Strengthening Sea Level Monitoring and Data Management in East Africa for Coastal Resilience and Community Safety
Inception Workshop, Mombasa, Kenya, 24-26 September 2025

Sea-level rise rates, trends and impacts in WIO region

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1. Introduction

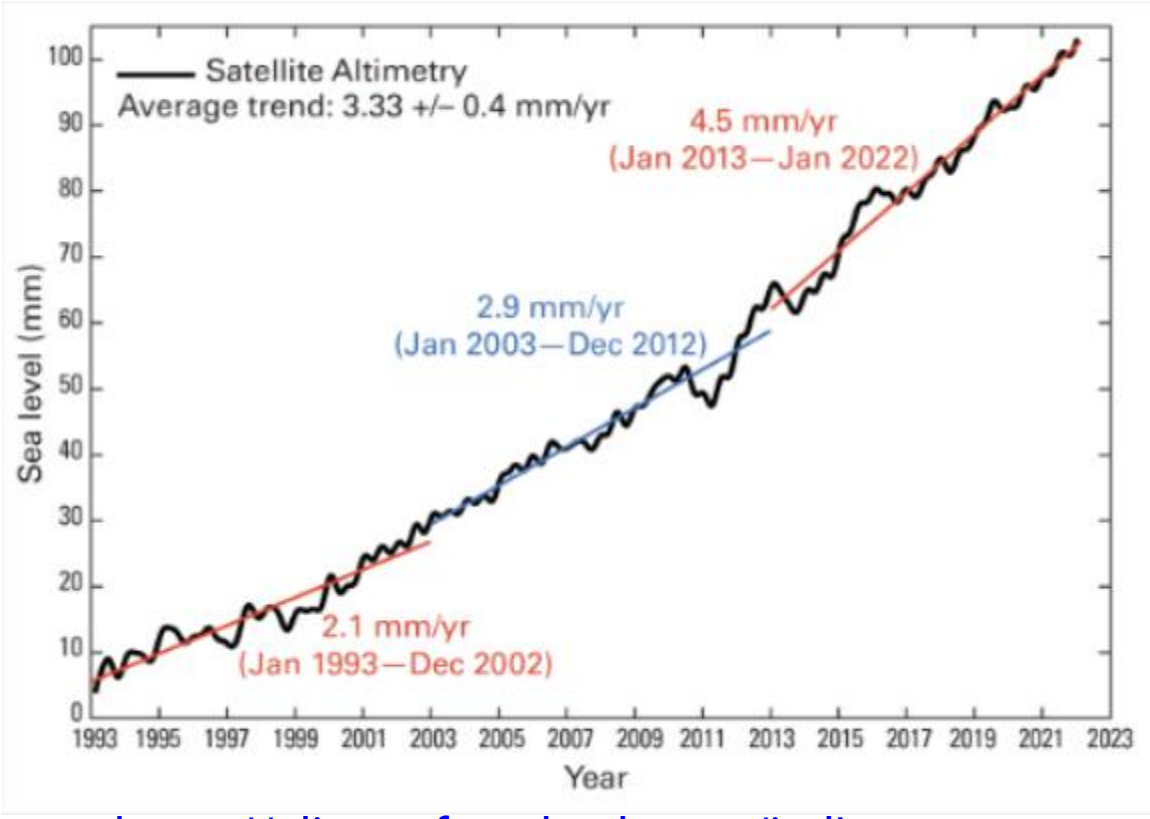
The **Global Mean Sea Level** (GMSL) has been rising at an accelerating rate, with the most recent data indicating a significant increase over the past few decades.

Since 1880, GMSL raised by **21–24 cm**

From 1993 to 2023:
— The GMSL raised about **11.1 cm**
— The average rate was **1.7 mm/year**.

Where:
— In 1993-2018 was: **3.3 mm/year**
— In 2006-2018 was: **3.7 mm/year**
— In 2024 was: **4.5 mm/year**

Future trend, by 2100:
— GMSL projected to rise by **28-55 cm**



Source: https://climatefactchecks.org/india-among-nations-facing-highest-threat-from-sea-level-rise-wmo/

1. Introduction (Cont.)

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The GMSL increase is primarily driven by global climate change, which causes **thermal expansion** of ocean waters and the **melting** of **land-based ice**, including glaciers and **polar ice** sheets.

With:

—Thermal expansion accounts for 50% of the rise

—Glacier ice loss: 22%,

—Ice sheet melting: 20%, and

—Changes in land-water storage: 8% of the total.

Source: https://share.google/C0EmXQBkQYcIjTDsm/

2. Sea-level rise rates and trends in WIO

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Sea level rise is not globally uniform and varies regionally. In several ocean basins, the sea level has increased by as much as 15-20 cm in relation to the year 2000.

The strength of winds and ocean currents naturally varies by region, affecting how much and where the deeper ocean layers store heat.

The **Western Indian Ocean is one of the global hotspots for sea level rise**:

— In the 18th century, the sea level rise rate was **0.3 mm/year**
— in the 19th century was: **0.4 mm/year**,
— in the 20th century was: **1.7 mm/year** ,
— between 2004 and 2015 was: **3.5 mm/year** ,

Projections for the 21st century is: **8-16 mm/year**.

2. Sea-level rise rates and trends in WIO

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The table show the actual Sea-level rise rates in some countries in the WIO, compared with regional and global figures

Madagascar exhibits the highest rate (7.5 mm/year)

followed by Mozambique (6.0 mm/year)

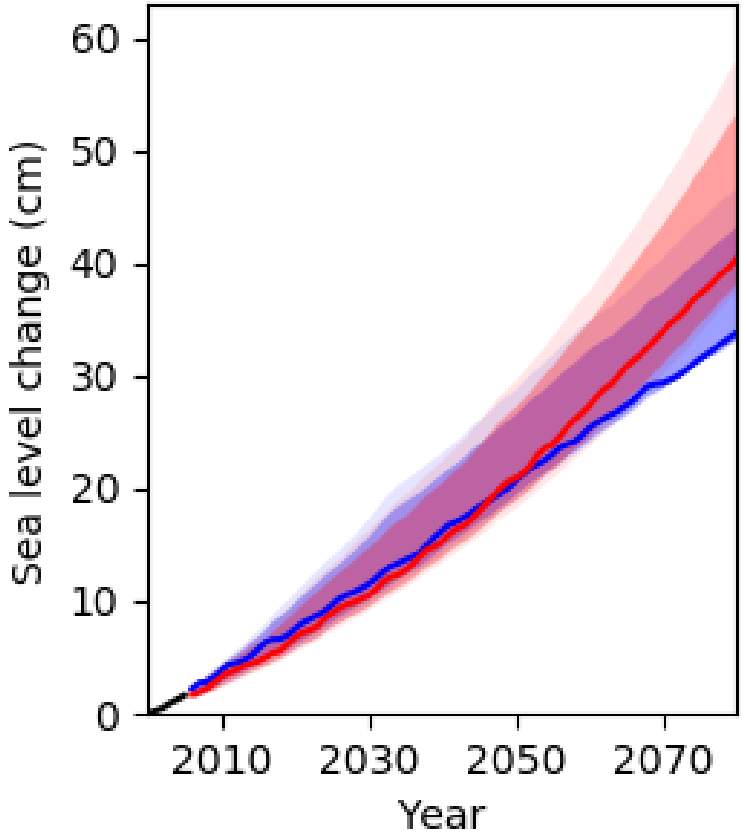
Seychelles exhibits the lowest (3.0 mm/year) in the region

Source: Sea Level Change, Historical. [Climate Change Knowledge Portal]

Country	mm/year	References
Kenya	3.4	Africa faces disproportionate burden from climate change and adaptation costs. [wmo.int]
Madagascar	7.5	Madagascar: Climate Change. [UNEP GRID-Arendal]
Mozambique	6.0	Mozambique: Sea Level Change, Historical. [climateknowledgeportal.worldbank.org]
Seychelles	3.0	Sea level rise: Seychelles identifies locations for urgent coastal protection. [Seychelles News Agency]
Western Indian Ocean	3.5	The islands of the South West Indian Ocean faced with rising sea levels. [aivp.org]
Global	4.5	How fast is sea level rising? [royalsociety.org]

2. Sea-level rise rates and trends in WIO-Kenya

The sea level off the coast of Kenya is projected to rise, compared to year 2000 levels, as follows:
—in 2030, rise by 10 cm
—in 2050, rise by 21 cm, and
—in 2080, rise by 40 cm.



Projections for sea level rise off the coast of Kenya for different GHG emissions scenarios, relative to the year 2000. Source: file:///C:/Users/geral/Downloads/GIZ_Climate-risk-profile-Kenya_EN_final.pdf

2. Sea-level rise rates and trends in WIO-Madagascar

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Madagascar is experiencing a significant **sea level rise of 7-8 mm/year**. -
A rate a lot higher than the global average.

This accelerated rate is primarily due to the combined effect of global climate change factors and specific regional influences, e.g.:

— **Ocean Currents and Temperature**: Regional ocean currents and water temperature, influencing local sea levels. The Western Indian Ocean, where Madagascar is located, is warming faster than the Atlantic and Pacific Oceans.
— **Sterodynamics**: The combined effects of ocean warming and changes in ocean currents.
— **Vertical Land Movement**: Sinking land, leading to a faster *relative* sea level rise.
— **Regional Weather Phenomena**: El Niño-Southern Oscillation (ENSO) and tropical cyclones, influencing interannual and intra-annual variability in sea levels. Madagascar experiences, on average, three to four cyclones per year.

Source: https://share.google/images/HdJ9XdHXZIXZJOMpy

2. Sea-level rise rates and trends in WIO-Mozambique

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The sea level rise rate in Mozambique is **exceeding the global average, with some coastal regions experiencing increases of over 6 mm/year**.

This rate is nearly double the global average.

The reasons for high sea-level rise rate are similar to those of Madagascar, i.e.:

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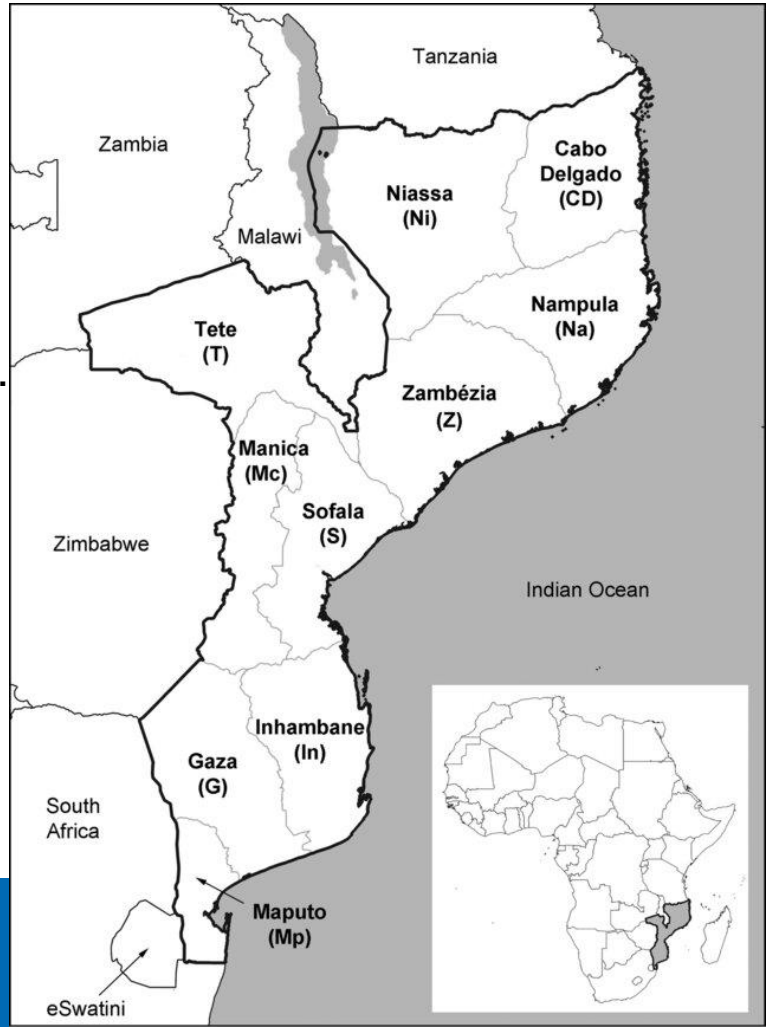
— **Ocean Currents and Temperature**: The Western Indian Ocean, where Mozambique is located, is warming faster than the Atlantic and Pacific Oceans.
— **Sterodynamics**: The combined effects of ocean warming and changes in ocean currents.
— **Vertical Land Movement**: Sinking land, leading to a faster *relative* sea level rise.
— **Regional Weather Phenomena**: El Niño-Southern Oscillation (ENSO) and tropical cyclones, influencing interannual and intra-annual variability in sea levels. With Mozambique experiencing, on average, three to four cyclones per year.



2. Sea-level rise rates and trends in WIO-Seychelles

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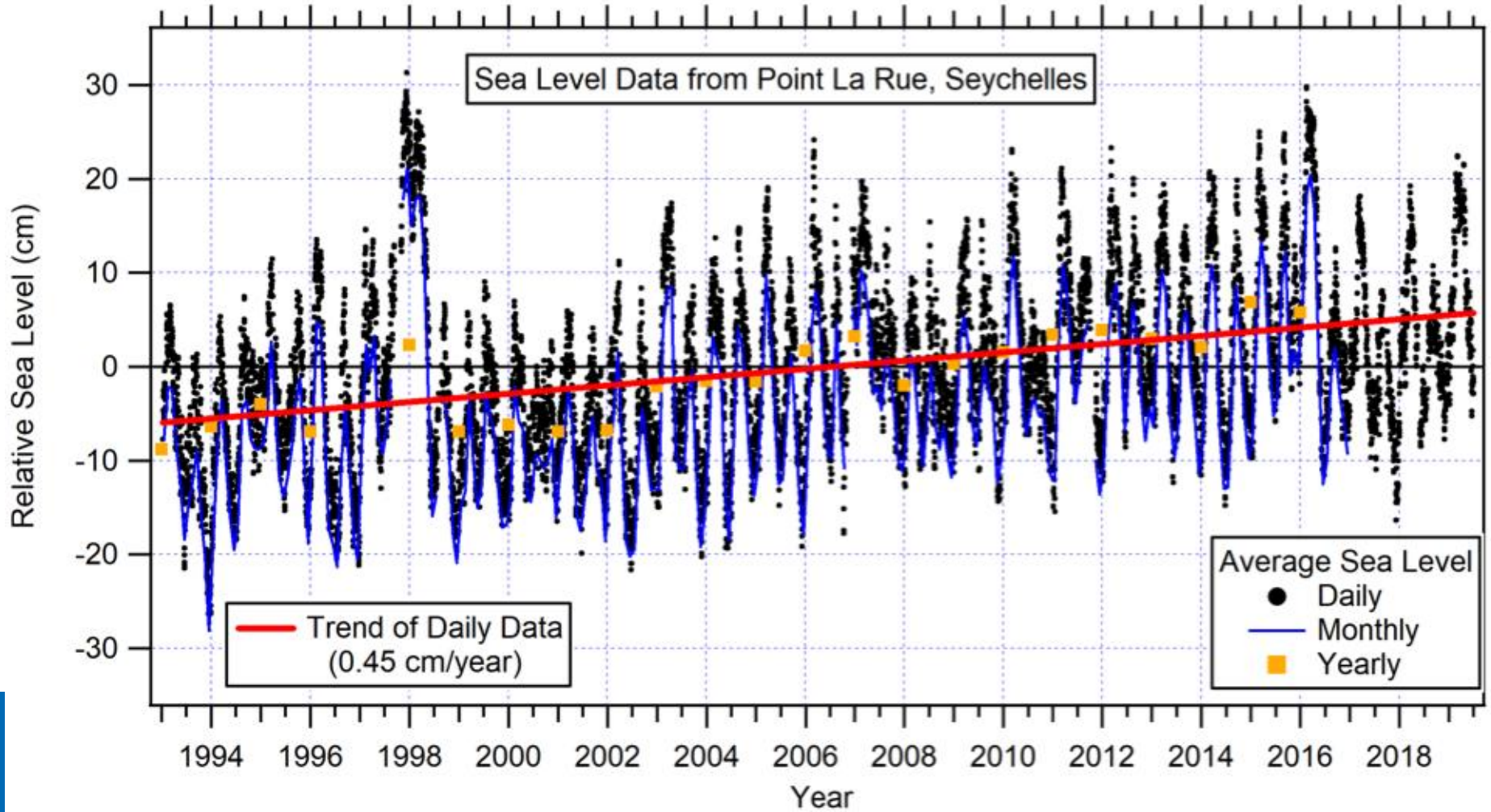
The rate of sea level rise in Seychelles is currently about 3 mm/year. – the lowest in the region.

- In 2020-2050, would rise 13-26 cm.
- In 2050, sea level rise is projected to reach 25 cm.
- In 2100, it is expected to reach 78 cm.

Relative to the historical period (1995–2014)



3. Sea-level rise impacts and mitigation/adaptation measures in WIO region

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General

Impacts

The implications of sea-level rise in the Western Indian Ocean regain are severe. Due to the combined effect of increased rates and extensive coastal and island low laying areas.

Threats include:

- Flooding of - and salt intrusion in - coastal areas.
- Flooding and destruction of infrastructure.
- Damage to crucial economic sectors like tourism and fisheries.
- Increasing the intensity of the impacts of cyclones.

Mitigation/adaptation measures

Countries in the regions are engaged in:
Mitigation through:

- Reduce emissions –energy efficiency,
- Increase carbon absorption in forestation projects.

Adaptation through:

- Implementing multi-hazard early warning systems,
- Sustainable water resource management, and ecosystem-based adaptation.

3. Sea-level rise impacts and mitigation/adaptation measures in WIO region - Kenya

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Impacts

In Kenya, the sea-level rise exacerbates existing challenges:

- Saltwater intrusion into freshwater sources, and contamination of municipal and agricultural water supplies.
- Threats to coastal ecosystems and infrastructure, harbours, roads, tourisms buildings and residence houses.

Mombasa, a major coastal city, is particularly at risk, with an estimated area of 4-6 km^2 likely to be submerged with a sea level rise of just 30 cm.

Economic implications are substantial:

- Potential losses in tourism, fisheries, shipping, and agriculture,
- Including an estimated $472.8 million loss in exported mango, cashew nut, and coconut, if 1 m sea level rise

Mitigation/adaptation measures

Kenya contributes to mitigation efforts through:

- National climate change action plans, and
- Investments in renewable energy.

Kenya is a leader in geothermal power, which helps reduce reliance on fossil fuels and thus lowers carbon emissions.

3. Sea-level rise impacts and mitigation/adaptation measures in WIO region - Kenya

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Mitigation/adaptation measures

Key adaptation measures include:

— **Infrastructure Development and Protection**: Strengthening existing infrastructure and constructing new, climate-resilient structures to withstand the impacts of sea level rise and associated extreme weather events.
— **Ecosystem Conservation and Restoration**: Protecting and restoring coastal ecosystems (mangroves, seagrass, coral reefs), that act as natural barriers against rising sea levels and storm surges.
— **Water Management Strategies**: To combat saltwater intrusion into freshwater sources, measures such as improved water harvesting techniques, desalination, and efficient irrigation systems.
— **Community-Based Adaptation and Early Warning Systems**: Engaging local communities, including refugee populations, in adaptation planning.
— **Livelihood Diversification**: Supporting coastal communities in diversifying their livelihoods away from climate-sensitive sectors, reducing their vulnerability to sea level rise impacts, promoting climate-smart agriculture and other resilient economic activities.
— **Policy and Planning Integration**: Kenya's NAP emphasizes mainstreaming climate adaptation into national and county-level development planning.
— **Research and Data Collection**: Continuous monitoring and evaluation of climate impacts, including sea level rise, to guide decision-making.

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Impacts

The impacts of sea level rise on Madagascar are severe, include:

— Damage to infrastructures, particularly roads and bridges,
— Threats to the health and sanitation sectors by impacting water supply and increasing the risk of diseases.

Infrastructures threatened by flooding, rapid sea level rise and coastal erosion include:

— The Toamasina Ambalamanasy Airport (TMM), situated at a low elevation near the ocean and rivers, is vulnerable to flash flooding and storm surges.
— Road connecting Toamasina to Antananarivo (RN2), and RN5 extending north,
— A railway line south of Toamasina, running on a narrow strip of land between the Indian Ocean and Lake Farihy Ampitabe.

Mitigation/adaptation measures

Madagascar is actively engaged in climate change:

Mitigation through:

— Reduce its emissions, and
— Increase carbon absorption, forestation.

Adaptation through:

— Implementing multi-hazard early warning systems,
— Resilient infrastructures: the port of Toamasina is undergoing expansion with protective measures like a new breakwater,
— Sustainable water resource management, and
— Ecosystem-based adaptation.

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Impacts

The impacts of sea level rise on Mozambique are severe, as most of coastal areas lay below MSL, include:

— Damage to infrastructures, particularly roads and bridges,
— Threats to the health and sanitation sectors by impacting water supply and increasing the risk of diseases.
— Increasing intensity of cyclones.

The implications include: increased frequency of flooding, coastal erosion, and salinization of soils and freshwater aquifers, which impacts municipal and agricultural water supplies and natural ecosystems.

— Mozambique Island, a UNESCO World Heritage Site, is particularly vulnerable to these threats, because lays below MSL.
— Coastal cities of Beira and Quelimane, lay below MSL, so threatened to submerge on minor Sea-level rise.

3. Sea-level rise impacts and mitigation/adaptation measures in WIO region - Mozambique

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Impacts (Cont.)

In Mozambique, the cyclones have caused the destruction of infrastructures estimated over US$290 million, in the past 5 years, including:

6,552 km of roads, over 35 bridge, 3,928 classrooms, 321 hospitals, 438,324 houses.

	Infrastrutures destoryed									
Cyclone	Bridges	Roads [km]	Hospitals / Health units	Classrooms	Houses	Electricity wires (km)	Electricity poles	Water systems	Cost of rehabilitation [Milliom 10^6 USD]	Source
Jude	20	330	41	691	88000	73	1300	43	5.2	https://en.wikipedia.org/wiki/Cyclone_Jude
Chido			118	1100	35000				124.0	https://en.wikipedia.org/wiki/Cyclone_Chido
Dikeledi	13	67	43	291	27470					https://en.wikipedia.org/wiki/Cyclone_Dikeledi
Freddy		5448	50	1500	146000		150		80.0	https://en.wikipedia.org/wiki/Cyclone_Freddy
Gombe	2	707	69	346	141854		2741		81.9	https://en.wikipedia.org/wiki/Cyclone_Gombe
	35	6552	321	3928	438324	73	4191	43	291.1	

3. Sea-level rise impacts and mitigation/adaptation mea in WIO region - Mozambique

Mitigation/adaptation measures

Key adaptation measures include:

— **Infrastructure Development and Protection**: seawalls and drainage channels were built and rehabilitated in Beira, seawall were build in Maputo Costa do Sol Beach, ports were expanded and strengthened in Nacala, Beira and Maputo.

— **Ecosystem Conservation and Restoration**: Extensive mangrove forestation, to restore ecosystem services and protect the cost against storm.

— **Water Management Strategies**: To combat saltwater intrusion into freshwater sources, measures such as improved water harvesting techniques, desalination, and efficient irrigation systems.

— **Community-Based Adaptation and Early Warning Systems**: rehabilitation of wetlands, nature based flood protective systems (dikes), improved stoves,

— **Livelihood Diversification**: including resilient agricultures,

— **Policy and Planning Integration**: Kenya's NAP emphasizes mainstreaming climate adaptation into national and county-level development planning.

3. Sea-level rise impacts and mitigation/adaptation measures in WIO region - Seychelles

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Impacts

The impacts of sea level rise on Madagascar are severe, include:
— Damage to infrastructure, particularly roads and bridges,
— Threats to giant marine turtles.

Seychelles is a low-lying archipelago, thus, highly vulnerable to flooding. It is projected that most of the islands could be underwater within 50 to 100 years.

Of particular importance: Despite consistently rising sea levels, most of Aldabra Atoll's shoreline hasn't changed since 1960 - It have shown remarkable resilience, due to the fact that the outer, ocean-facing shore, composed of solid limestone ridges, exhibits greater resistance to sea level change, compared to the inner shore with more loose sediments.

Mitigation/adaptation measures

Seychelles government has identified priority areas for coastal protection, including Au Cap, North East Point, and Beau Vallon on Mahe, and Anse La Blague on Praslin.

These efforts involve coastal infrastructure development projects, such as rock armouring to prevent sand migration.

The country is actively seeking international support and funding from various sources like the Global Environment Facility (GEF), Adaptation Fund, and Loss and Damage Fund to mitigate the effects of coastal erosion and sea level rise.

4. Concluding remarks

Sea-level is rising and in increasing rate

Due to thermal expansion of ocean water and melting of ices in the sea and on the land.

Most of the costal areas of WIO region is a low laying area and prone to cyclones

Thus, the impacts of sea-level rise include:

— Flooding of costal area,
— Damage to infrastructures,
— Threats to ecosystems and biodiversity,
— Saltwater intrusion,
— Erosion.

The SEAMARCS would contribute in MSL prediction and monitoring.

Mitigation/adaptation measures

Mitigation

— Reducing emissions,
— Fostering energy efficiency,
— Promoting renewable energy,
— Increasing carbon absorption (forestation)
— Fostering earlier warning systems.

Mitigation

— Mainstreaming climate change in planning,
— Adaptation strategies and plans,
— Implementing protective infrastructures against flooding (NbS)
— Smart livelihood activities – resilient agriculture

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