Designerly reflections on data visualization

Changing environment and its impact on Ghoramara Island, Sundarbans

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Approval Sheet

This Design Research Seminar project titled “Designerly Reflections on data visualization: Changing environment and its impact on Ghoramara Island, Sundarbans ” by Alivia Chaudhuri (Roll Number: 216330017) and Sagarika Dam (Roll Number: 216340005) is approved for partial fulfillment of the requirement for the degree of ‘Masters in Design’ at the Industrial Design Centre, Indian Institute of Technology, Bombay.

Guide: 

Venkatesh Rajamanickam

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Declaration

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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Date: 1 March 2023
Place: Mumbai

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1 Abstract

In recent years, the delta of Sundarbans has experienced various climate-related challenges, including rising sea levels, erosion of islands, and severe cyclones. These changes have had far-reaching effects, especially on the people living there. We visualize the data of one such island in the Indian Sundarbans delta, severely affected by erosion, known as Ghoramara island. Through an examination of the available scientific literature and a brief field study, this paper seeks to provide a comprehensive visual overview of the current state of the climatic parameters of the area and its environmental refugees targeted toward policymakers. This paper is a designerly reflection on the data visualization we created on the same.

Keywords

Data visualization, Sundarban, climate change, environmental refugees.

2 Introduction

Climate change is one of the most pressing issues of our time, and its impact can be seen all around us. The United Nations defines climate change as long-term shifts in temperatures and weather patterns. (United Nations, 2021) . One of the regions particularly vulnerable to climate change's effects is the dynamic ecosystem of the Sundarbans delta near the Bay of Bengal.

The Sundarbans is the largest contiguous mangrove forest in the world. The ecosystem is listed as 'endangered' under the IUCN Red List of Ecosystems, 2020. Four protected forests in the delta are UNESCO World Heritage Sites, and it also became a Ramsar site in 2019. The delta spans across India and Bangladesh for 10,000 km^2. Sediments from major rivers like Ganga, Brahmaputra, and Meghna draining into the Bay of Bengal have given rise to the Sundarbans delta.

The estuarine landscape is constantly changing due to the interplay between high and low tides. It is a carbon sink, which means it absorbs more carbon from the atmosphere than it releases. The mangroves are a natural barrier against storm surges and cyclones. Without the Sundarbans, Kolkata as a city would not exist. (Mallick, 2023)

The forest is home to numerous species of plants, fish, birds, and animals, including the emblematic Bengal tiger and estuarine crocodile. It is not only ecologically significant but also plays an important role in the lives of 4.5 million people who rely on its resources for their livelihoods. (World Wildlife Federation India, 2021). Out of the 104 islands in Indian Sundarbans, 54 are inhabited.

The focus area of our study—Ghoramara Island, located in the northwest, is one such inhabited island. It has been experiencing severe erosion over the past several decades due to a combination of natural and human-induced factors. Rising sea levels and increased intensity of cyclonic storms are some climatic factors. human activities, such as the construction of guiding walls upstream near Haldia port, have also played a role in the degradation of the island. Another two islands near the area—Bedford (Bengali name 'Supuribhanga') and Lohachara have already submerged in the 1980s.

Img 1. A- Contextual area of study in India. B- Sundarban. C- Sagar, Kakdwip, Ghoramara islands in the west. D - Map of Ghoramara island

2.1 About Ghoramara

Ghoramara island extends between 21°53'56"N to 21°55'37"N latitude and 88°06'59"E to 88°08'35"E longitude. It is said that an Englishman's horse was killed by a tiger in the area, so the island was named Ghoramara, which translates as "killing a horse."

2.1.1 Erosion

Over the past 30 years, the island's land area has shrunk in half. In 1954, the island's total area was 18.65 km^2. In 1990, it became 6.08 km^2; in 2020, the island is only 3.75 km^2. (Halder et al., 2022)

The loss of land has displaced the inhabitants, who have now become 'environmental refugees'. It has brought a significant change in their lifestyle and occupation. Many are looking for alternate residences and sources of livelihood.

Earlier, the primary occupation of the inhabitants was paddy cultivation. However, due to the island area shrinking and many people losing their lands, there is now a dearth of agricultural land. Most people have shifted occupation to become daily wage laborers, workers in betel leaf farms, or building embankments by the 100-day MGNREGA job scheme. (Kapoor, 2018).

The continuous and rapid shrinking of the island, combined with the severe aftermath of many major cyclones that occur annually, has negatively impacted the island's population. The most recent cyclone Yaas in 2022, completely inundated the island—damaging homes, schools, crops, and ponds. Many families have been forced to leave the island in search of safer places to stay. Families who could afford to migrate moved to areas like Sagar island and Kawkdip, specifically villages like Bankimnagar, Phuldubi, Jibantala, and Gangasagar. *(via field research)*

3 Motivation

We believe that the situation of Ghoramara Island highlights the urgent need to address climate change and its impacts on vulnerable communities.

Many researchers have studied the circumstances surrounding Ghoramara over the years. Data has been collected and analyzed, pointing to the bleak future of submerging entirely in the coming years. However, there is an absence of holistic visualization of the data. We aim to fill that gap and tell the story of Ghoramara island and its people.

3.1.1 Environmental Refugees

The 1951 Refugee Convention defines refugee status based on five grounds: race, religion, nationality, and being a member of a particular social group or political opinion. Environmental refugees do not fit into any of these definitions, depriving them of legal protection. (Sawant & Sanjeev, 2022). Over the coming years, India will face mass migration due to environmental factors. Thus it is essential to have an inclusive definition.

3.1.2 Policies regarding environmental refugees

The migration observed is not limited to Ghoramara but is becoming common for thousands of people from all over the Sundarbans. Unfortunately, India has no policy yet that addresses rehabilitating and compensating the displaced masses. At the moment, they are done on an ad hoc basis. (Koshy, 2022)

3.1.3 Authors' motivation

Our motivation is to encourage policymakers to consider the plight of environmental migrants and take necessary action to aid them. Growing up in West Bengal, a personal connection also drives us to empathize with the plight of the people of Sundarban and the disappearing islands, parts of which fall into the UNESCO world heritage sites.

4 Objective

We started with a broad objective to study how climatic factors affected the people of Sundarbans. After a brief background study, the island of Ghoramara came across as the most affected island. Our research goals were to

- Identify the global and local climatic factors leading to drastic environmental changes.
- Find and collect data on changes in climatic parameters like sea level rise, rate of shoreline movement, etc., over time.
- Collect data on the life and livelihood of the inhabitants of Ghoramara.

We aimed to design a suitable visualization for policymakers highlighting the above data. It is crucial to driving policy-level changes to address the effects of climate change, especially for environmental refugees who bear the brunt of it the most.

In the next section, we describe the climatic and anthropogenic data collected and the insights we got from the field study.

5 Literature Review

We did a literature survey on the topics of climate change indicators, Ghoramara's hydrodynamic conditions, and its population's qualitative variables.

5.1 Climate change indicators

5.1.1 Sea surface temperature

Ocean and atmospheric patterns primarily govern the earth's climate. (Valentine, 2020) Sea surface temperature is one of the best indicators of a warming climate. It also affects the rise in sea level and causes the possibility of more cyclones.

According to a study done for the Bay of Bengal basin, the increase in sea surface temperature is correlated to increased wind speeds (intensity) of cyclones. (United States Environmental Protection Agency, 2022). Four subdomains in the Bay of Bengal were studied, and the subdomain closest to the Sundarban area showed a gradual yet increased rate of sea surface temperature over the years. While in 1996, the sea surface temperature was 27.9 ℃, by 2016, the temperature had increased to 29.8 ℃. (Albert & Bhaskaran, 2020)

5.1.2 Sea level rise

There are three types of sea level rise—Global, Absolute, and Relative. The Global Mean Sea level (GMSL), observed from tide gauges and altimetry observations, was 1.4 mm/yr from 1901–1990. It drastically increased to 3.2

mm/yr over 1993–2015. According to the IPCC, the sea level rise predicted is 15 mm/yr in 2100. (International Panel on Climate Change, 2022). Though data for the Sundarban area differs from various sources, the conclusion remains the same. The rate of sea level rise is much higher in the Sundarban Bay of Bengal area compared to the GMSL. The absolute sea level rise from 2002 to 2014 along on the coast of the Bay of Bengal is 5.5 mm/yr. (Kusche, 2016) One study reports that the Bay of Bengal has the highest sea level rise in the world, estimated at 10 mm/yr. (Rahman et al., 2011)

5.1.3 *Cyclones*

The frequency of major cyclones has increased over the years in the Sundarban area. Higher-grade cyclones have occurred every year, sometimes twice yearly. The India Meteorological Department classifies tropical cyclones in the following categories (IMD, 2016):

Maximum sustained surface wind speech in knot (kmph)	Nomenclature
Less than 17 (<31)	Low Pressure Area (L)
17 to 27 (31–49)	Depression (D)
28 to 33 (50–61)	Deep Depression (DD)
34 to 47 (62–88)	Cyclonic Storm (CS)
48 to 63 (89–117)	Severe Cyclonic Storm (SCS)
64 to 89 (118–166)	Very Severe Cyclonic Storm (VSCS)
90 to 119 (167–221)	Extremely Severe Cyclonic Storm (ESCS)
120 and above (>222)	Super Cyclonic Storm (SuCS)

Table 1: Cyclone classification

Some of the major cyclones to hit Ghoramara island were:

- Aila in 2009, a Severe Cyclonic Storm (SCS)
- Bulbul in 2019, an Extremely Severe Cyclonic Storm (ESCS)
- Fani in 2019, a Very Severe Cyclonic Storm (VSCS)
- Yaas in 2021, a Very Severe Cyclonic Storm (VSCS)

The rate of major cyclones which have affected the island has become a lot more than it was even ten years back.

Out of all of the aforementioned cyclones, Yaas created the most devastating impact on Ghoramara. As the cyclone hit during high tide, the island was submerged for 30 minutes without any land in sight. The able-bodied inhabitants, like the men, climbed up to the roofs of the buildings. Few who could not do so, like the elderly and women, had to use extreme means to ensure survival. They were tied to the trees to prevent washing away in the tidal surge. The aftermath was quite devastating too. There was much structural damage, loss of property and valuables, and the Khasimara school were destroyed. Due to the saline water inundating the fields, crops could not grow for two years after the cyclone.

5.1.4 Sea salinity

The sea salinity fluctuated over the years, there was no observable trend from the literature review. However, the inhabitants reported that the water had become more saline.

5.2 Effect on the island

5.2.1 Erosion, net shoreline movement

The significant and pressing problem of Ghoramara island is coastal erosion. It was earlier happening on the southwest coast. As of 2023, it is now at north of the island. The sensitive ecosystem's morphology is changing fast as a result of anthropogenic and natural factors. The total area has decreased from 18.65 km^2 in 1954 to 3.75 km^2, as seen in 2020. (Biswas et al., 2012), (Roy Dasgupta et al., 2021). We studied the change in total area over time.

We also looked at a few statistical methods used to calculate shoreline change rates. According to Adarsa, Samina ,and Biswas (Biswas et al., 2012), the most common ones are end-point rate (EPR) and net shoreline movement (NSM). Most of these methods use satellite imagery (LANDSAT satellites of NASA/USGS). For our visualization, we have stuck to change in the area of the island as the other methods are more catered towards a more scientific audience.

5.2.2 Change in land use pattern

Severe erosion has led to a change in land use pattern. Table 2 below summarizes the changes. It highlights that around 10 km^2 of land used to be agricultural land, but now it has become just 1 km^2. The forest cover occupied 27% of the island in 1954, which is now almost gone.

Change in Land Use Pattern	**1954**		**2018**	
Land use	Area (km^2)	% of total area	Area (km^2)	% of total area
Agricultural land	10.12	54.27	1.7173	45.79
Built up area	0.26	1.39	0.4742	12.65
Tidal flat (can be mudflat or sand flat)	2.96	15.87	0.1174	3.13
Water body	0.26	1.39	0.1845	4.92
Forest + Vegetation including plantation	5.05	27.08	0.8812	23.5
Marshy Land	0	0	0.3754	10.01
Sum	18.65	100	3.83	100

Table 2: Change in land use pattern

5.2.3 Change in occupation

A study (Roy Dasgupta et al., 2021) noted a diverse range of occupational activities of the people. The primary occupation has shifted from agriculture to day labor. The island's socioeconomic conditions are poor, as a sole source of income is hardly sufficient for the people. The saline water

contamination from the sea, erosion of fertile land, and cyclonic inundation do not provide scope for agricultural produce. Ironically, constructing embankments to prevent erosion also provides a scope for masonry work.

5.3 Push and pull factors of migration

The push factor of migration is a force that drives people away from a place, and the pull factor is what attracts them to a new location. (Lee, 1966). In Ghoramara, climate insecurity, land loss, habitat loss, and decreasing resources are the most significant push factors. Though the island's people do not want to leave their homes, they are left with no option. Some families are changing homes and shifting inland, i.e. moving towards the higher areas within the island. Others are migrating from Ghoramara to other areas like Sagar Island and Kakdwip. The field study gave us further details about the number and new residences of rehabilitated families by the government. Migration puts additional pressure on the resources of the destination areas and threatens the livelihood of existing inhabitants. (Ghosh & Hazra, 2016)

Pull factors of migration include better job opportunities outside. Mostly the men go to places like Kerala, Mumbai and Kolkata for jobs. Locals who are not migrants are undoubtedly drawn in by the migrants' altered way of life and follow them.

Around 70% of the people are trying to find an alternate residence outside. However, most of this island's people are poor and have no other option except to wait for the government's help. There are no policies in place to help environmental refugees like the people of Ghoramara.

6 Background study on Data Visualization

In addition to studying the climatic environment of Ghoramara, we also studied different types of data visualization, types of data, and what visuals best represent those data.

6.1 Types of data

Data Type - is the measurement scale that describes the information's nature. For our project, we have categorical data (nominal data: names of major cyclones; ordinal data: severity of cyclones) as well as quantitative data (interval data: number of cyclones in the last decade; ratio data: wind speed of a storm)

Data Semantics: The real-world meanings of the data, such as whether the data represents temperature or height measurements. It focuses on organizing data that reflects the primary meaning rather than solely on the relationships and attributes of the data. For our visualization, we used animation to show water filling up for sea level rise and people leaving on boats to depict migration. This type of pictorial representation augments the meaning and understanding of data.

Data Behaviour: Encompasses the trends, patterns, and shape of the data values relative to each other. For example, in our visualization, we have overlapped area charts to show the population fall trend that indicates migration.

6.2 Types of visualizations

According to the book Designing for Information (Meirelles, 2013), there are 5 main types of information visualizations-

1. **Hierarchical structures-** ones that show relationships and order of hierarchy between data
2. **Relational structures -** connections or networks amongst data
3. **Temporal structures-** Time is an abstract concept and not inherently visual. We experience time as moving forward in one direction. Thus X axis often is used to represent time. In our visualization, we use a constant timeline to represent temporal data.
4. **Spatial structures-** A diagram of spatial distribution of relative positions of data. Maps are the most common representations of spatial data.
5. **Spatio-temporal structures-** All changes require time to transform, reorganize, remodel, or disappear. Temporal processes happening in the dimension of space are spatiotemporal structures. Geographic changes for our project are dynamic, often challenging for designers to represent in static form. Thus we chose animated video as our medium to depict the complexities of the data.
6. **Textual structures-** abstraction on a literary or textual corpus.

6.3 Linear narrative

Our visualization follows a linear narrative of the beginning, middle, and end. We are starting with how Ghoramara was before and the hurdles it faced over 50 years owing to environmental and non-environmental factors. Finally, we end our visualization with an infographic of the current situation. We have different scenes or panels in the animated visualization. Using multi-panel data is more effective when there is narrative data involved. (Borkin, 2013)

7 Insights from Primary Research

7.1 Conversation summary with expert

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

- **Discussion about the estuarine river system:** When discussing climate change, most always discuss the sea, not the river. Ghoramara's problem is not just due to climate change but also due to reduced silt deposition.
- Natural freshwater inflow has been reduced due to encroachment and human activities. 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.
- **Artificial constructions on the course of Ganga:** There are also many interventions on the Ganges in the upper casement area. Dams and barrages stop the velocity of the river. The sedimentation falls on the river bed, making it shallow and flooding its flood plains.
- **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 and became a major cause of the Ghoramara island sinking.

- **The current state of Ghoramara's erosion:** In the southwest part of the island, boulder protection was built, but the erosion gradually shifted to the northwest part of Ghoramara. Presently, the erosion has completely shifted to the north part near Khasimara.
- **Rehabilitation of environmental refugees:** The criteria for getting compensation from the government for rehabilitation under the Gitanjali scheme is that one needs to possess a piece of land. Unfortunately, this is often impossible for the people of Ghoramara due to their poor socio-economic conditions.

7.2 Fieldwork

A brief visit to the island of Ghoramara was conducted to collect primary-level data and observe the scene 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.



Img 2 - Interviewees

Sanjiv Sadhan - Gram Pradhan Md. Aftabuddin - resident Shiuli - resident

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

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

1. Erosion has been happening on the island for the last 44-45 years.
2. 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 the rest relocated to other places on Sagar island.
3. Currently, people are migrating to nearby villages like Bankimnagar, Phuldubi, Jibantala, Kamalpur,and Gangasagar on Sagar island. 70% of people have started buying land in Kakdwip island.

Img 3: Presence of no gradual shoreline and jagged edges of land broken and washed away with high tide. A date-palm tree is already underwater.

4.
5. 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.
6. Following is a list of schemes they benefit from. We would like to highlight that there are no schemes for migrating-
    - Lakshmi bhandar Scheme
    - Khaddo Suraksha Scheme (Ration for food)
    - Krishak bondhu
    - Tapashili bondhu (For SCs)
    - Social welfare scheme for pension
    - Kanyashree
    - Rupashree
7. 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 ease. The island is very sustainable in itself. It has a net 0 carbon emissions.
8. 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 neighbors do not know each other and lead 'urban' lives

Img 4: Ghoramara Gram Panchayat's record of data (written in Bengali)

9. 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 the 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. A 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.
10. However, a recent cyclone shelter has been inaugurated in Ghoramara that has facilities for protecting people as well as cattle.

Img 5: Cyclone center built in 2023

11. Exactly a year ago, in May 2020, the super cyclone Amphan caused comparatively lower 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.
12. 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.

13. The Khasimara school was destroyed due to the cyclone's combined effect and being located in an area susceptible to severe erosion.

Img 6: Area where the Khasimara primary school used to exist. Bits of concrete still remain there

14. 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), and Raypara (165 students, 3 teachers). The student-to-teacher ratio is poor because most youths leave the island in search of better opportunities.
15. Healthcare facilities include a health sub-center where a community health officer connects 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.
16. If the Gram Pradhan has to request rehabilitation of the people whose houses are affected by erosion, he must file a block-level request. 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 crippling Ghoramara are poor socioeconomic conditions, climate insecurity due to vulnerability due to cyclones and rising sea levels and erosion due to the Haldia port guiding wall.

8 Methodology

8.1 Scope of work:

Since we had already defined the particular study island, our data collection focused on it.
We narrowed our scope to show temporal data of 4 climate indicators:

- Sea surface temperature
- Data on major Cyclones that have hit the area (wind speed, severity index, tidal surge height)
- Sea level rise
- Salinity and pH of water over time

Projecting with this we added,

- Total area of Ghoramara island

- Change in population over time
- Change in land use pattern
- Its effect on change in occupation
- Current demographic statistics of the island

Most of the data we have portrayed are from peer-reviewed journals and the researchers themselves have collected some. We have clubbed a few publications' data together to develop a continuous timeline from the 1970s.

9 Analysis and findings from the data

Since we had small to medium batches of data, we used spreadsheet tools like Google Sheets to clean up and examine the data. Some data, like demographic data, are snapshots in time, whereas climate data is usually recorded as changes over time, like years or decades.
Briefly, we found the following:

- Sea surface temperature - has increased from 28 ℃ to 30 ℃.
- Cyclones- though the frequency of cyclones forming over the Bay of Bengal has decreased, their intensity has increased.
- Sea level rise - sea level has doubled from 2.2mm to 4.4mm in the last two decades.
- Salinity and water pH - Salinity is measured in pre-monsoon and post-monsoon phases. The data about salinity and pH were inconclusive, showing a slight dip and not much variations across time. However, during the primary study, it was found that the water has become more saline, and new fish species have come into the ponds.
- Total area of Ghoramara island - had decreased by 88%
- Change in population over time - No official record of how many people had left the island, when they left, and the reason for relocation. We analyzed the migration by looking at census data of the last 60 years and plotting the recorded population vs. the expected population (calculated by multiplying the growth rate with the existing population). Currently, 4500 people live in Ghoramara.
- Change in land use pattern - Agricultural land has drastically reduced from 10 km^2 to 1 km^2, thus affecting the livelihood of farmers. Otherwise, the island's soil is very fertile, and rice and betel leaves continue to grow there.

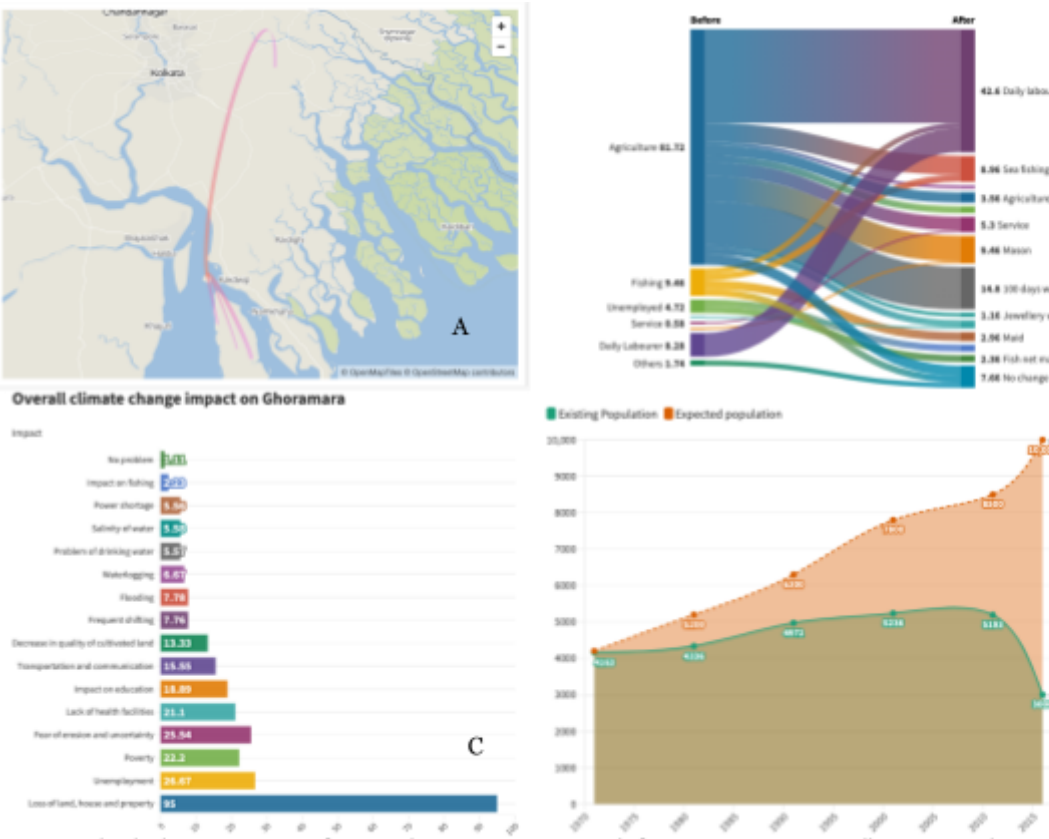
10 Ideation and Iterations

Knowing the data well is extremely important to generate new ideas. Systematically collecting and organizing data took considerable effort before the ideation process began.
We first drew high-level design elements, such as the layout and axes, followed by sketching data points based on their perceived ideas of data behavior.

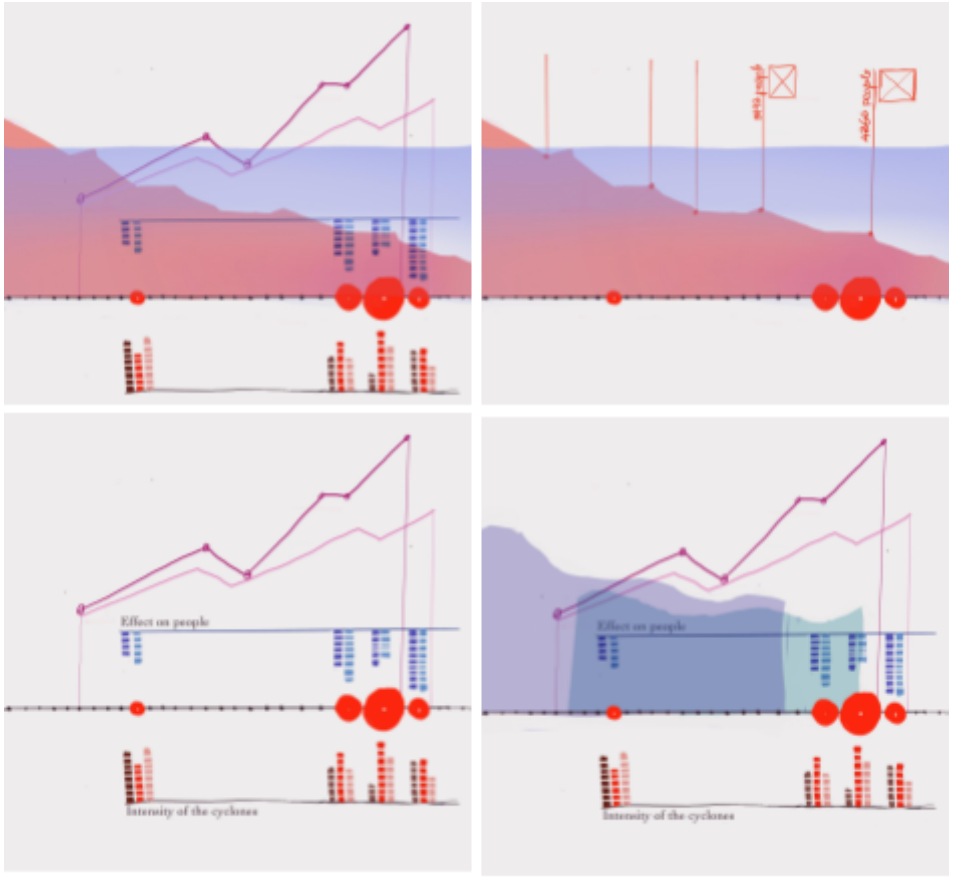
Initially, we created separate visualizations for each parameter. It resulted in a long-format presentation with 8-10 charts. (as seen in Img 7).

However, this was not ideal for policymakers who already have to go through reports and statistical charts. In order to make an impact, we changed our approach and tried to combine multiple visualizations together. After mapping the data on a common timeline from 1954, a lot of the data came together. A large-scale visualization was made, with the timeline being the central part of it.

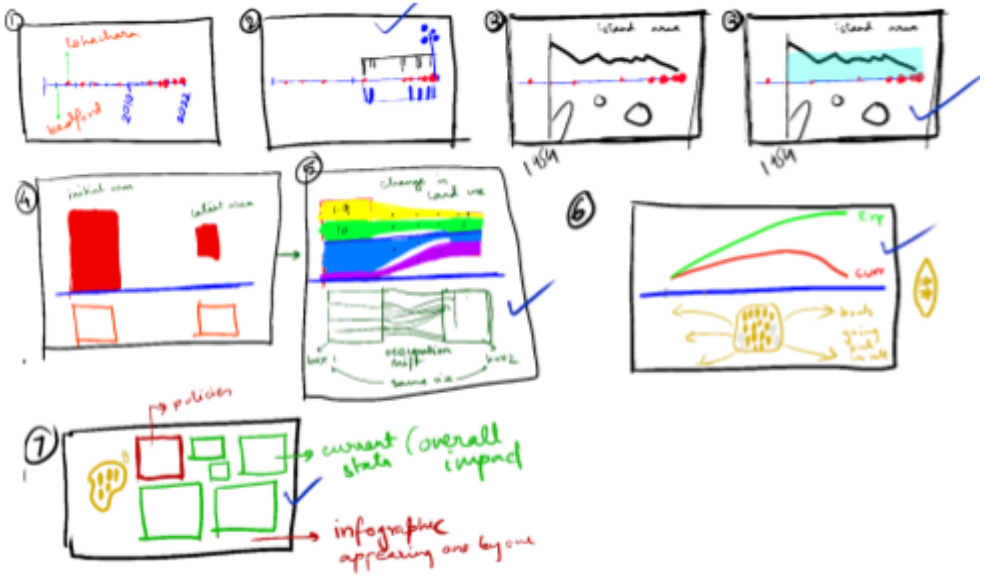
In static visualization, the viewer controls the flow of information. We chose a video format to control the pace and flow of information; we chose a video format. We decided to use some basic animations that show the temporal nature of the data.



Img 7: Individual representation of various data. A- Migration, B- Shift in occupation, C- overall impact, D - drop in population



Img 9: Sketches for layering multiple datasets



Img 10: Rough storyboard for video

11 Final Design

Here is the link to our final visualization video. Following are some of the visualizations from the animation video:

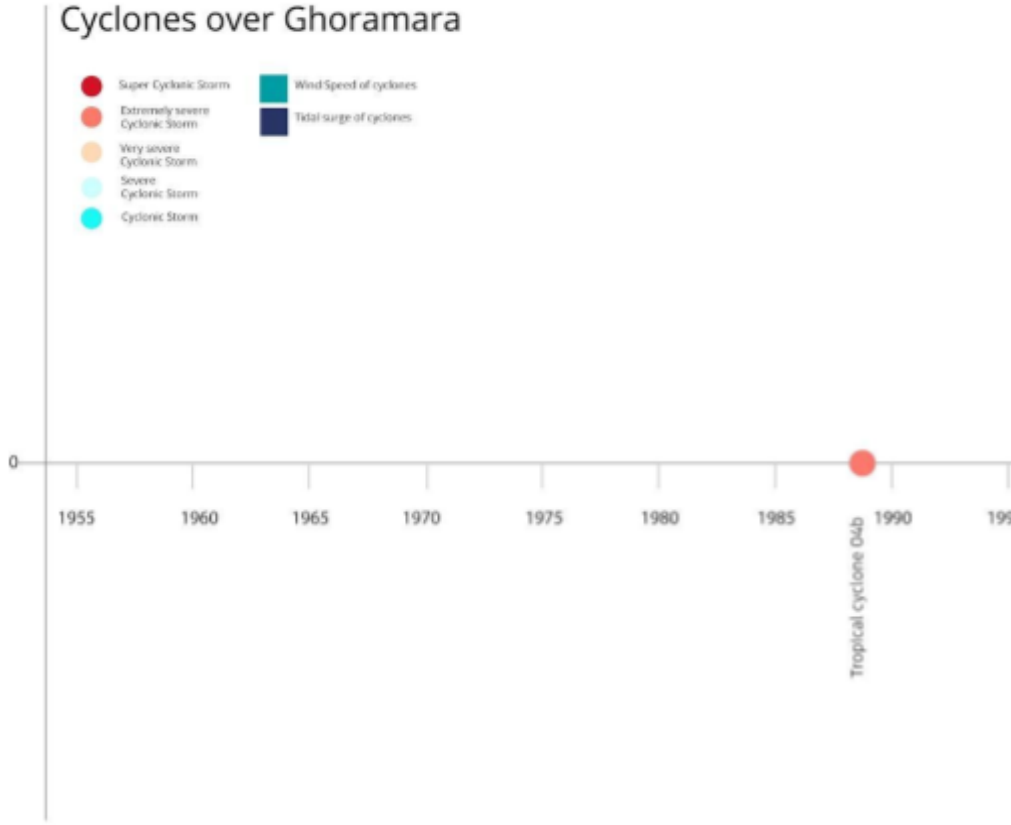


Image 11: Panel 1 - Cyclones over Ghoramara

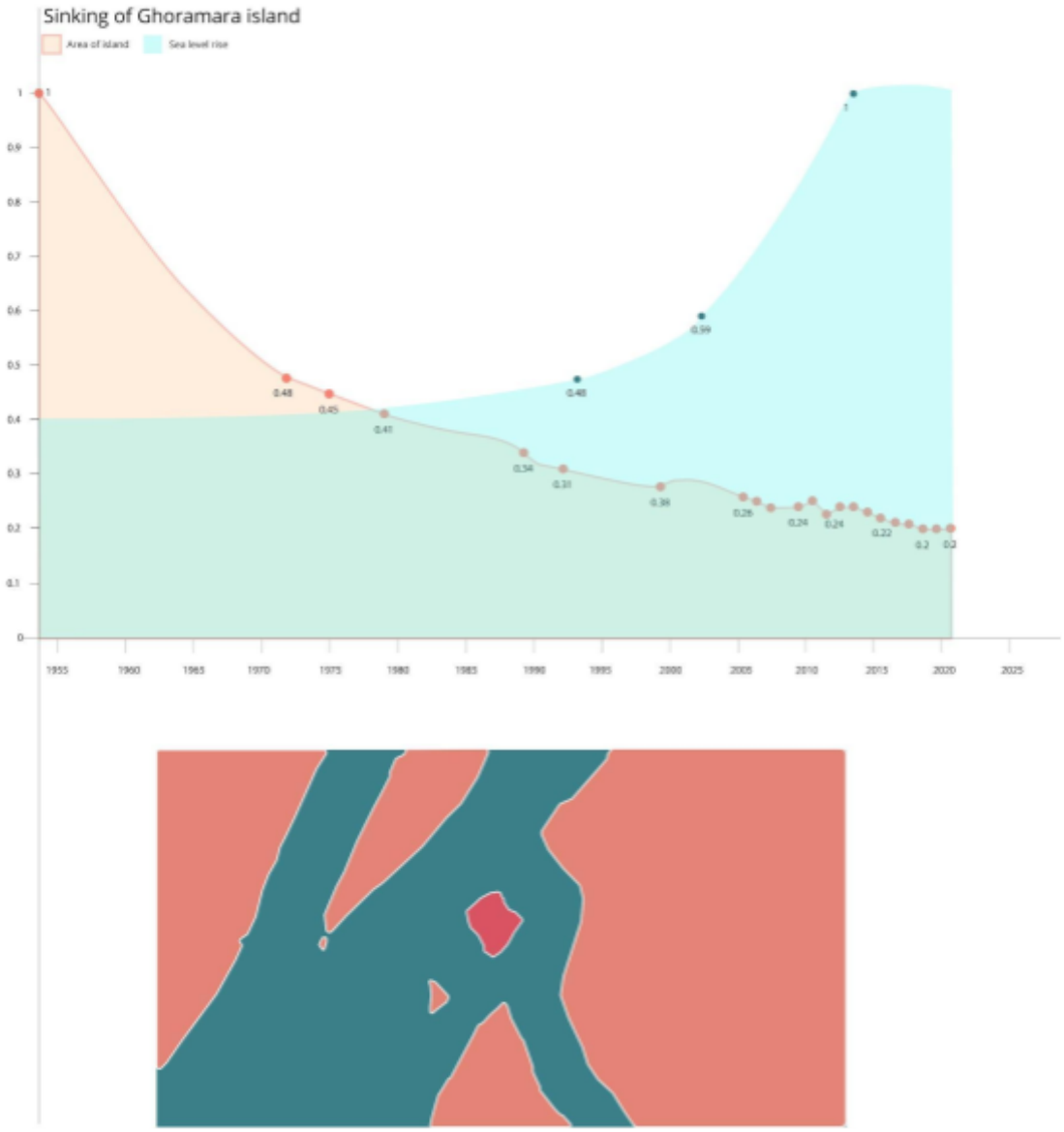


Image 12: Panel 2 - Sinking of Ghoramara Island

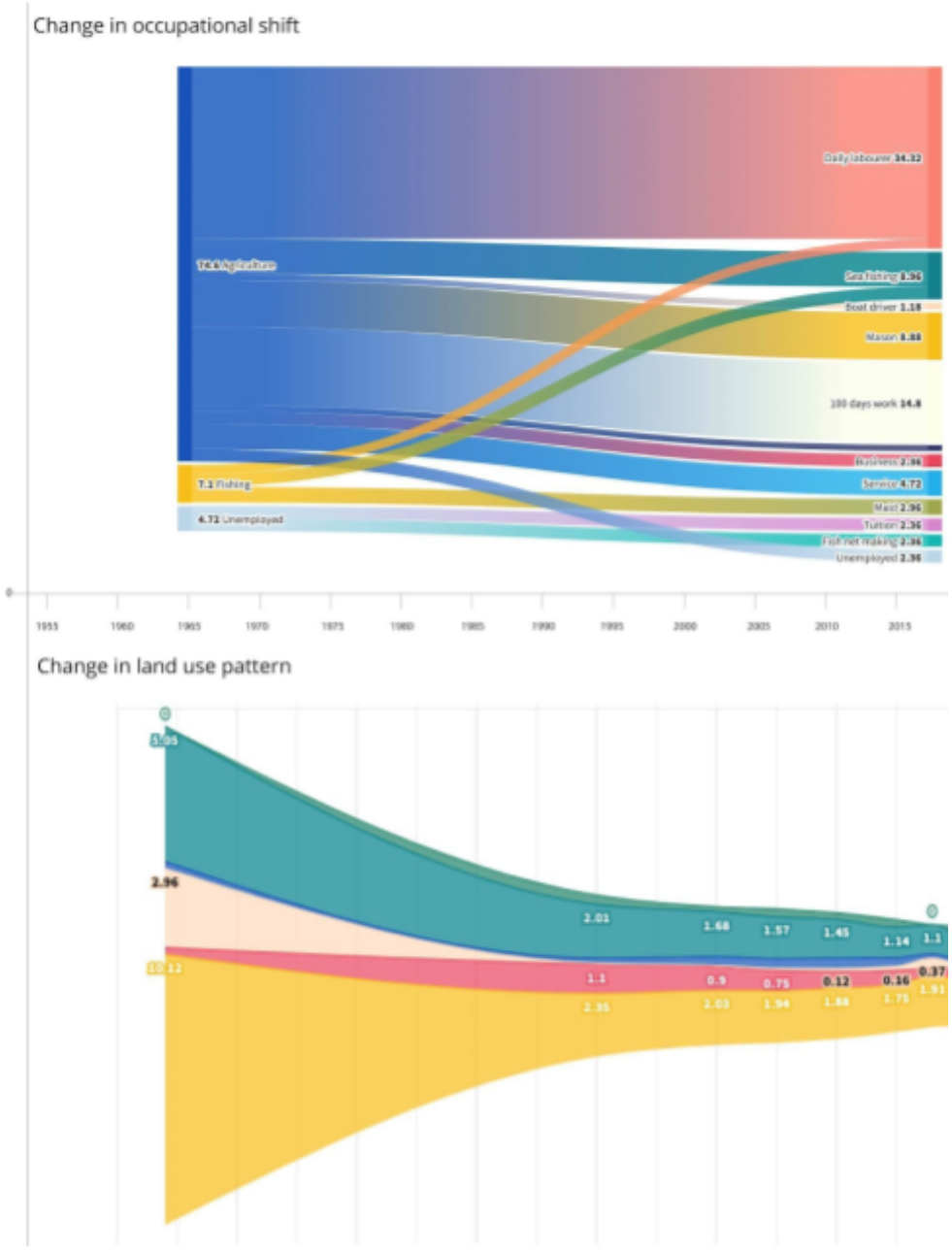


Image 13: P anel 3 - Change in occupation and land use

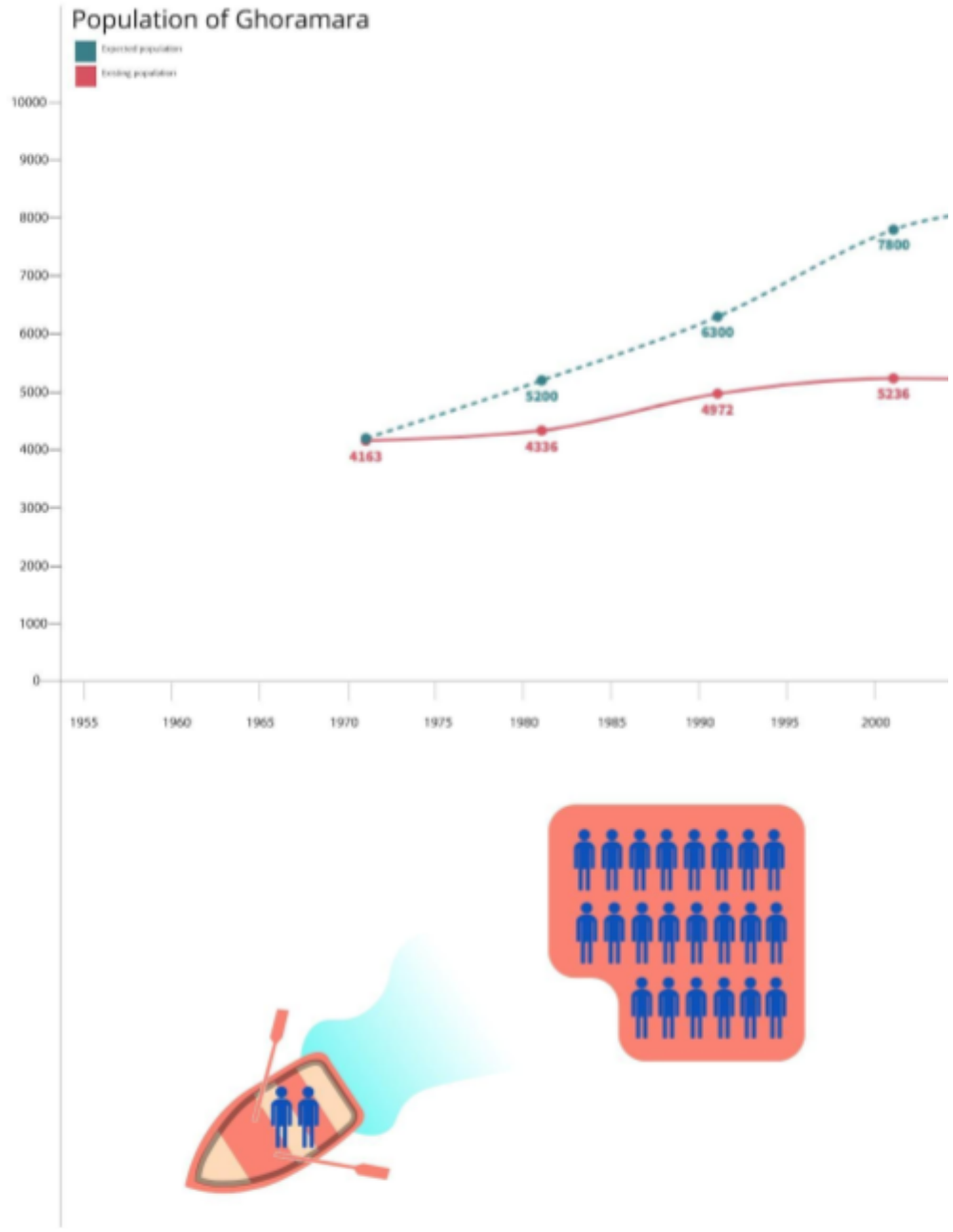


Image 14: Panel 4 - Ghoramara island

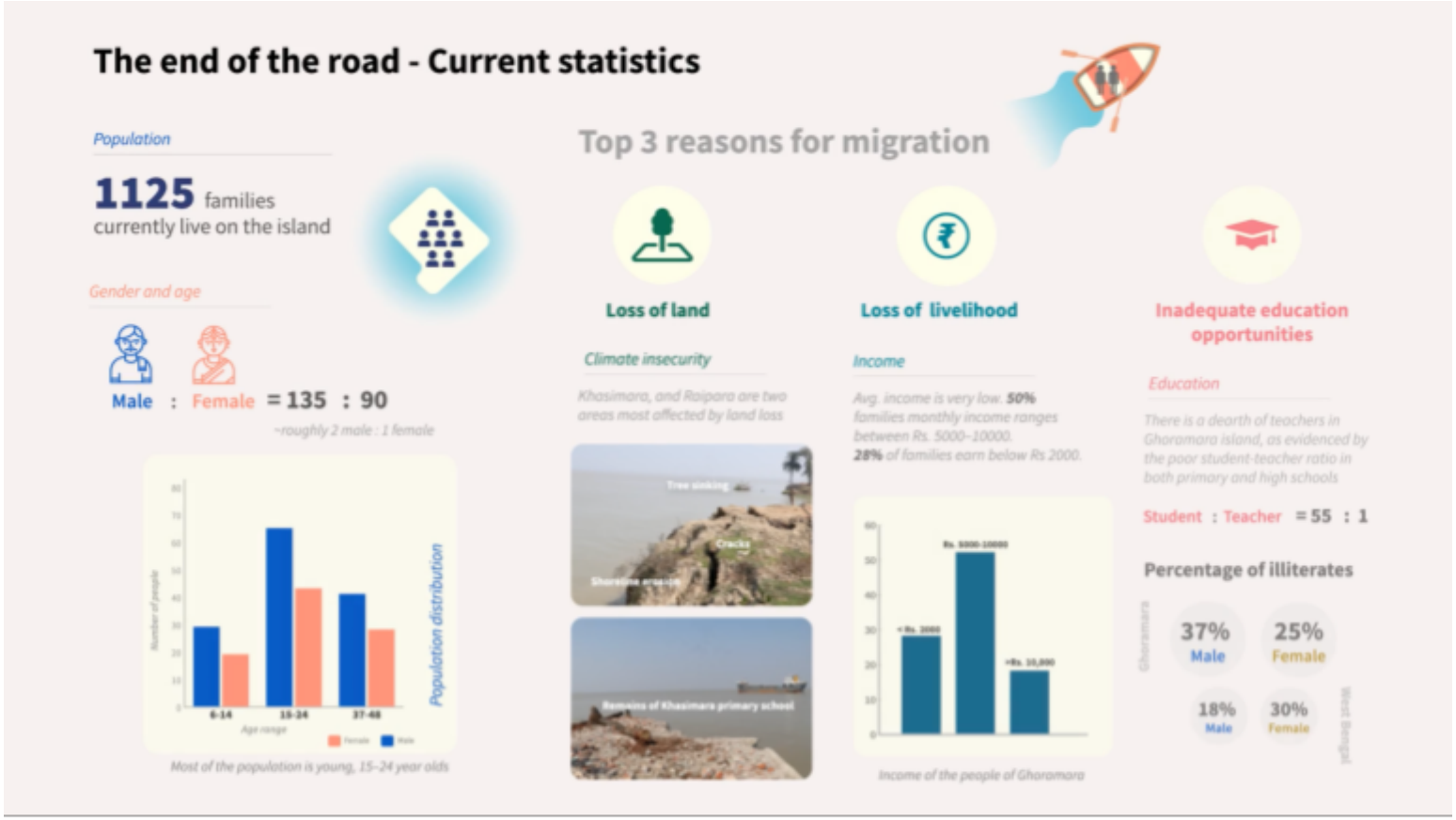


Image 15 - Panel 5: Infographics on current situation of Ghoramara

12 Discussion

Reflecting on the design solution we created, effective data visualization should guide the audience through the data, helping them understand the context and meaning behind the information. While data visualization can be complex, we have tried to present the information simply and intuitively.

Many visualizations add a layer of interactivity that allows the audience to explore the data independently. However, we have not explored interactivity in our solution. We have relied on amination and tooltips to enhance engagement. Below we have outlined our design process:

1. *Research and defining-*
    a. Research led us to the dearth of policy for environmental refugees and lack of holistic visualization for the same
    b. Given these discoveries and the project's scope, we decided to focus on the plight of Sundarban through the story of one island Ghoramara.
    c. To present a holistic picture of the story of Ghoramara due to its climatic factors, we approached it vicariously through a narrative.
    d. A narrative makes the urgent situation more relatable and shows the policymakers Ghoramara's past to save Ghoramara's future. We believe that numbers on a table do not move people, but stories move people.

2. *Analysis -*
    a. After primary and secondary research from various sources, we studied four climatic indicators
    b. We discovered that the non-climatic indicators also added to the island's decline. We also collected data on how people's livelihoods have changed over time.
    c. The plight of the people and island was decided to be our main narrative.
    d. We created a master table that showed all these changes over the years.
    e. To analyze the trends in data, we created basic graphs.

3. *Ideation phase-*
    a. We sketched rough ideas to create novel visualizations.
    b. Brainstorming which graphs we can use to represent each data set best so that they do not seem standalone, but each leads to building the storyline.
    c. We reached the final design concept after experimenting with 4-5 concepts.
    d. The medium was finalized to be an animated video.
    e. Storyboarding was done to decide the order and flow of visualizations and transitions.

4. *Why animated video?*
    a. Visualizations that flow into one another through video tell a better story.
    b. Animation can be a tool to capture people's attention. A video has more emotional impact than static images, which is better for communicating the story.

c. Time sequences or logically ordered series can benefit from animation. (Sanyal, 2021)
d. Without animation, when a chart is changed or filtered, it becomes difficult to intercept the movement of data points from one place to another. In these cases, animation steps in. This concept is called object constancy. It allows a graphical element to be tracked throughout a transition. Object constancy allows individuals to understand and see the changes rather than having to identify each new point. The simple changes in charts and trends affect how we perceive data. We are connected to the insights we draw from the data. (Sanyal, 2021)
e. The narrative is in the designer's control.
f. We can draw the audience's attention to the aspects we want to highlight in our visualization.

5. *Explaining our visual design choices:*

a. Color

We chose a triadic color palette. All three colors are distributed evenly around the colour so that one color has no clear dominance. The scheme is always vibrant and helps distinguish data points and values.

b. Typography

We chose Source Sans Pro because the numerical have the same lining, are tabular , and are multiplexed. Sans serif fonts work

Img 14: Triadic color palette

better for scientific presentation and numbers compared to serifs. In line means that they are all the same height upon lining up the numbers. Tabular figures are when every number is the same width. It is easy to see at a glance how many figures a number has, like 124.09 can be easily compared with 834.08. Multiplexed also means the numbers are the same width in regular as well as bold weight. (France, 2020)

6. *Explaining our visualization choices:*
a. The center of focus of our design is a simple timeline. This is because we are telling Ghoramara's story over the years.
b. Divide the page symmetrically to give detailed information about a certain topic.
c. Cyclone gradation (categorical data) based on color as per Indian Meteorological Department classification.
d. Tidal surge height and wind speed - bar graphs to show data for all four cyclones we decided to concentrate on (Aila, Bulbul, Amphan, Yaas).
e. The area of the island (one of the main data) is shown in 2 ways:

i. Aerial view of Ghoramara and nearby islands changing over the years- this shows the contextual morphological changes as well
ii. The area chart for reducing land area (also acts as a cross-sectional elevation for the rise in sea level) depicts the current situation on the island. The data does not have any trend or pattern to be shown here.

13 References

Albert, J., & Bhaskaran, P.K. (2020). Ocean heat content and its role in tropical cyclogenesis for the Bay of Bengal basin. *Climate Dynamics*, *55*, 3343–3362.

Biswas, A., Jana, A., & Shamina, S. (2012, October). Morphological Change Study of Ghoramara Island, Eastern India Using Multi Temporal Satellite Data. *Research Journal of Recent Sciences*.

Borkin, M.A. (2013, December). What Makes a Visualization Memorable? *IEEE Transactions on Visualization and Computer Graphics*, *19*(12), 2305-2315.

France, T. (2020, June 8). *Choosing Fonts for Your Data Visualization | Nightingale*. Nightingale Magazine. Retrieved March 6, 2023, from https://nightingaledvs.com/choosing-fonts-for-your-data-visualization/

Ghosh, T., & Hazra, R. (2016, June). MIGRATION PATTERN OF GHORAMARA ISLAND OF INDIAN SUNDARBANIDENTIFICATION OF PUSH AND

PULL FACTORS. *Asian Academic Research Journal of Social Sciences and Humanities*, *3*(6).

Halder, B., Ameen, A. M., Bandyopadhyay, J., Kheder, K., & Yaseen, Z. (2022). The impact of climate change on land degradation along with shoreline migration in Ghoramara Island, India. *Physics and Chemistry of the Earth Parts A/B/C*, *126*(10), 1015.

IMD. (2016). *WMO/ESCAP PANEL ON TROPICAL CYCLONES ANNUAL REVIEW 2016*. RSMC. Retrieved March 5, 2023, from https://rsmcnewdelhi.imd.gov.in/uploads/report/29/29_779539_annual-review-2016.pdf

International Panel on Climate Change. (2022). *Chapter 4: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities — Special Report on the Ocean and Cryosphere in a Changing Climate*. IPCC. Retrieved March 5, 2023, from https://www.ipcc.ch/srocc/chapter/chapter-4-sea-level-rise-and-implications-for-low-lying-islands-coasts-and-communities/

Kapoor, A. (2018). *INCHING CLOSER LIFE ON THE SINKING ISLAND OF GHORAMARA*. The City University of New York. https://academicworks.cuny.edu/cgi/viewcontent.cgi?article=3721&context=gc_etds

Koshy, J. (2022, March 31). India prepared for 'climate refugees', government tells Lok Sabha. *The Hindu*.

Kusche, J. (2016). Sea level budget in the Bay of Bengal (2002–2014) from GRACE and altimetry. *Journal of Geophysical research Oceans*. https://doi.org/10.1002/2015JC011471

Lee, E. (1966). A Theory of Migration. *Demography*, *3*(1).

Mallick, R. (2023). *Researcher on climate resilience* [CEPT Ahmedabad].

Meirelles, I. (2013). *Design for Information: An Introduction to the Histories, Theories, and Best Practices Behind Effective Information Visualizations*. Rockport Publishers.

Rahman, A. F., Dragoni, D., & Masri, B. E. (2011, December 15). Response of the Sundarbans coastline to sea level rise and decreased sediment flow: A

remote sensing assessment. *Remote Sensing of Environment*, *115*(12), 3121-3128.

Roy Dasgupta, I. D., Banerjee, T., & Saha, A. (2021). Impact Analysis of Island Erosion and the Changing Pattern of Livelihood, a Case Study of Ghoramara. *Journal of Geography & Natural Disasters*.

Sanyal, S. (2021). *Animating Data Visualization: Bringing Analytics to Life*. Analytics Insight. Retrieved March 6, 2023, from https://www.analyticsinsight.net/animating-data-visualization-bringing-analytics-to-life/

Sawant, N.H., & Sanjeev, A. (2022, April). Climate Refugees in India: A Wake-up Call for an Inclusive Policy. *India Quarterly: A Journal of International Affairs*, *78*(2), 371-380. https://doi.org/10.1177/09749284221090706

United Nations. (2021). *What Is Climate Change? | United Nations*. the United Nations. Retrieved March 5, 2023, from https://www.un.org/en/climatechange/what-is-climate-change

United States Environmental Protection Agency. (2022, August 1). *Climate Change Indicators: Oceans | US EPA*. EPA. Retrieved March 5, 2023, from https://www.epa.gov/climate-indicators/oceans

Valentine, K. (2020, June 8). *NOAA collects a lot of data on the ocean. Here are 4 ways we use it. - Welcome to NOAA Research*. NOAA. Retrieved March 5, 2023, from https://research.noaa.gov/article/ArtMID/587/ArticleID/2637/NOAA-collects-a-lot-of-data-on-the-ocean-Here-are-4-ways-we-use-it

World Wildlife Federation India. (2021). *About Sundarbans*. WWF India. Retrieved March 5, 2023, from https://www.wwfindia.org/about_wwf/critical_regions/sundarbans3/about_sundarbans/