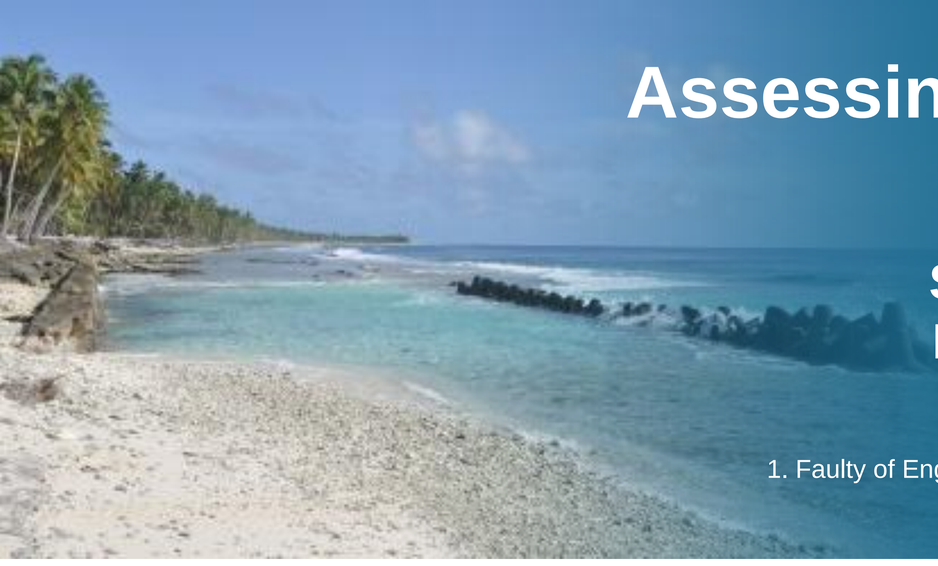

Assessing adaptation options for small island states: Case study of the Maldives

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Introduction and Setting

The Maldives comprise 1,192 low-lying coral atoll islands in the Indian Ocean spread over 298 km² (Figure 1), with land elevations typically within 1.5 m of mean sea level. 198 of the islands are inhabited, with one third of the nation's population of 320,00 living in the capital Malé, which has a population density of 50,000 people / km². The islands are dependent on tourism and fisheries. With global mean sea levels rising, there are concerns regarding how the islands will adapt and cope with extreme water levels.

This on-going research is part of the EU FP7 funded project, IMPACT2C (Quantifying projected impacts under 2°C of warming), which aims to evaluate the impacts of sea-level rise, equivalent to a 2°C rise in temperature with respect to pre-industrial. To determine this, new data is being collected including island elevation and population changes. Presently the drivers and pressures of coastal change, together with adaptation options are being assessed.

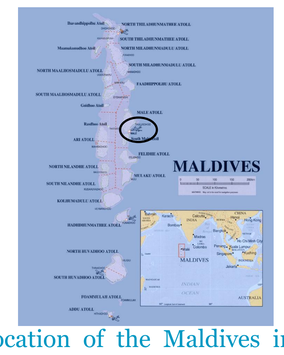


Figure 1. Location of the Maldives in the Indian Ocean, and the nation's capital, Malé.
(http://www.asiatravel.com/maldives/maldives_gifs/maldives_map.gif)

Pressures on the Coast

These are divided into two categories:

PHYSICAL

Global mean sea level projections suggest rises in excess of 1 m are possible during the 21st century, and specific downscaled studies have been produced for the Maldives[1]. Tide gauge records are not deemed reliable, so cannot offer observational support[2]. Flooding already occurs due to marine sources, as well as intense rainfall events. Coastal erosion occurs along 60%-70% of the nation's coastline (Figure 2).

Figure 2. Evidence of coastal erosion.
(Ali Shareef, 2007)

HUMAN RELATED / INDUCED

The country has an annual population growth rate of 1.7%[3], with many people migrating to the capital city, where population density is high (Figure 3). Many of the islands are artificially covered, so adequate drainage is essential. Developments on other islands include land reclamation and harbour construction, which has disturbed sediment movement resulting in greater erosion. Sand mining is illegal, but in some places still occurs. Some islands do not have any protection to minimise erosion and flooding.

Figure 3. The densely populated capital of Malé, Maldives.
(http://commons.wikimedia.org/wiki/File:Male_maldives.jpg)

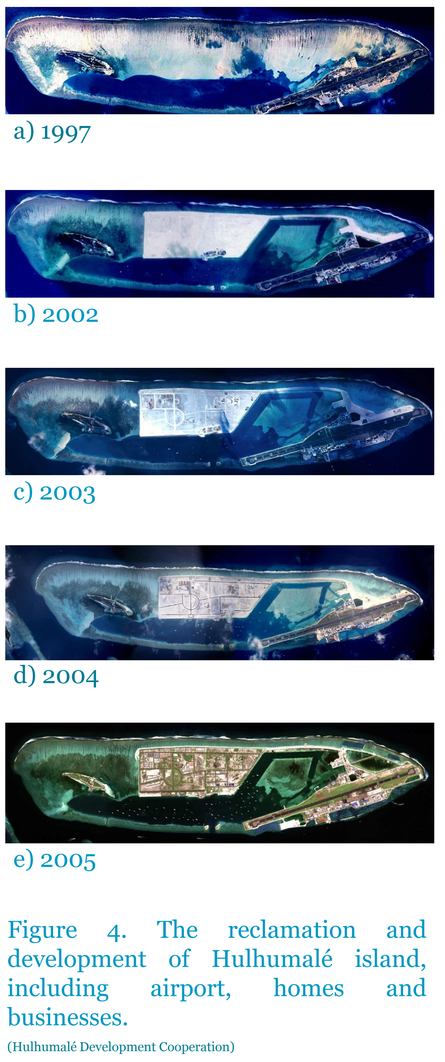
The Maldivians are responding to these pressures today through land reclamation, coastal protection and management.

RESPONSE TO COASTAL CHANGE: A CASE STUDY OF HULHUMALÉ.

With high population density in the capital city, the Maldivian government commissioned the creation of a new island, Hulhumalé, 1 km north of the capital. Constructed on a reef since the late 1990s the island serves to improve the quality of life, revitalise the economy , attract a broad base of investments and house a new airport (Figure 4). The 200 hectares of reclaimed land (roughly 7.7 km by 1.8 km) cost US$32 million[4].

One reason the reef was chosen was its proximity to the capital, and this was proved a successful reason when 5,180 applicants were made to for just 100 one-bed apartments[5]. Population increased from 5,000 (2006) to 20,000 (2012).

The island is constructed to 2 m above mean sea level. As the island is totally artificial, sheet piling and other defences help protect infrastructure from extreme wave events.



a) 1997
b) 2002
c) 2003
d) 2004
e) 2005

Figure 4. The reclamation and development of Hulhumalé island, including airport, homes and businesses.
(Hulhumalé Development Cooperation)

Adaptation and Long-Term Prospects

Figure 5. Beach, revetment and vegetation, acting as protection in Hulhumalé
(Land & Marine Environment Resource Group Ltd, 2010)

Coastal adaptation choices can be defined as 'protect', 'accommodate' or 'retreat'. Today the island's engineers employ soft (e.g. nourishment) and hard engineering methods (e.g. bulkheads, breakwaters, revetments, groynes, drainage, pumping), or a mix of both methods. Land reclamation is popular and this can be designed with marine hazards including sea-level rise in mind. Hence, Maldivian engineers have raised Hulhumalé to 2 m above mean sea level, and are elevating other reclaimed land to 0.2 m to 0.3 m higher than existing land. This raises the issue of costs and availability of suitable sand to allow this reclamation and land raising to continue, as well as its compatibility with tourism and fisheries. At the other extreme, retreat in built-up areas is an option of last resort, and at a national scale this could imply moving to another country.

Conclusions

Many scientists paint bleak pictures of how small island nations will cope with sea-level rise and changes to extreme events. Whilst this is a major issue, the Maldivians are working towards adaptation to different drivers and causes of coastal change today as they are already under great pressure. Far from their nation disappearing, the Maldivians are reclaiming land. However, this does not mean they are not without future problems. Whilst one could suggest islanders could build their way out of the problem, they have a limited resource base and financial constraints. Further research needs to envisage the full range and causes of long-term change, determine exactly what areas are at risk and review potential methods to adapt to long-term coastal change.

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http://www.impact2c.eu/

Header photograph © Ahmed Shan, EPA, Maldives

1. RIMES (2011) Development of high-resolution regional climate model for the Maldives. Report No. 3: Downscaling process, Results and Uncertainties.

2. Woodworth, P.L. (2005). Have there been large recent sea level changes in the Maldive Islands? Global and Planetary Change, 29, 1-18.

3. Ministry of Planning and National Development (2006). Statistical Yearbook of Maldives. http://www.planning.gov.mv/publications/yrb2006/intro.htm.

4. GADL International Ltd (2011) Feasibility study for construction of a bridge between Male' and Hulhumale Final report, REP-217093-01. Ove Arup and Partners, Hong Kong.

5. Human Rights Commission of the Maldives (2008) Rapid assessment of the housing situation in the Maldives. http://displacementsolutions.org/files/documents/HousingAssesmentEng.pdf.