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Indian Ocean Small Island States: Indicators of Dangerous Anthropogenic Influences of Climate Change?

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1 Study Overview

This project was initiated to support the Barbados Plan of Action-2005 that recognizes the uniqueness and vulnerabilities of Small Island Developing States, or SIDS (Figure 1). A meeting was held on Mauritius earlier this year that was intended to re-focus the world's attention on SIDS. The December 2004 Indian Ocean tsunami was a tragic way of acentuating their vulnerabilities.

While there are over 50 SIDS worldwide, only four are the focus of this study: Comoros, Mauritius, Seychelles, and Maldives (Figure 2). Each of these four SIDS contains numerous islands, with the Maldives containing about 1190. Typical conditions on SIDS are shown in Figure 3.

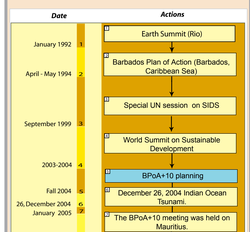

Figure 1. How this Study Came to be: To support Barbados Plan of action-2005

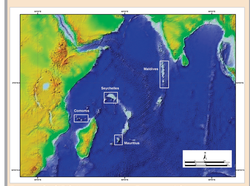

Figure 2. SIDS that are the Focus of Study

- Small Island Developing States
- Located in Indian,Pacific, and Atlantic Oceans, and seas such as Mediterranean and Caribbean (over 50 world wide)
- Typical conditions of SIDS of concern to us:
  - Materialistically poor
  - Limited modern infrastructure
  - Islanders' perceptions are that climate change is causing existing problems to worsen quickly
  - Environmental injustice: SIDS do not exert influence on climate, but are among the most vulnerable to climate change

Figure 3. What are SIDS

2 Basic SIDS Information

Each of these SIDS exhibits extraordinary natural beauty (Figure 4), particularly beautiful beaches and oceans. However, both natural and environmental hazards exist on all of the SIDS, from active volcanic and tsunami hazards to solid waste landfills and coral loss from soil erosion on the islands (Figure 5).

Figures 6 through 13 summarize different informational items regarding the SIDS. A comparison of population and size of each SIDS is made to New Orleans (Figure 6). With the exception of the Maldives, all of the SIDS have rugged mountains (Figure 7) that limit where villages and agricultural practices can exist. The Maldives, in contrast are very flat and low-lying.

These SIDS are very poor monetarily (Figure 8), and rely on tourism for much of their GDP (Figures 9 and 10). On the Maldives the tourist industry has grown so much that typically more tourists are present than islanders (Figure 11 and Figure 12). These countries all rely on imported oil as their major source of energy for electricity generation, making these countries very vulnerable to price spikes (Figure 13).

Figure 4. Representative Scenes from SIDS

Figure 5. Hazards and Environmental Issues

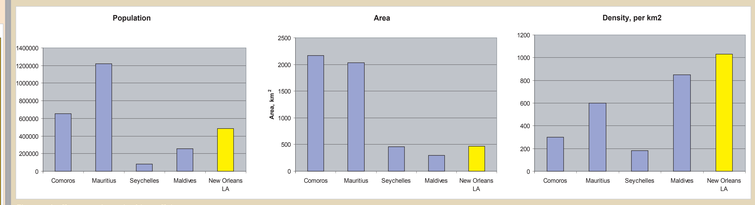

Figure 6. Comparison to New Orleans

Figure 7. Maximum elevations on each SIDS

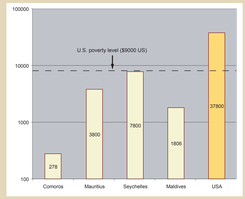

Figure 8. GDP per capita by SIDS (US $)

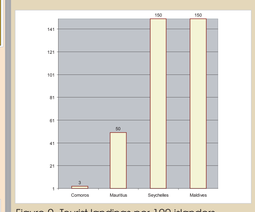

Figure 9. Tourist landings per 100 islanders

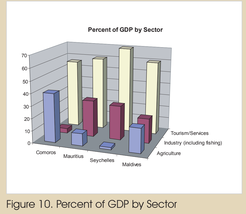

Figure 10. Percent of GDP by Sector

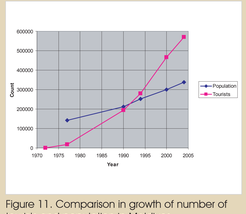

Figure 11. Comparison in growth of number of tourists and population in Maldives

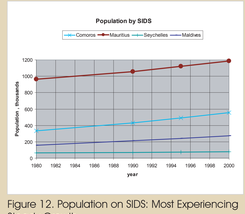

Figure 12. Population on SIDS: Most Experiencing Steady Growth

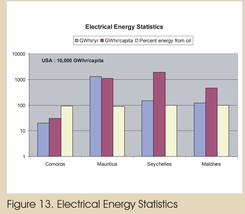

Figure 13. Electrical Energy Statistics

3 Climatic Influences

Regardless of how aggressively society responds to control greenhouse gas emissions, global sea level will continue to rise at least over the next three centuries (Figure 14). This is bad news for these SIDS, as the option of retreating from sea level rise is not viable on at least one of the SIDS (Maldives), and may be too expensive an option on the remaining SIDS.

While it appears the relative or local sea level is rising in the Maldives and Seychelles, data appear to show that on Mauritius, the relative sea level may be decreasing (Figure 15). Even so, as sea level rise begins to accelerate, even relative sea level rise will occur on Mauritius, too (Figure 16). As Figures 17 and 18 show, by the year 2100, most of the Maldives will possibly be submerged, even if only seasonally, or during high tidal events. The December 2004 Tsunami submerged many of the islands temporarily (Figure 19).

Figure 20 shows a range of predicted global temperature increases over the next few centuries. They show that temperatures are going to increase regardless of the atmospheric greenhouse gas concentrations. Since these SIDS all have dry seasons each year (Figure 21), this could exacerbate dry or drought conditions even during normal precipitation years.

Tropical cyclones are present in this part of the world (Figure 22). Mauritius and Comoros are especially vulnerable.

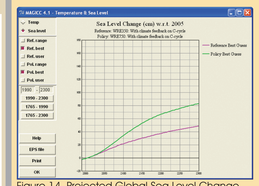

Figure 14. Projected Global Sea Level Change (cm) w.r.t. 2005 Over Next 3 Centuries

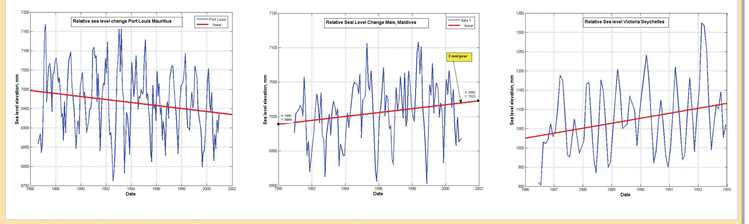

Figure 15. Historical Relative Sea Level Change: Mauritius, Maldives, and Seychelles

Island	Estimated 20th Century RSL change	Predicted RSL change During 21st Century (mean case)
GLOBAL	+180 mm	+360 mm (±100%)
Mauritius	-500 mm to +100 mm	-150 mm to +460 mm
Seychelles	+300 mm/yr	+300 mm to +800 mm
Maldives	+300 mm/yr	+300 mm to +800 mm
Comoros	+300 mm	+300 mm to +800 mm

Present global rate of sea level rise : 1.8 mm/yr

Figure 16. Comparisons of Past and Projected Ralative Sea Level (RSL) the SIDS

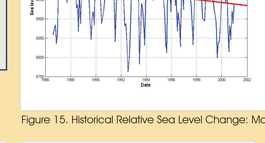

Figure 17. Vertical Distribution of Land Above MSL in Maldives: Present

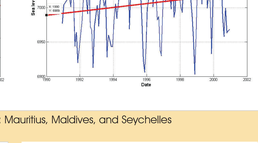

Figure 18. Vertical Distribution of Land Above MSL in Maldives: Now and Year 2100

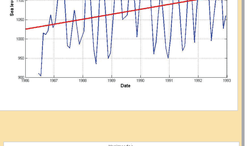

Figure 19. Tidal Levels-Selected Locations on Maldives December 2004, with Tsunami Signal Shown

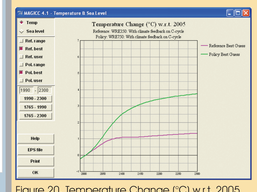

Figure 20. Temperature Change (°C) w.r.t. 2005

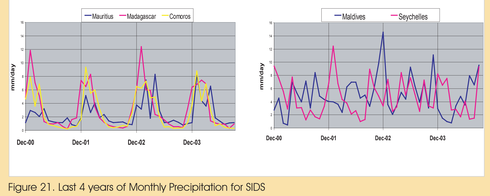

Figure 21. Last 4 years of Monthly Precipitation for SIDS

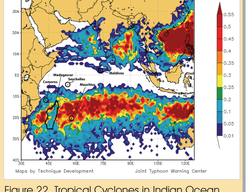

Figure 22. Tropical Cyclones in Indian Ocean

4 Example Vulnerabilities

Figures 23-28 illustrate vulnerability to the availability of water resources caused by a number of factors, including climate related (warming, increased evapotranspiration, sea level rise, and population growth). An index of freshwater availability has been created and shown in Figure 24. This index is the difference in precipitation and evapotranspiration, normalized to population. Thus as the climate warms and population grows this index gets smaller. The purple colored values are deemed to be in the critical range by the UNEP.

Figure 28 illustrates the vulnerability of two major airports on the SIDS to sea level rise and coastal waves. Both the major airports on the Maldives and Seychelles are within 1 to 3 m above msl, and both were damaged by the December 2004 tsunami. When these airports are inoperable, the ability to bring important supplies to these islands rapidly, as well as tourists, is greatly impaired.

Figure 23. Vulnerability Issues Example: Water Resources

SIDS	(P-E)/Population		
	Year 1980	Present	Year 2050
Comoros	2,100	1,300	380
Mauritius	1,700	1,400	460
Seychelles	6,800	5400	1800
Maldives	130	75	30
USA	-	4300	-

Figure 24. Estimated Changes freshwater availability by 2050 (gal/(cap-day))

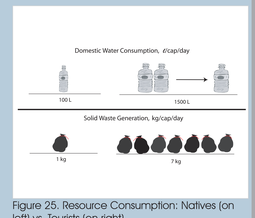

Figure 25. Resource Consumption: Natives (on left) vs. Tourists (on right)

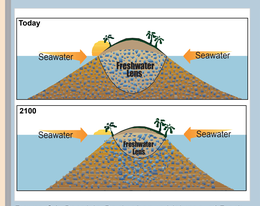

Figure 26. Possible Reduction in Volume of Freshwater Lens on Maldives by 2100

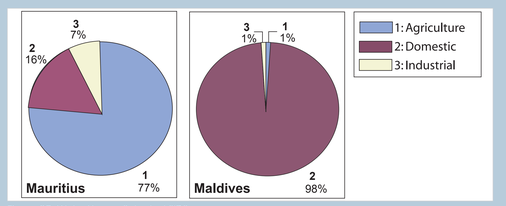

Figure 27. Water Use on Selected SIDS

Figure 28. Vulnerability of Airports to Sea Level Rise

5 Adaptation

(Figures 29-31) A picture has emerged for these islands as being "forgotten", since they are so remotely located. The 2004 Indian Ocean tsunami temporarily highlighted their vulnerability, but will the world provide the outside assistance these islands need to fight growing concerns of climate effects coupled with poverty, a growing population, and dwindling natural resources? In spite of the obstacles, there are success stories to build upon (Figure 31). The most important of these is the resiliency of the people who live with pending natural disasters as well as long term survival issues.

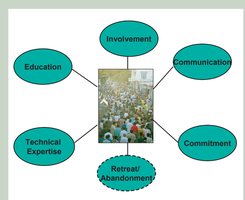

Figure 29. How Society as a Whole Could Adapt

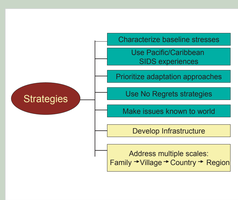

Figure 30. Potential Adaptation Strategies

Seychelles
- Waste management and sanitary sewage treatment on the increase.
- Desalination facilities constructed; service for up to 45,000 people.

Maldives
- Desalination beginning to augment natural supplies
- New island under construction with airport and city: Hulhumale
- Extensive infrastructure development initiated

Overall
- Resiliency of people following Tsunami

Figure 31. Success Stories