual data capture).
    - Despite repeated efforts to sample, some patches that were accessible were also omitted to avoid bird hits; We found many birds (especially crow sp.) use the mangroves to nest. The presence of swift sp. was also a deterrent in certain areas.
- Active sand mining areas were not visited considering staff safety concerns and to avoid any local conflicts.
- For CHM we have used reference data sets of year 2020 by Lang et al. (2022).

Gothe-Borthkat mangrove patch showing damaged area

CONCLUSION

IMPACTED CLUSTERS

During the Nisarga cyclone, much of the damage took place on the plantation of Casuarina equisetifolia and its associated large species. The highest impact of the cyclone in mangrove areas was primarily limited to two clusters, Velas-Bankot (57 ha) and Dighi-Diveagar (30 ha).

Table 1 MK Trend-based damage classes in mangrove vegetation areas (area in ha)

Clusters	Anjarle-Paj	Aravi	Ade-Utambar	Dighi-Diveagar	Kelshi-Sakhari	Shrivardhan-Kalinje	Velas-Bankot
Total area	252	93	141	3552	299	809	1623
Undamaged	130	48	39	2815	214	620	764
Negligible	98	35	72	585	76.7	166.29	564
Low	14	6.1	18	85	5.93	15.16	149
Sparse	5	2.53	7.85	37	1	4	89
Moderate	3	0.77	3.41	21	0.8	2	47
High	0.5	0.1	0.8	9	0.4	1	10
Total impacted area	121	45	102	737	85	188	859

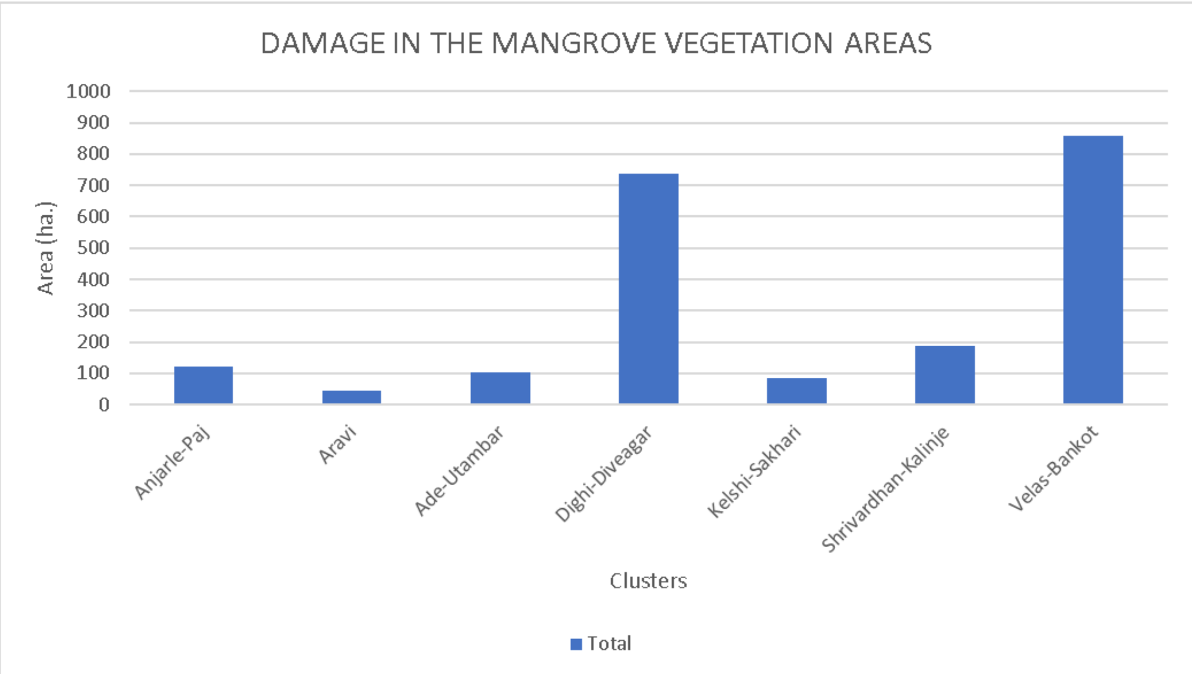

Figure 4 Overall damage in mangrove vegetation areas.

The overall impact on mangroves was highest at Velas-Bankot, followed by Dighi-Diveagar, Shrivardhan-Kalinje, Anjarle-Paj, Ade-Utambar, Kelshi-Sakhari and Aravi.

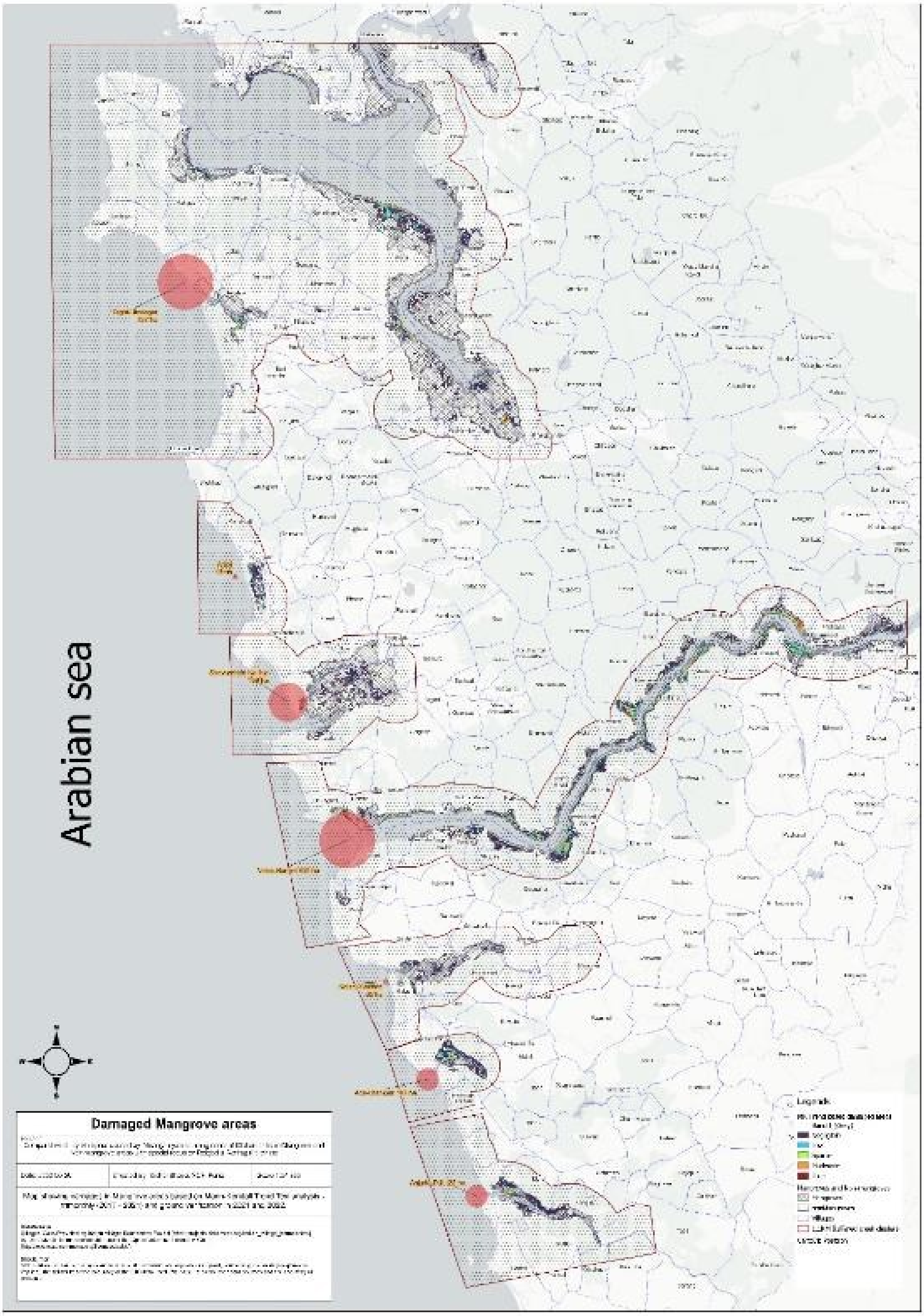

Figure 5 Overview of damaged mangrove areas

Table 2 MK trend-based damage classes in non-mangrove vegetation areas (area in ha)[3]

Area/Cluster	Anjarle-Paj	Aravi	Ade-Utambar	Dighi-Diveagar	Kelshi-Sakhari	Shrivardhan-Kalinje	Velas-Bankot
Total	3809	1588	1117	27699	2790	2664	8985
Undamaged	2790	1372.34	595.83	22080.7	1639.00	2030.79	5519.26
Negligible	888	168.78	462.21	5022.24	984.54	457.97	3083.75
Low	73	18.65	32.21	329.17	78.01	79.29	261.85
Sparse	39	13.08	13.86	150.99	39.05	52.92	80.52
Moderate	15	10.27	8.99	87.73	34.71	31.33	30.24
High	3	4.85	3.72	28.28	14.28	12.04	9.07
Total Impacted	1018.04	215.63	520.99	5618.41	1150.59	633.55	3465.43

The majority of the damage in non-mangrove areas was due to the uprooting or death of Casuarina and Coconut plantations in the vicinity of the seashore. Dighi-Diveagar, Velas-Bankot, Kelshi-Sakhari, Anjarle-Paj, Shrivardhan-Kalinje, Ade-Utambar and Aravi were most impacted.

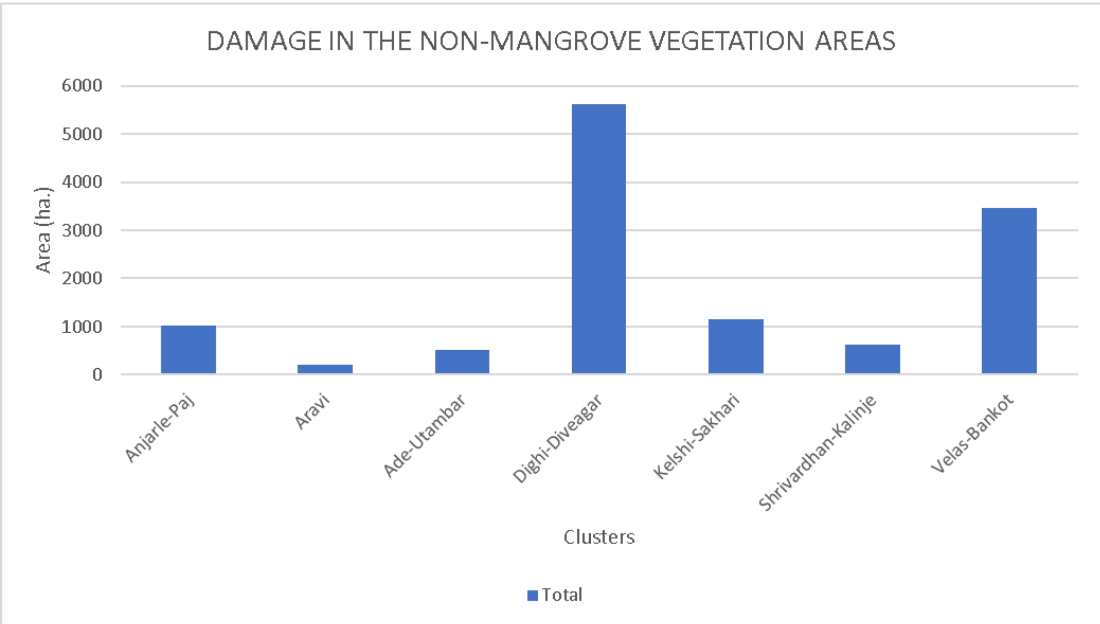

Figure 6 Overall damage in non-mangrove vegetation areas

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[3] Major non-mangrove coastal vegetation was dominated by *Casuarina*, Coconut, Areca Nut, Mango and Pandanus

Ade-Utambar showed maximum damage to the mangrove vegetation. It was followed by Velas-Bankot (53%), Anjarle Paj and Aravi (48% each). Kelshi-Sakhari (28%), Shrivardhan-Kalinje (23%) and Dighi-Diveagar (21%) were worst hit.

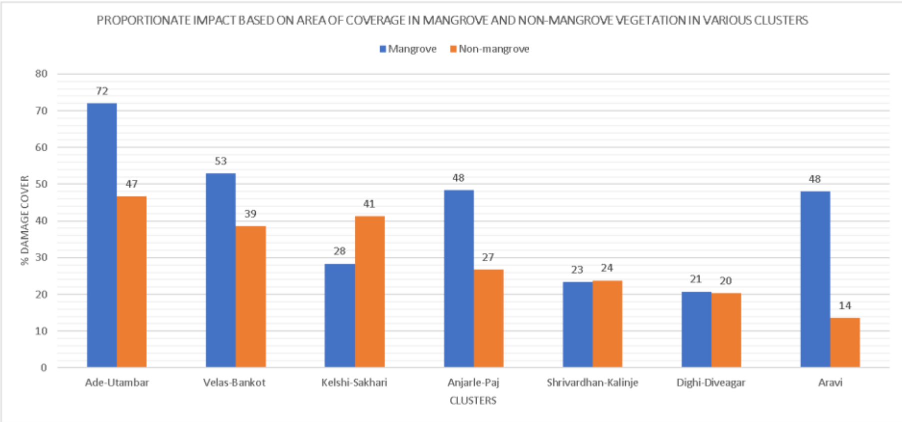

Figure 7 Proportionate impact based on area of coverage in mangrove and non-mangrove vegetation in various clusters

ROLE OF MANGROVES

Mangroves in various creeks under study have played a major role in stabilizing and protecting sediments and acted as an adequate buffer to minimize damage. Compared to the non-mangrove areas, the mangrove vegetation received less damage in Moderate and High impact classes, suggesting the vital role of mangroves during cyclones.

Table 3 Damage to mangrove and non-mangrove vegetation in Moderate and High impact classes (Area in Ha.)

	Anjarle-Paj	Aravi	Ade-Utambar	Dighi-Diveagar	Kelshi-Sakhari	Shrivardhan-Kalinje	Velas Bankot
Mangrove vegetation	3.5	1.77	4.21	30	1.2	3	57
Non-mangrove vegetation	18	15.12	12.71	116	48.99	43.37	39.31

The mangroves and other coastal vegetation seem to have reduced damages to houses in many areas, if not all. On the other hand, most of the non-mangrove areas, especially the sandy shores, were either eroded or accreted with sediments due to wind and wave action.

Understanding the short- and long-term impacts of cyclones on sediment movement is essential to developing a shore protection and restoration policy.

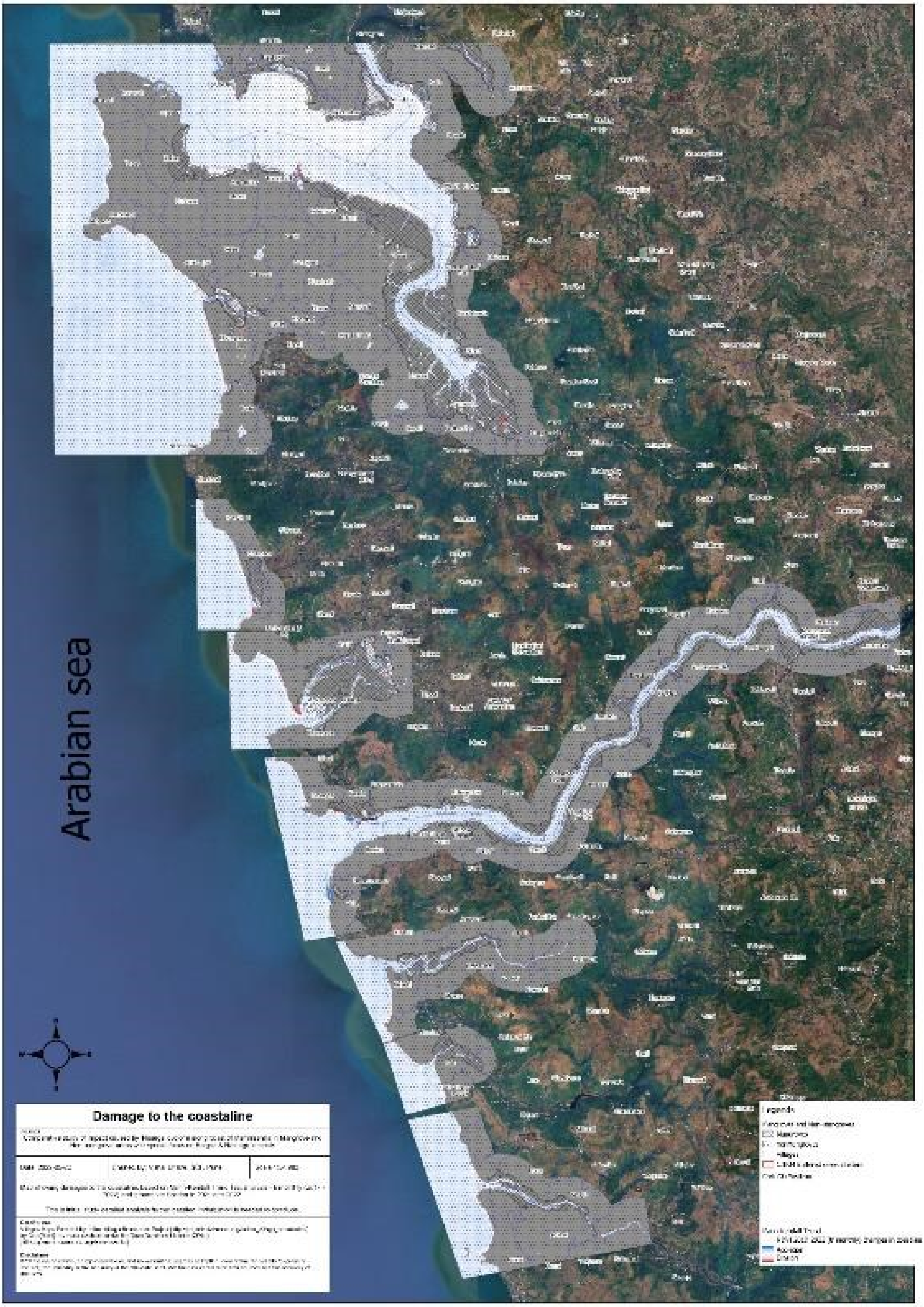

Figure 8 Map showing areas with damaged coastline

RECOMMENDATIONS

There is a 52% rise in the frequency of cyclones in the Arabian Sea over the last two decades (Deshpande et al., 2021). Compounded with sea-level rise, it will make the coastal areas of Maharashtra vulnerable to various impacts. The shoreline management approach needs to be re-visited, considering worst-case scenarios in the near future.

LONG-TERM

- Changes in mangrove/ non-mangrove vegetation community need to be monitored on a long-term basis to understand its community structure and the response of the vegetation to the cyclones and sea-level rise, and to evaluate the recovery profile. This will aid in developing state-level mangrove and non-mangrove-related restoration policies.
- For non-mangrove species, climate-resistant and low-maintenance species could be ideal such as *Pandanus fascicularis* and *Thespesia populnea* or any other local species that used to occur on our shores before they were taken over by *Casuarina* spp.
- For mangrove species, multi-species afforestation is absolutely essential, especially considering the maximum damage to *Avicennia marina and other large tree species such as Rhizophora mucronata, Sonneratia alba* and *S. apetala*. However, each site requires a site-specific approach for mangrove restoration or re-densification. A detailed analysis of each impacted creek should be undertaken to decide on a restoration strategy.
- Coastal protection needs to be enhanced with climate-resilient and nature-based solutions, which can be evolved through site-specific studies and traditional knowledge of the local communities. Beach nourishment is gaining traction in several states as a more effective shore protection measure than hard structures.
- Kharland bunds or other hard structures provide only short-term benefits and they only facilitate a shift in the erosion/accretion pattern to other locations. A recent study entitled 'Coastal structures along Tamil Nadu and Puducherry coast' by the National Centre for Coastal Research, MoES, pointed out the issues related to hard structures.
- A large-scale campaign is necessary for building climate-resilient coastal communities. The same can be included in the 'Climate Action Plan' of the State of Maharashtra as well as the annual action plan of the Mangrove Foundation of the Government of Maharashtra. The vulnerability of coastal areas to climate change, sea-level rise and increased frequency of cyclones is a reality. The local communities need to be exposed to the real challenges and new opportunities that may emerge in the times to come.
- The mapping of all existing structures such as sea walls, groynes, Kharland bunds, artificial reefs, mangrove plantations, *Casuarina* and other plantations

on habitats like sand dunes and backshore areas need to be undertaken. Studies should also include the assessment of impacts (both positive and negative) of these interventions. It will aid in identifying the efficacy of such measures and developing a policy that will address the coastal degradation issues holistically.

MEDIUM-TERM

- Considering the dynamic nature of shore profiles and the data that is available onshore erosion/accretion, highly vulnerable areas need to be identified for undertaking shore protection through a combination of engineering and nature-based solutions.
- Inundation of coastal areas is a reality and new frontiers of conflict seem to be emerging in the form of coastal land degradation and the invasion of mangroves in productive agricultural lands, leading to the loss of livelihood among a large section of small and medium landholders. It will thus require systematic mapping of such areas and developing a policy framework to deal with the situation. Increased frequency of cyclones and sea level rise, compounded with the construction of sea walls, groynes, etc., will only worsen the situation.
- Thus, to mitigate the situation with landowners, line departments must engage actively to build trust and provide or at least expose them to mangrove-based alternate livelihood options. It will not only protect the livelihood lost due to the invasion of mangroves in the private agricultural lands but also encourage the locals to protect these sentinels of the shores. Mangrove-based livelihood such as sericulture, apiculture, mangrove pickle, mangrove tea, ornamental fish culture, seaweed culture and fodder enrichment for cattle feed needs to be explored.

SHORT-TERM

- The most impacted non-mangrove areas, as envisaged in this report, should be restored through locally available non-mangrove species on priority. The areas that require priority restoration are Ade-Utambar (47%), Kelshi-Sakhari (41%), Velas-Bankot (39%), Anjarle-Paj (27%), Shrivardhan-Kalinje (24%), Dighi-Diveagar (20%) and Aravi (14%). *Casuarina* proved to be ineffective as a wind barrier during the cyclone; hence, its plantation should not be carried out. However, before carrying out any restoration work, there must be a rapid consultation with the local communities to understand their traditional knowledge, support and participation.
- For mangrove restoration through re-densification, the highly impacted areas can be considered as envisaged in the report. The areas that require priority restoration are Ade-Utambar (72%), Velas-Bankot (53%), Anjarle Paj and Aravi (48% each), Kelshi-Sakhari (28%), Shrivardhan-Kalinje (23%) and Dighi-Diveagar (21%). Single species use must be avoided; instead, multi-species mangrove communities should be used for re-densification. The report provides

an overview of the mangrove community structure at various sites. It can be used to devise a species list for mangrove re-denitrification.

- Caution should be taken not to undertake the plantation of mangroves or any other species on non-vegetated mudflats frequented by migratory birds. Caution should also be taken to not undertake non-mangrove species afforestation on key sand dunes used by roosting birds and nesting sea turtles. For example, in a recent study, Katti et al. (2020) reported Kalinje mangroves and mudflats as roosting sites for gulls and terns. In January 2018, a flock of 3,000 Lesser Black-backed Gull (*Larus fuscus*) and in December 2018 a flock of 4,000 gulls and terns, predominantly comprising Lesser Black-backed Gull and Brown-headed Gull (*Chroicocephalus brunnicephalus*), was seen arriving to roost at this site. The Velas Agar and Diveagar Beach sandy shores are known to host a congregation of gulls and terns, suggesting that this area could be used as a staging site during northward migration. Over 4,000 individuals of gulls and terns were recorded at Velas Agar. The flock composition was majorly that of Lesser Black-backed Gull, Brown-headed Gull and Black-headed Gull (*Chroicocephalus ridibundus*).

A view of Adkhal mangroves from Anjarle bridge