

P3 Final Report:

Visualizing ecological change in the context of Indian Sundarbans

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Approval Sheet

Interaction Design Project 3 titled “Visualizing ecological change in the context of Indian Sundarbans” by Alivia Chaudhuri (Roll Number: 216330017) is approved for partial fulfillment of the requirement for the degree of ‘Masters in Design’ in Interaction Design at the Industrial Design Centre, Indian Institute of Technology, Bombay.

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I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated, or falsified any idea/data/fact/ source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Glossary of Terms:

Climate Change

Biosphere

The part of the Earth comprising all ecosystems and living organisms—in the atmosphere, on land (terrestrial biosphere), or in the oceans (marine biosphere), including dead organic matter.

Adaptation

Adjustment of natural or human systems to a new environment.

Anthropogenic

Made by people or resulting from human activities.

Climate

In a narrow sense, climate is usually defined as the "average weather." According to the World Meteorological Organization, the classical period is three decades over which quantities such as temperature, precipitation, and wind are measured.

Climate Change

Climate change refers to any significant change in the measures of climate lasting for an extended period. In other words, climate change includes major changes in

temperature, precipitation, or wind patterns, among others, that have occurred over several decades.

Ecology

Ecology is the study of the relationships among living creatures, including humans, and their local physical environment

Ecosystem

Any natural unit or entity, including living and non-living parts, that interact to produce a stable system through a cyclic exchange.

Ecotone

Ecotones are areas of abrupt transition between ecological communities, ecosystems, or ecological regions along an environmental or another gradient. Estuaries like Sundarbans are ecotones.

Habitat Fragmentation

A process during which larger areas of habitat are broken into several smaller patches of smaller total area, isolated from each other

Sea Level

There are different measures of sea levels and their rise-absolute, relative, global and local.

Absolute sea level rise- Absolute (or eustatic) sea level represents the sea height relative to the center of the Earth.

Relative sea level rise (RSLR) represents the combined effect of sea level rise and vertical land subsidence.

Mean sea level refers to the average height of all of the Earth's ocean basins. It can be *global* or *local* (at a particular location).

Salt Water Intrusion

Displacement of fresh or ground water by the advance of salt water due to its greater density, usually seen in coastal and estuarine areas.

Sea Surface Temperature

The temperature in the top several feet of the ocean, measured by ships or buoys.

Storm Surge

An abnormal rise in sea level accompanying a cyclone or other intense storm. It is measured by the difference between the observed sea surface level and the level that would have happened without the storm.

Vulnerability

The degree to which a system is susceptible to, and adaptive to the adverse effects of climate change and extremes.

Data Visualization terms

Data: Fundamentally, data is equal to information.

Microdata: Individual data obtained in studies and surveys directly observed or collected from a specific observation unit.

Data point or datum: Singular of data. Refers to a single point of data.

Quantitative data/variables: Information that can be handled numerically.

Qualitative data/variables: Information that refers to the quality of something. Ethnographic research, participant observation, open-ended interviews collect qualitative data.

Indicator: Typically used as a synonym for statistics describing the socioeconomic environment, e.g., sea level rise is a climate change indicator.

Statistic: A number that describes some characteristic or status, of a variable, e.g., a count or a percentage.

Spatial data: Spatial data is any data that directly or indirectly references a specific geographical area or location.

Time series/temporal data: Any data arranged in chronological order.

Variable: Any finding that can change or vary.

Numerical variable: Usually referring to a variable whose possible values are numbers.

Categorical variable: A variable that distinguishes among subjects by putting them in categories (e.g., gender). Also called discrete or nominal variables.

Terminology Used with Collections of Data

Aggregate data: Aggregate data are statistical summaries, meaning that the data have been analyzed in some way.
E.g.: Mean sea level rise in the last decade.

Dataset: A collection of related data items, e.g., the responses of survey participants.

Database: A collection of data organized for research and retrieval. Example: Census data 2011.

01 Abstract

In recent years, the Sundarbans Delta has faced numerous accelerating climate-related challenges, including rising sea levels, island erosion, and increasing temperatures. These changes have had far-reaching effects, particularly on economically disadvantaged and marginalized communities residing in the area.

To provide a comprehensive overview of the current state of the Indian Sundarbans delta, we conducted a brief field study, examined available peer-reviewed scientific literature, and consolidated data from various sources to shape a compelling narrative. We designed relevant visualizations that engage and inform the user. Our target audience is the general public, who read national English newspapers and possess a basic understanding of science, mathematics, and geography. The expected outcome is a website that presents the story and effectively conveys insights through interactive data visualizations. Our aim is to increase awareness about the ecologically significant Sundarbans and foster the audience's understanding of the impacts of climate change.

02 Introduction

2.1 Climate Change

Climate change is one of the most urgent issues of our time. Its impact can be felt and seen all around us. The

United Nations defines climate change as long-term shifts in temperatures and weather patterns. (UN, 2020) One of the regions particularly vulnerable to climate change's effects is the dynamic ecosystem of the Sundarbans.

2.2 About Sundarbans

The Sundarban Biosphere, formed by three main rivers, Ganga, Meghna, and Brahmaputra, is the largest delta in the world. Literally meaning 'beautiful forest,' Sundarban is one of the richest ecosystems in the world, consisting of a complex intertidal network of rivers, creeks, marshes, mudflats, and alluvial floodplains. It is the world's largest contiguous mangrove forest area (UNESCO, n.d.). It is also known for its biodiversity, such as the emblematic Royal Bengal tiger and several species of dolphins and reptiles. About 40% of the nearly 10,300 km² of the Sundarbans forest lies in West Bengal, and 60% is in Bangladesh.

The forest is a natural carbon sink through sequestration, i.e., it absorbs more carbon than it releases in the atmosphere. It is a powerful bio-shield that protects the city of Kolkata, its 14 million inhabitants, and other human settlements from cyclones, tidal surges, and other adverse natural events that otherwise would have taken a massive toll on human life and property. (Source: Primary respondent Riya Mallick, CEPT, Researcher on Climate Resilience in Sundarbans)

2.3 Global Recognition

Recognizing the importance and uniqueness of the Sundarbans, UNESCO declared the four portions of the forest a World Heritage Site in 1987. The UNESCO Man and the Biosphere Program has included it in the Global Network of Island and Coastal Biosphere Reserves. It became a Ramsar wetland site in 2019. Due to the current accelerating nature of climatic hazards and anthropogenic activities, the area's ecology has been disturbed. It is listed as 'endangered' under the IUCN Red List of Ecosystems, 2020.

2.4 People of Sundarbans

While the Sundarbans region is celebrated for its ecological attributes, it is a difficult place to inhabit. (World Bank, 2014) A number of natural hazards, including cyclonic storms, soil and water salinization, loss of land, rising sea levels, and regular tiger attacks, have combined to make this area dangerous to live in. 4.4 million people (Govt. of India, Census 2011) rely on the forest and ecological resources for livelihood.

03 Objective

This project aims to develop an interactive data story presented in the form of a website to facilitate the general public in comprehending the present ecological condition of the Sundarbans. It seeks to provide a holistic understanding of the region's current state, incorporating historical trends that span the past century.

Given the extensive scope of ecological data related to the Sundarbans, the content has been meticulously organized into four distinct chapters; lithosphere, focusing on the terrestrial land; the hydrosphere, encompassing the ocean and atmosphere; the biosphere, delving into the diverse flora and fauna of the forest; and the anthroposphere, examining the human-made systems within the region. This bottom-up categorization approach enables a focused interpretation of the most pertinent data elements, thereby presenting a holistic picture of the Sundarbans.

04 Motivation

Bridging communication gap: Much research has been done on Sundarban by climate researchers. However, a significant communication gap exists as the data published in scientific journals remains inaccessible and incomprehensible to the general public.

Novel data story: Currently, there is a lack of visualizations or infographics that give an overall view of

the Sundarban biosphere. Consequently, the number of people aware of the nature of the ecological decline of Sundarbans is few.

Enhancing decision-making: There is also a growing importance of mediating important scientific information to policymakers, administrators, and the general public in an easy, understandable way. Visualizations can help individuals make informed decisions, become more attuned to environmental changes, and potentially advocate for sustainable solutions.

Growing interest in HCI: According to Ferreira et al., the HCI community has shown a growing interest in the topic of climate change data visualizations, especially considering the communication and interaction complexities it poses.

Personal motivation: As someone who grew up in West Bengal, a personal connection drives me to empathize with the plight of the people of Sundarbans and the eroding islands, some of which are UNESCO world heritage sites.

05 Background Study

The following section provides an in-depth examination of the literature concerning the ecology and climate of Sundarbans. Additionally, there is a section exploring contemporary climate visualizations.

5.1 Indian Sundarbans book

One of the most authentic sources of information on Indian Sundarbans is found in a book called “*Bharatiyo Sundorbon- ekti bhougolik rooprekha*” (Translation: Indian Sundarbans - a geographic outline) written by Kalyan Rudra and JN Lahiri. According to the authors, they highlight a few unexplored key ideas like the contribution of the sea and river in the formation of Sundarbans and define the number of islands that currently exist, both inhabited and uninhabited. (Rudra & Lahiri, 2022)

They raise a few questions and try to answer them in the book. These are the key points they discuss-

- Impact of global warming and climate change on this delta in the near future
- Changing land morphology in the area
- How are the fifty lakh people living in the periphery of the forest surviving and adapting to the changing climate?
- Devastating impacts of severe cyclones like Aila, Amphan, Bulbul, and Yaas in the last decade.

A significant contribution of the book is the inclusion of an up-to-date map showcasing the Indian Sundarbans (refer to the map below). It holds value as it represents the local data, considering the dynamic and ever-changing nature of the boundaries and defined land.



Map of Indian Sundarbans (2021) drawn by the authors, labelled in Bengali

5.2 Published research on Climate

5.2.1 Summary of the papers read

A number of papers were read not only to understand climate and ecology but also to gather information on each relevant topic of erosion, ocean data, cyclones, and impacts on human life. Overall, these studies demonstrate the complexity and importance of the ecology of the Indian Sundarbans and highlight the need for continued conservation efforts to protect this unique ecosystem. Here is a summary of the main ideas:

5.2.2 Changes in shoreline pattern

There have been several papers published on the underlying ecology of the Indian Sundarbans, addressing topics such as erosion, time-series analysis on the shoreline patterns, and climate change impacts. It is the world's most populous and largest delta.

The landforms are undergoing rapid changes due to the combined impact of various natural and human-induced factors. Continuous tidal action and land subsidence due to tectonic activity lead to the sedimentation, formation, and erosion of islands. However, the rate of erosion is unbalanced and rapid. (Mitra, 2015)

An assessment by Chatterjee et al., 2015, conducted using multi-temporal satellite images, revealed significant area loss exceeding 30% of the land area. Two islands exhibited extreme variations, with Lohachar Island being

completely submerged and Nayachar Island gaining over 30 km² of land.

5.2.3 Estuarine dynamics

Estuaries serve as a crucial part of the Sundarbans ecosystem, serving as a transition zone between the freshwater of the rivers and the saline water of the Bay of Bengal. It has high biological productivity, providing habitat to marine species like fish, reptiles, and birds. Additionally, it plays a role in filtering seawater, mitigating floods, and protecting coastlines from erosion. A paper (Bera, B., Bhattacharjee, S., Sengupta, N., et al., 2022) published in 2021 found that the mangrove forest has a high carbon storage capacity, i.e., it absorbs more CO₂ from the atmosphere than it releases (carbon sequestration).

5.2.4 Climate change indicators

Climate change indicators are measurable numerical parameters used to quantify the changes occurring in the Earth's climate system over time. These indicators provide objective data. They are often derived from scientific observations, measurements, and climate models. Following is a brief summary of the main quantitative indicators of climate change.

5.2.5 Sea surface temperature

The oceans and atmosphere govern the Earth's climate. Sea surface temperature is one of the best

indicators of a warming climate, as the ocean plays a significant role in the Earth's climate system, absorbing and storing large amounts of heat. It is also relatively more consistent and stable compared to atmospheric temperature. Sundarbans is located in the mouth of major rivers leading to the Bay of Bengal, so referring to Sea Surface Temperature is more applicable than land surface temperature.

According to a study done for the Bay of Bengal basin, the increase in sea surface temperature is correlated to increased wind speeds of cyclones. (Albert & Bhaskaran, 2020). For my visualization, I collected data on the temperature rise from 1850 to 2017 in a particular location in the Sundarbans, near the Bay of Bengal (21.5°N, 88.5°E). Based on predictions of greenhouse gas concentration trajectory (scientifically known as Representative Concentration Pathway) along with socioeconomic development scenarios, predicted data shows that temperature may rise by 4°C. This data was extracted from a climate model named CMIP6 (Coupled Model Intercomparison Project Phase 6: ACCESS-ESM1-5)

5.2.6 How are climate futures predicted?

Climate futures are predicted through scientific modeling. These models simulate the interactions between the climate system, human activities, and policy choices to project future climate conditions.

The Representative Concentration Pathways (RCPs) are a set of greenhouse gas concentration trajectories widely used in climate modeling. They represent different future pathways of greenhouse gas emissions. RCPs range from low to high emissions scenarios, with RCP 2.6 representing a stringent mitigation pathway and RCP 8.5 representing a high-emission scenario.

In recent years, Shared Socioeconomic Pathways (SSPs) have been developed to complement the RCPs. The SSPs capture different societal, economic, and technological advancements, providing a range of plausible future development trajectories. There are 5 pathways-SSP 1 to 5, with 1 being the most green sustainable scenario and 5 being the worst case scenario.

5.2.7 Sea level rise

Rising sea levels and warming ocean temperatures are making the Sundarbans more vulnerable to storm surges and flooding. The Global mean Sea level Rise (GSLR), observed from tide gauges and altimetry observations, was noted as 1.4 mm/year from 1901–1990. It drastically increased to 3.2 mm/year from 1993–2015. According to the IPCC, the sea level will be as high as 1.5 metre in 2100. (IPCC, 2021). The rate of sea level rise is much higher in the Sundarban Bay of Bengal area

compared to the GSLR. One study reports that the Bay of Bengal has the highest sea level rise globally, estimated at 10 mm per year. (Rahman & Dragoni, 2011)

5.2.8 Cyclones

Sundarbans delta is one of the most cyclone-prone regions in the world. It is particularly vulnerable due to its low elevation, high population density, and lack of adequate infrastructure and resources to cope with extreme weather events. (Sarkar & Chakraborty, 2021)

The frequency of intense cyclones has increased over the last decade, sometimes twice yearly. The India Meteorological Department classifies tropical cyclones into the following categories (Indian Meteorological Department, n.d.)

Cyclones like Aila, Bulbul, Amphan, and Yaas have caused widespread damage and loss of life. (Hazra et al., 2002) Efforts are underway to improve the resilience of the Sundarbans. These include the construction of cyclone shelters, early warning systems and developing community-based disaster preparedness programs.

5.2.9 Salinity

The salinity of water and soil is affected by a range of factors like tidal cycles, rainfall patterns, and the influx of freshwater from rivers. The western part of Sundarban is relatively less saline than the eastern part due to the presence of the Hugli River. (Pramanick, 2016)

Direct impacts of high salinity can lead to the death of mangrove trees, especially the less salt tolerant Sundari and Golpata species. This reduces the overall extent and health of the forest. It affects the wildlife that depends on the mangroves for habitat and food.

Human activities such as shrimp farming (*“meen dhora”* as referred to by the locals) and water diversion also contribute to changes in salinity levels.

5.3 Biodiversity

The Sundarbans is recognized as a global biodiversity hotspot, home to a lot of plants and animal species. A 2011 WWF report focused on the impacts of climate change on the Sundarbans, particularly on the region's flora and fauna. The study concluded that the Sundarbans are highly vulnerable to climate change, and urgent conservation efforts are needed to protect their unique biodiversity. There are around 25 species of reptiles, mammals and birds, including the Royal Bengal Tiger, Ganges River dolphins, various sea turtles, and waterfowls that are considered endangered as per the IUCN Red List of Endangered Species.

5.3.1 Man and forest

In a forest-society interface, unplanned overexploitation of natural resources is widespread. Due to the pressure of an ever-increasing population, the Sundarbans also saw the destruction of over half of its

mangrove forest for wood production, land reclamation for settlement, and aquaculture.

There are high instances of human-tiger conflict at the edge of the protected forest where settlements and tiger habitats overlap. These conflicts pose challenges for both safety and tiger conservation efforts.

5.3.2 Socio-economic conditions

The area also suffers from poverty and uncontrolled migration. The socioeconomic conditions of the people living in the Indian Sundarbans are influenced by geographical location, vulnerability to natural disasters, lack of infrastructure, and limited access to education and healthcare. (Das & Datta, 2014)

Livelihood: The primary occupation of the people living in the Sundarbans is agriculture and fishing. However, due to the effects of climate change, the yield of crops has decreased. Most of the population now migrates outwards or are daily laborers. Many people are also environmental refugees (migrants due to climate) to escape their sinking habitats. (Ghosh, 2016)

Sundarbans lack basic infrastructure such as roads, electricity, and communication facilities. This lack of infrastructure has hindered economic development in the region. However, various government and non-governmental organizations are working towards improving the situation by providing better infrastructure and facilities.

5.4 Existing Visualizations on Climate and Ecology

When we talk about climate change visualizations, there are mainly 2 kinds- **global climate simulators** that run on large amounts of scientific data and the other are **interactive narratives** and **journalistic pieces**.

5.4.1 Climate Simulators

There are a number of global climate simulators that allow users to test and visualize the long-term impacts of climate change. Most of these tools take data from reports by IPCC (Intergovernmental Panel on Climate Change) or satellites like the NASA Earth Planet Observatory. Here are a few of them that I have explored so far:

Climate Policy Simulator

1. [EN ROADS Simulator](#) - It is a climate policy simulator that helps users understand the long-term impacts. It is slightly more advanced than its predecessor, the [C-ROADS](#) simulator. It provides policymakers, media, and the general public with the ability to explore.

Creators: Climate Interactive, MIT, Ventana Systems, and UML Climate Change Initiative collaborated to develop this policy simulator

Global Climate Tools and Simulators

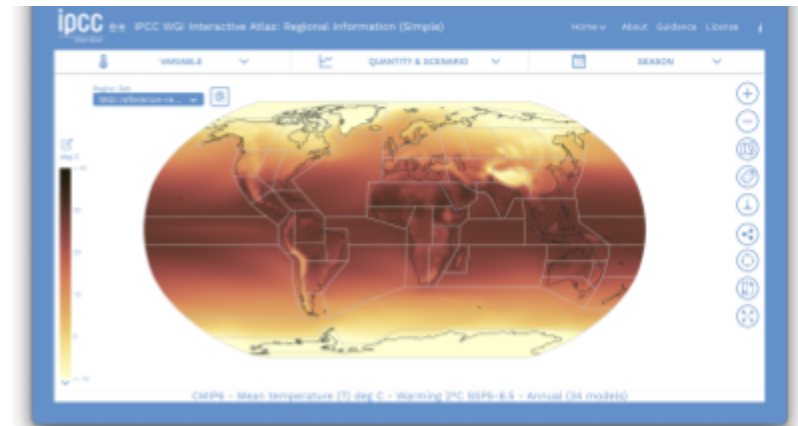
2. [Interactive Atlas IPCC](#) - It is an interactive tool showing world maps, along with charts. It is meant



EN Roads climate simulator

for climate researchers. It draws from the observed and projected climate change information underpinning the Working Group I contribution to the 6th Assessment Report of 2021.

Creators: Intergovernmental Panel on Climate Change



IPCC Interactive Atlas

3. [Climate Time Machine](#)- NASA shows how some of Earth's key climate indicators - sea ice, sea level rise, temperature, and CO₂ have changed over time through simple animations.

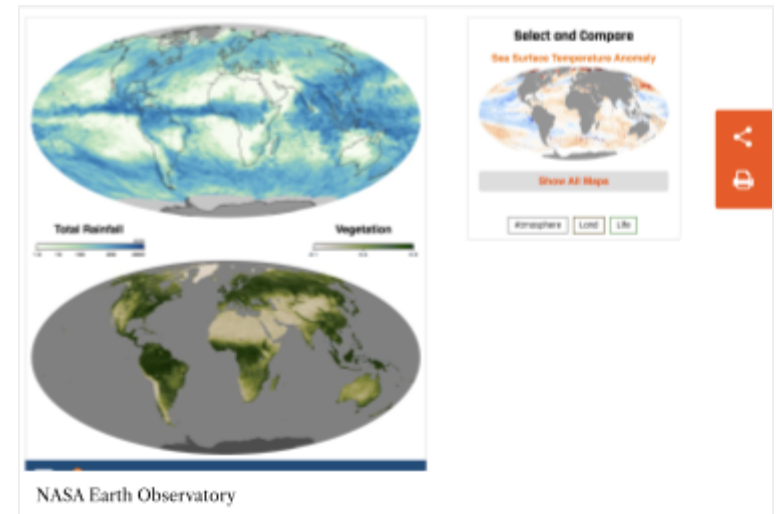
Creators: NASA



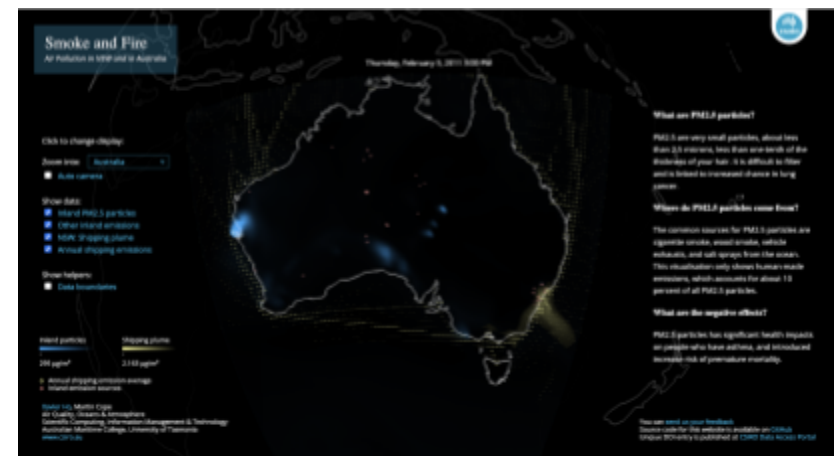
Sea level rise shown in NASA's climate time machine

4. [Earth Observatory](#)- Global maps containing temporal data of snow cover, water vapour, natural vegetation, cloud fraction, etc, from 2000 to 2022. The interface makes it easy to compare two parameters at a glance.

Creators: NASA



5. [Smoke and Fire](#) is an interactive visualization of particulate matter 2.5, which are very small particles, <2.5 microns in the polluted air of Australia. The visualization is minimal yet effective
Creator: Xavier Ho



Smoke and Fire - Air pollution in Australia and NSW

Gamified Experiences

6. [ClimaRisq](#)- A roleplaying digital card game where the player has to roleplay as a policy maker and choose cards to balance the levels of “popularity,” “ecology” and “finance” for as long as possible by making strategic decisions. This lets the user feel how tough it is to balance development and sustainability.

Creators: Université Paris Saclay



7. [Ecological Footprint Calculator](#) - a sequential quiz that lets users find out their ecological footprint in a graphical manner. It compares the resource demand of individuals and businesses against Earth's capacity for biological regeneration.

Creators: Global Network Footprint

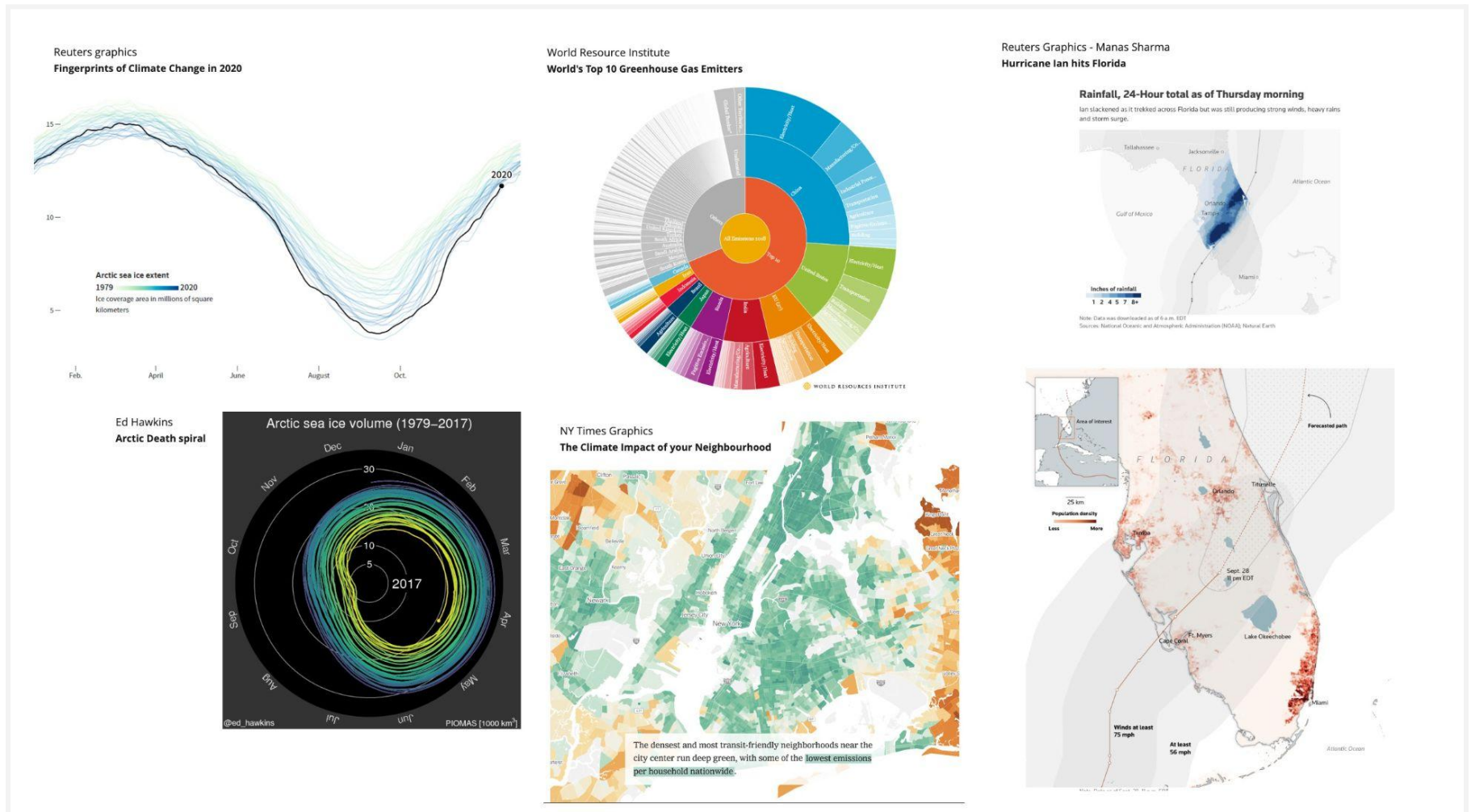


Ecological footprint quiz

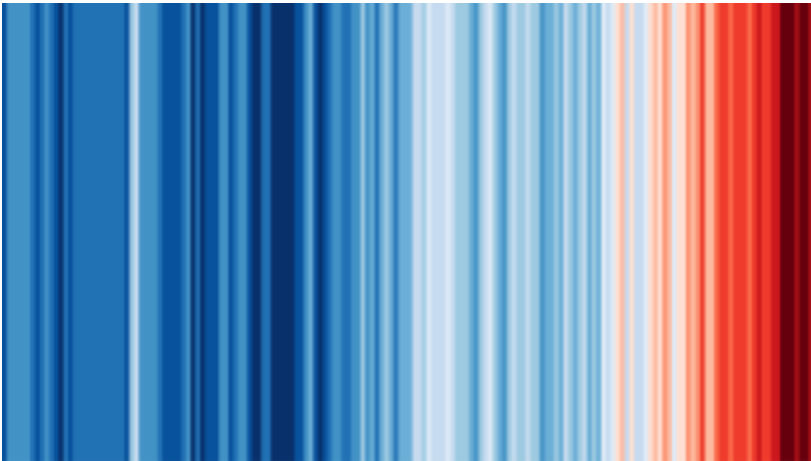
5.4.2 Climate Visualizations

I explored existing data visualizations, infographics, and data journalism, to gain insights into effective storytelling, interaction pattern, and visualization techniques.

Reuters Graphics, NY Times infographics were helpful sites full of data stories and interactive narratives. It helped me shape the final product.



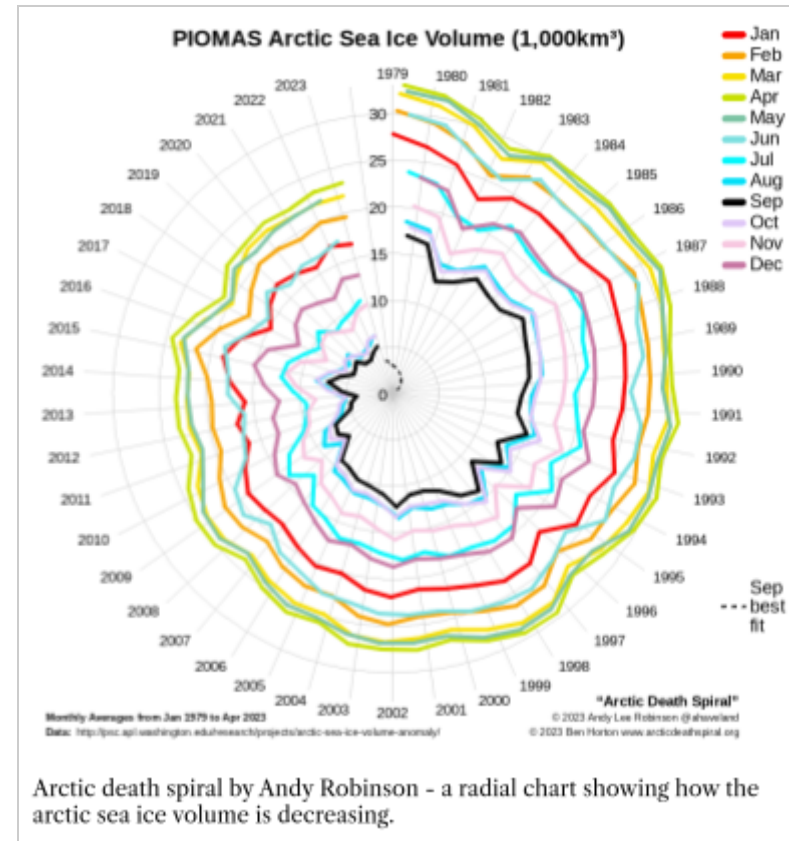
Climate Stripes



Climate stripes showing global warming by Prof. Ed Hawkins

This is a famous style of visualizing rising global temperatures created by climate scientist Prof. Ed Hawkins. At first, data from 1990–2020 was available. The visualization gave a sense of the uniform heating that was taking place. The vertical gradient bars on hovering give the exact measure of temperature for that year.

Arctic Death Spiral



This visualization shows the monthly variation of polar ice and how it is decreasing with each year. A similar visualization exists called 'Climate spiral' which is a video on rising global mean temperature.

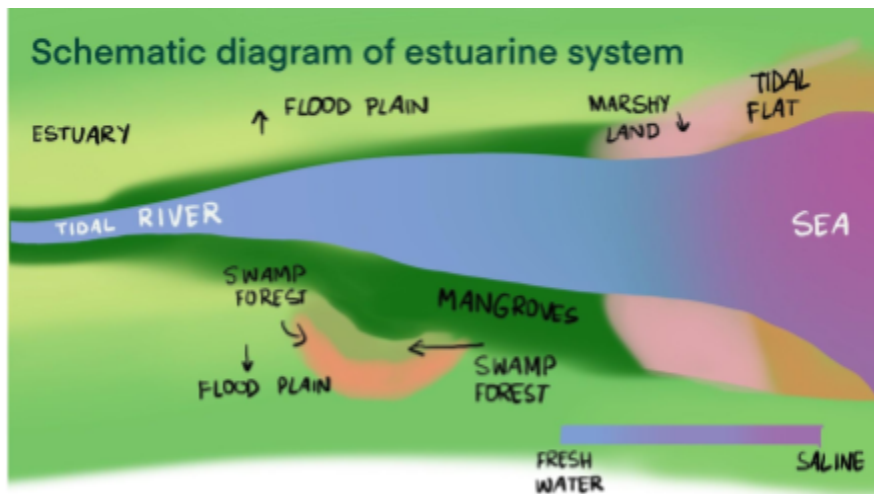
06 Primary Research

6.1 Subject Matter Expert consultation

In conversation with Prof. Tuhin Gosh, Department of Oceanographic Studies, Jadavpur:

A discussion with an expert in this field, Professor Tuhin Ghosh, yielded many eye-opening facts about the story of Sundarbans. Following is a summary of the conversation with him.

- *Discussion about the estuarine river system:* People always discuss the sea, not the river, when discussing climate change. Sundarbans' problem is not just due to climate change but also due to reduced silt deposition.



Schematic diagram of an estuary—the transition zone of a river to sea

- *Natural freshwater inflow has been reduced:* There are also many artificial interventions on the Ganges in the upper casement area. Dams and barrages stop the velocity of the river. The sedimentation carried by the river thus falls before reaching Sundarbans, making the riverbed shallow and flooding the adjacent encroached plains.
- *Wave action:* However, high sea levels and tidal action continue to break sediments from the island's shores. Because of that, sedimentation has decreased, which has disturbed the delta formation and led to erosion.

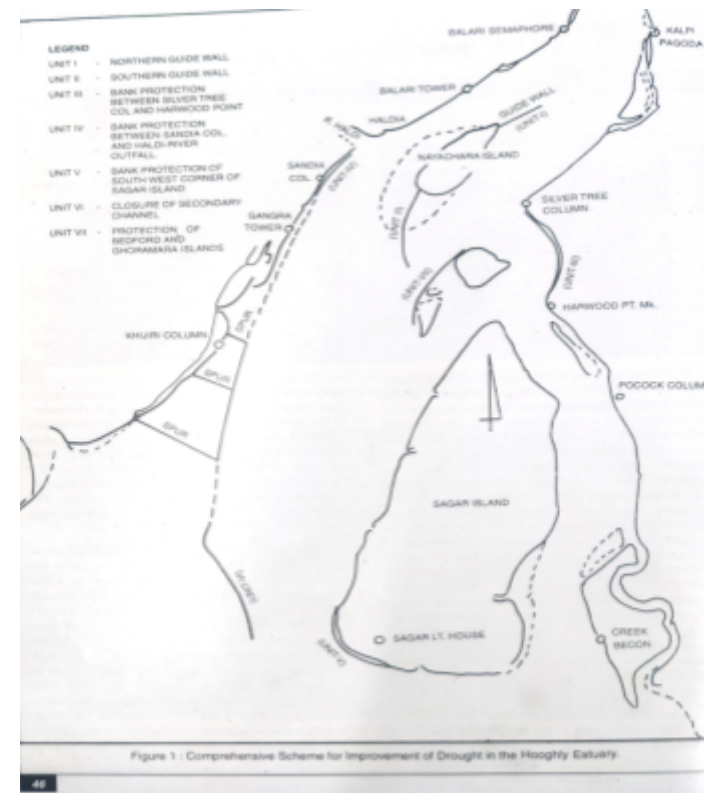


Figure 1 : Comprehensive Scheme for Improvement of Drought in the Hooghly Estuary

Plan for construction of guidewalls in the estuary (1980)

- *Guidewall construction in Haldia:* Seven guide walls (concrete walls) had been suggested to the Kolkata Port Trust. Only two were constructed to balance the rivers from shifting eastwards because of a tilted tectonic plate. The project was abandoned midway. However, no data is officially available on this controversial topic which is one of the major causes of unnatural erosion.
- *Recognition of environmental refugees:* There are no policies in place in India and globally that recognize and rehabilitate the forced displacement of migrants. Instead of ‘climate migrants’, it is better to use the term ‘environmental refugees’ so that the blame is not shifted to climate, for which no one immediately can be held responsible.
- *Difficulty in availing government aid:* The criteria for getting compensation from the government for rehabilitation is often challenging for the locals.

In conversation with Jyotinindranarayan Lahiri, founder and editor of Sudhu Sundarban Charcha

- In 1780, James Renel created the first map of the delta and published it in Bengal Atlas. In 1830, Dampier created the Dampier-Hodges line drawn to mark the northern boundary of the Sundarbans delta which is still followed.

- In 1977, people settled in areas that were previously No Man’s Land after a change in the ruling party of West Bengal.
- In the late 80s, Bedford and Lohachara islands near Ghoramara disappeared.
- In the late 90s, the alarming rate of erosion of Ghoramara was reported.
- More areas are quickly being eroded where people live near the embankments. Some of those places are Mousuni, Baliara, G Plot, and Jambudweep. He believes there will soon be a severe land crisis, and many will become environmental refugees.
- The whole area is underdeveloped and poverty-stricken with a high population density
- Awareness is important as we need to assist Sundarbans in developing human resources while conserving nature at the same time.

6.2 Findings from the field

I visited the island of Ghoramara, situated in the Hugli estuary, north of Sagar island—the biggest island of Sundarban. These are my observations:

- The island suffers from climate insecurity (especially rising sea levels, cyclonic damage, and erosion). The people live in poor socioeconomic conditions.

- The erosion on the island is extreme. Chunks of land around 8–10 ft often wash away during high tide.



The crack demarcates the part of shoreline that will soon wash away. At a distance, a datepalm tree is seen which was previously above sea level

- People who live near such areas are shifting inwards to the higher parts of the island.
- Those who can afford it buy land for alternate residences in nearby islands.
- Most of the able-bodied men have migrated to other states in search of better livelihood opportunities.

- There is no electricity on the island, and people have very sustainable habits. The net carbon output of the island is zero.
- There is a powerful sense of community amongst the inhabitants of Ghoramara.
- Main occupations are agriculture and daily labor.

07 Scope

For the purposes of this project, the focus largely remains on ecological changes in the Indian Sundarban islands, mainly in the following areas-Canning, Joynagar, Kultali, Basanti, Gosaba, Mathurapur, Kakdwip, Sagar, Namkhana and Patharpratima.

We present the current status of the climatic conditions and the region's inhabitants, along with the changes over the last 100 years. Spatio-temporal changes of the delta, along with human dependence and its effects, are essential in understanding the overall phenomenon. Associated concepts, such as ecosystem services, estuarine dynamics, climate resilience, human adaptation and policies implemented, have not been mentioned to make them more consumable to a general audience.

It also remains restricted to a general overview of Sundarbans touching upon 4 particular topics- the erosion of islands, rising temperature and sea level, endangered

species, and challenges faced by the people living in the region.

08 Target Audience

According to Andy Kirk's book 'Data Visualisation: A Handbook for data-driven design' (Kirk, 2019), we usually design visualizations for these audiences:

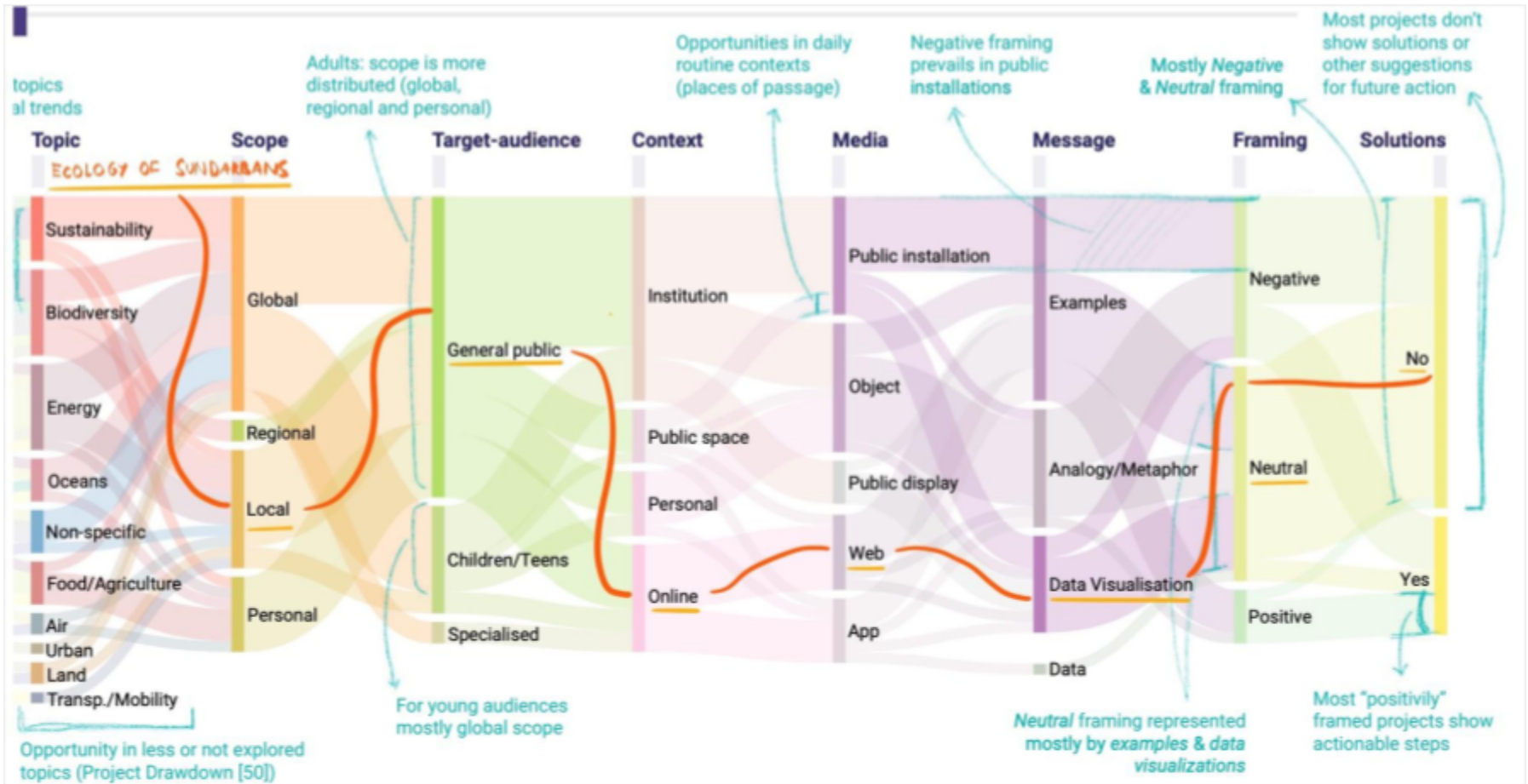
1. *Novice*: first exposure to the subject, but does not want oversimplification
2. *Generalist*: aware of the topic, but looking for an overview understanding and significant themes
3. *Managerial*: in-depth, actionable understanding of intricacies and interrelationships with access to detail
4. *Expert*: more exploration and discovery and less storytelling with great detail
5. *Executive*: only has time to glean the significance and conclusions of weighted probabilities.

My project is made for the **general public** (individuals who are *generalists*), such as college graduates and working professionals. They possess a fundamental understanding of science, numbers, and geography and are familiar with the concept of climate change. However, their knowledge of the subject is not extensive. A suitable example would be readers of national English newspapers like The Hindu and Times of India, who engage with a wide range of topics, both national and international.

09 Positioning

Positioning of the project:

Based on a review paper by Ferreira et al. on climate change communication in HCI, the below framework has been developed to describe existing viz. on climate change. My project (*highlighted in orange*) deals with a new topic on the ecology of Sundarbans. It talks about the local environment, targeted towards the general public. The medium is an online website, mainly consisting of data visualization. It does not provide solutions to the problem, and the framing of the content is neutral.



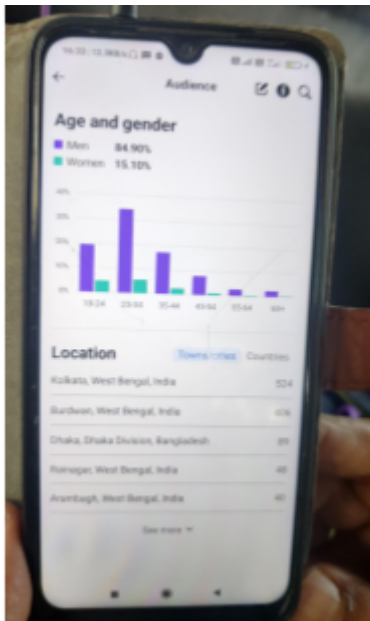
Positioning my project w.r.t other climate viz in HCI (shown in orange)

Positioning of final product:

[Sudhu Sundarban Charcha](#) (link to the website) is one organization that publishes a quarterly Bengali magazine. They wish to support the locals living in the Indian territory of Sundarban. They have written various articles and magazines and collect field data from time to time.

According to the organization, there are primarily three types of audiences that they engage with. There are users who have an inherent interest in knowing more about Sundarbans. Then there are researchers, journalists, and climate enthusiasts actively studying the area.

Thirdly, some users casually browse through their website and magazines occasionally. The users accessing their magazines and other print media are 45+ years old, but the users visiting the website and social media pages fall in the 25–34 age group.



Analytics of the sundarbancharcha website

10 Project outcome

1. **Real-world outcome:** In the future, Sudhu Sundarban Charcha organization can use the website to dispense information to their website visitors.
2. **Information dispensing:** The target audience must understand and interpret the written content, illustrations, and visualizations.
3. **Definition of success:** Users should be able to grasp the essence of the narrative without investing a lot of time in deciphering the data. They should sense the urgency associated with the changing ecology without perceiving it as distant from their own lives.

11 Data

11.1 Data Collection

Data collection is the process of gathering information on variables of interest to answer questions and visualize and evaluate outcomes. Most of the data collected in this project has been from the following sources:

1. Peer-reviewed scientific journals and articles.
2. Reports from IPCC (Intergovernmental Panel on Climate Change), IRS (Indian Remote Sensing Organization), WWF (World Wildlife Foundation), etc.
3. Few of the data has been collected from primary sources and visit to the Sundarbans.
4. Projected data from a climate model (CMIP6) Coupled Model Intercomparison Project Phase 6.
5. Data from various papers were combined at times to bring out the whole picture.

The collected data was cleaned to make it suitable for geospatial and temporal visualizations. A few tasks, like matching names of the same villages with different spellings (eg, Jaynagar vs. Joynagar), were manually examined and edited. Various places' latitude and longitude data were also collected. Here is a [link to the compilation of the data](#), along with sources.

11.2 Types of Data

Data can either be discrete or continuous. However, according to Stanley Smith Stevens, there are four types of data. They are as follows:

1. *Categorical*- Categorical attributes have no order among the entries. They simply fall into a given category. For example, male and female.
2. *Ordinal data*- Ordinal data always have inherent order among the entries. They can be quantitative or ordinal (not necessarily quantitative). However, they cannot be arithmetically operated upon.
3. *Interval*- Data in numeric scales in which we know the exact values and the difference between the values is constant.
4. *Ratio* - Divergently ordered values that have a neutral point (or a zero mark). Values to either side of this mark grow sequentially away from it.

There are also a few other classifications of data based on form, such as:

1. *Temporal data*- Tracks time series data and linearly moves in one direction. E.g., Change in forest cover over the years. It can also be cyclical; data wrapped around in a repetitive loop.
2. *Links*- This datatype simply depicts the relationship between items. These are typically found in a network diagram.
3. *Positions*- Positions are spatial data, providing a location in a 2D place or 3D space. Cartograms, heatmaps visualize this kind of data. E.g., the number

of tiger attacks in Sundarbans, based on village names, blocks, and districts on a map.

4. *Hierarchical data*- Data ordered within larger groups forming a cluster. E.g., Species and subspecies of various living organisms.

11.3 Dataset types

The types mentioned above of data are typically arranged into the following datasets. Sometimes they can be arranged into complex combinations as well.

1. Tables

These are the most common dataset types. A typical spreadsheet is a table. Rows are used to encode 'items', and columns are used to encode 'attributes.' Cells that are at the intersection of these data types contain values.

2. Networks

This dataset type is efficient for encoding items and the relationships between them. Each node is used to encode an item, and the links are used to encode relationships.

3. Fields

Fields are effective in depicting continuous phenomena measured at any attribute. Spatial field can be regularly sampled in space to attain the values at those intervals. These can be used to encode attributes into a spatial layout, like contour lines.

11.4 Semantics of Data

The real-world meaning of data is important for communicating the impact of climate and anthropogenic changes. The narration and data can be structured in a way, augmented by metaphors to add meaning.

12 Storytelling

The word "storytelling" has a long history, during which it has been used in many ways in different domains. As a result, it invokes meaning and nuance without having a single agreed-upon definition. (Lee et al., 2015) Nevertheless, most definitions of storytelling tell that it is



Data storytelling by Lydia Hooper. Figure from <https://venngage.com/blog/data-storytelling/>

some sort of **controlled delivery or presentation of information as a causal chain of events**.

This delivery is often with a temporal or narrative structure. We aim to build a website that contains components that form the “story” (structures, elements, and concepts) and those that influence the “telling” part of storytelling (people and channels).

Structure- nonlinear narrative containing information on four key subsystems that describe the ecology.

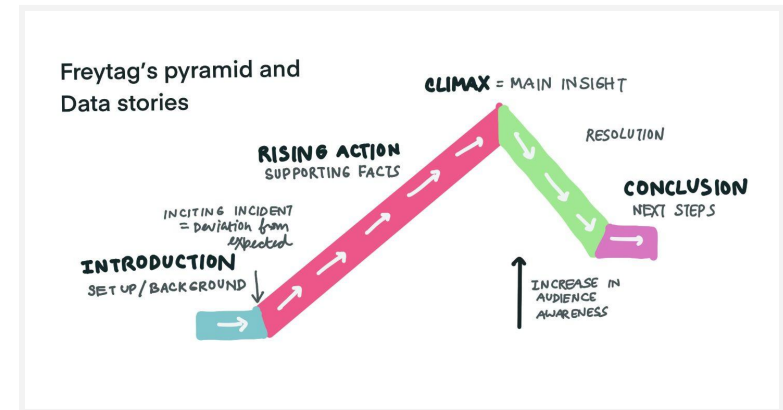
Elements- paragraphs of text, images and diagrams, static visualizations, and interactive visualizations.

12.1 Data Story

A gripping narrative, along with insightful charts, can hold a lot of explanatory power by providing a wealth of information to the audience. Thus it becomes vital to understand the skillful combination of data, visuals, and narrative of data storytelling. (Segel & Heer, 2010)

1. **Story in the context of data storytelling:** Data visualizations are often the central aspect of data stories, but narratives are equally important. Here, a story is an account of connected series of events. The user reads the narrative elements and creates meaning from various data points.
2. **Audience perception:** Storytelling also help to engage the audience and connect with them emotionally. Data visualization can help influence how people perceive a topic, especially if they value scientific methods.

3. **Freytag’s pyramid:** Freytag’s pyramid is a way of organizing a narrative. It has five parts—set up, inciting incident, rising action, climax, and resolution.



In the context of data stories, a setting is established at the beginning. The inciting incident highlights how something has changed in the environment that introduces a new problem. This leads to a build-up and finally to the central insight (climax). The audience has more knowledge and can draw conclusions or take the following steps (resolution).

4. **Signal and noise:** Signal refers to the meaningful data designers want the audience to see and understand. It represents key insights or messages. On the other hand, "noise" refers to irrelevant or extra elements in the data that do not contribute to the interpretation. Noise can be data outliers or inconsistencies that obscure the underlying

patterns. A balance must be struck between the two to make the data story effective.

12.2 Types of Narratives

Here are some of the basic narrative structures used in data stories—

1. **Linear Narrative:** This is a traditional narrative structure where the story unfolds in a sequential manner. The information unfolds to the user in a linear fashion.
2. **Exploratory/ Interactive Narrative:** This form allows the audience to explore the data visualization at their own pace and in their preferred order. Exploratory designs have interactive elements and navigation options that let users dig deeper into specific aspects and uncover additional information, thereby becoming active participants in the narrative.
This project falls under this category of narrative.
3. **Explanatory/Persuasive Narratives:** In this type of analysis, the visualization designer has ‘something specific’ to communicate. The aim is to influence the audience's perception, opinion, or behavior by presenting data in a persuasive manner. It often uses emotional appeal. My story is not taking a climate activist approach but rather letting the user uncover insights from the visualizations.

13 Factors to consider when designing:

Based on the primary and secondary research, the following factors were considered while designing visualizations for the project:

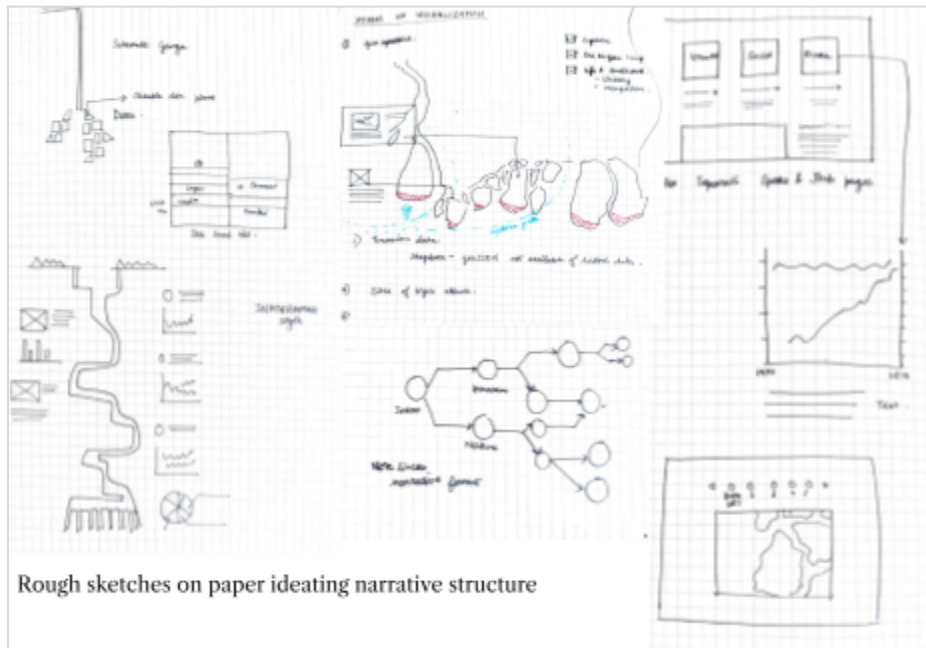
1. **Context of use:** The website will be for a general audience who read national English newspapers like Times of India or the Hindu. Therefore, the visualizations will primarily be in English, and the context will be explained so that the local data is easily understandable to them.
2. **Choice of encoding:** The data encoding and design should accurately communicate the information to the audience for straightforward interpretation
3. **Attention of users:** Since the users are expected to be in browsing mode, it is essential to capture their attention through catchy headlines and visuals.
4. **Sequence of narration:** Usually, story parts are shown in a meaningful order or with a link between them. This depends on whether the intention is entertainment or persuading the target audience with provocative viewpoints.
5. **User Autonomy:** Either the user digs through the data story themselves or the story itself explains every phenomenon to the user.

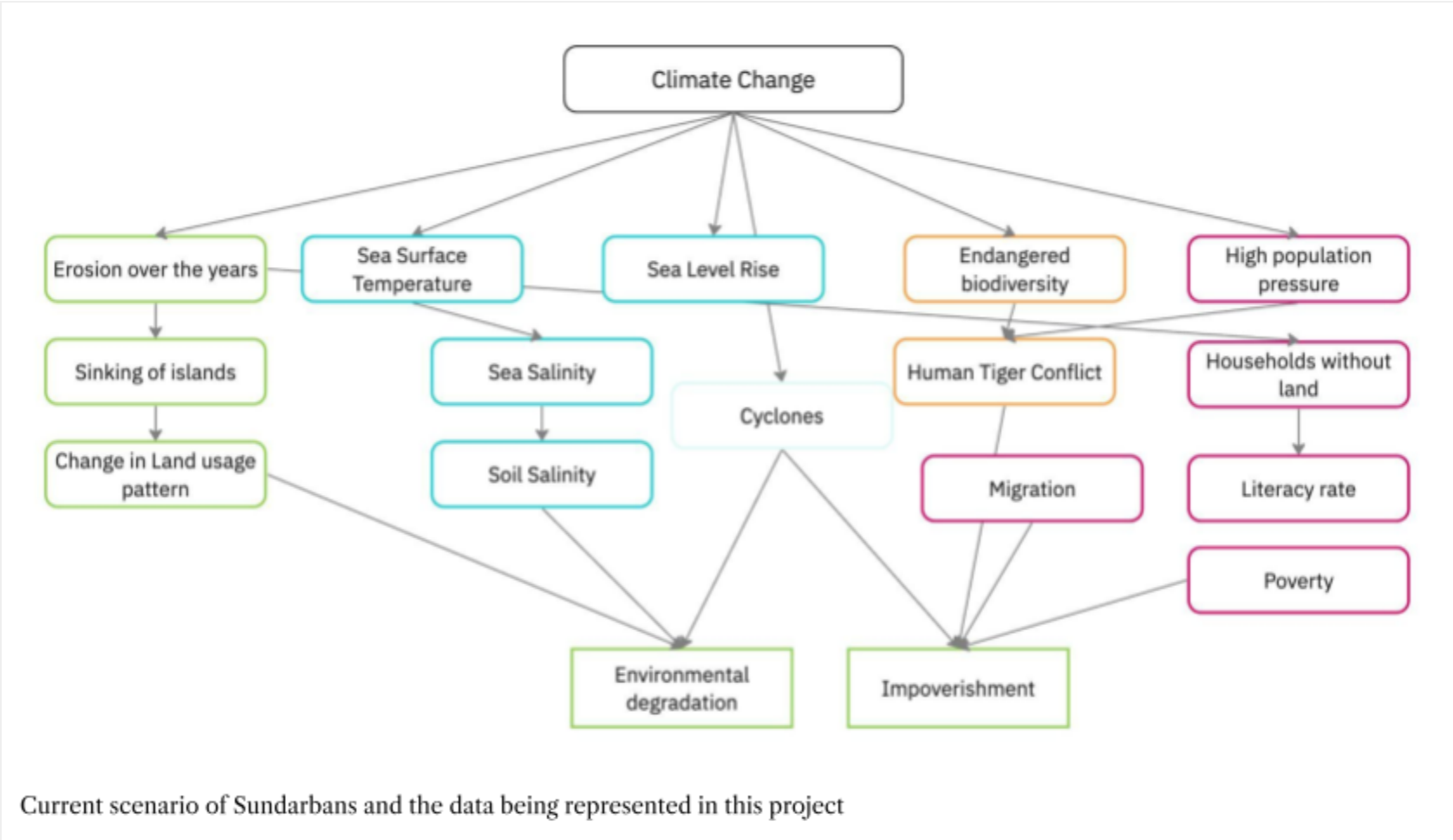
14 Design Explorations

Based on the strategies identified, a number of ideas on how to dispense the data story were generated. Here is the initial basic structure of my story:

14.1 Chapters-

1. Lithosphere
 - a. Temporal morphological data of total area loss and loss from the islands
 - b. Reason for land loss
 - i. Mangrove cover loss
 - ii. Guide walls project in Haldia port
2. Atmosphere
 - a. Cyclonic data and severity index
 - b. Rainfall over the land
3. Hydrosphere
 - a. Climatic Oceanographic data like sea surface temperature
 - b. Sea level rise
 - c. Sea salinity
4. Biosphere (both flora and fauna as well as social ecology)
 - a. List of existing and endangered species of Sundarbans
 - b. Tiger attacks and victims
 - c. Population of the blocks and islands
 - d. Occupation of the people
 - e. Literacy and poverty levels
 - f. Migration





14.2 Medium-Fidelity Wireframes

At this stage, various layouts, and navigation patterns were explored through medium and low-fidelity wireframes. Below are the ideas illustrated and explained, with the user task, interaction pattern, navigation, and narrative style.

A. Editorial style Data Storytelling

STORY OF THE BEAUTIFUL FOREST

Climate change is reshaping our world and lorem ipsum Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

SCROLL TO CONTINUE +

LAY OF LAND

DIVE INTO THE STORY

BROWSE MORE

GALLERY

STORIES FROM THE PEOPLE

ALL VISUALIZATIONS

Idea	Telling a story through data+ photos + interview excerpts of people
Navigation	Dive into one chapter, read text + viz
Task	Browsing, and deep dive into a particular chapter e.g Bonbibi (forest and biodiversity)
Visual language	Graphical visualization with supporting text in lower hierarchy
Interaction	Explorative narrative. Scrolling, point and hover interaction

A. Editorial style Data Storytelling

CHAPTER 1 **LAY OF LAND**

Aerial imagery shows the varied contours of water and land.

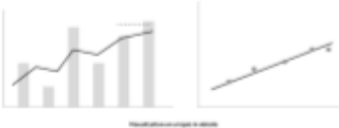
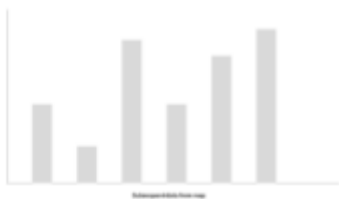
1.1 Land Loss Data

1.2 Interventions on River Ganges

1.3 Dredging and construction on River Hooghly



1.1 LAND LOSS DATA



CHAPTER 1

LAY OF LAND

Sinking Islands



CHAPTER 2

GONE WITH THE WIND

Frequent Cyclones



CHAPTER 3

RISING WAVES

Indicators from the sea



CHAPTER 4

BONBIBI

Forest and Biodiversity



CHAPTER 5

FORCED ADAPTATION

Life and livelihood



Names of the chapters

Nested page has detailed visualization on the chapter

STORIES FROM THE PEOPLE

Five excerpts from the interviews of the people of Sundarban, a disappearing world.



Aftabuddin
Male, 74

“

Shiuli
Female, 34



“

People relate to people the most. Hence excerpts from interviews of Sundarban's locals.

B. Gallery like presentation

Idea

Let people explore the subchapter thumbnails and choose to view a particular viz

Navigation

Dive into one sub-chapter

Task

Browsing like in an art gallery, and deep dive into a particular visualization

Visual language

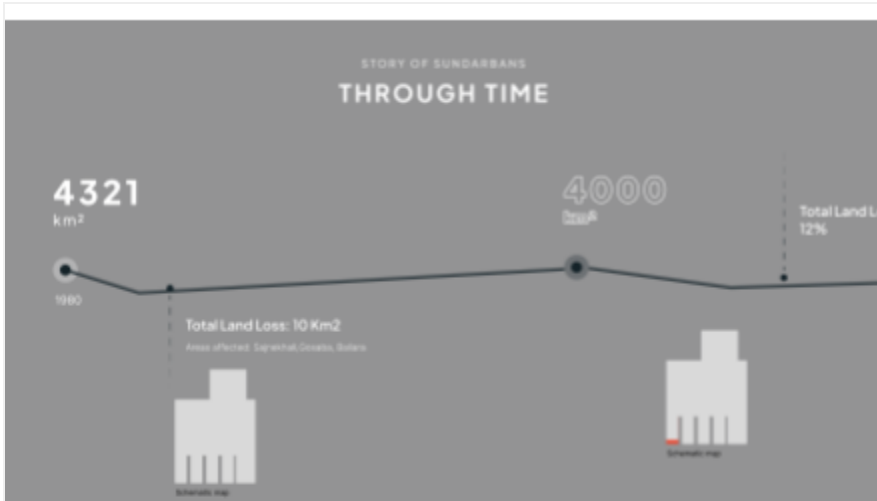
One graphical/geo-spatial visualization in full screen view

Interaction

Explorative Narrative. Horizontal Scrolling hover

	Daily labours	Agriculture	Self-employed rural artisans	Labourers (organized sector)	Others (Organized sector)
Canning - 1	43.93	19.75	10.53	7.93	11.85
Canning - 2	81.55	24.91	5.11	3.63	4.89
Jaynagar - 1	53.31	14.57	10.24	9.24	12.46
Jaynagar - 2	44.45	23.31	13.29	11.81	7.83
Kulad	47.45	36.67	5.76	4.92	5.19
Basant	49.44	22.44	5.96	4.69	7.2
Gosaba	41.54	35.19	5.35	6.26	10.45
Maharapur - 1	55.97	16.77	9.58	6.12	11.56
Maharapur - 2	58.42	21.47	6.46	4	9.66
Kakdwip	54.93	23.33	4.72	8.8	11.76
Sagar	54.97	23.45	3.95	4.15	7.28
Narikhana	53.54	23.64	5.42	3.87	8.52
Patharpattina	58.54	23.64	5.42	3.87	8.52
Average	48.84	23.54	4.85	5.42	11.1

Source: Living with changing climate • Created with Datawrapper

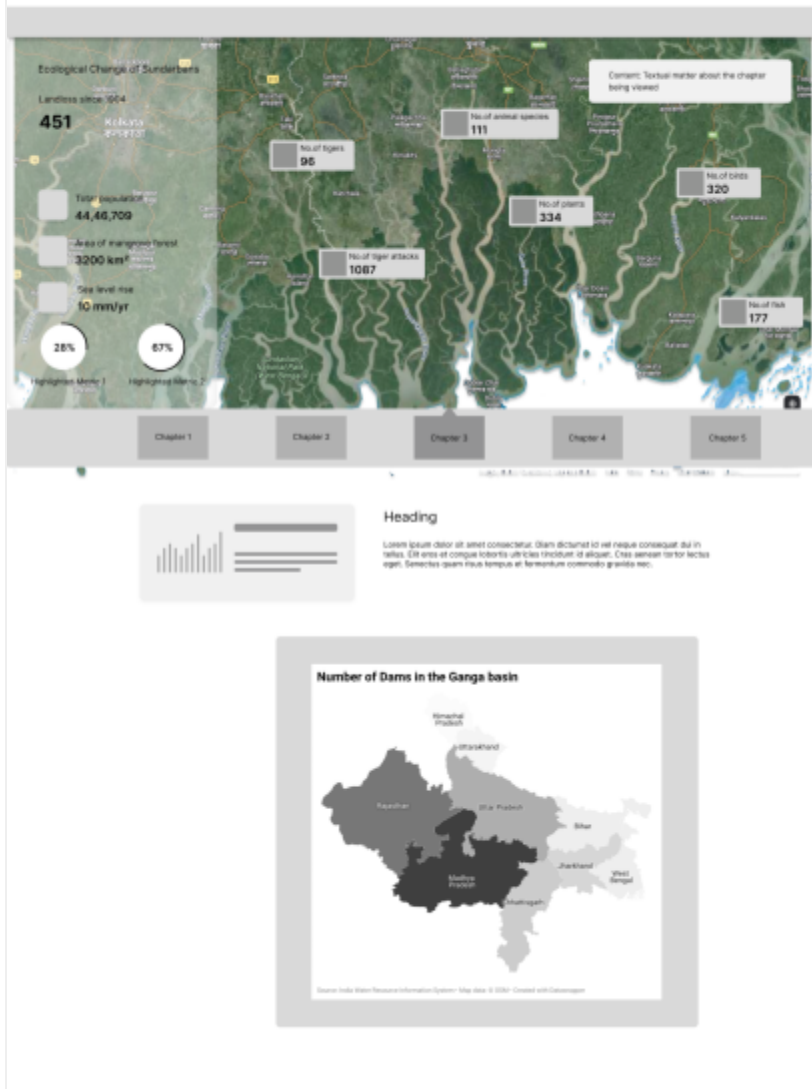


C. Timeline

- Idea** Temporal history of Sundarbans
- Navigation** Mainly time series data will be visualized, so the navigation will be sequential
- Task** User will get a feel of how ecology has changed over time. Clicking on one will expand more details
- Visual language** Minimal design with linear flow and schematic diagrams
- Interaction** Linear Narrative. Horizontal Scrolling, hover



D. Chapterwise overlay on geo-spatial visualization



Idea

Placing both geospatially relevant and irrelevant data on satellite map

Navigation

1 out of 5 chapters shown at a time, global sticky navigation

Task

See the main data, understand spatial data on map, scroll to expand to detailed viz

Visual language

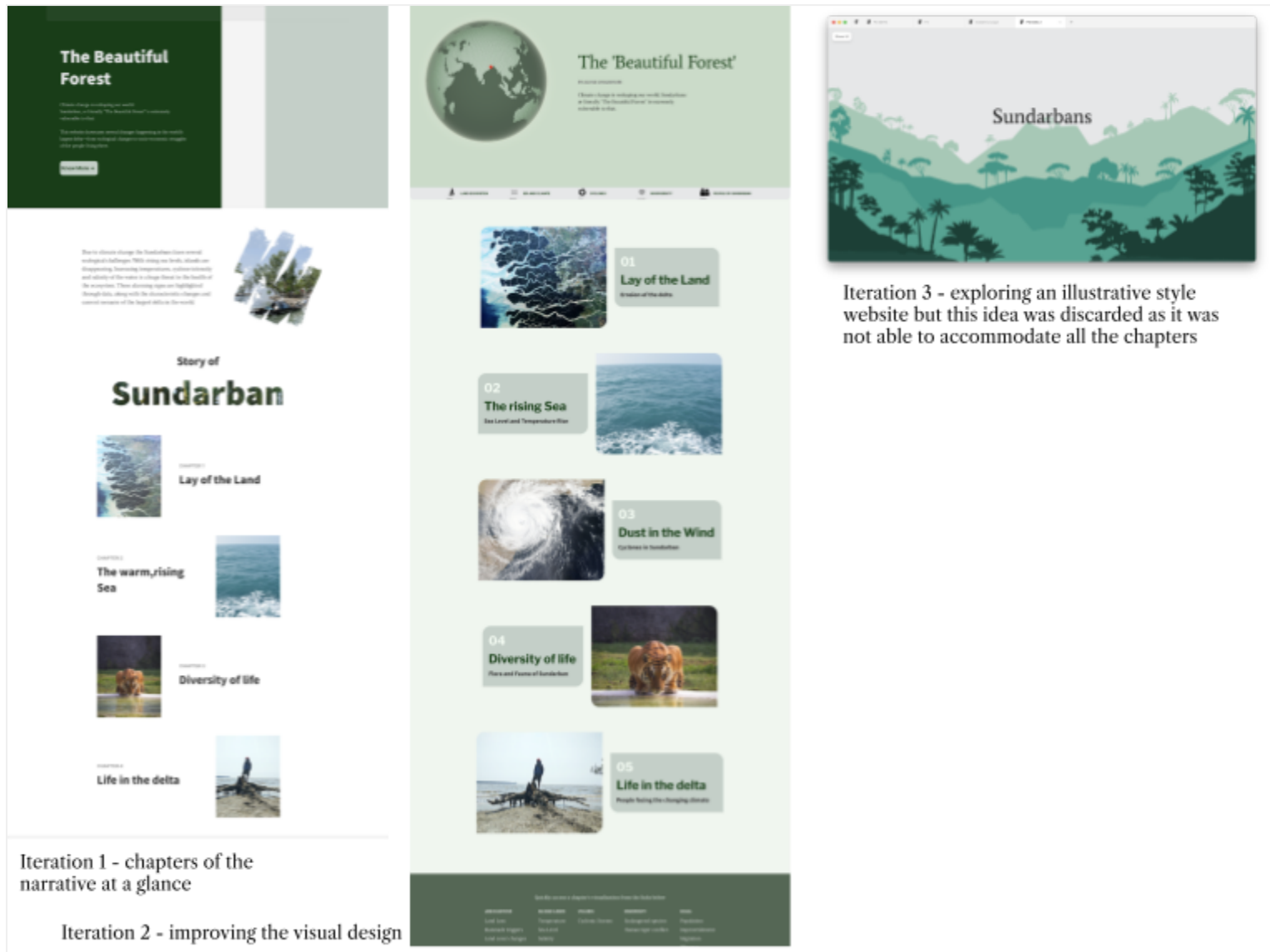
Cards with insights on map

Interaction

Branched Narrative.
Interaction- click on chapters to change options

14.3 High-Fidelity Website Design

After wireframing, I used Framer to make the final iterations for the website. Here are some of the high-fidelity wireframes.



15 Data Visualization Explorations

Ideas were generated in 2 phases, with one part focusing on how the information will be dispensed (the website) and the other part on how the information will be

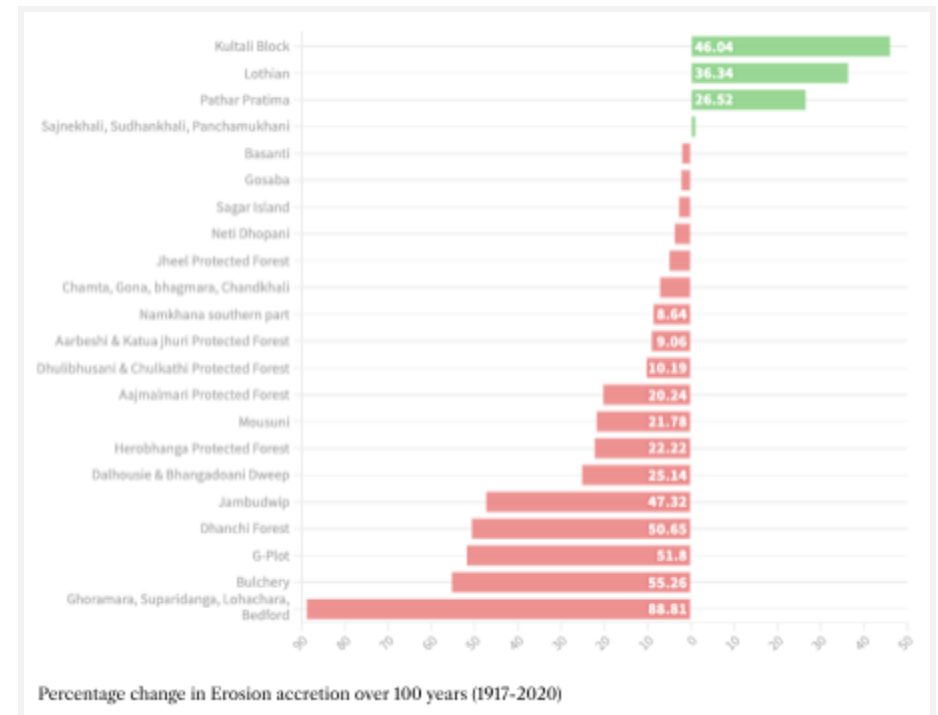
15.1 Terrestrial: Erosion of Islands

Islands of Sundarbans are eroding (and even sinking) fast. Loss of land is the biggest concern of the area. Sea level rise, land subsidence, and incomplete guide wall construction of Haldia port all contribute to it.

Idea 1: Diverging Bars

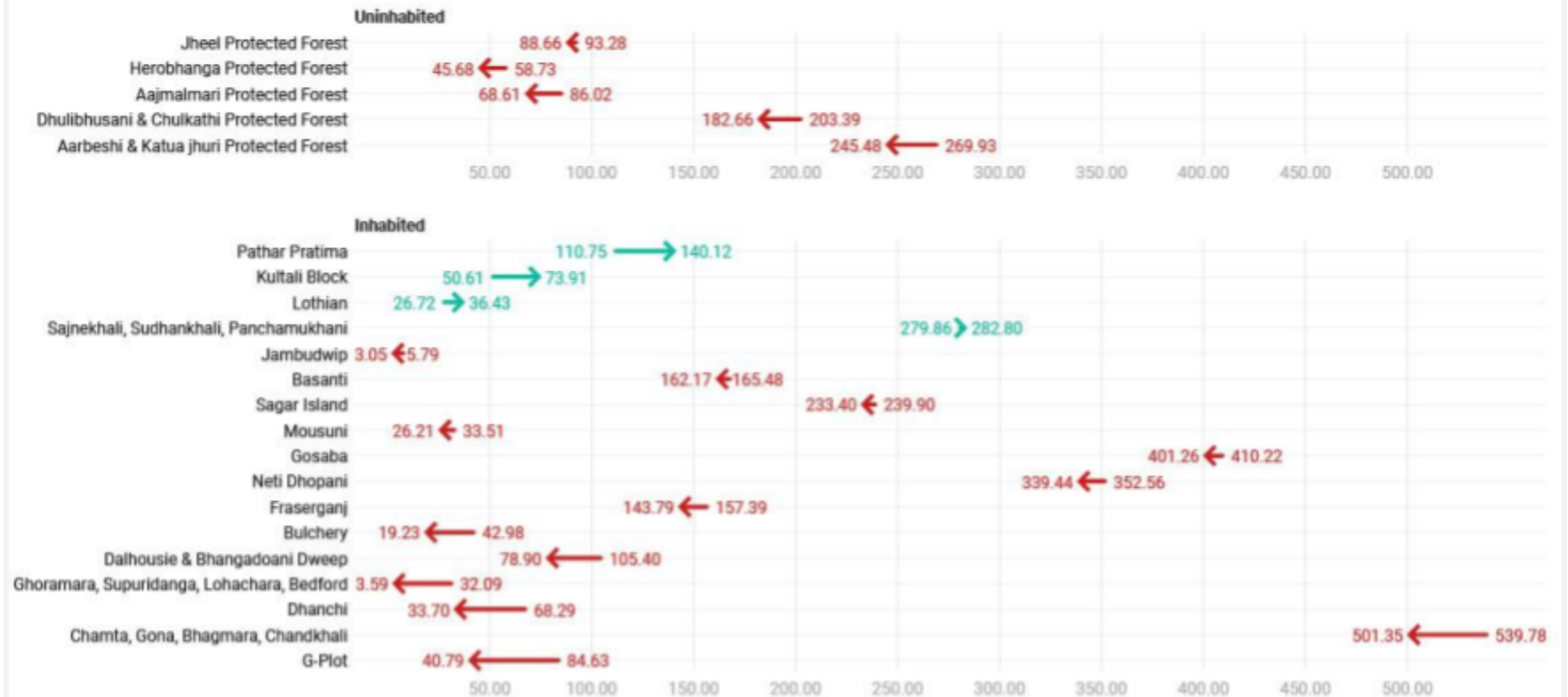
- **Description:** Percentage change in the total area of certain island/island blocks has been visualized. The green bars towards the right show the areas that have increased in size, i.e., accretion has occurred. The red bars going to the left show the islands that have lost area, i.e., erosion has occurred.
- **Information:** Temporal change in the island(s) area.
- **Visual encoding:** Bidirectional bar chart
- **Pros:** The user is able to understand immediately that loss is disproportionately more than gain and get an idea of how the islands are disappearing.
- **Cons:** Percentage change can be huge even when the island is relatively small in size.

visualized. (data visualization). Initial ideas are listed below for each chapter of the data story:



- **Interaction:** Static visualization

Erosion accretion of islands



Change in area of the islands

Idea 2: Arrow Plot

- Description:** Net magnitude change in the total area of certain island/island blocks has been visualized.

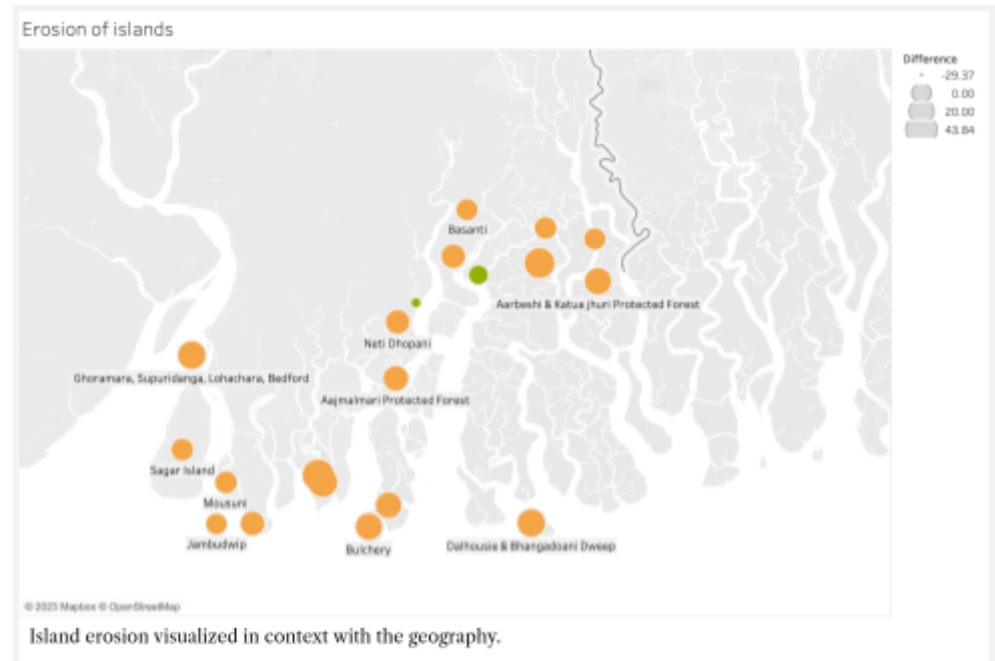
The green arrows show that area has increased in size, i.e., accretion has occurred.

The red arrows show lost area, i.e., erosion has occurred. The islands are categorized into inhabited and uninhabited areas.

- **Information:** Temporal change in the island(s) area.
 - **Visual encoding:** Arrow chart plot
 - **Pros:** Easy to understand the trend of decrease and by how much.
 - **Cons:** Not visually appealing
 - **Interaction:** Static visualization
 - **Synthesis/new discoveries:** Most inhabited islands are undergoing erosion, so the visualization hints that people living there face problems and have to migrate/resettle frequently.
-

Idea 3: Symbol map

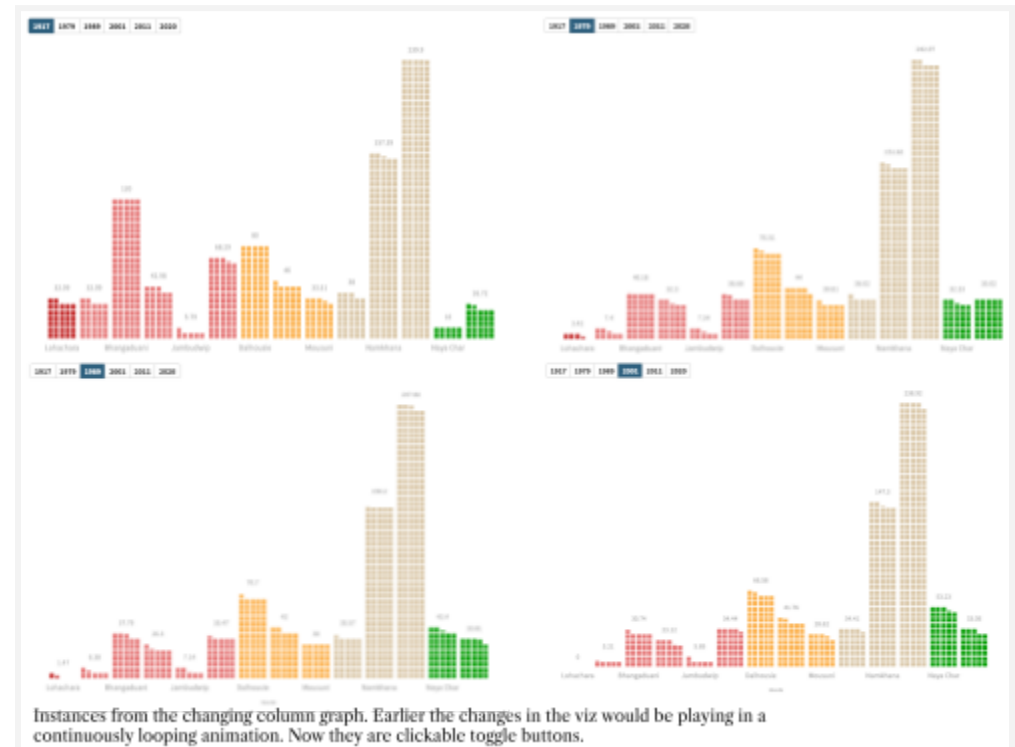
- **Description:** Change in area of island blocks has been visualized. The size of the circles shows the magnitude of area change. The colours show decrease or increase.
- **Information:** Temporal change in the island(s) area.
- **Visual encoding:** Geospatial symbol map
- **Pros:** Easy to see location of area change
- **Cons:** Small differences in data is hard to see. Overlapping taking place and area is not a good indicator of change.
- **Interaction:** Interactive visualization, zoom and pan around the map; hover for tooltip.



- **Synthesis/new discoveries:** Geographical reasons for erosion, like being located nearer to sea, coast or rivers.
-

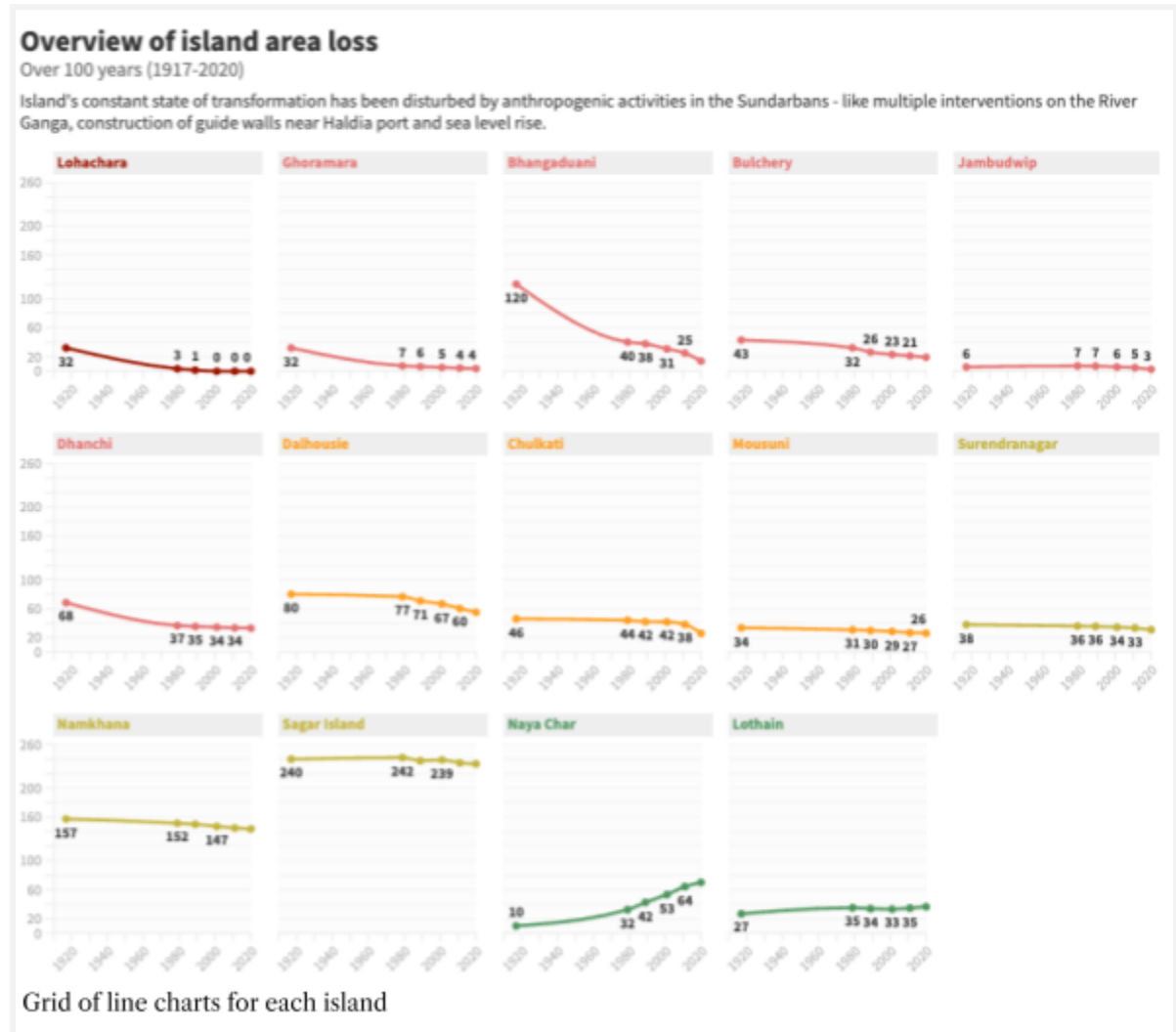
Idea 4: Animated Column chart

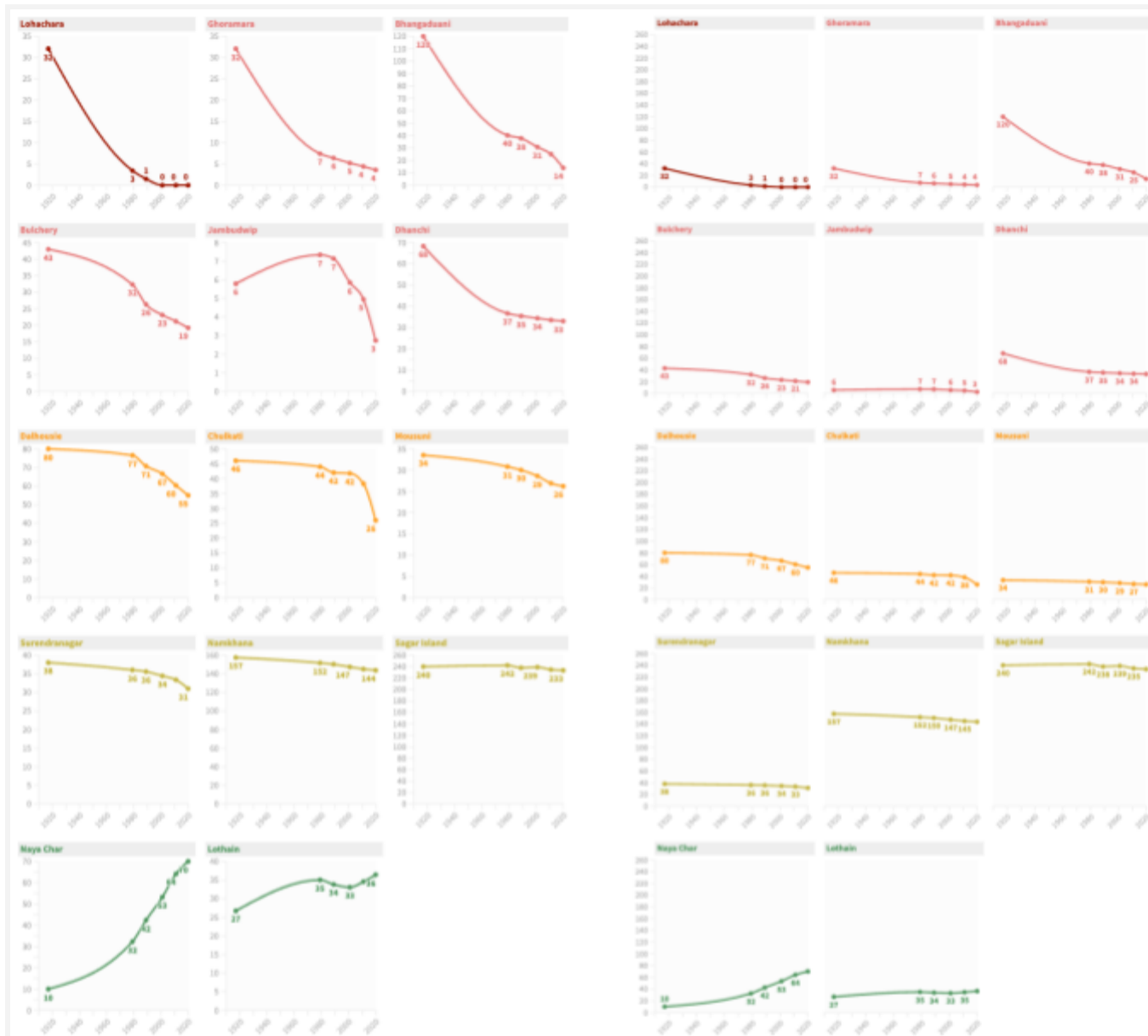
- **Description:** A change in area of island blocks has been visualized. Colors indicate the degree of loss. (red=major area loss; yellow = minor area loss, green= area gain and so on)
 - **Information:** Temporal change in the island(s) area.
 - **Visual encoding:** Column graph (animated). Height indicates the area. Chunking indicates which blocks the islands belong to. 1 small square denotes 1 sq. km
 - **Pros:** Animation can effectively tell a story over time. As the loop plays, we can view how many islands have lost a lot of land over the years.
 - **Cons:** User cannot view a particular year's data unless they pause at a certain year. The years are also not at equal intervals, so playing them in a loop is unjustified.
 - **Interaction:** Play/pause button for looping animation
 - **Synthesis/new discoveries:** Gives a sense of how erosion and accretion work in a balance. It also visually represents how erosion is happening more on the islands.
-



Idea 5 (finalized) : Grid of line charts

- Description:** Temporal change in the area of island blocks has been visualized. The line chart shows the trend across the years of different islands.
- Information:** Temporal change in the island(s) area.
- Visual encoding:** Grid of line charts, semantic coloring to show categorical data (red=major area loss; yellow = minor area loss and so on)
- Pros:** Easy to see where the trends over time and how most have lost land. Bucketing them into categories of major, moderate, minor, extreme, and area gained also helped.
- Cons:** Few users felt the visualization was not convincing enough because they expected the lines to be steeper.
- Interaction:** Interaction on hover
- Synthesis:** Varying sizes of the islands and comparison of decrease in area is clear.





For this grid of charts, Y axis was not a common one. Hence all the slopes were varying.

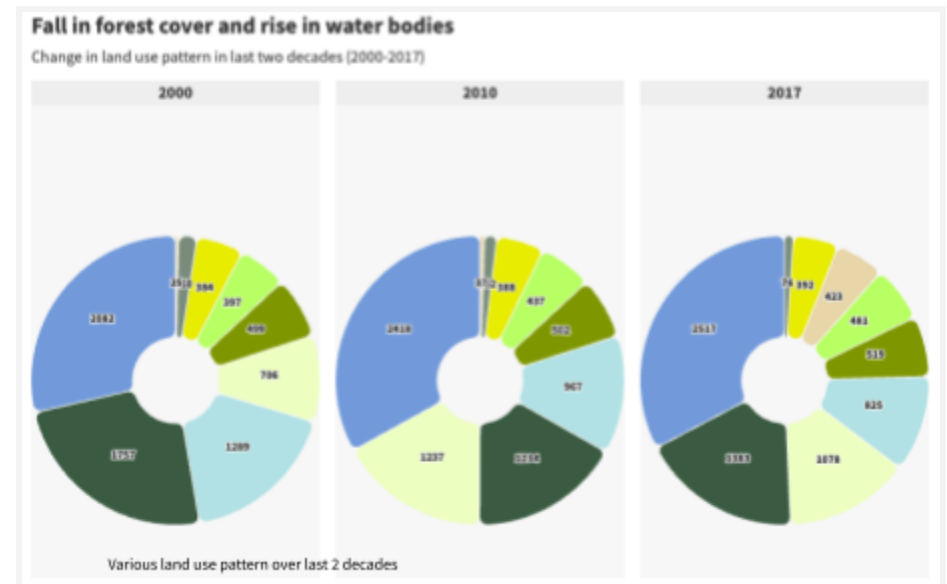
Corrected - Same grid of chart but with continuous time axis and shared Y axis

15.2 Terrestrial: Land cover change pattern

Due to the loss of land, the land usage pattern has also changed. Here we show the data of the last 20 years, especially how mangrove cover, swamps have reduced and rivers, sandy beaches have increased.

Idea 1: Pie charts

- **Description:** Land cover is changing from population pressure as well as land erosion.
- **Information:** *Percentage change* in land cover over the last 20 years.
- **Visual encoding:** The area of slices depicts the land area each year. Colors show a semantic association.
- **Cons:** Quantity is represented by slices, and estimating quantity from angles is challenging.
- **Interaction:** Static visualization

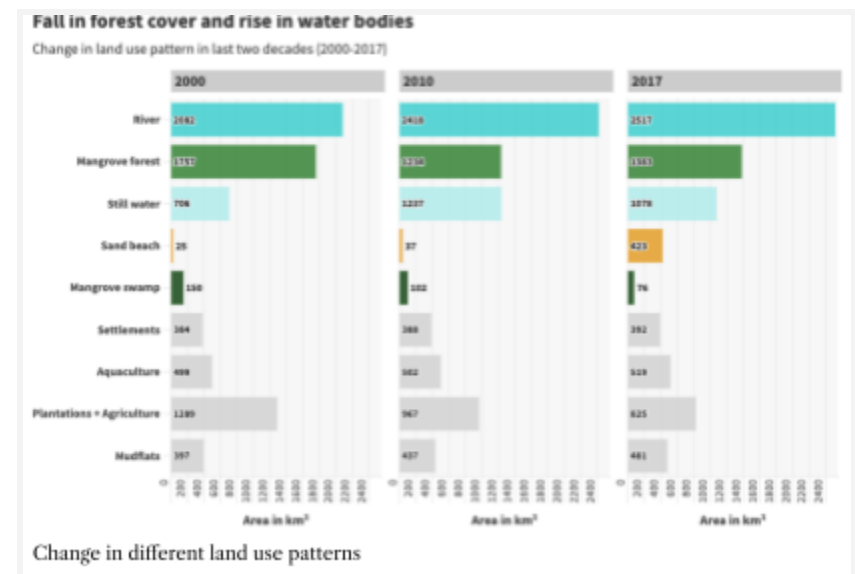
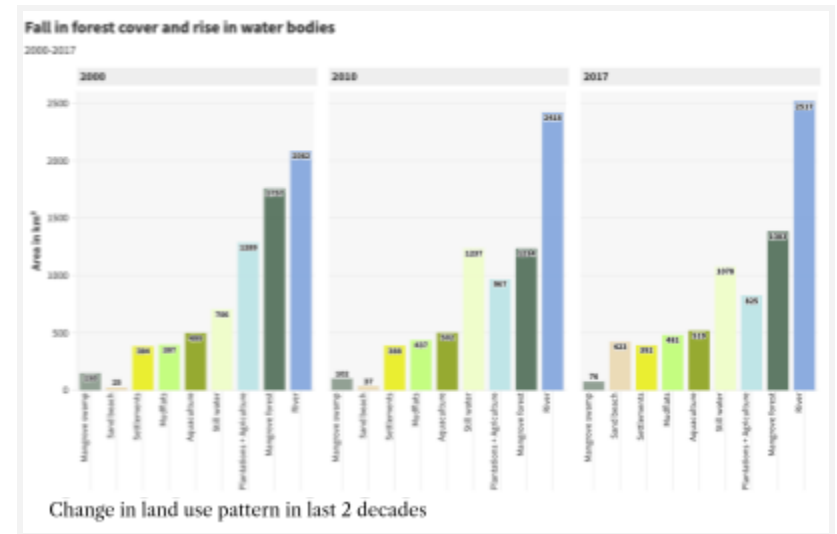


Idea 2: Grid of column/bar

- **Description:** Growing population settlements that are clearing out mangrove forests. Area of rivers is increasing, which is a direct indication of land erosion.
- **Information:** Land cover pattern change in the last 20 years.
- **Visual encoding:** Instead of percentage of land cover, now the different areas are shown by the length of bars. Colors show a semantic association.
- **Pros:** User understands the area under each LULC (land cover/land use) and changes at a glance.
- **Cons:** Not a novel way to visualize. The labels of X axis have poor readability.
- **Interaction:** Static visualization.

Idea 3

The same visualization but made in groups of bar charts so that the eyes can run across each of the categories without facing difficulty in reading the labels. Also, the significant categories have been highlighted through colour.



16.1 Climatic Change Indicators: Sea Surface Temperature

Below are some of the ideas for SST visualization of Sundarbans (21.5 and 88.5 lat.& long):

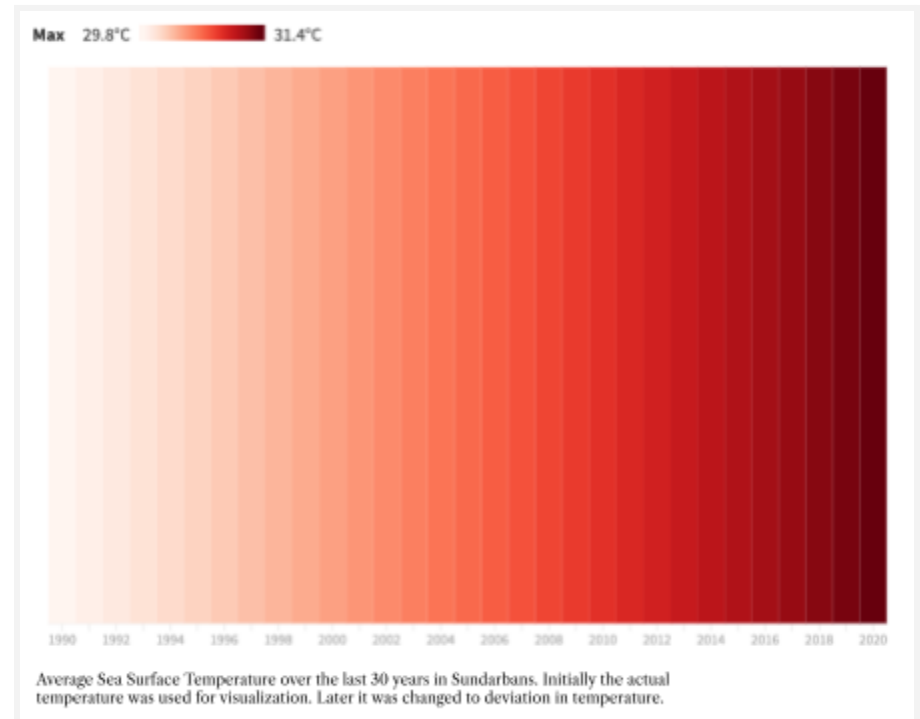
Climate stripes

It was divided into historical data that has been recorded through ships, coastal stations, etc., till the year 2015. From 2015 onwards, various climate model predictions exist for every degree of rise in global temperature. It is essential to report all the predictions, including bleak scenarios with fossil fuel-dependent development and stringent policies put in place with sustainable practices.

Idea 1- Stripes showing observed data

- **Information:** Recorded sea surface temperature till now in Sundarbans. (The data set from Berkeley Earth).
- **Pros:** Presents scientific information in an engaging way.
- **Cons:** Climate stripes is a famous visualization by Ed Hawkins and not novel in climate data viz. The Y axis is not utilized and the exact value is difficult to find without hover interaction.

- **Interaction:** The exact deviation in temperature (be it + or -) for that year is displayed on hover.

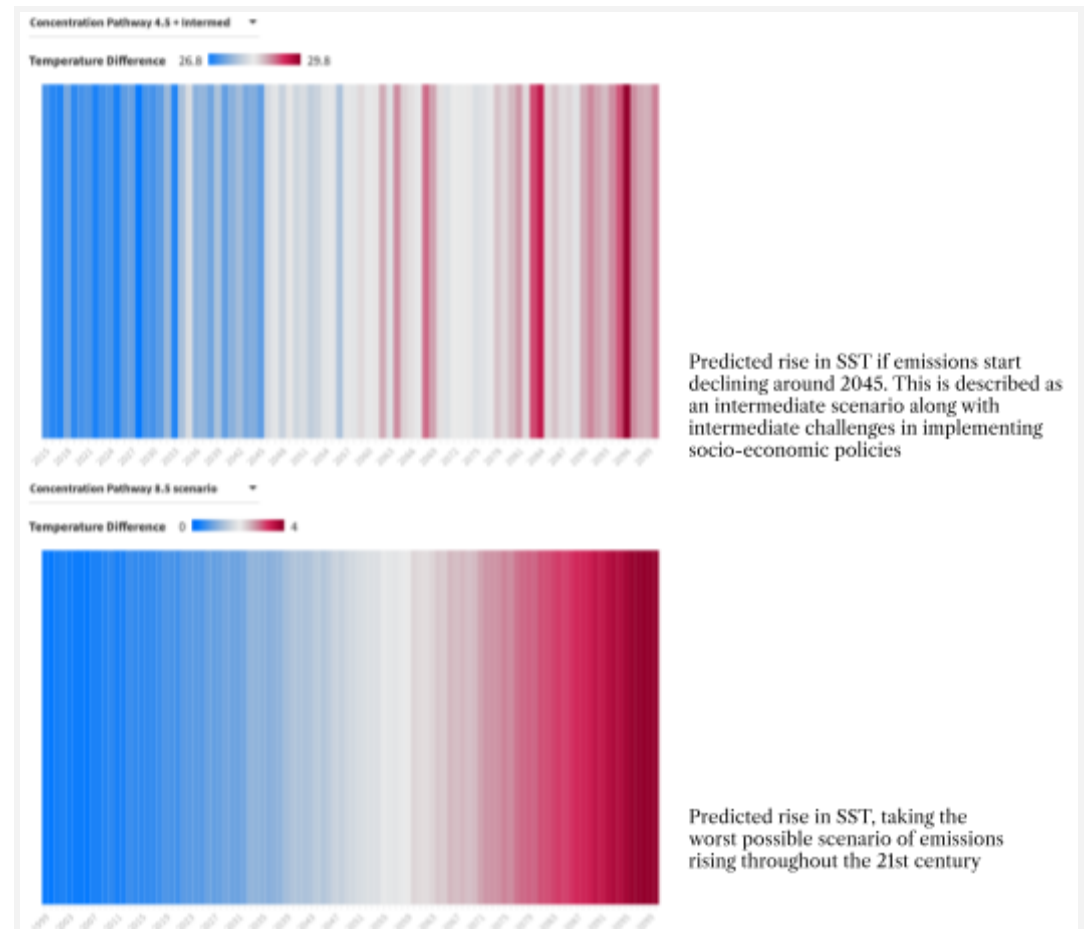


Idea 2- Temperature deviations & future scenarios

Instead of showing the temperature directly, showing how far it will get will be a more effective and interesting data point. Here the bars show 'anomaly', which means a deviation from the mean temp of 30 years. Blue means it has gone below the global average temperature, and red means it is going above the global average.

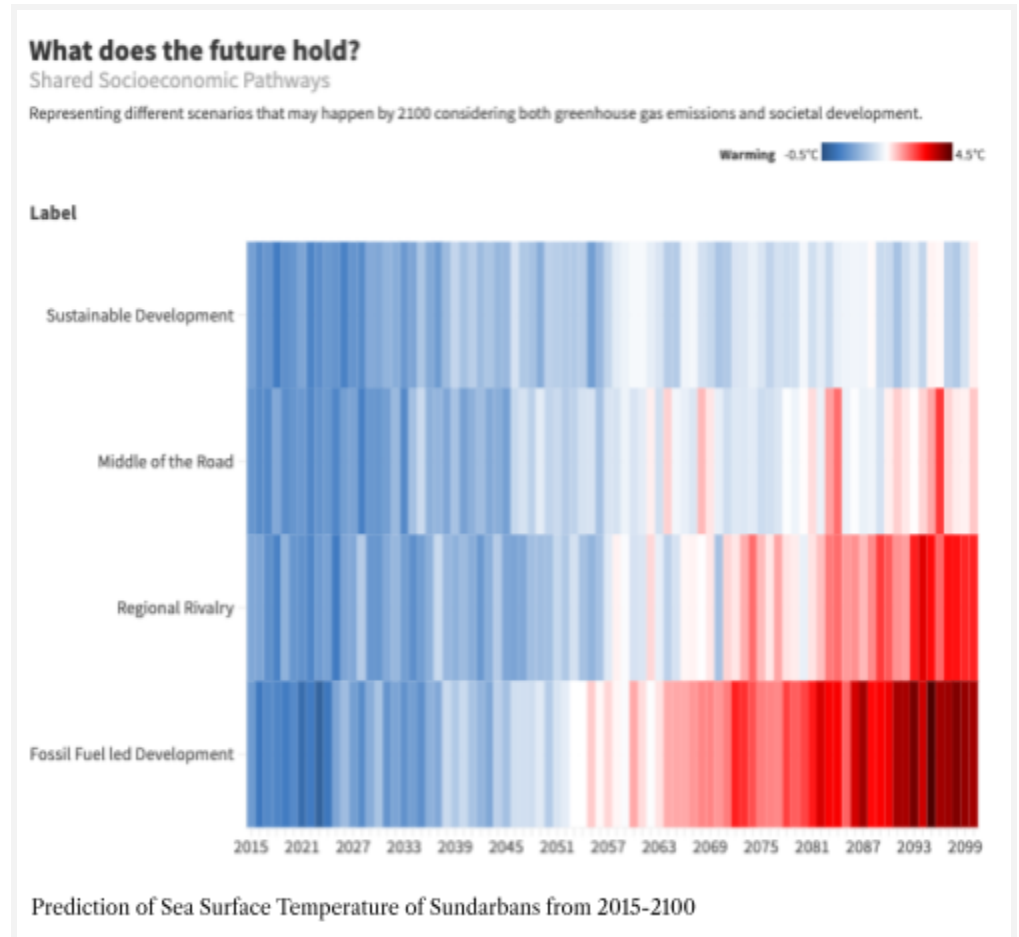
A divergent gradient color scheme has been used for each 0.1°C rise or fall. A dropdown interaction was added for future scenarios.

(These scenarios show concentration pathways that represent when greenhouse gas emissions and predict future temperatures accordingly.)



Idea 3 (finalized)

The dropdown interaction was removed, showing all predicted scenarios at a glance. The height of each strip was reduced to accommodate four within one graph.

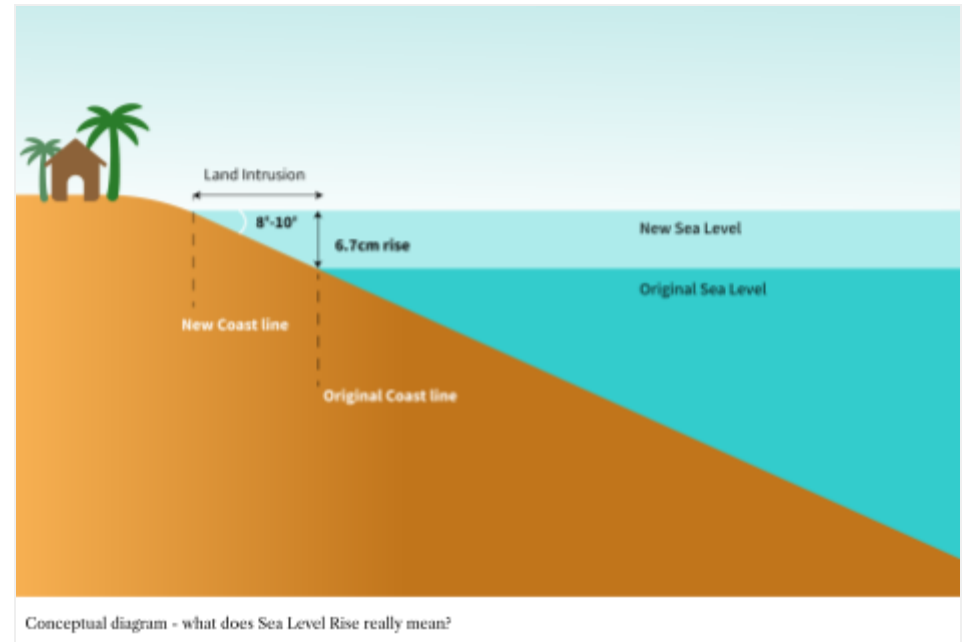


16.2 Climatic Change Indicators: Sea Level Rise

When we talk about Sea Level Rise (SLR), we often say —“the sea is rising by 3 mm per year.” But that does not strike a chord with us because we fail to see the physical impacts like erosion of beaches, flooding and land intrusion.

Idea 1 - Conceptual Explanation of Sea Level Rise

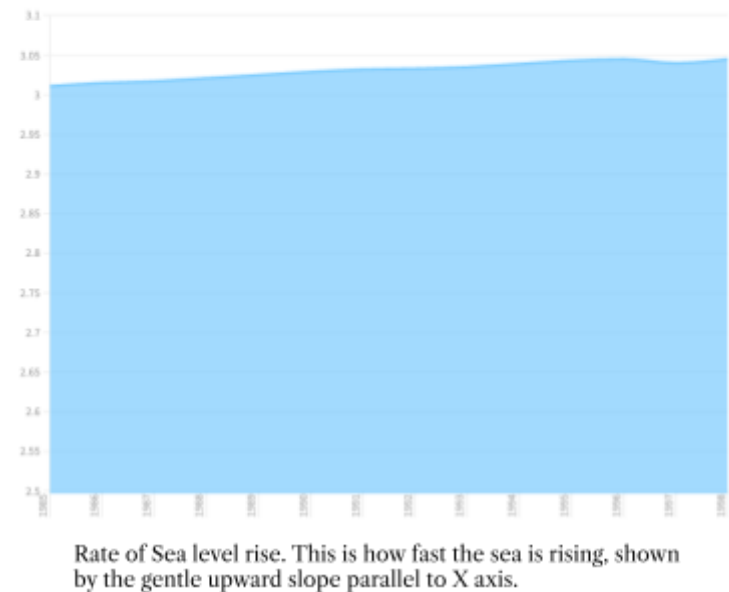
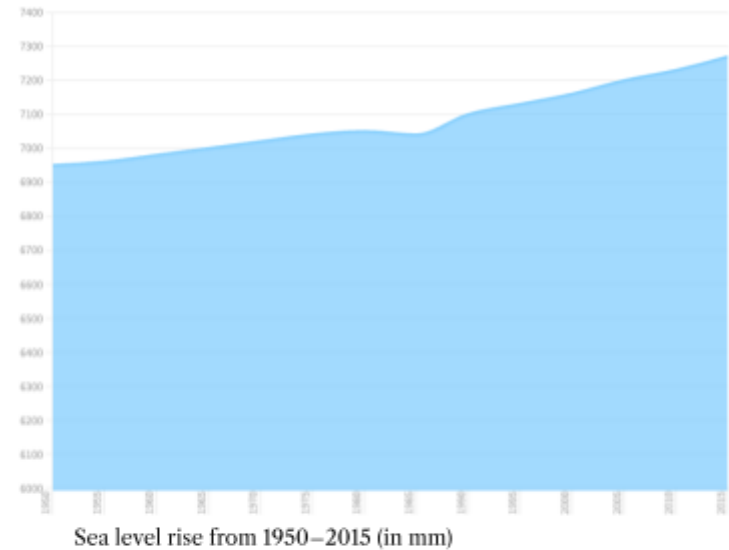
On the right is a schematic diagram explaining the meaning of SLR.



Idea 2 - Sea Level Rise and its rate

Description: Both the sea level rise and the rate of sea level rise have been plotted. It shows that the Bay of Bengal has been rising steadily.

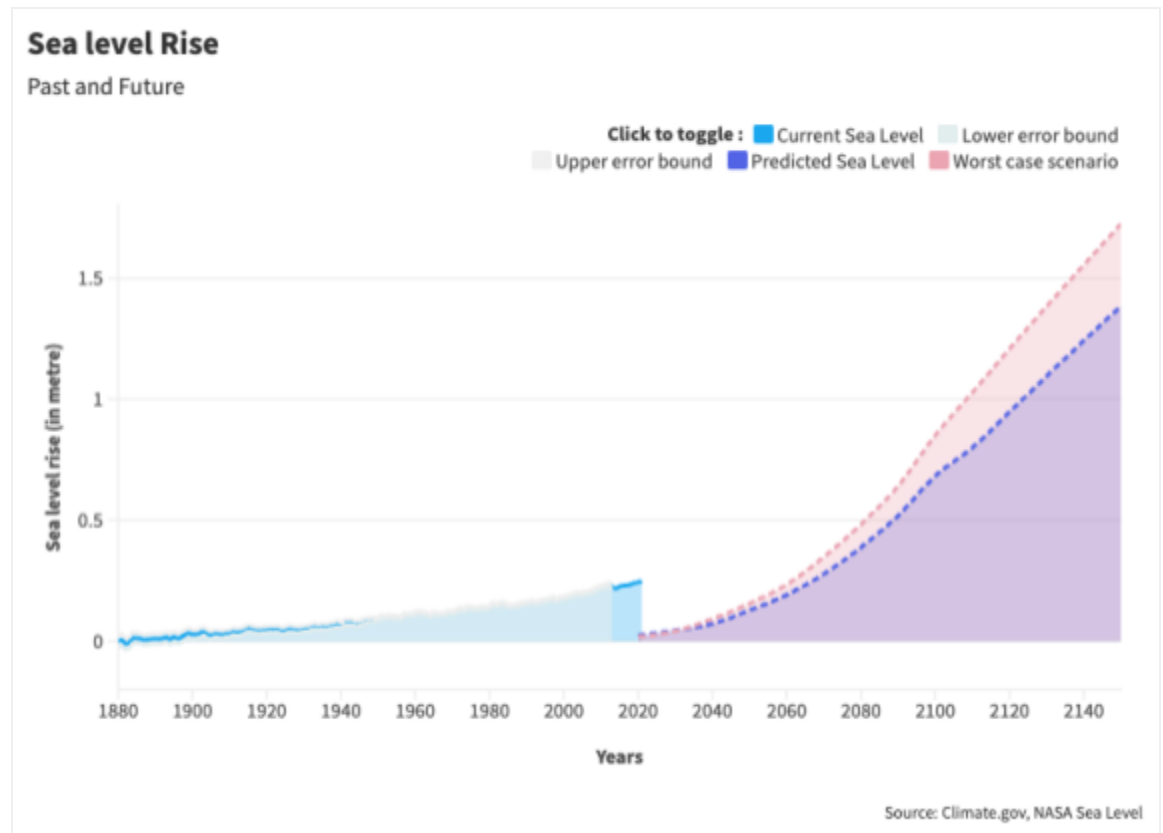
- **Information:** Height of sea level vs time in mm
- **Visual encoding:** The area graph shows changes in total sea level.
- **Pros:** Area semantically represents the rising sea
- **Cons:** In an attempt to amplify the minute changes in the data, both these charts have a Y axis starting with a kink (not starting from 0). This visually pronounces the minute changes in the sea level.
- **Interaction:** Static visualization



Idea 2 - Sea Level Rise - historical and predicted

Description: Observed data and future predicted data till 2150 extracted from climate model to show the rising Bay of Bengal (measured from a station in Sagar island).

- **Information:** Height of sea level vs. time in meters
- **Visual encoding:** Area chart
- **Pros:** When the 2 datasets are displayed side by side on the same time axis, users can see SLR and realize that the sea is rising faster than predicted.
- **Cons:** Climate experts say that predicted data cannot be compared to the observed data.
- **Interaction:** Interactive visualization, user can toggle between charts by clicking on legend

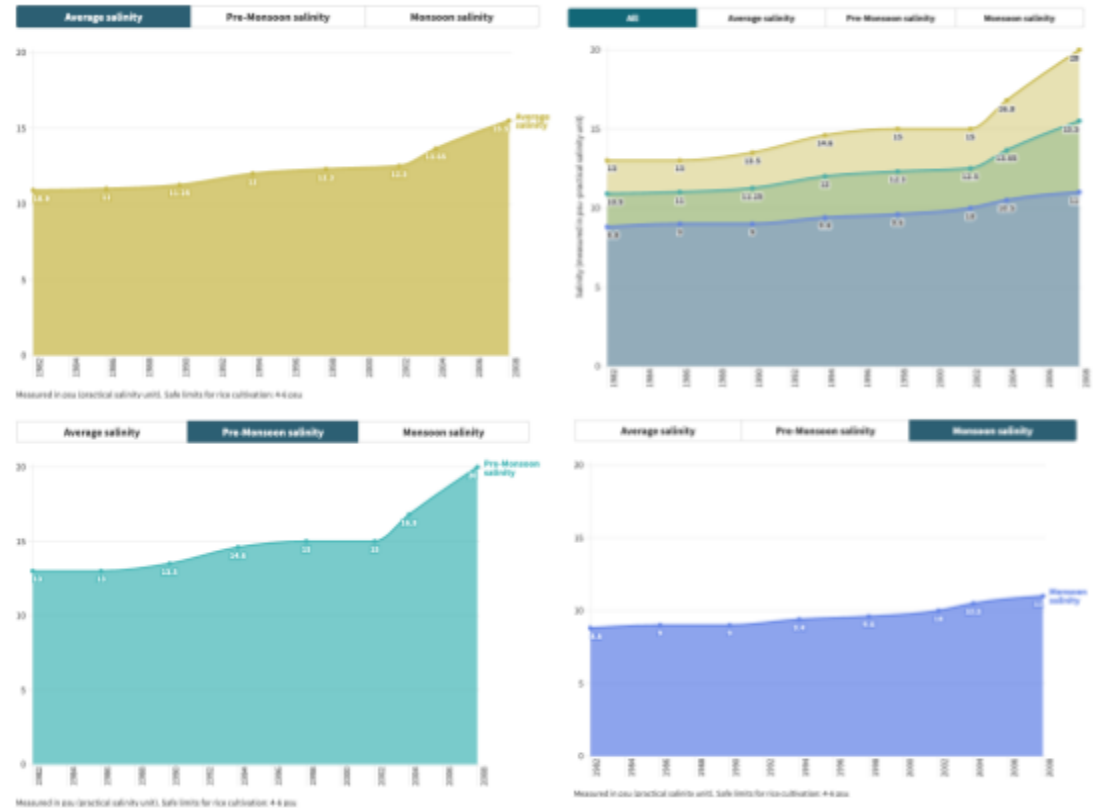


16.3 Water Salinity

Idea- Area graph

Description: Pattern of salinity changes in the waterbodies and coast of Sundarbans is shown.

- **Information:** Salinity measured in practical salinity units is shown.
- **Visual encoding:** Area chart
- **Pros:** Dynamic environment showing varying salinity per season is understood easily. One can compare all of them together as well.
- **Interaction:** Click on the tabs on top to switch between seasons.



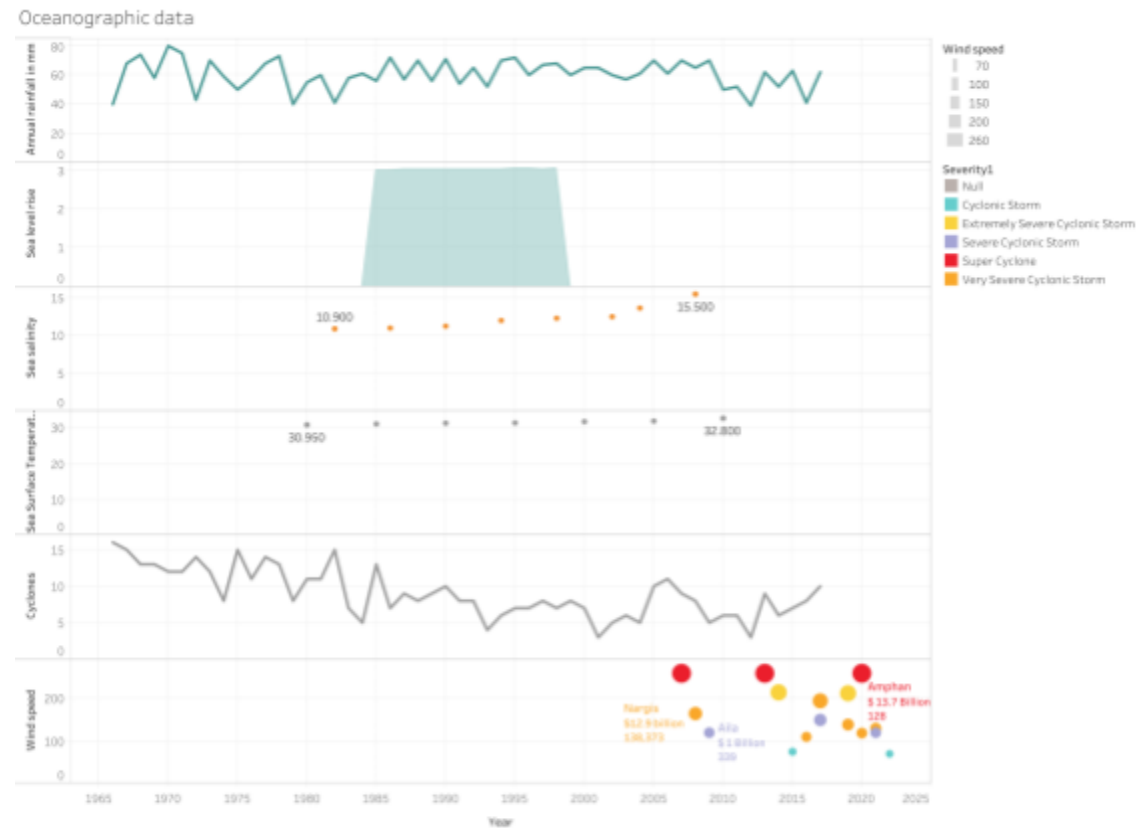
Salinity of ocean water is 35 practical salinity units (psu)
 Safe limits for rice cultivation: 4-6 psu
 We can see that salinity decreases after monsoons arrive.

17.1 Extreme Weather events: Cyclones

Idea 1- Line, area and bubble chart

Description: The intention was to show cumulative oceanographic data. The cyclones have decreased in frequency but intensity has increased.

- **Information:** All oceanographic data represented together (1920-2020).
- **Visual encoding:** Line and Area charts
- **Con:** Viz looked overwhelming and was not giving any insights to users.
- **Interaction:** On hovering, tooltips show exact value

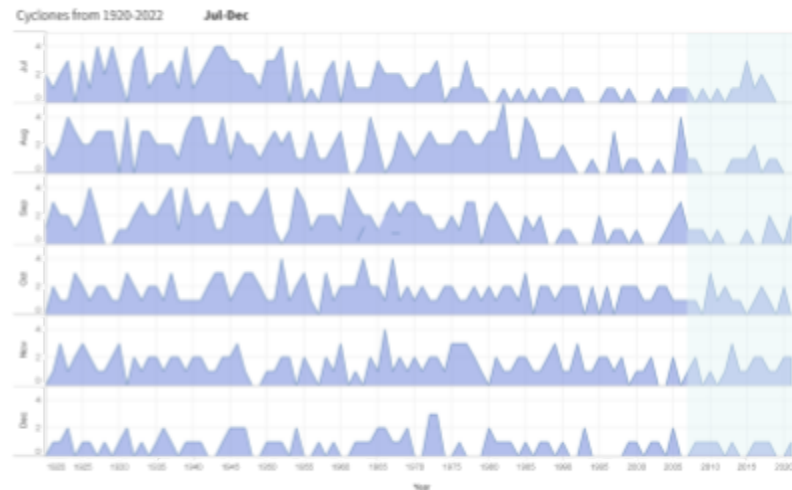
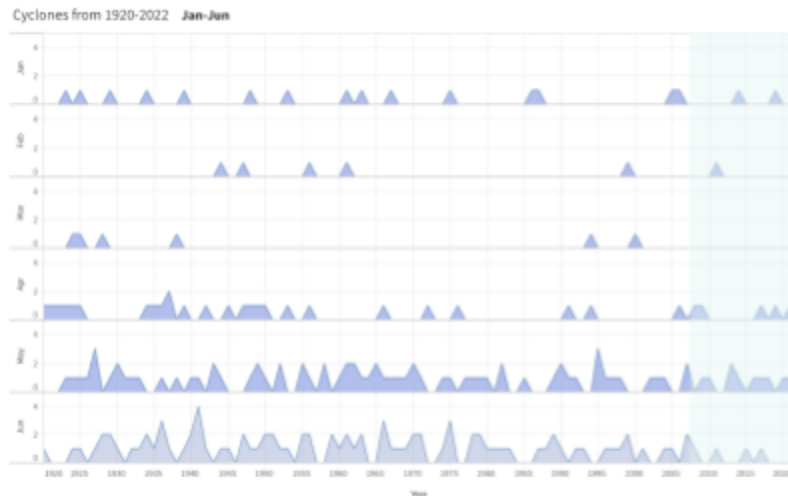


Trying to combine all oceanographic data together to see if climatic conditions and cyclones had any correlation with each other

Idea 2: Area chart

Description: Plot of cyclones that have happened in the last decade in the cyclone capital of India, Sundarbans.

- **Information:** Cyclones over the last decade (1920-2020). This chart was used in addition to the next viz. to give a complete picture of the cyclones
- **Visual encoding:** Area chart
- **Pros:** Easy to see which months see the most number of cyclones.
- **Interaction:** Static



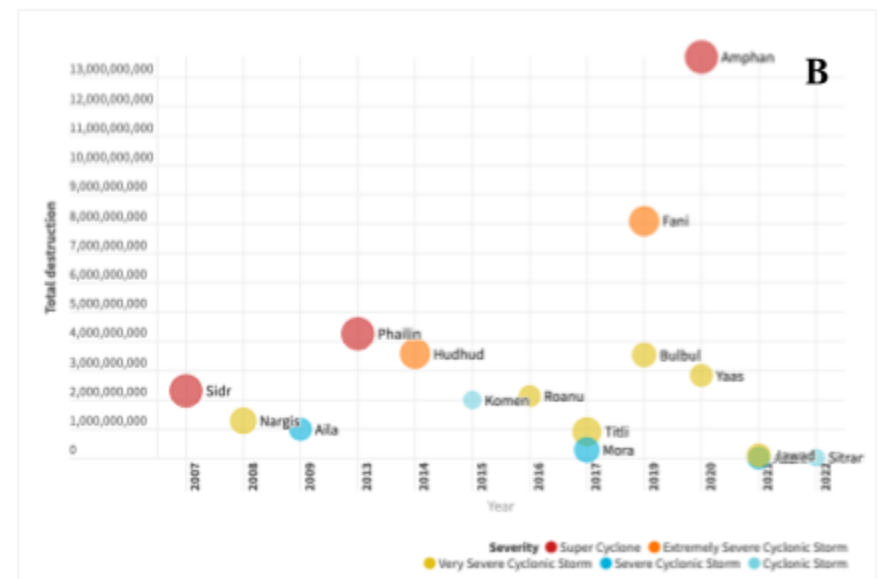
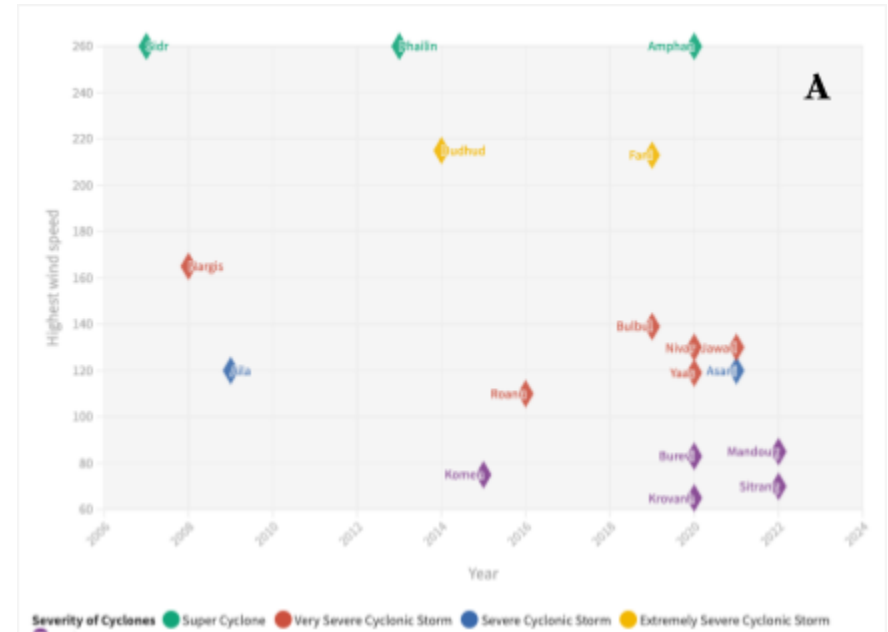
Idea 3: Bubble chart

Description: The major cyclones that hit Sundarbans in the last 15 years have been shown.

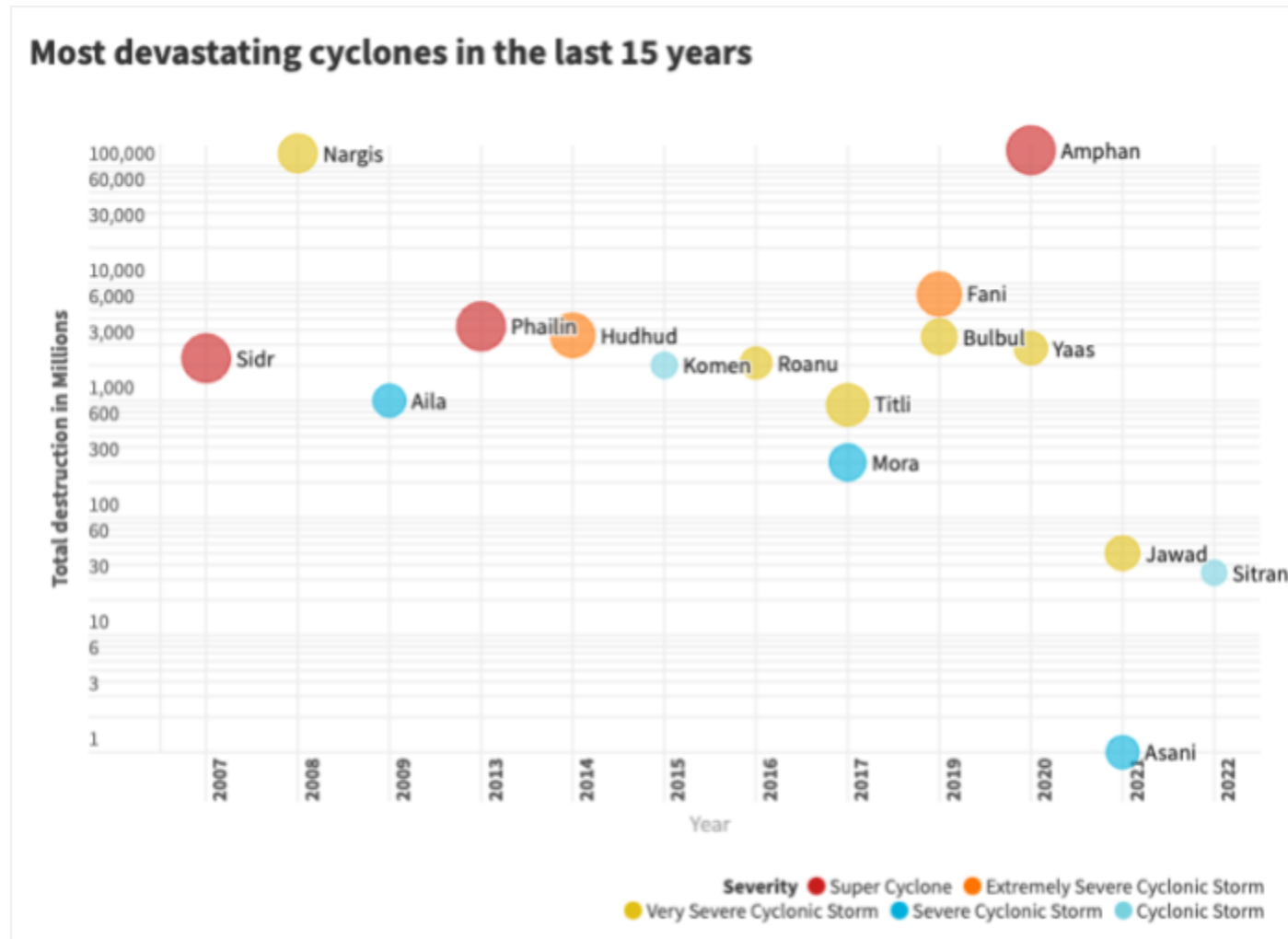
- **Visual encoding:** Bubble/Symbol chart
- **Iterations:** As seen in A, the wind speed was plotted on the Y axis and the years on the X axis. However, the severity of the cyclone shown through colours was already capturing that data. Hence, in B, a new data point - total destruction measured in USD was plotted on the Y axis.

Later, the linear scale was changed to a logarithmic scale to give a better understanding of large numbers like millions and billions to users.

- **Interaction:** Hover to reveal information, click legends to toggle



Idea 4: Bubble chart (finalized)



Y axis was converted to a logarithmic scale. This is to overcome “huge number blindness” —more natural to how humans perceive large numbers like millions and billions.

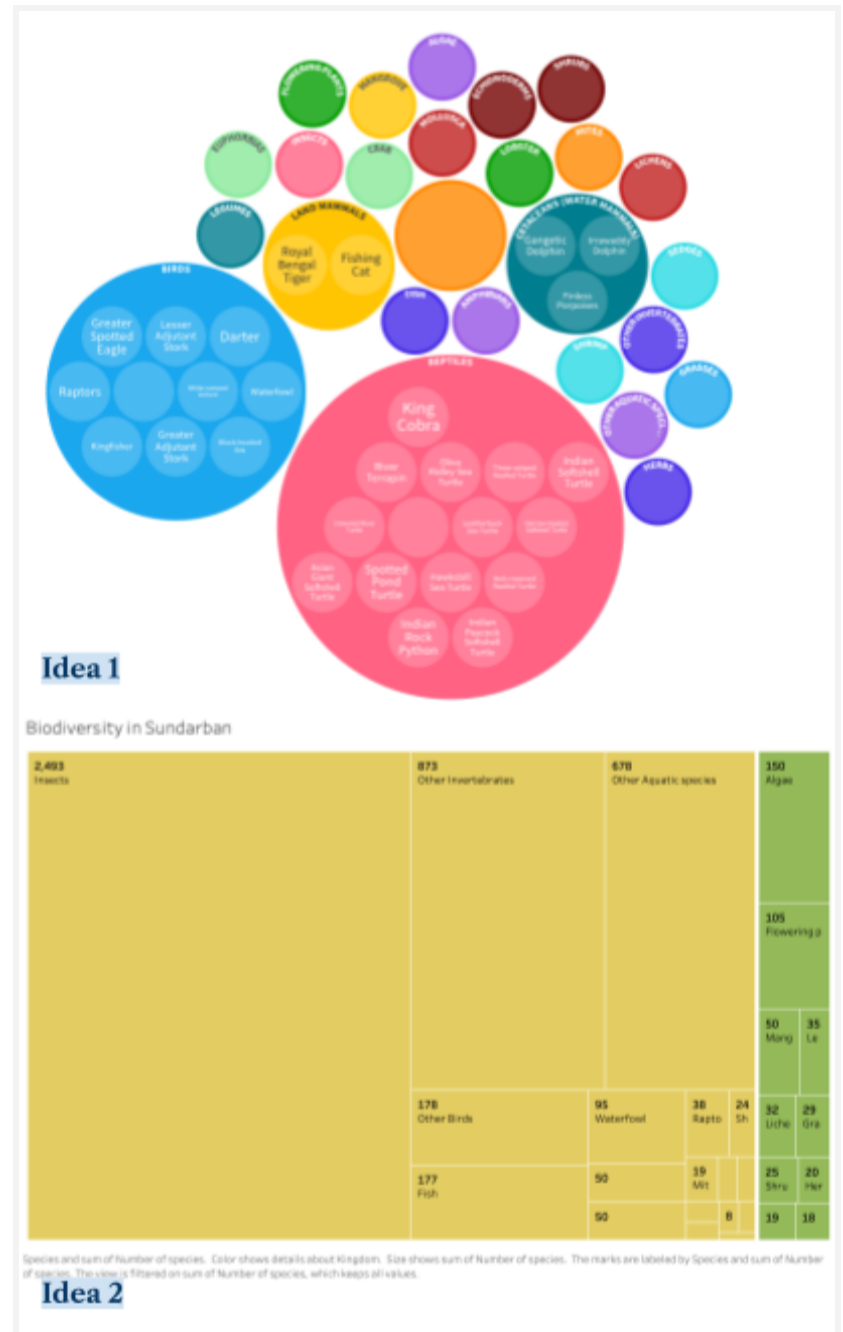
18.1 Biodiversity of Sundarbans

Idea 1&2: Hierarchical Viz

Description: Sundarbans is home to multiple rare species of reptiles, birds, mammals and plants. There are many critically endangered species that reside here.

Visual encoding: Hierarchical Bubble chart and treemap

Cons: The bubble chart only gave information on which species belongs to which family of fauna. The treemap showed the number of species per family and the 2 green shades showed fauna and flora respectively. However, the visualizations were not dense enough.



Idea 3: Hierarchical Radial chart

Visual encoding: Radial chart that starts inwards and branches into the diverse wildlife found.

- The green ones are various types of plants and the rest are reptiles, mammals, birds, marine species, etc.
- The bar on the circumference shows the number of species.
- Names of species radiating outwards are the most endangered ones.
- Circles depict the endangerment status according to IUCN (International Union for Conservation of Nature).
- Illustrations were added to depict what the animal looks like.

Endangered species of Sundarbans

This chart depicts some of diverse flora and fauna of Sundarbans. The numbers denote the variety of each animal or plant. Labels outside the circle list a few species along with their IUCN Endangerment status.

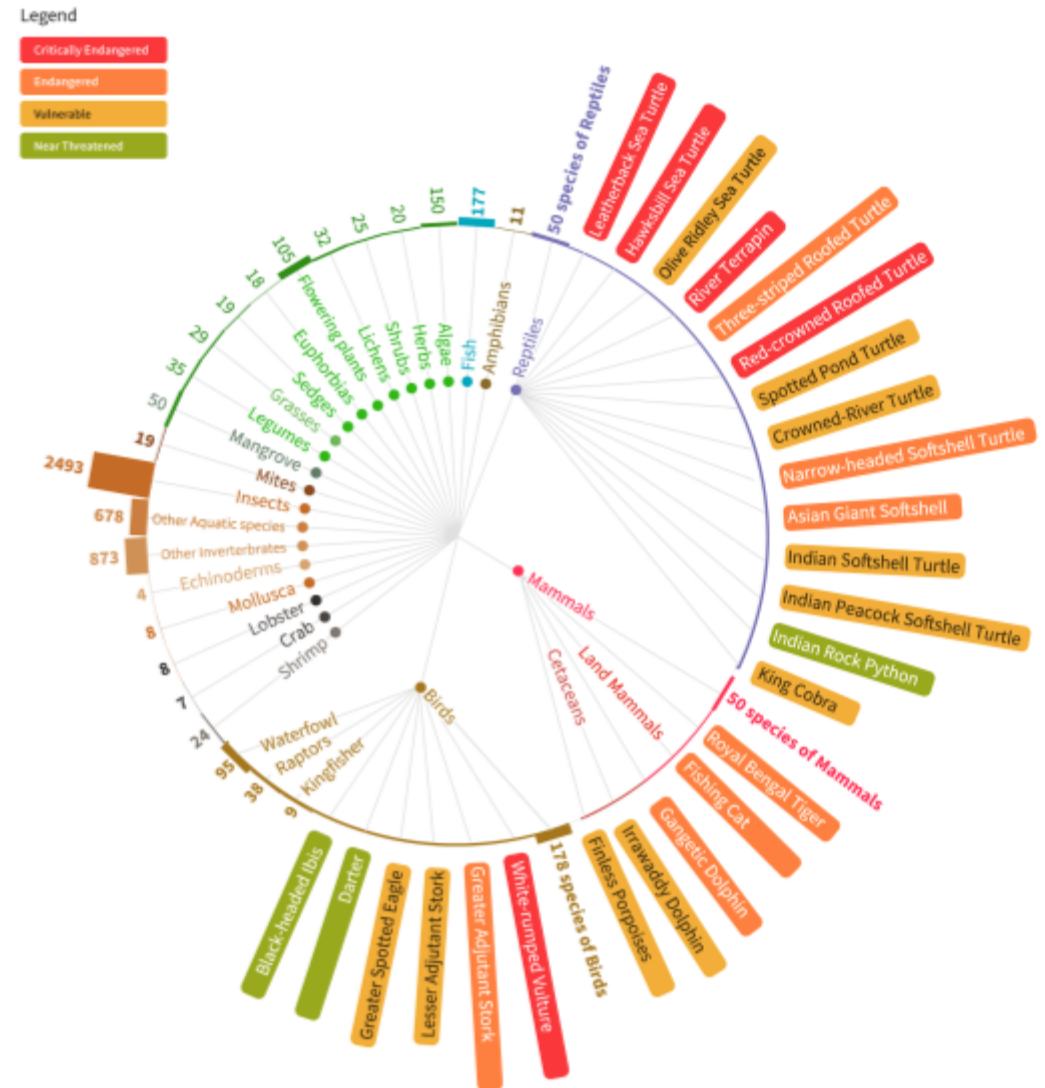


Idea 3

Idea 4: Hierarchical Radial chart (finalized)

The previous viz was improved by adjusting the colors, removing the illustrations and incorporating the endangerment status with the name of the animal.

Interactivity: Static



18.2 Human Tiger Conflict - record of all cases since 1980

Idea 1- Geospatial Heatmaps

Description: Due to the pressure of an ever-increasing population, deforestation took place which resulted in high instances of human-tiger conflict

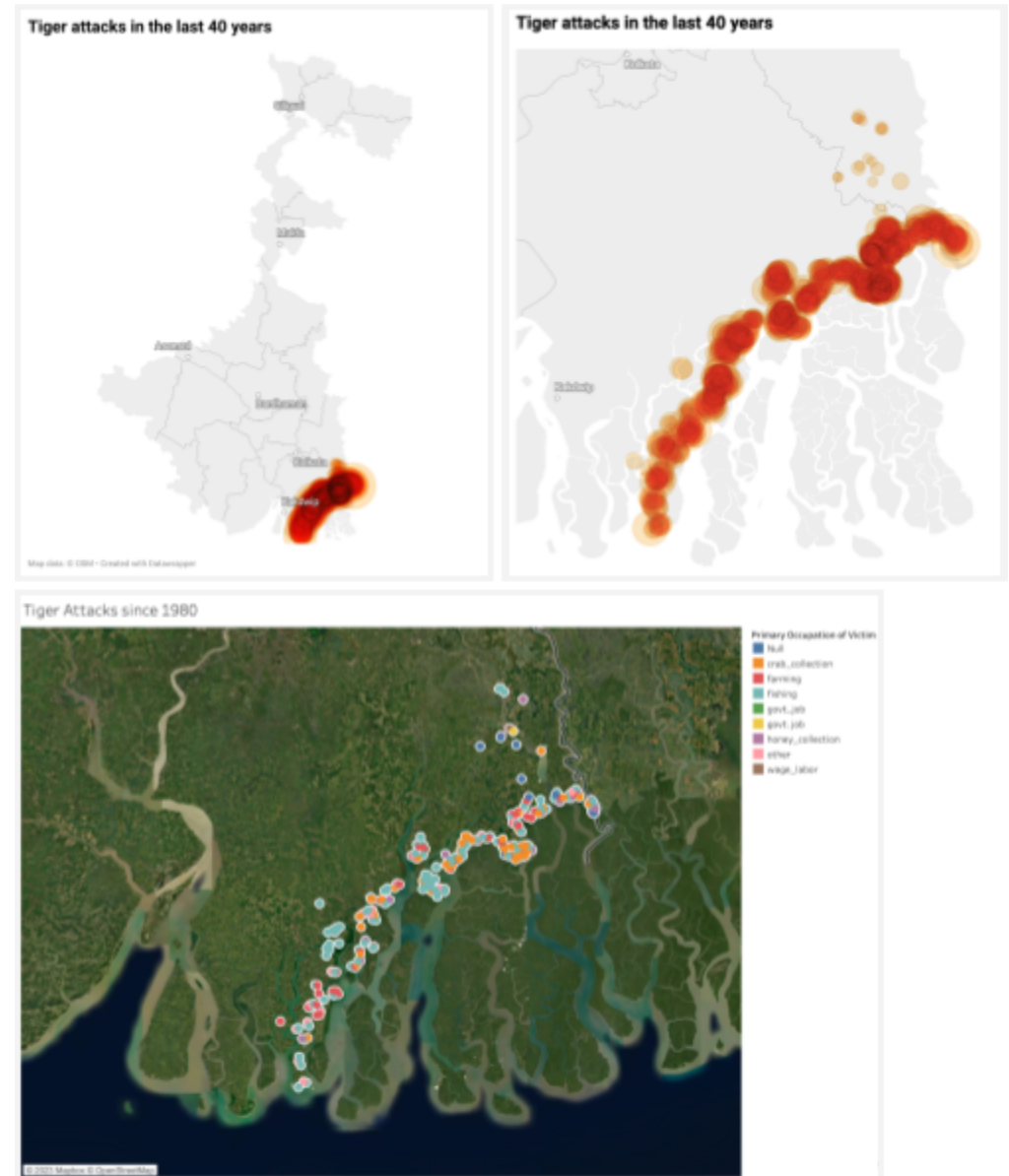
Visual encoding: Heatmap

Pros: Gave a sense of number of victims. An immediate insight was that the attacks mainly happened in certain areas. Upon superimposing with a geographical map, it showed that the attacks were most frequent at the edge of the forest.

Iteration:

Attempted to make it more relevant by showing satellite terrain images and geographical map with forest area. Additional data on the occupation of the victim was also shown through colours of the dots.

Cons: Viz was not dense enough.

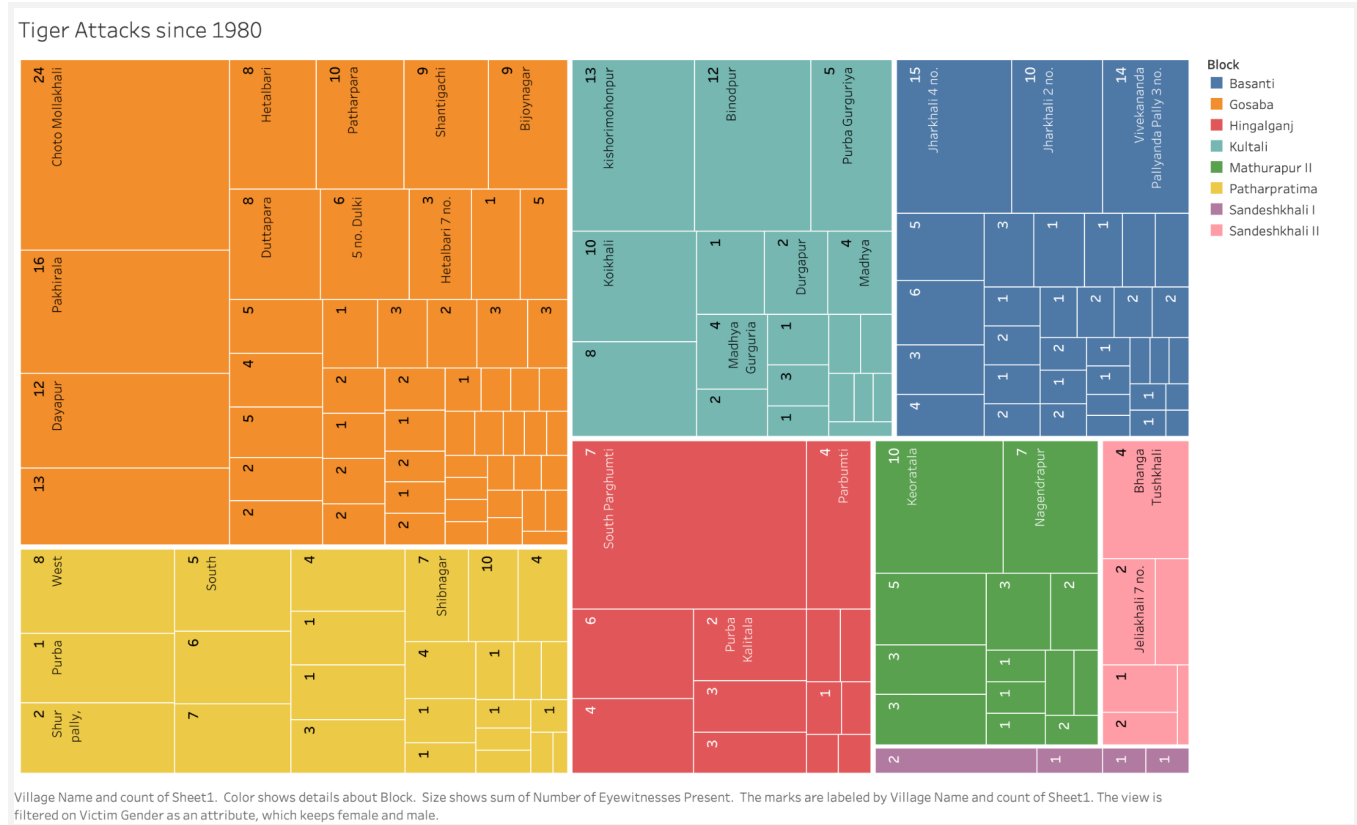


Idea 2 - Treemap diagram

Description- The same data has been visualized hierarchically according to blocks and villages, annotated with number of deaths from tiger attacks.

Pro- The most vulnerable places (blocks) like Gosaba became more obvious.

Con- Lost the geospatial insights



Idea 3 - Spatial heatmap, scatter map on zoom

Description- Heatmap diagram that reveals symbol information on zooming.

Visually, the map was designed to look like spots of a tiger.

Iteration- On zoom, cross and triangle can be seen. The symbol shows the type of attack (death or injured victim), and the number denotes the age of the victim.

Later, time of attack (day or night) data was added as an additional layer to it.

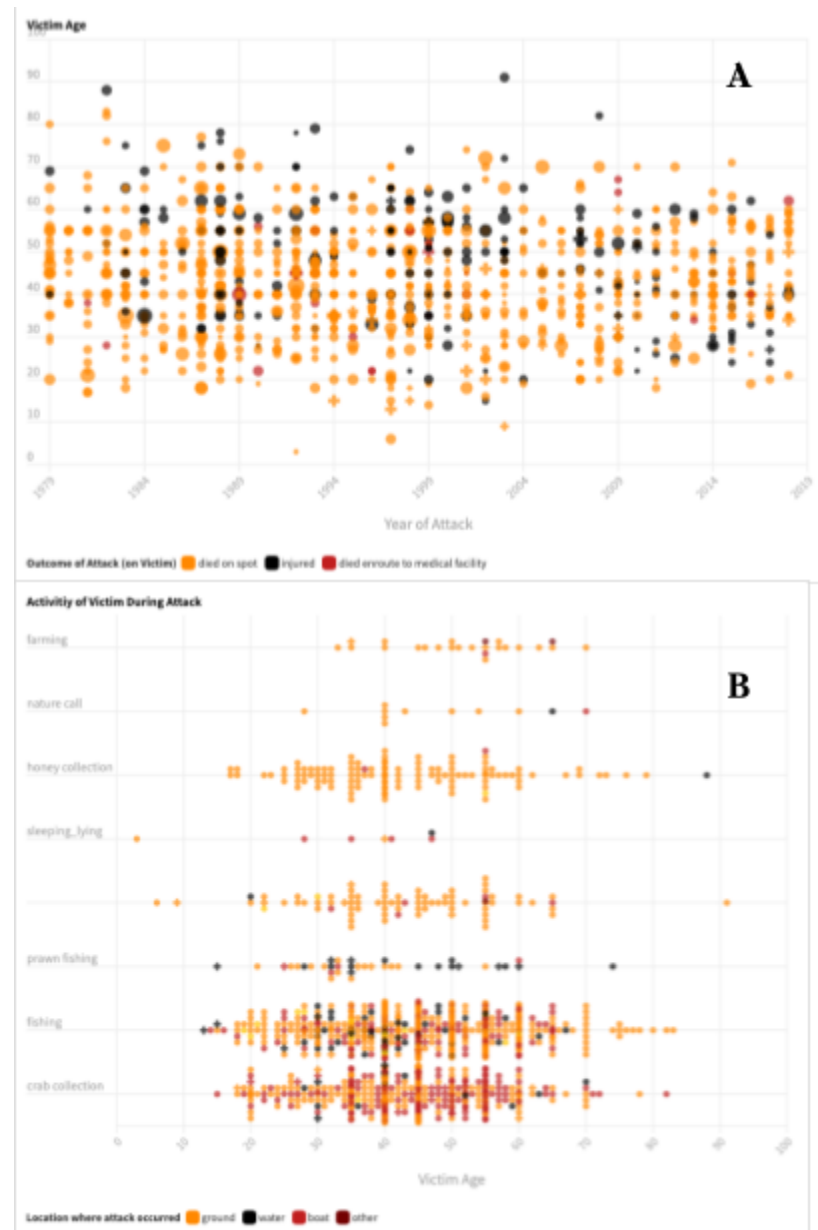


Idea 4 - Scatter diagram

Description: Scatter diagram of victims according to the age of victims and year of the attack. The size of the dot represents the number of dependants (family members). Circle denotes male victim, cross denotes female. Colors have been used to show if the attack resulted in death on spot, death en route to a medical facility, or injured.

Iteration: The same kind of visualization was used to show the activity of victims during the attacks. This revealed that most of the fishermen and crab collectors in the age group of 35- 60 years were at risk.

Interaction: Clicking on tabs and legend changed the display of the chart

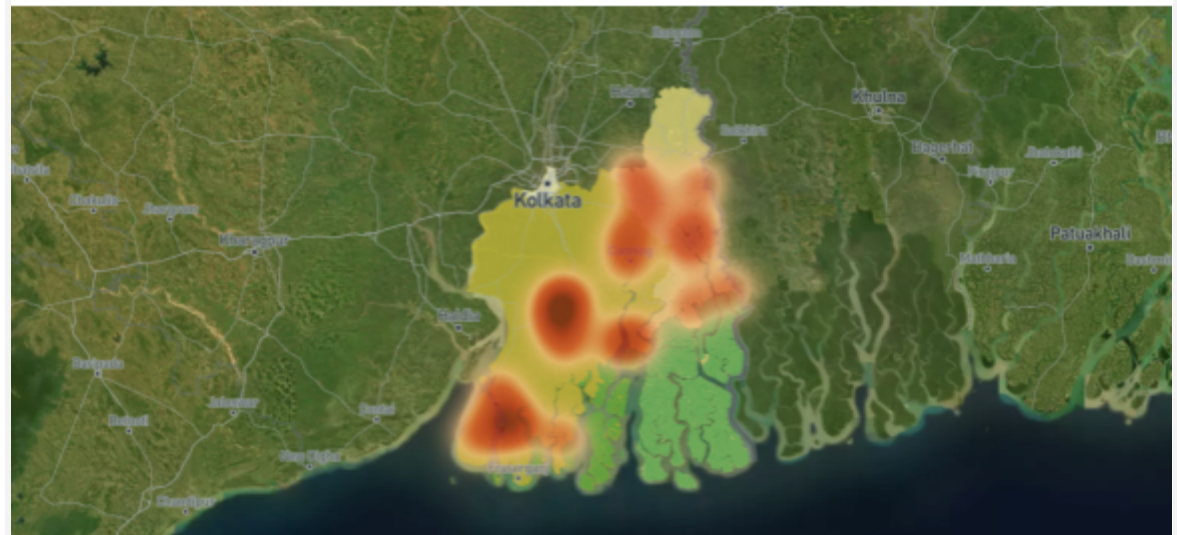
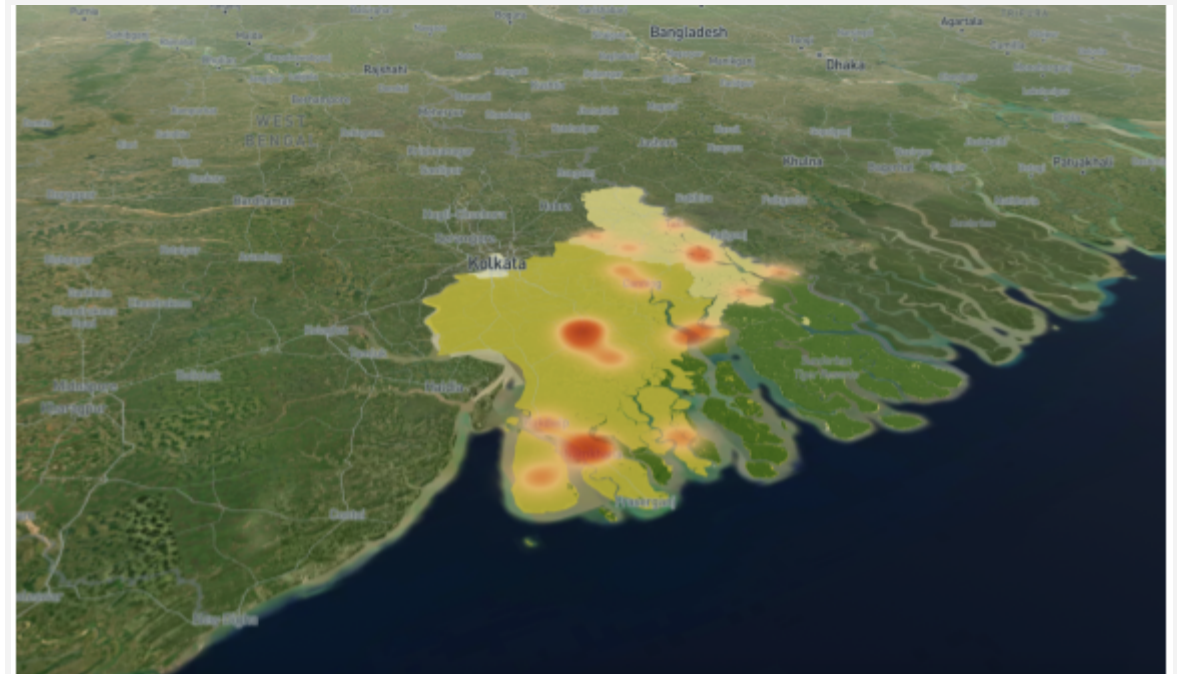


19.1 Social issues- High population density

Idea 1- Population heatmap

Description: Despite being a fragile ecosystem, 44 lakh people live in this delta. The changing climate affects them.

The average population density is close to $987/\text{km}^2$, extremely high compared to the national average of $435 \text{ persons}/\text{km}^2$.



Idea 2- 3D Population Map

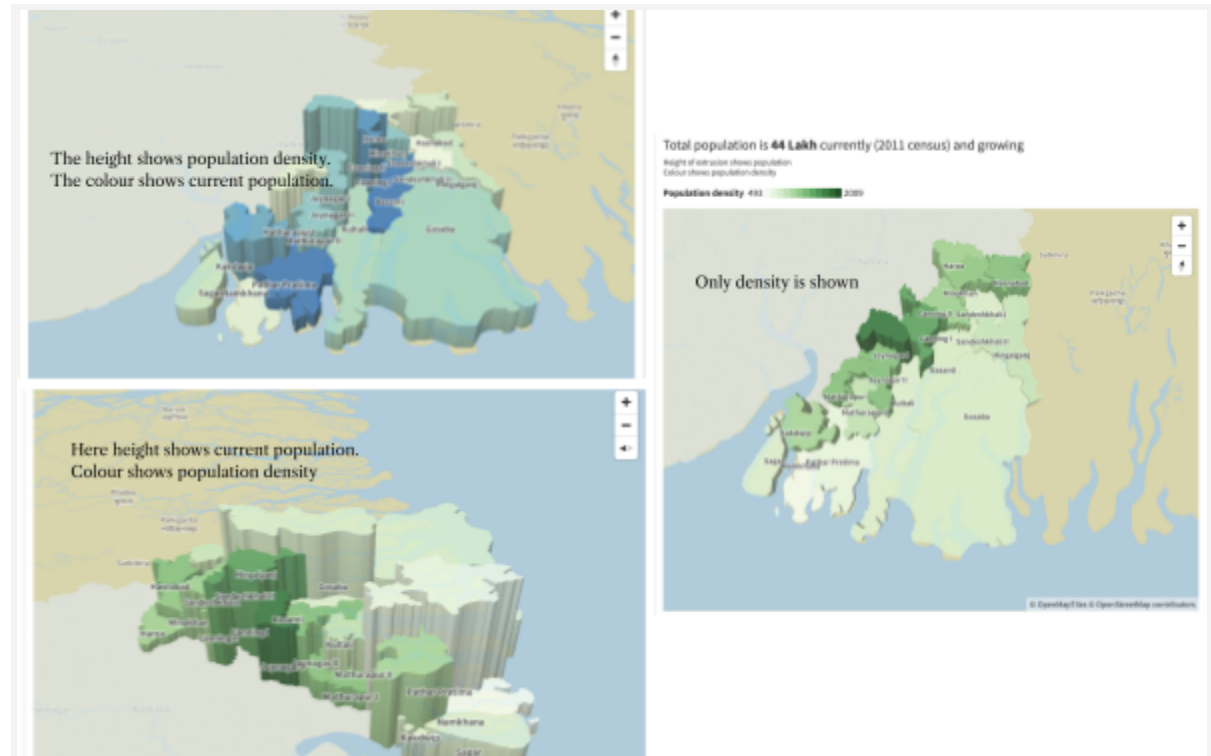
Description: High population and population density of Sundarbans

Visual encoding: Height of the 3D extrusion showed population density, and the colour was representing the population through a sequential scale.

Interactivity: Zoom in and zoom out through scaling motion, rotation of the map using the CTRL button of keyboard.

Pros: Two types of data are represented together.

Cons: Users needed clarification on what the colour and height corresponded to. Hence I decided to show only the population density of the blocks through height as well as colour.



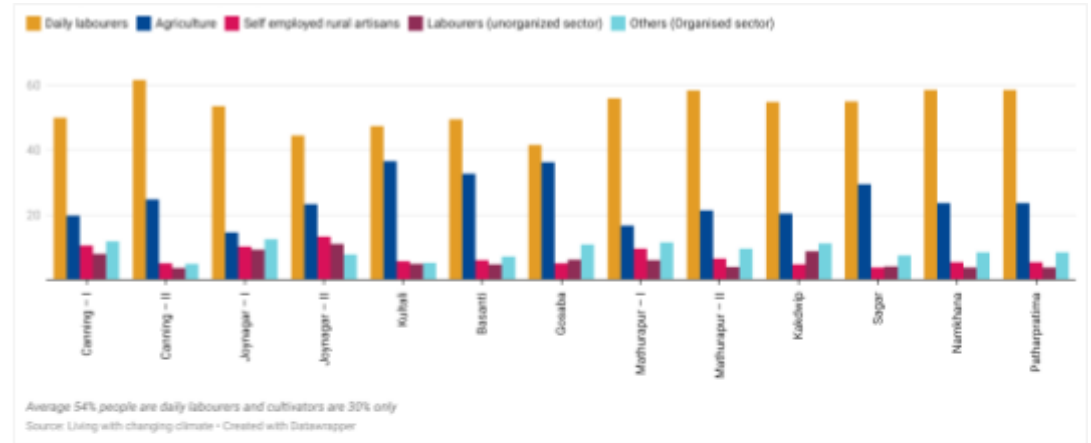
19.2 Pattern of occupation

Idea 1- Grouped bar/column charts

Description: People depend on daily labour and 100 days of work as their main source of income. This is a sign of impoverishment.

Information: Current scenario of occupation of the people of Sundarbans.

Iteration: At first, the groupings were done according to blocks. However, this was not relevant much for the target audience, so the groupings were done as per the occupation type.



19.3 Social issues- Migration

Idea - Arc map

Description: Said to be one of Asia's most significant environmental migrations, almost 75 percent of families here have their young ones working in states as distant as Kerala, Tamil Nadu, and Gujarat.

have their young ones working in states as distant as Kerala, Tamil Nadu, and Gujarat.

Visualization: Arc map to show migration intra and interstate. The thickness of the arcs corresponds to the percentage of people migrating.

Interaction: Zooming on map, hover to see migrant %.



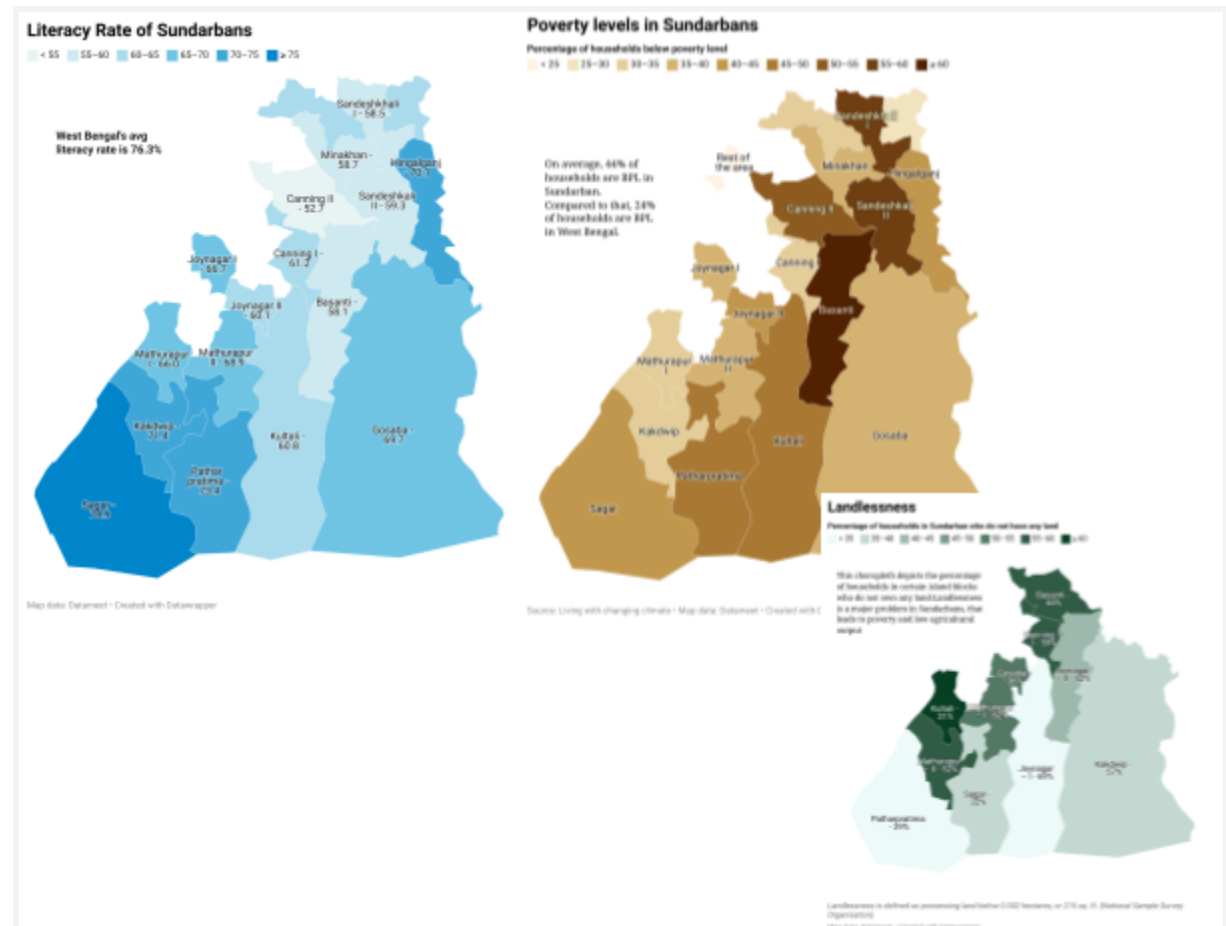
19.4 Social issues- Low Literacy, Poverty and Landlessness

Idea - Choropleth

Description: Various socioeconomic indicators like poverty levels, literacy rate, and landlessness has been shown through choropleths.

Visualization: Choropleth is the standard approach for putting data on a map - Percentages have been shown on a base geography of administrative blocks of Sundarbans.

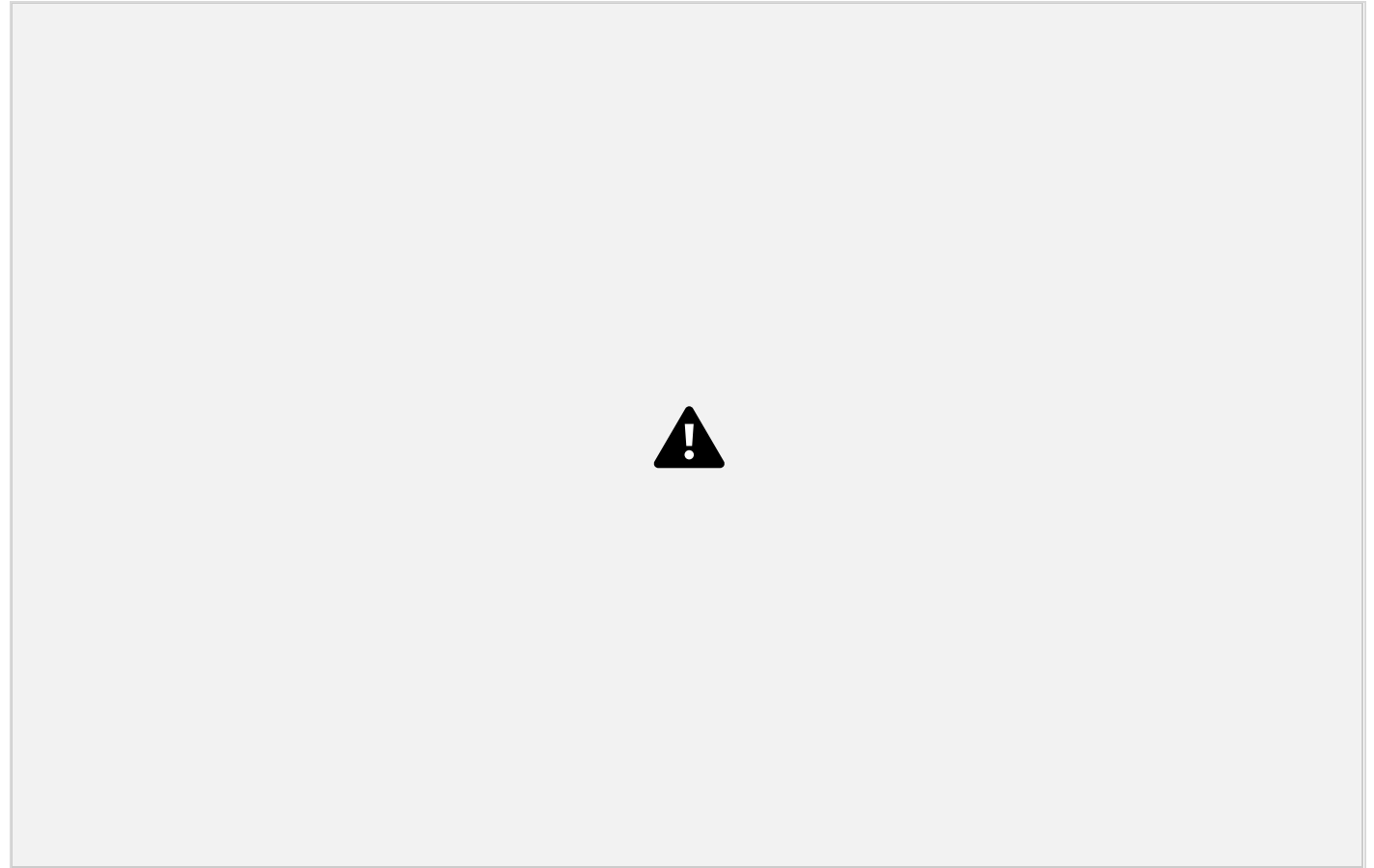
Interaction: Hover and zoom into map



20 Final Design Output

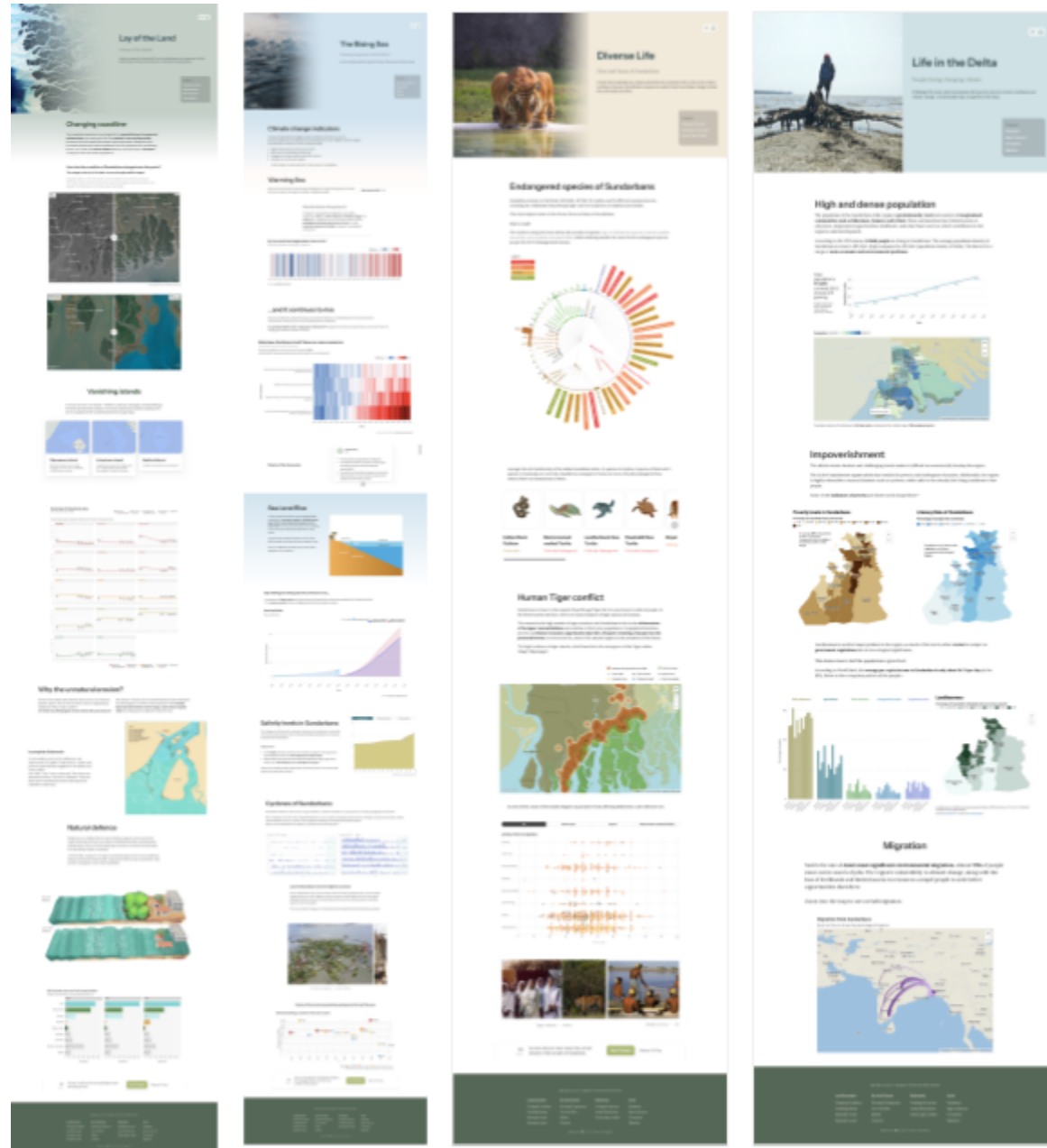
Here is the final outcome of my project: [The Beautiful Forest](#)

Please view it only on a laptop/desktop in the scope of this project.





Please visit the website for a better viewing experience:
[The Beautiful Forest](#)



Screenshots from each chapter

21 Evaluation Steps

21.1 Evaluation Plan

According to Burns et al., Visualizations can be evaluated by taking inspiration from Bloom's taxonomy. There are two classifications of taxonomies of visualizations:

1. Taxonomies of objectives - can the viz answer user's goal or question?
2. Taxonomies of actions- can the viz direct concrete actions to achieve an objective?

(Burns et al., 2020). Based on the first point, below is the evaluation metric of visualization that I plan to use for my project (evaluation table on next page)

Level in Bloom's taxonomy	Description	User Tasks
Knowledge	Recall basic facts and definition	<ul style="list-style-type: none"> • Retrieve points • Locate Value • Identify axis labels
Comprehension	Understand the context and information	<ul style="list-style-type: none"> • Summarize main theme • Describe key takeaway • Explain the topic of visualization
Application	Apply knowledge to a new problem or represent it differently	<ul style="list-style-type: none"> • Use a percentage and total to calculate a number • Calculate the difference between two points
Analysis	Break down a concept into parts and understand their relationship	<ul style="list-style-type: none"> • Describe a trend • Describe the relationship between two variables • Identify what data was used to come to a conclusion
Synthesis	Use knowledge to create something new	<ul style="list-style-type: none"> • Predict a future value • Suggest a new visual representation
Evaluation	Judge the value of information, backed by evidence	<ul style="list-style-type: none"> • Justify a conclusion based on data • Judge which design is more appropriate

21.2 Results

The website was presented to users on their laptops, and they were asked to think aloud as they explored the website. The complete narrative was evaluated on a summative basis. (N = 8)

(Details of participants: 5 female, 3 male, 25-32 years)

What went well

- Overall, each user took around 20-25 mins to go through the website.
- One of the main concerns—the users did not feel information overload at any point.
- Users felt they were getting reliable, in-depth information about the area.
- They felt a sense of urgency and doom while seeing the warming climate stripes visualization—which fulfilled its objective.
- Users appreciated the interactivity in the visualizations and spent time exploring the maps, and charts on their own.
- A few second-order syntheses were evident from the think-aloud session as the users drew their own conclusions.
- Flow of the narrative was found to be well-paced.

What could have been better

- Some transitions and navigation between pages were not obvious.

- Interactivity was not obvious in some visualizations. E.g., Users did not understand that they had to press ctrl to rotate the map or click on the legend to toggle between states
- Users did not know the word meaning of certain technical terms like ‘morphology’ or ‘anthropogenic.’ These words were either rewritten or explained in context.
- Majority of the final visualizations were decided after formative testing. Details of the iteration are written beside each visual in Section 15 of the report (Data Visualization ideations)

22 Discussion

The project attempts to provide a holistic overview of the climatic changes and ecology of the Indian Sundarbans by visually representing the data.

Although the Sundarbans is a region that has been extensively researched, there was a lack of a streamlined database for its climate data. While large international organizations such as NASA, IPCC, CSIRO, etc., have global records, accessing specific data for a particular region proves challenging and demands significant processing power. Reading through numerous academic papers provided valuable insights, but consolidating the information into a timeline required considerable effort.

This project focuses on a few selected major topics, which were finalized after a field visit to the north-western Sundarbans (specifically, Ghoramara Island). Immersion in the field is essential when addressing a topic like climate change, as it has become a ‘buzzword,’ and the true picture may not always be fully apparent. Having collected and analyzed the data, we acknowledge that some subjects, such as—change in natural vegetation, wildlife habitat degradation, greenhouse gas emissions, climate resilience, and mitigation and adaptation strategies, etc., are extensive enough to warrant dedicated design projects of their own and have not been included in the scope of this project.

When it came to ideation, some of the visualizations were data-dense, while others appeared more basic. However, after conducting multiple user tests, we were able to refine and improve the visualizations. The

project would become more robust if tested with a larger sample of target users.

When designing a website with a heavy emphasis on visualization, it is important to ensure its responsiveness and accessibility. Since designers cannot control the specific device that users will use to access the website, the next step in this project would involve implementing responsiveness measures.

The significance of content writing, particularly in providing contextual explanations alongside illustrations, photographs, micro-interactions, and animations, played a crucial role in capturing users' attention and augmenting the viewing experience.

23 Conclusion

This data visualization project is the first of its kind on the ecological changes in the Sundarbans. It attempts to bridge the gap between the vast ongoing scientific research and communication to the general public. Given the scope of the project, time frame, and limited evaluation with 8 users, the target audience was able to grasp the fragility of this unique ecosystem. Data collection and cleaning up is an important part of data visualization, and climate data often comes with unique challenges. Journalistic articles often report exaggerated numbers, whereas scientific papers may become too technical to perceive for a designer. So it is important to first understand the basics behind what exactly is meant by

climate change, in which context it is being used, and how it is being measured. Since the term has become ubiquitous nowadays, collecting data from reliable sources and visiting the field to get the true picture is helpful. While the user may not necessarily be from Sundarbans or its nearby regions, our hope is that they will grasp the

message conveyed through compelling visualizations and interactive charts. We hope to have conveyed the pressing urgency of the degrading ecosystem and, in turn, contribute to raising awareness about it. We also hope to have made a significant contribution to the growing collection of interactive narratives of climate change.

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Annexure

Learnings from my visit to Ghoramara Island, Sundarban



Notes from Ghoramara:

- A brief visit to the island of Ghoramara was conducted to collect primary-level data and observe the scenario of the erosion, environment and the state of the island's people. The Gram Pradhan (head of the village) and two residents gave information about the current condition of their

island and how they have seen the weather change over time.

- A strong sense of community was observed, with less friction between people on matters of caste, religion, etc.

I spoke to three people, the Gram Pradhan (45M), village inhabitant (32F) and Imam of the village (75M).

Here is the summarized transcript of the conversation with Mr. Sanjiv Sadhan, Gram Pradhan of Ghoramara:



- Erosion has been happening on the island for the last 44-45 years.
- In 1972, Ghoramara island had many families living on it. The nearby island of Lohachara had been

gradually sinking for decades. In 1988 some of the last remaining people were evacuated, and Lohachara island was declared sunk. Some people came to Ghoramara, and rest relocated to other places on Sagar island.

- Currently, people are migrating to nearby villages like Bankimnagar, Phuldubi, Jibantala, Kamalpur and Gangasagar. 70% of people have started buying land in Kakdwip island.
- Thirty families have received the Pradhan Mantri Awas Plus scheme to relocate to Dhaspara in Samati nagar Gram Panchayat, Dakshin Haradhanpur, Sagar Island. The people who remain on the island do not have a reliable source of income, and most depend on welfare schemes. However, since the island is already in jeopardy and under government supervision, government policies do reach the people in need.
- Following is a list of schemes they benefit from-
 - a. Lakshmi bhandar Scheme
 - b. Khaddo Suraksha Scheme (Ration for food)
 - c. Krishak bondhu
 - d. Tapashili bondhu (For SCs)
 - e. Social welfare scheme for pension
 - f. Kanyashree
 - g. Rupashree
- After speaking to many of the people on Ghoramara, many expressed their reluctance to leave the island because of the fertile soil where

crops grow with quite an ease. The island is very sustainable in itself. It has a net 0 carbon emissions.

- There is a strong sense of trust and security in the community, which binds these people strongly to the place. The villagers report that they are pleased to stay there and do not want to shift to another island where people do not know each other and lead 'urban' lives.

ঘোড়ামারা গ্রাম পঞ্চায়েত		সংক্ষিপ্ত পরিচায়ক তথ্যাবলী	
আয়তন:	৩৬৭ বর্গ কি.মি.	প্রায়শি সংখ্যা:	৩৩০০
লোকসংখ্যা:	৩৬৭	মোটের সংখ্যা:	৩৭৩০
গ্রাম মহাসদ:	৪ টি	সচল জুও কাউন্সিল:	২৪
পান:	৭ টি	মেটথাল:	২৫ কি.মি.
গ্রাম পঞ্চায়েত সদস্য:	৫	নদী কাঁচ:	৬৭ কি.মি.
পঞ্চায়েত পরিষদের সদস্য:	৩	কৃষি ভূমি:	৬৩৭৭৭
পরিবার সংখ্যা:	৯৫৬	কৃষি জীবী পরিবার:	৯২৮
কল সংখ্যা:	৪৩৩৬	চুনি হীন কৃষি অধিক:	৭৭
পুল:	২২৪৬	গ্রাম বাজার:	২
মসজিদ:	২২২০	কাঁচা রাস্তা:	৭০০ মিটার.
উচ্চশিক্ষা প্রতিষ্ঠান:	৫৭৬	উঁট রাস্তা:	৩৫ কি.মি.
মধ্যশিক্ষা প্রতিষ্ঠান:	৩২৩০	কঙ্ক্রেট রাস্তা:	৭৩ কি.মি.
সেবার জল সরবরাহ প্রতিষ্ঠান:	৮৫	সচল নলকূপ:	৫৬
বি.পি.এল পরিবার:	৩৩৪	সুউন্নত বসকার:	২
NSAP ভাতা গ্রাহক:	৫০	উঁট দেওয়াল যুক্ত বাড়ী:	৪৫৯
		কাঁচা বাড়ী:	৪৯৭
		স্ব-নির্ভর দল:	৬২
		উঁট সংখ্যা:	৩
		সুদৃশ:	৩
		শিক্ষার হার:	৫৪%
		মার্কিনিক স্কুল:	৩
		প্রাথমিক স্কুল:	৩
		শিশু শিক্ষা কেন্দ্র:	৩
		অনুশীলন কেন্দ্র:	৩
		স্বাস্থ্য উঁট কেন্দ্র:	৩
		লাইব্রেরী:	৩
		স্ট্রাকচারাল অফিস:	৩
		রেগন দোকান:	৩
		মাসিক মাসিক শৌচাগার:	৪
		মাথি জুড়ি রাস্তা:	৫

- Ghoramara Gram Panchayat's record of data (written in Bengali)
- In May of 2021, Ghoramara suffered a lot during the Yaas Cyclone, during which the whole island was submerged under water for half an hour. Saltwater had completely inundated the island. This led to

contamination of the freshwater ponds and stagnation in the farmlands. During the flood, people climbed trees and rooftops to save themselves from being washed away in the tidal surge. The few unfortunate elders and women who could not seek refuge in time, were tied to the trees so they would not wash away in the cyclone. However, a recent cyclone shelter has been inaugurated in Ghoramara that has facilities for protecting people as well as cattle.



- New species of fish (locals call it monopiya) has arrived in the island after saline water filled the

pond during Yaas cyclone.



- Exactly a year ago, in May 2020, the super cyclone Amphan caused comparatively low havoc as the water inundation was lesser due to it occurring during low tide. Post cyclone, relief comes from NGOs and governments. A community kitchen was set up, and food, water and money were given. Despite all the help, they faced difficulties with procuring clothing for themselves.
- Some damage did not appear immediately but was long felt over the years. In the aftermath of the Yaas cyclone, no crops could be grown for two years on the land due to the soil being contaminated by the saline river waters. The Khasimara school was destroyed due to the combined effect of the cyclone as well as being located in an area susceptible to severe erosion.
- Area where the Khasimara school used to exist. Bits of concrete still remain there.



- There are 4 primary schools and 1 high school in Ghoramara. The high school has 385 students but only 2 permanent teachers and 5 part-time teachers. The primary schools are located in Mandirtala (125 students, 5 teachers), Ghatala (135 students, 6 teachers), Raypara (165 students, 3 teachers). The student-to-teacher ratio could be better because most youths leave the island in search of better opportunities. For healthcare facilities, there is a health sub center where a community health officer connects the patients with a doctor on Telemedicine calls. Doctors from Ramkrishna mission Rahara come every week. 5

ASHA workers are there who are social health activists to help the community.

- If the Gram Pradhan has to request rehabilitation of the people whose houses are affected by erosion, he has to file a request at a block level. The DM (District Magistrate) then discusses it with the Minister and makes necessary arrangements. This process takes time and comes with much bureaucratic red-tapism.
- To summarize, the top reasons that are crippling Ghoramara are poor socioeconomic conditions, climate insecurity due to vulnerability due to cyclones and rising sea level and the erosion happening due to the Haldia port guiding wall.