NATIONAL ADAPTATION PLAN OF ACTION

Republic of Maldives

DRAFT FOR COMMENTS

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Ministry of Environment, Energy and Water

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1 Introduction

"As for my own country, the Maldives, a mean sea level rise of 2 metres would suffice to virtually submerge the entire country of 1,190 small islands, most of which barely rise over 2 metres above mean sea level. That would be the death of a nation. With a mere I metre rise also, a storm surge would be catastrophic, and possibly fatal to the nation."
President Maumoon Abdul Gayyoom, UNGA, New York, 1987

This is the first National Adaptation Programme of Action (NAPA) for the Maldives relating to the adaptation to adverse effects of climate change. Maldives is among the most vulnerable to climate change and non-action is not an option. Assessing the magnitude of climate hazards to Maldives has already begun. Although it is not possible to accurately predict climate change and its adverse effects at the local level, the first Climate Risk Profile (MEEW 2006) and the Disaster Risk Profile (UNDP 2006) justifies the need to take preventive and adaptive action now. Thus NAPA identifies urgent and immediate actions for climate change adaptation.

The preparation of NAPA began in October 2004 with assistance and support from the Global Environment Facility (GEF) and United Nations Development Programme (UNDP). The preparation process was halted by the South Asian tsunami of December 2004, worst natural disaster to hit the country. Efforts to prepare the NAPA recommenced in December 2005.

NAPA process was based on the principles of broad stakeholder engagement, partnership building among focal agencies and ownership by the people of Maldives especially the atoll population. A multidisciplinary National Climate Change Technical Team was established as a first step to foster stakeholder engagement. Community consultations and awareness building activities were held for representatives from seven atolls of the Maldives and the capital Male'. Targeted awareness raising and activity-based learning was conducted for five secondary schools. Existing climate-related data for the Maldives was analysed with international expertise culminating in the first Climate Risk Profile for the Maldives. National experts produced vulnerability and adaptation related technical papers for priority sectors identified by the NAPA Working Group. Extensive stakeholder consultations were undertaken based on a prior agreed methodology to identify vulnerabilities and adaptation activities and prioritize these activities.

The NAPA is intended to be concise and brief and contains eight chapters. Following this introduction Chapter Two presents the goals and describes the National Adaptation Policy Framework. Chapter Three describes the country characteristics relevant to climate change adaptation. Chapter Four depicts the global and local climate hazards and risks. Chapter Five analyses vulnerabilities and the biophysical impacts of climate change. Chapter Six lists the adaptation needs and options identified through stakeholder consultations and present the set of locally-driven criteria that was used to select priority activities. NAPA concludes with Chapter Seven that presents key priorities and project profiles for adaptation to climate change in the Maldives.

2 Adaptation Policy Framework

This chapter presents the national adaptation goal and overall adaptation policy framework adopted for Maldives.

2.1 NAPA Goal

The goal of the NAPA is to present a coherent framework to climate change adaptation that enhances the resilience of the natural, human, and social systems and ensures their sustainability in the face of predicted climate hazards.

2.2 NAPA and National Development

Synergy with national development goals is one of the objectives of the NAPA and in the selection and prioritization of adaptation activities NAPA uses development goals stated in Vision 2020, Seventh National Development Plan (7NDP) and the Millennium Development Goals (MDGs).

The Maldives Vision 2020 provides the direction for future sustainable development of the Maldives and is the basis for national policies. Vision 2020 was outlined by His Excellency President Maumoon Abdul Gayoom in his Independence Day address to the nation on 26th July 1999. NAPA will contribute to the achievement of the Vision 2020 particularly through providing a planned approach to combat the climate change threat.

The 7NDP lays down the development policies and strategies of the Government for the period 2006 to 2010. All the policies and strategies in the 7NDP are targeted at improving the quality of life for the people living in the Maldives, particularly the poor, the disadvantaged and the vulnerable groups. A key principle of the 7NDP is that the development policies should not compromise the ability of future generations to achieve non-declining per capita well being. The proposed way forward is optimal use of the available natural resources and the protection of critical natural capital such as coral reefs and fish breeding grounds.

The specific goals of the 7NDP are:

- Eliminate extreme poverty, increase equity and promote gender equality
- A stronger diversified economy
- Improved access and expanded opportunity
- Better, effective and affordable education and health care
- Stronger families and communities
- Protecting the environment and making people and property safer
- Promote justice, human rights and good governance

At the September 2000 United Nations Millennium Summit, nations of the world committed to achieve the Millennium Development Goals (MDGs). The goals and targets are; (1) Eradicate extreme poverty and hunger; (2) Achieve universal primary education; (3) Promote gender equality and empower women; (4) Reduce child mortality; (5) Improve maternal health; (6) Combat HIV/AIDS malaria and other diseases; (7) Ensure environmental sustainability and; (8) Develop a global partnership for development.

2.3 The Framework

Figure 1 provides a simplified picture of the policy framework for adaptation to climate change in the Maldives. It attempts to present the interactions among climate hazards and risks; exposure and vulnerability of the systems; the desired adaptation outcomes; and adaptation strategies.

It is acknowledged that a complete adaptation policy framework would be much more complex than is depicted here. Because of the limitations in human knowledge on complex systems such as society and ecosystems it is not possible to have a perfect adaptation policy framework. However, there is plurality of values in the framework presented here as it attempts to bring climate change into the national development agenda and identify key interrelationships.

Societies have always lived with risks and shocks. Sustainable societies are those that have devised mechanisms to help reduce or mitigate risk and cope with the effects of shock. The focus of the adaptation framework is on the climate change related risks, hazards and shocks and the **first** component of the framework is the climate change related hazards. Other types of risks such as growth collapse, balance of payments, financial crisis and technology or trade induced shocks are also shown which may impact the vulnerable systems and hence adaptation outcomes.

According to the IPCC vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC Ref). Adaptation refers to "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Ref). For the Maldives NAPA, adaptation is a multi-dimensional goal that aims to increase resilience of the vulnerable systems against climate hazards and risks to achieve sustainable development.

The **second** component of the adaptation policy framework is vulnerable systems. The vulnerable systems are characterized by high vulnerability through exposure to different specific climate hazards, as well as being strategically important at national level. For the purposes of the Maldives NAPA 'system' comprises of natural, human and produced systems.

Natural systems are the natural and environmental resources broken down into; (i) renewable natural resources; (ii) non-renewable resources; (iii) the ecosystems and services which support and maintain the quality of land, air and water; (iv) the maintenance of a vast genetic library, referred to as biological diversity and (v) land the space in which human activities take place (Saeed 2005). Human system refers to human lives, human health and knowledge, skills and competences of individuals (Saeed 2005). Produced systems are the human-made material resources that can be used to produce a flow of future income which includes the basic infrastructure (transport, shelter, buildings, water, energy and communications), and production equipment (machinery and tools) (Saeed 2005).

The adaptation policy framework is capable of providing a variety of outputs, depending on how it is applied and the **third** component depicted on the right hand side of the adaptation framework are the sustainable development outcomes. Sustainable development is not an easily defined concept and it is almost impossible to define how much of it is adequate. The essential elements of sustainable development can only be understood relative to place, time, local context, culture and value systems. The goals of the Seventh National Development Plan of the Maldives (2006-2010) are taken as a good basis for understanding the development outcomes relative to present time and local context.

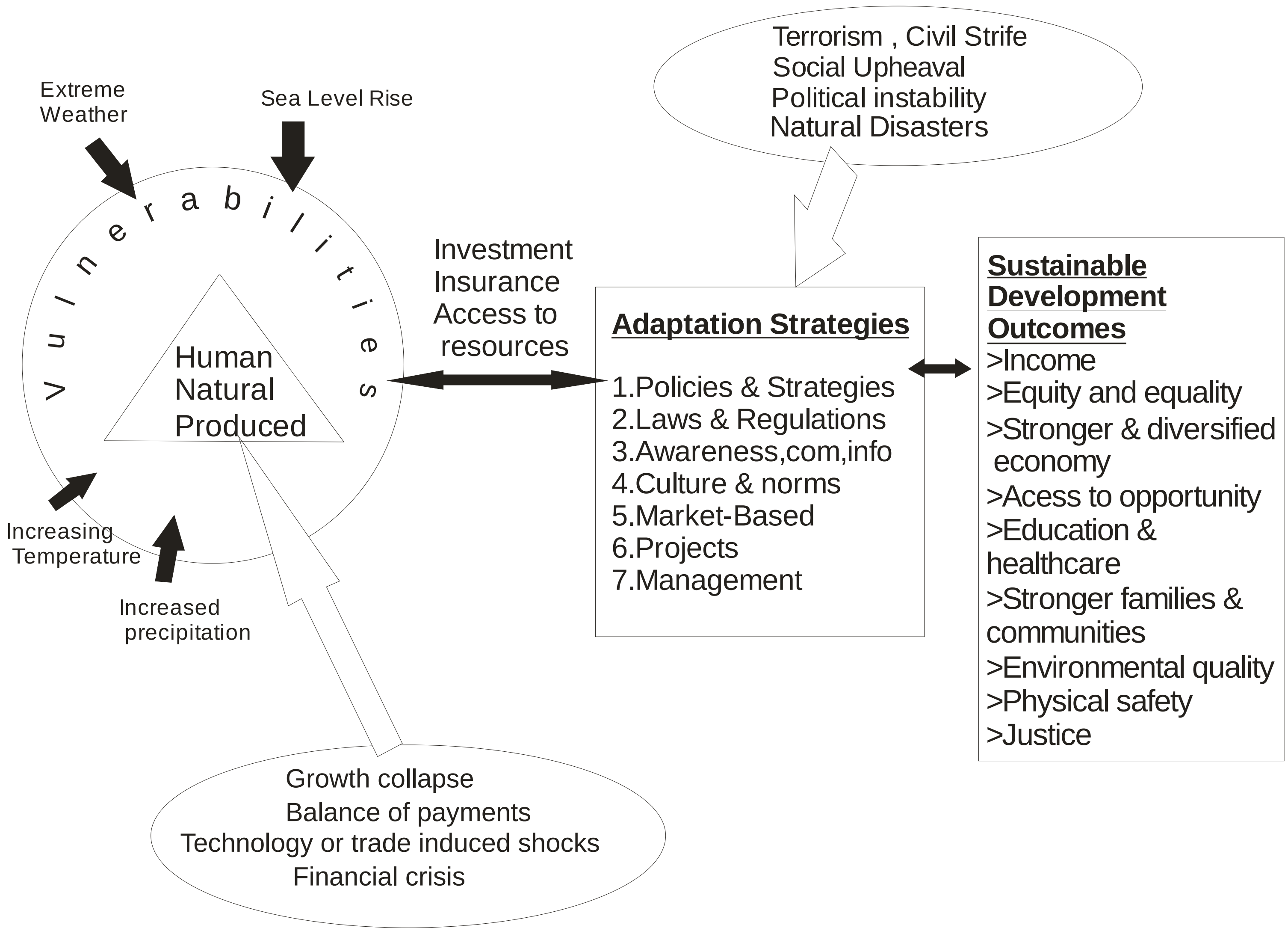

Figure 1 Conceptual framework of NAPA illustrating the complex relationship between sustainability and adaptation to climate change

A society's ability to enhance resilience of the vulnerable systems through time depends on choices made by individuals, firms, communities and governments on how to use and transform the opportunities they have in terms of the systems and how they mitigate or reduce the risk of climate change to the systems. The **fourth component** of the adaptation policy framework is the structures and processes that interact with the systems to influence adaptation. In order to enhance the resilience of the systems and produce development outcomes individuals often create horizontal and vertical relationships and undertake repeated transactions in the realms of the economy, the polity and the community. Signals are picked up on what are the needs of the society and potential uses of the systems. Then the relative values of the all the possible uses of resources for all possible users are weighed up. This requires the generation of information, fostering learning and knowledge.

In order to achieve the development outcomes for present and the future, there has to be a process for maintenance, replacement and renewal of the systems. This process needs to be equal to or exceed the processes of depreciation, degradation and loss in the system. Replacement would not automatically take place and deliberate investment decisions are needed. On the other hand, climate change poses dangers or irreversible losses to critical systems. Hence, a policy of prudent insurance is needed as well.

In the NAPA the structures and processes are termed adaptation strategies and the signals on what are the needs of the society and the relative values of these strategies were obtained through carefully planned stakeholder consultations and national workshops.

The **final component** of the adaptation framework is the barriers to implementation. There are several socio-political shocks and stresses that could affect speedy implementation of national adaptation activities such as political instability, social upheaval and terrorism. Such shocks have a tendency to alter and reshape national priorities over the short and medium-term. Natural shocks such as tsunamis, storms and epidemics also reshape priorities in the short-term.

Given that national priorities do not change then the key barrier to implementation of adaptation strategies are weak institutions. Although the strategies are clear most of the organizations lack strategic direction and human, financial and technical resources to implement strategies.

Lack of knowledge, education and awareness among the public on the science and impacts of climate change tends to reduce the demand the public place on the government and private sector to supply adaptation and mitigation to climate change.

3 Country Characteristics

This chapter provides the country profile of Maldives and the background information that supports the vulnerabilities highlighted in Chapter Five.

3.1 Geography and Coral Reef Geology

Maldives is a double-chain of coral atolls made up of 2041 distinct coral reefs forming 25 natural atolls and is located in a north to south direction on the Laccadives-Chagos submarine ridge in the Indian Ocean. Maldives stretches along 860 km and is 80-120km wide (Figure 2).

Figure 2 Location of Maldives

Diagram of a Coral Island structure (Height, water table, seasonal sand migration, vegetation etc..)
Photograph of low lying coral Island
Satellite Image of a part of Coral reefs

The coral reef system of Maldives comprises of 16 complex atolls, five oceanic *faros* with ring-shaped reefs exposed to the open ocean and four oceanic platform reefs which are exposed to the open ocean and lacking deep lagoons (Naseer 2006). Figure 3 shows a diagrammatic outline of these major coral reef structures. The depth of water within the atolls varies between 30m and 80m while that outside the atolls is 100s of metres within the Maldives Inner Sea.

Figure 3 Diagrammatic outline of major coral reef structures
(Source: (Naseer 2006)

Out of the 2041 distinct coral reefs that make up Maldives, about 529 reefs are found on the rims of the 16 complex atolls, five forms the rims of the five ocean *faros* and four are the oceanic platform reefs. The rest are found as patch reefs within the lagoons of the complex atolls. The total surface area of these major reef structures including the atoll lagoon is 21,372.72 km^2 (Naseer 2006).

Table 1 Reef statistics for Maldives
(Source: (Naseer 2006)). (combined with map on major reef structures)

Map of Major coral reef structures (modified from Naseer) with bathymetry shading combined with Table 3 on reef stats.

Only 20% of the total surface area of the atolls is found to be reef which is approximately 4,500km^2 (Table 1). The largest atoll in Maldives is *Thiladhunmathi* Atoll with a total surface area of 3,788 km^2. *Huvadhoo* Atoll is the second largest with a total surface area of 3,278 km^2. *Thiladhunmathi* Atoll has the largest reef area (approximately 500 km^2) while *Ari* Atoll has the second largest with 489 km^2 approximately.

3.2 Land and Beach

Maldives is the sixth smallest sovereign state in terms of land with an estimated 235 km^2 of land divided over 1190 islands. This figure includes 11-13 km^2 of beach and 9-11 km^2 of reclaimed land. Land area is about 1% of the total reef area. The coastline of Maldives is estimated to be 1,900 – 2,300 km long (Shaig 2006).

Figure 4 Convert table 3 (land size and utilisations) to a map.
(Source: (Shaig 2006))

Table 3: Land utilisation based on island size (Adapted from Shaig (2006)) [To be converted to map]

Island Size Range	Total No. of Islands	Land Area (sqkm)	No. of Utilised islands	Land Area of utilised islands	% of utilised islands	% of total area utilised
1-25ha	949	56.53	177	18.75	18.7%	33.2%
25-50ha	124	44.69	84	30.97	67.7%	69.3%
50-100ha	66	45.15	55	38.31	83.3%	84.9%
100-250ha	33	47.67	32	47.45	97.0%	99.5%
250-500ha	7	20.35	7	20.35	100.0%	100.0%
500+ha	3	16.40	3	16.40	100.0%	100.0%

Out of the total 1190 islands, 375 islands are being currently utilized. These islands represent 74% of the total land area. (Shaig 2006). Figure 4 shows land utilization based on island size, 90% of islands with area greater than 50ha are currently in use. Even though the number of unutilized islands is high these are islands with area less than 50ha. **Table 2** shows the 10 largest inhabited and uninhabited islands.

Table 2 The 10 largest inhabited and uninhabited islands in Maldives
(Source: (Shaig 2006))

	INHABITED		UNINHABITED	
	Atoll/Island	**Area (km^2)**	**Atoll/Island**	**Area (km^2)**
1	L.Gan	6.1250	S.Gan	2.8917
2	S.HIthadhoo	5.2570	GDh.Gan	2.5065
3	Gn.Fuvahmulah	5.0140	GDh.Kaadedhdhoo	1.8747
4	L.Isdhoo	3.7305	Sh.Madidhoo	1.0692
5	HDh.Hanimaadhoo	3.0366	L.Kadhdhoo	1.0332
6	K.Kaashidhoo	2.8071	Th.Kalhufahalafushi	1.0251
7	HA.Filladhoo	2.7000	HA.Maafahi	1.0152
8	HA.Baarah	2.6757	GDh.Maavaarulu	0.9819
9	N.Kedhikolhudhoo	2.1501	HDh.Keylakunu	0.9054
10	HDh.Nolhivaramu	2.0961	Sh.Farukolhu	0.8775

Table 3 Islands with major land reclamation
(Source:(Shaig 2006))

Island	Atoll	Area Reclaimed (ha)[1]	% of island reclaimed	Rationale
Hulumale'	Male'	189	100%	Population Pressure
Male'	Male'	82	41%	Population Pressure
Maamigili	A. Dh	80	51%	Economic and infrastructure
Hulhule	Male'	76	58%	Infrastructure
Thinadhoo	G Dh	66	60%	Population Pressure
Hithadhoo	S	53	10%	Population Pressure
Thilafushi	Male'	49	100%	Infrastructure
Naifaru	Lh	37	68%	Population Pressure
Thulhaadhoo	Baa	14	66%	Population Pressure
Hinnavaru	Lh	12	54%	Population Pressure

Over 150 islands are reported to have undertaken land reclamation. Table 3 provides some of the major land reclamation projects in the last 30 years. All the major reclamation (except A.Dh.Maamigili) in inhabited islands is for alleviation of population pressure on land. Hulhumale’ (refer to Figure 2) is a mass of land of 189 ha developed entirely by land reclamation with the intention to reduce population pressure on Male’. Islands such as H.Dh.Kulhudhuffushi and A.Dh.Maamigili have undertaken land reclamation for development of port and airport respectively. Reclamation in resorts for economic benefits has become common in recent years resorts.

[1] Estimated values derived from comparing 1969 and 2001-2006 satellite and aerial photos.

3.3 Climate

Maldives has a tropical climate and the weather is driven by two monsoons. The south-west monsoon from May to November is the wet monsoon and the north-east monsoon January to March is the dry monsoon.

Temperature variations during the two monsoons are minimal. Daily temperature varies between 31°C (daytime) and 23°C (night). The mean maximum temperature is 30.4°C and the mean minimum temperature is 25.7°C (Figure 5). The highest temperature recorded in the Maldives is 36.8°C on 19 May 1991 and the lowest is 17.2°C on 11 April 1978 (Meteorology 2006). Humidity ranges from 73 to 85 per cent (MEC 2004; Meteorology 2006).

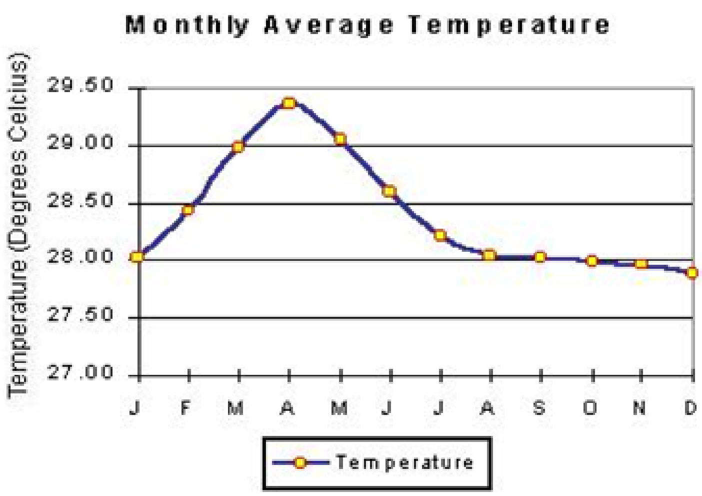

Figure 5 Monthly average temperature
(Source: (Meteorology 2006))

Average monthly SST ranges from 28°C to 29°C, rarely increasing above 30°C. Mean monthly SST is lowest in December and January reaching its highest in April and May. During May 1998 mean monthly SST was 1.1°C above the highest mean monthly SST (30.3°C) expected in any 20 year period (Edwards A.J., Clark S. et al. 2001).

The annual average rainfall for Maldives is 2,124.2mm (Ahmed 2006). Southern atolls on average receive 2,277.8mm of rainfall annually while northern atolls receive 1,786.4mm.

Lowest annual rainfall recorded in the last 30 years is 1346.5mm in 2002 at Hanimaadhoo and the highest is 3185.7mm in 1978 at Gan. The highest rainfall recorded within 24 hours to date is 219.8mm on 9 July 2002 at Kaadedhdhoo (Meteorology 2006).

3.4 Water

The hydrogeology of the country is that of typical coral islands and freshwater is a very scarce resource. Surface freshwater is lacking throughout the archipelago with the exception of a few swampy areas. The freshwater aquifer lying beneath the islands is a shallow lens, 1m to 1.5m below the surface and no more than a few meters thick, formed by the percolation of rainwater through the porous sand and coral. Thickness of the aquifer is determined by net rainfall recharge, size of the islands and permeability of the soil column, all of which vary from island to island.

Traditionally people depended on shallow groundwater wells to get access to the freshwater lens for drinking water. However, 90 per cent of the atoll households used rainwater as the principal source of drinking water in 2004. The total capacity for rainwater storage then varied across the atolls between 2,147,500 litres in *Gaafu Dhaalu* atoll and 217,000 litres in *Vaavu* atoll (MEC 2004). The present capacity of rainwater storage is expected to be much higher with the free distribution of thousands of HDPE rainwater tanks following the tsunami of 2004. In Male', 100 per cent of the population has access to piped desalinated water. XX m3 of water is produced daily in Male' consuming about xxx m3 of diesel. Following the tsunami XX no. of islands now have desalination plants which are being operated daily or on emergency basis in some of those islands.

3.5 Soil

Soil is generally made up of medium-sized calcium carbonate sand grains formed from the weathering of the calcareous coral formations (FAO 2005). A typical soil profile is made up of a thin sandy layer at the top, a layer of organic matter 15-40cm deep, layer of hardpan 30-50cm deep before reaching unweathered bedrock (MFAMR 2006). The soil is absent of silt and clay reducing the adsorption capacity only to the organic matter layer while the medium sized calcium carbonate grains result in high infiltration rates (FAO 2005; MFAMR 2006). The pH ranges from 8 to 8.8 with an average of 8.5 due to high calcium content of the soil causing deficiencies in micro-nutrients. In addition, the soil lacks nitrogen and potassium due to excessive leaching making the fertility low (MFAMR 2006).

3.6 Biodiversity

Terrestrial flora and fauna in Maldives is typical of small islands. So far 583 species of vascular plants have been recorded out of which 323 are cultivated species and 260 are native and naturalized species (Adams 1984). Nearly 200 species of birds including seabirds, shorebirds and land birds have been recorded. Five subspecies have been identified as endemic to Maldives. There are130 species of insects, two species of native fruit bats, geckoes, garden lizards each, one species of frog and toad each, 11 species of mushrooms and two species of snakes have been documented. The two subspecies of the bats, namely, *Pteropus gigantus ariel* and *Pteropus hypomelanus maris* are the only native mammals endemic to Maldives (MHAHE 2002; MEC 2004).

Marine biodiversity of Maldives is rich and diverse. Fish and coral are the most widely studied where 1090 species of fish, 36 species of sponges, 180 species of stony corals and 250 species of hermatypic corals have been identified. In addition, 9 species of whales, 15-20 species of sharks and seven species of dolphins and five species of turtles have also been observed. Altogether 285 species of algae, five species of seagrass, 400 species of mollusks, 350 species of crustaceans and 80 species of echinoderms have been documented (MHAHE 2002; MEC 2004).

66 wetland and mangrove areas have been documented across 13 atolls (Reference?). Untawale and Jagtap (1991) identified 13 species of mangroves as well as six species of plants and 37 species of fungi associated with mangrove habitats. Mangroves are generally of the closed type, found in depressions in the centre of an island. Some islands have fringing mangroves along brackish water areas (MHAHE 2002).

3.7 Population

Population of the Maldives stood at 298,842 during Census 2006 and passed the 300,000 mark in July 2006 (MPND 2006). This is more than four times the population of 72, 237 recorded in the first census of the country in 1911. Figure 6 shows the population of the Maldives by atoll. It is important to note that in 13 out of the 21 atolls the population declined in the census period 2000-2006.

Figure 6 Population distribution
[Population distribution map by Atolls (will also show land area, density, No of Inhabited islands per atoll) – PUT THIS MAP INSTEAD OF TABLE BELOW]

Population density among the atolls and the islands differs greatly across the country. According to the 2006 census preliminary data (MPND 2006), more than a third of the total population (104,403 persons) lived in the capital Male'. Addu Atoll has the next highest population at 17,922, while Vaavu Atoll has the smallest population at 1,614.

Apart from Male', there are only three islands that have a population greater than 5,000. They are Hithadhoo (9,407), Fuvahmulah (7,642), and Kulhudhufushi (7,206). In 2006, the number of islands that had a population between 5000 and 1000 people was 57, while 60 islands had between 1,000 and 500 people and 74 islands had a population of less than 500 people.

3.8 Health

The health status of the Maldivian population has improved significantly over the last two decades with all the indicators showing steady improvement (MHAHE 2002; MPND 2006). In 2005, the infant mortality rate figure was 12, maternal mortality was less than 1 per thousand and life expectancy was 72.2 years. The population per practising doctor was 775 in 2005.

Communicable diseases such as malaria and vaccine preventable diseases such as polio, neonatal tetanus, whooping cough and diphtheria have been successfully eliminated. Although mortality due to diarrhoea and acute respiratory infections has been reduced to zero, they continue to cause significant morbidity to children and adults, indicating inadequate access to safe water and sanitation. The number of cases of acute gastroentritis increased by 50% from 15,000 cases in 2004 to 21,000 cases in 2005. Vector borne diseases such as dengue and scrub typhus have emerged as major communicable diseases of public health concern (Figure 7 and Figure 8).

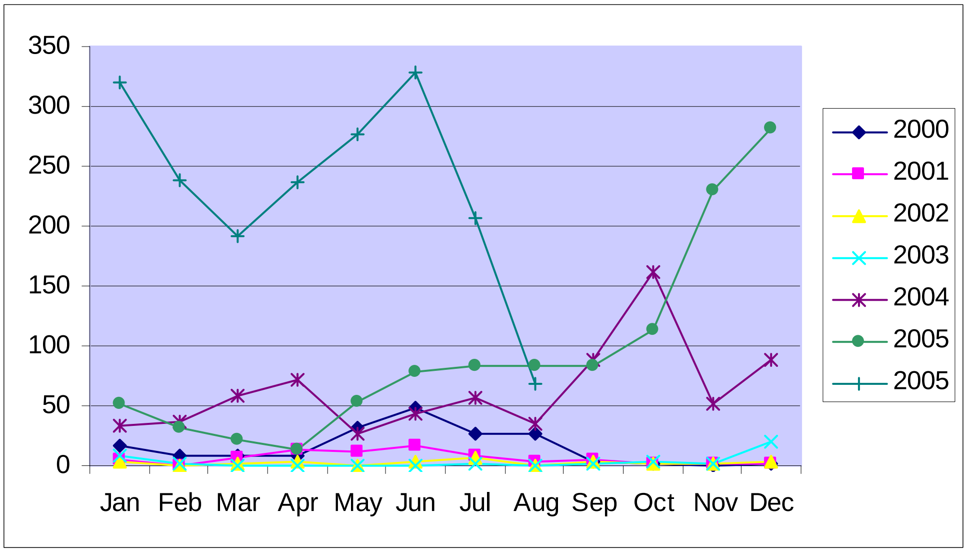

Figure 7 Incidence of dengue in Maldives 2000-2005
(source: epidemiological surveillance records, DPH)

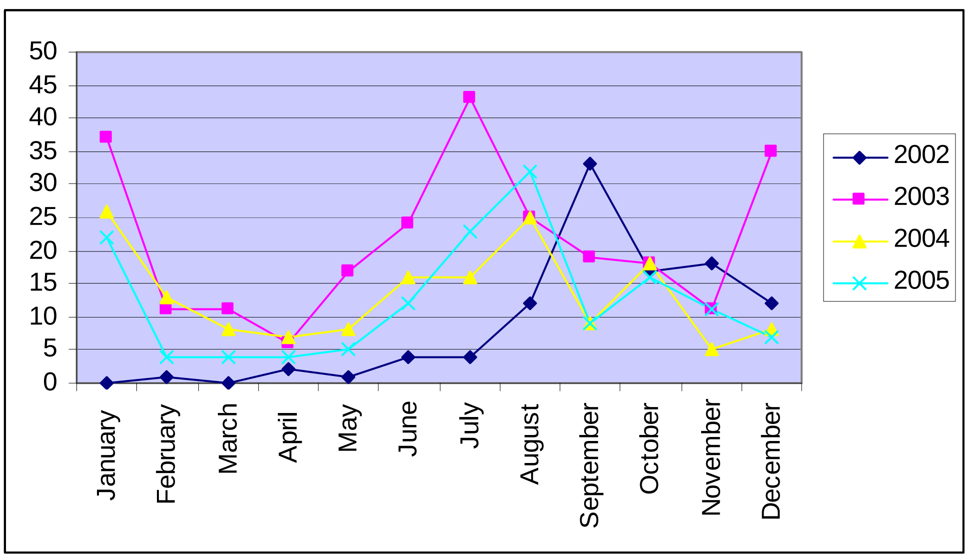

Figure 8 Incidence of scrub typhus in Maldives 2000-2005
(source: epidemiological surveillance records, DPH)

3.9 Poverty

From 1997 to 2004, there is evidence of significant increases in income (MPND 2006). The headcount ratio shows that in 1997 the proportion of population having less than Rf 15 per person per day was around 45 per cent, while by 2004 it had come down to about 20 per cent. Using the purchasing power parity one dollar as the poverty line, one per cent of the population (around 2,000 people) lived in poverty in 2004.

Even though income levels has been increasing, income inequality between Male' and the atolls has increased. There is also evidence that northern atolls are becoming poorer relative to southern atolls (MPND 2005). The profile of poor households shows that poorer households are larger in size, with a larger share of women, and more likely to be headed by a female. The likelihood of being poor is higher when engaged in agriculture, fishing and local manufacturing and lower if engaged in tourism, trade, transport or government (MPND 2006).

3.10 Infrastructure

Major infrastructure needs to be shown on one of the maps

Significant investments have been made to improve infrastructure in the country. At present there are five airports of which two are international and three are domestic airports. There are three major commercial sea ports in Maldives. By 2005 more than 105 harbours have been constructed across the inhabited islands. A further 23 harbours have been constructed in airport islands, resort islands and islands leased for special economic and administrative purposes. There are six causeways located in Laamu and Seenu atoll (Shaig 2006).

There are more than 1200 over-water structures, namely rooms, spas and restaurants across the existing resorts. There are at least 350 piers, both in the resorts and in inhabited islands without a harbour (Shaig 2006). Tourism infrastructure makes up the bulk of economic infrastructure both in terms of investment value and quantity.

Other infrastructure include environmental services, utilities and communications infrastructure. Environmental infrastructure includes waste management systems (include no.), sewerage systems and erosion mitigation measures such as near-shore breakwaters and groynes. Utilities infrastructure include powerhouses (no.?) and desalination plants and their distribution systems. Communication infrastructures are those associated with telecommunications (Shaig 2006). At present there are 32,296 fixed phone lines and 203,620 mobiles phone lines in use (MPND 2006).

3.11 Economy

The annual gross domestic product (GDP) increased from Rf 385 million in 1978 to Rf 7,934.0 million in 2005 (MPE 1988; MMA 2004). The estimates of 2005 show that tertiary sector dominates the GDP with 73%, while the secondary and primary sectors contribute 17% and 10% respectively (MPND 2004).

3.11.1 Tourism

Tourism contributes about one third to the GDP and the sector accounts for 17,000 direct jobs (World Bank, Asian Development Bank et al. 2005). In December 2004, 600,000 tourist arrivals within a calendar year was recorded (MoT 2005). Bed capacity has reached more than 21,156 in 2005 with 87 resort islands and is expected to grow significantly over the next three years with the opening of 53 new resorts (MPND 2004).

3.11.2 Fisheries

Fisheries contributes about 7% of the GDP, is the largest contributor to exports and is the most dominant in terms of employment of the local labour force, employing over 15,000 fishermen. The total fish catch was a record 186,000 metric tons in 2005 and export revenue is over US$ 100 million (Figure 9) (Adam 2006; MPND 2006). Tuna makes up 97% of export revenue. In the Maldives, fish other than tuna species are classified as reef fish and recently increasing local demand and access to export markets has transformed the reef fishery.

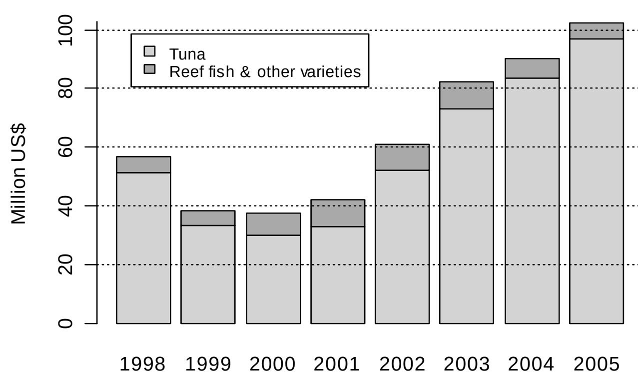

Figure 9 Export revenue for tuna and reef fish / other varieties, 1998 – 2005. Note: 2005 data is preliminary
(Source: (Adam 2006).

3.11.3 Agriculture

Agriculture plays a minor role in the economy and the sector contributed only 2.8% to GDP in 2000 (MPND 2004). The sector is constrained by the limited availability of cultivatable land and the abundance of cheap imports of vegetables and fruits. The total cultivable land area is estimated at 2670 ha, including 1770 ha on inhabited islands and 900 ha on uninhabited islands (MFAMR 2006). Some of the products that are presently farmed are tender coconuts, water melon, banana, cucumber, pumpkin, coconut, papaw, cabbage, taro and brinjal.

4 Climate Change and Climate Variability

This chapter summarises the global predictions based on the IPCC Third Assessment Report and describes the national scenarios based on the Climate Risk Profile for the Maldives (MEEW 2006) and the Disaster Risk Profile for Maldives (UNDP 2006) for the different climatic hazards.

4.1 Global Predictions

4.1.1 Sea level rise

The IPCC Third Assessment Report (TAR) shows that global average sea level rose between 10 and 20 cm during the 20th century at the rate of 1-2mm/year. Future sea level is projected to rise under all IPCC SRES scenarios. Global mean sea level is projected to rise by another 9 to 88cm between 1990 and 2100. The projected rate of increase is 5mm/year, with a range of 2-9mm/year (IPCC 2001).

4.1.2 Precipitation

Global average water vapour concentration and precipitation are projected to increase during the 21st century. By the second half of the 21st century, it is likely that precipitation will have increased over northern mid-to high latitudes and Antarctica in winter. At low latitudes, there are both regional increases and decreases over land areas (IPCC 2001).

4.1.3 Global Average Surface Temperature

There is evidence to suggest that the global average surface temperature has increased since 1861. The best estimate over the last 140 years shows that the global average surface temperature had increased by 0.6±0.2°C over the 20th century. It is also reported that globally it is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record since 1861 (IPCC 2001). In addition, 2005 is reported as the warmest year since 1890s (NASA 2006).

On average between 1950 and 1993, night-time daily minimum air temperatures over land increased by about 0.2°C per decade. This is about the twice the rate of increase in daytime daily maximum air temperatures, which is 0.1°C per decade. The increase in sea surface temperature over this period is about half that of the mean land surface air temperature. Similarly, the global ocean heat content had also increased since the late 1950s (IPCC 2001).

The global average surface temperature is projected to increase by 1.4 to 5.8°C over the period 1990 to 2100. The projected rate of warming is much larger than the observed changes during the 20th century (IPCC 2001).

4.1.4 Extreme weather

Global climate models currently projects an increase in sea-surface temperature of approximately 1°C by 2050s. Recent variations over the tropical Pacific Ocean and the surrounding land areas are related to the fact that warming episodes (El Nino), has been relatively more frequent or persistent than the opposite phase (La Nina) since the mid-1970 (IPCC 2001). This finding is supported by World Bank (2000), which states that there is evidence to indicate that El Nino conditions may occur more frequently, in the central Pacific and northern Polynesia.

4.2 National

The Climate Risk Profile for the Maldives (CRP) is based on observed data for Hulhulé (Latitude 4 N; Longitude 73 E). Except for the sea level data, which were sourced from the University of Hawaii web site, all the data used in preparing this climate risk profile were provided by the Department of Meteorology. While data for Hulhulé cannot characterize the climate conditions for the entire country, they do provide a general indication of current climate risks for the Maldives (MEEW 2006).

4.2.1 Sea Level Rise

The observed long term trend in relative sea level for Hulhulé is 1.7 mm/yr. But maximum hourly sea level is increasing by approximately 7 mm/yr, a rate far in excess of the observed local and global trends in mean sea level (Figure 10).

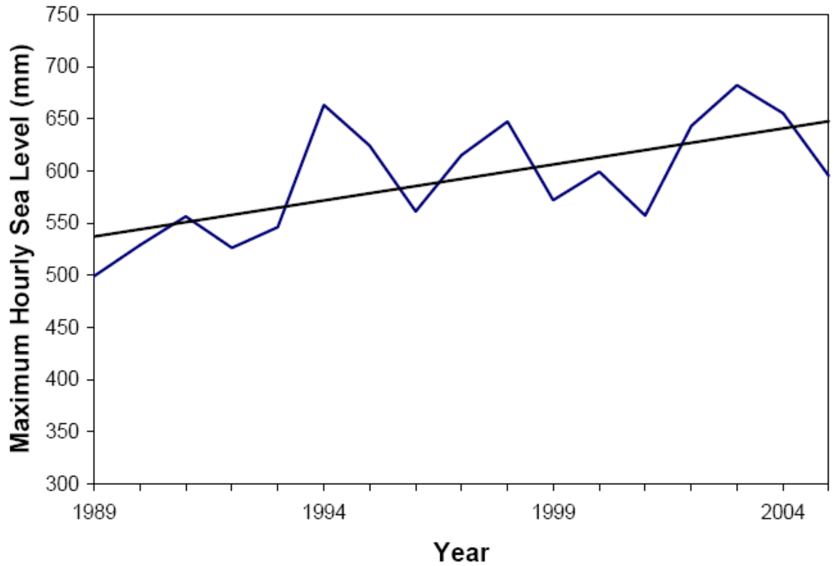

Figure 10 Maximum hourly sea level, by year, for Hulhulé (1989 to 2005). Also shown is the linear trend in these values over the same period
(Source: (MEEW 2006)).

For Hulhulé an hourly sea level of 70 cm above mean sea level is currently a 100-year event. It will likely be at least an annual event by 2050.

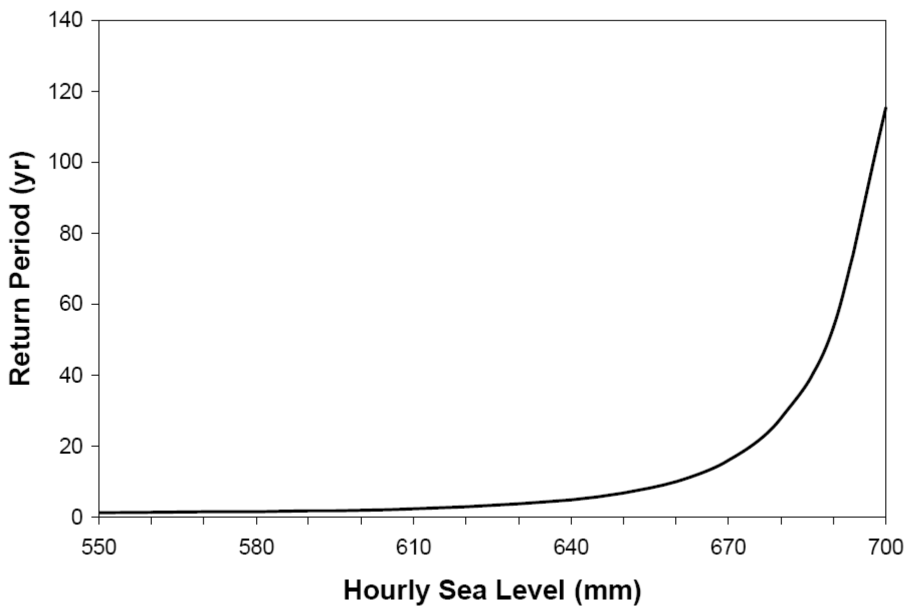

Figure 11 Relationship between hourly sea level and return period for Hulhulé, based on observed hourly sea level for 1989 to 2005
(Source: (MEEW 2006)).

4.2.2 Storm Surge and Storm Tide

In the Disaster Risk Profile for Maldives (UNDP 2006), it was reported that the maximum storm surge height was 1.32m in a storm with a return period of 500 years (Table 4). If coupled with high tide, it could generate a storm tide of 2.30m.

Table 4 Probable maximum storm tide
(adapted from (UNDP 2006))

Return Period (Years)	Pressure drop hPa	Storm Surge Height (m)	Average Tide height (m)	Storm Tide (m)
100	20	0.84	0.98	1.82
500	30	1.32	0.98	2.30

The study also reported the following (Table 5) forecasted maximum storm tides for different part of Maldives.

Table 5 Probable maximum storm tide by region
(adapted from (UNDP 2006))

Hazard Zone	Storm Surge Height (m)	Average Tide height (m)	Storm Tide (m)
Southern Atolls	-	-	0.00
Central-west Islands	0.45	0.93	1.38
Central-east Islands	0.60	0.93	1.53
Northwest Islands	0.99	0.98	1.97
NorthEast Islands	1.32	0.98	2.30

This analysis assumes two sea level rise predictions revised by IPCC: medium prediction of 0.48m and high prediction of 0.88m (Table 6). Based on these assumptions, scenarios, and given the average height of Maldivian islands is 1.5m above Mean Sea Level, a sea level rise itself would cause regular tidal inundations in most islands even at the medium prediction. The high prediction could certainly cause regular inundations in almost all islands. Storm surges can create up to 2.78m waves under medium prediction, enough to completely inundate a medium to small sized island. A storm surge at high prediction could cause a 3.18m wave that could inundate even the largest of islands. These surges do not take into account regular monsoonal wind generated flooding which is considered the most common in Maldives (Shaig 2006; UNDP 2006).

Table 6 Storm tide estimates for medium and high sea level rise scenarios
(Source: (Shaig 2006))

	Present Day			Predicted Scenario 2080-2100			
				Medium (0.48m)		High (0.88)	
Zone	**Storm Surge Height (m)**	**Average Tide height (m)**	**Storm Tide (m)**	**Average Tide height (m)**	**Storm Tide (m)**	**Average Tide height (m)**	**Storm Tide (m)**
Southern Atolls	-	0.93	NA	1.41	NA	1.81	NA
Central-west Islands	0.45	0.93	1.38	1.41	1.86	1.81	2.26
Central-east Islands	0.60	0.93	1.53	1.41	2.01	1.81	2.41
Northwest Islands	0.99	0.98	1.97	1.46	2.45	1.86	2.85
NorthEast Islands	1.32	0.98	2.30	1.46	2.78	1.86	3.18

4.2.3 Precipitation

No significant long term trends are evident in the observed daily, monthly, annual or maximum daily rainfall. Figure 12 shows the maximum daily rainfall recorded at Hulhule'.

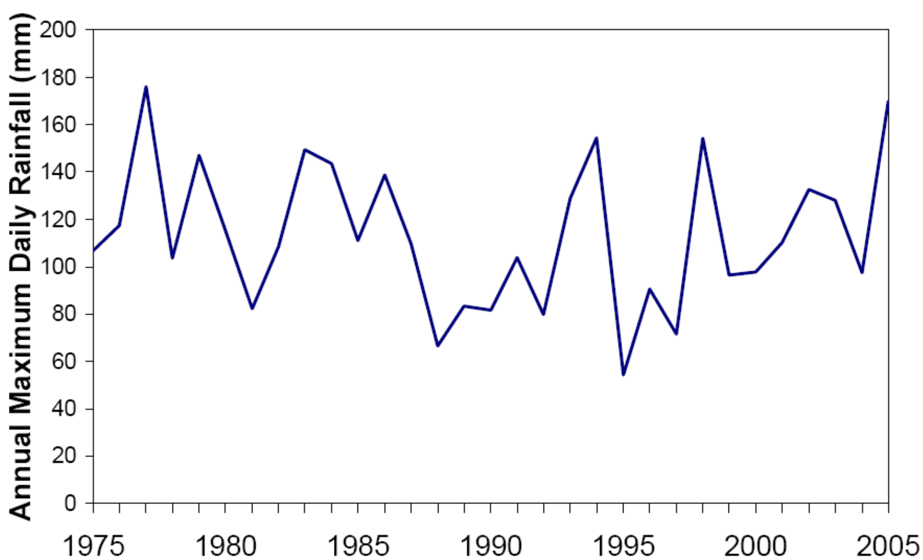

Figure 12 Maximum daily rainfall, by year, for Hulhulé (1975 to 2005)
(Source: (MEEW 2006)

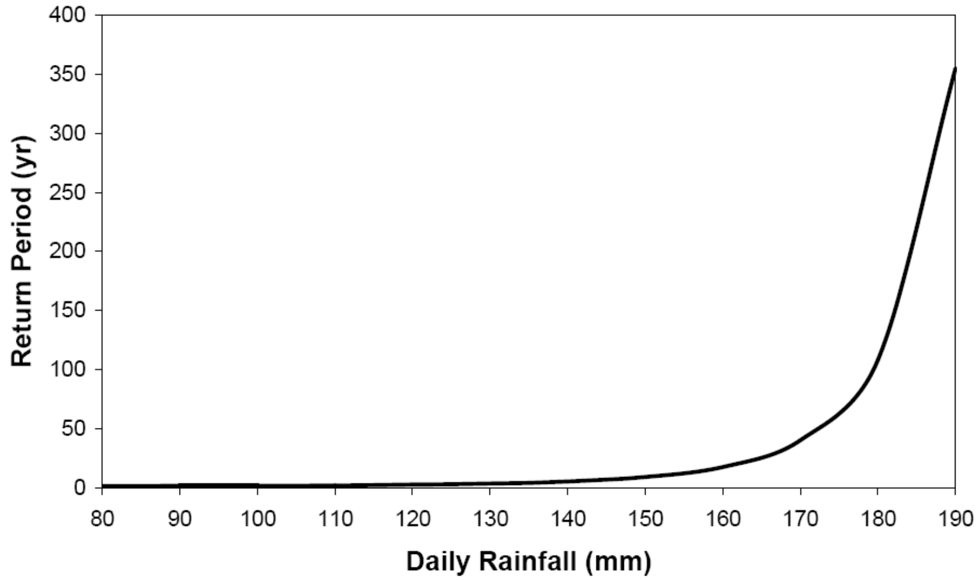

Figure 13 Relationship between daily rainfall and return period for Hulhulé, based on observed daily rainfall for 1975 to 2005
(Source: (MEEW 2006)

Currently a daily rainfall of at least 160 mm is a relatively rare event at Hulhulé, with a return period of 17 yr (Figure 13). An extreme daily rainfall of 180mm is currently a 100-year event. It will likely occur twice as often, on average, by 2050. An extreme three-hourly rainfall of 100mm is currently a 25-year event. It will likely become at least twice as common, on average, by around 2050.

4.2.4 Wind

Currently an extreme wind gust of 60 kt has a return period of 16 years. It is estimated that this will reduce to 9 years by 2025.

Maldives lies out of the tropical cyclone zone due to its proximity to equator. However, there have been incidents from the past where cyclonic storms have passed over Maldives and their still remain the probability for future such events. Figure 14 shows the tracks of cyclonic system over Maldives in 128 years.

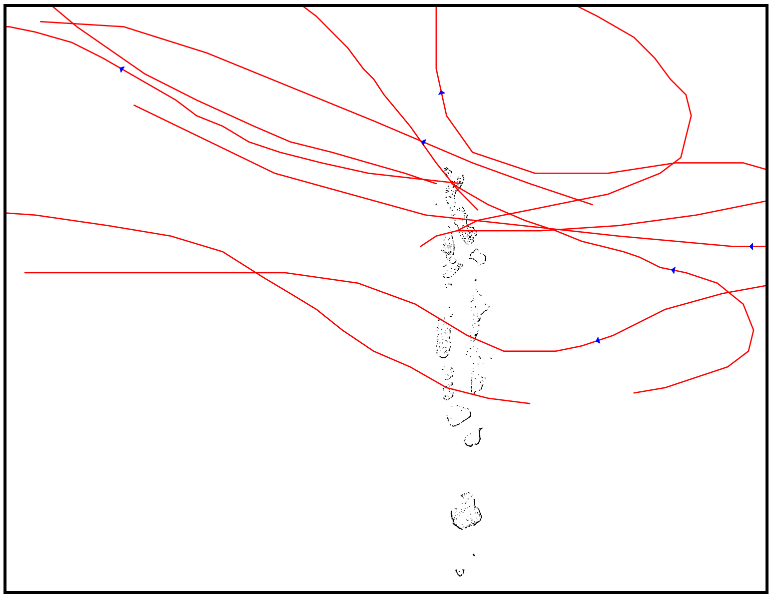

Figure 14 Cyclone tracks over Maldives between 1877-2004
(adopted from (UNDP 2006))

There is a clear pattern of northern Maldives being exposed to more frequent freak storms than the south. Based on the historical records of wind data, following are the predicted return periods for cyclonic activity (Table 7).

Table 7 Return period of wind speeds associated with cyclones in Maldives
(Source: (UNDP 2006))

Type	**Wind Speed (knots)**	**Return periods (years)**
Tropical Depression	28-33	10-20
Tropical Depression	34+	23
Cyclone	65+	134.6

The following maximum wind speeds based on 500 year return period cyclones was also predicted (Table 8). It includes a probable category 3 cyclone for the northern Maldives.

Table 8 Cyclone hazard zone in Maldives and the probable maximum wind speed
(Source: (UNDP 2006))

Hazard Zone	**Probable Maximum Wind Speed (knots)**	**Saffir-Simpson Scale (Hurricane Category)**
Southern Maldives	0.0	0
South Central	55.9	0
Central	69.6	1

North Central	84.2	2
Northern Maldives	96.8	3

4.2.5 Temperature

There is relatively high confidence in projections of maximum temperature. The annual maximum daily temperature is projected to increase by around 1.5 C by 2100. A maximum temperature of 33.5 is currently a 20-year event. It will likely have a return period of three years by 2025.

4.2.6 Sea Surface Temperature

An increasing trend of the sea surface temperature (SST) has been observed in the Maldives coast at both locations studied i.e S.Gan and Male' (Singh O.P., Khan T.M.A. et al. 2001; Khan T.M.A., Quadir D.A. et al. 2002). Large a seasonal variation in the SST trends at Gan was observed and SST and Mean Tide Level (MTL) trends at Male' are consistently increasing during all the seasons and the rising rates are very high. The annual mean SST trends at Male' and Gan are 0.2±°C and 1.1-1.6°C/decade respectively. Higher trends were observed around Male' than those at Gan, the reason being that Gan is located near the equator.

5 Vulnerabilities and Impacts

This chapter presents the vulnerabilities to and impacts of climate change on the eight main sectors namely (i) Land, Beach and Human Settlements; (ii) Critical Infrastructure; (ii) Tourism; (iv) Fisheries; (v) Human Health; (vi) Water Resources; (vii) Agriculture and Food Security and (viii) Biodiversity.

The Vulnerabilities and impacts to these sectors have been identified based on vulnerability assessments and stakeholder consultations. Vulnerability assessments were undertaken for land and beach, infrastructure, fisheries, human health and coral reef.

5.1 Land, Beach and Human Settlements

Maldives is the most vulnerable country to the predicted impacts of sea level rise due to the small size, unconsolidated nature and extremely low elevation. The land area is 235sqkm making Maldives the sixth smallest sovereign state (Shaig 2006). The land is divided into 1190 small coral islands out of which 375 islands are currently in use (176sqkm). Although 815 islands are unutilized this represents only 25% of the total land area (59sqkm). Approximately 188 sqkm of this land area is less than 1m above mean sea level (MHAHE 2001).

Since 80% of the land area is less than 1m above mean sea level, the present predictions of sea level rise threatens the existence of the nation. 44% of the settlement footprints of all islands are within 100m of coastline which translates to 47% of all housing structures and 42% of the population being within 100 of coastline in year 20002. Majority of the islands (121 islands) have more than 50% of their housing structures within 100m of coastline compared to (77 islands) with less than 50% (Shaig 2006).

Over the last 6 years more than 90 islands (45% of all islands) have been flooded at least once and 37 islands have been flooded regularly or at least once a year (Shaig 2006). The tsunami of 2004 flooded all but nine islands and required evacuation of 13 islands

[2] Based on Maldives Population and Housing Census 2000 data

(MPND 2005). In addition, 97% of inhabited islands reported coastal erosion in 2004, of which 64% reported severe coastal erosion (Shaig 2006). Given the current susceptibility to sea level rise and storms, with wind gusts of 60knots predicted to return every nine years, ocean-induced severe weather could prove catastrophic.

The severe weather event of May 2004 alone caused flooding in at least 71 inhabited islands (Shaig 2006). The tsunami of 2004 displaced more than 15,000 people and 82 people lost their lives and 26 people went missing (MPND 2005). Total damages of the tsunami of 2004 were estimated to be US$470 million, (62% of the GDP) out of which US$298 million were direct losses (World Bank, Asian Development Bank et al. 2005).

5.2 Critical Infrastructure

The location of infrastructure within close proximity to the coastline makes them highly vulnerable to sea level rise and associated storm conditions. The infrastructure of the two international airports is within 50m of the coastline. About 30% of the infrastructure of the Male' International airport lies within this range and additional land reclamation done on the island towards the ocean-ward side has resulted in parts of the island being within 15m of the wave break zone (Shaig 2006).

More than 90% of all resort infrastructure and 99% of all tourist accommodation, which make up the most crucial economic product of the country, are within 100m of coastline. The average width of a tourism island is a mere 190m with 63% of resort islands having a width less than 200m and 88% less than 300m. Furthermore, 70% of all fisheries infrastructure are within 100m of coastline where proximity to beach is taken as an advantage (Shaig 2006).

The average width of inhabited islands is 566m resulting in all infrastructures built within 233m maximum from the coastline. 80% of the powerhouses in inhabited islands and resort islands are located within 100m of coastline. 90% of the islands have their waste disposal sites within in 100m of coastline and on the ocean-ward side of the island. More than 75% of communications infrastructures are located within 100m from the coastline. In addition, land reclamation on some islands have encouraged settlements and associated infrastructure to be located close to the coastline (Shaig 2006).

All infrastructures on an island are at the low elevation of 1.5m above mean sea level. Over-water structures in resorts are built above the average highest tide requiring high investment. The average height of the causeways and bridges is 1.6m above mean sea level. Guidelines for setting up powerhouses require the machinery to be placed on concrete pads usually 6-12 inches high (Shaig 2006).

If sea level continues rise as predicted by IPCC (IPCC 2001; 2001) and appropriate adaptation measures are not taken frequent inundations could virtually obliterate the critical infrastructure damaging the economy threatening safety and security of the people. The scale and magnitude of damage that may be caused to infrastructure can be deduced from historical records.

The flooding event of 1987 caused damages worth USD4.5 million to the Male' International Airport alone (MHAHE 2001). During the three 6ft waves of 2004 tsunami, over-water structures in resorts were amongst the most impacted. The damage to transport and communications infrastructures were estimated to be US$20.3 million where 4,200m length of quay wall and 15,000m of harbour/sea walls and breakwaters were damaged or destroyed (World Bank, Asian Development Bank et al. 2005).

5.3 Tourism

Maldives is the World's Leading Dive Destination and Indian Ocean's Leading Destination according to the World Travel Awards 2006 (World Travel Awards 2006). Every year more than 600,000 tourists arrive in Maldives contributing one third to the GDP. The sector has created more than 17,000 jobs. The tourism industry, directly and indirectly, also accounts for a high portion of government revenues. Lease payments from hotel projects were $48 million in 2004 with bed and departure taxes contributing $41 million and custom duties another $43 million (World Bank, ADB, UN 2005 Joint Needs Assessment).

Tourism in the Maldives is closely related to diving and as such the vulnerability of coral reefs to climate change. Corals thrive in a narrow temperature range and are highly sensitive to changes in temperature. Given the current predictions for increase in SST and the observed relatively more frequent or persistent El Nino episodes, coral bleaching is expected to rise rapidly and significantly (IPCC 2001). During the bleaching event of 1998, an estimated 98% of shallow water corals died in Maldives (Naseer 2006). Corals are also made vulnerable to climate change due to the calcification process which is sensitive to atmospheric CO_2 concentration and SST. The calcification rate of corals is expected to decline by 14-30% by 2050 (IPCC 2001) (Need to be included in the Ch4). Increased bleaching coupled with reduced calcification will affect coral growth and reef integrity and, reduce the ability of the reef to keep up with sea level rise. Furthermore, mass spawning of corals which are the building blocks of a coral reef and its sustainability make them particularly vulnerable to climate change. A miss in a major spawning event can be disastrous to coral recruitment and the replenishment and recovery of coral reef (Naseer 2006).

According to previous studies 25-35% of tourists visit primarily for diving and 70-80% of tourists on any resort at any given time were snorkellers (Westmacott S. 1996). Annual number of dives made by tourists exceeds half a million and in 1997 the earning from a single dive was about US$35. Damage to coral reefs of a popular shark diving spot in 1995 and 1996 reduced the number of divers resulting in a loss of revenue of US$500,000 in a single year (Anderson C. 1997).

Tourism is also at risk from flooding and beach erosion. According to previous studies 70% of tourists visit the Maldives primarily for beach holidays. In 2001, 45% of tourist resorts reported varying degrees of beach erosion (MHAHE 2001). How many resorts experienced flooding? How many resorts required evacuation? The impacts of the tsunami of 2004 indicates the losses that tourism sector may incur due to flooding associated with sea level rise. The tourism sector incurred the highest in both direct and indirect losses. Direct losses were estimated to be US$100 million. Indirect losses were through tourist arrivals which sharply declined to 7600 compared to 17,000 at the same time of the previous year (World Bank, Asian Development Bank et al. 2005).

5.4 Fisheries

Fisheries is the main livelihood activity with 20% of the population dependent on fisheries as the major income earning activity. It employs over 15,000 fishermen and contributes 7% to the GDP. Fisheries is also the primary source of dietary protein for the Maldivians (Adam 2006).

The total fish production in 2005 was 158,576t of which more than 80% was tuna. Since tuna is the main fishery, the fisheries sector is highly vulnerable to climate change as tuna is highly attuned to the biophysical conditions of the pelagic environment, particularly ENSO and associated changes in SST. During the 1997/1998 El Nino the Indian Ocean purse seine fishery was shifted to the east, unlike other years owing to the elevated depth of the 20degC isotherm (Marsac and Le Blanc 1998). In Maldives during the El Nino years, catch rates of skipjack tuna are depressed while catches of yellowfin tuna are elevated and the effect is reversed in La Nina years (Adam and Anderson 1996; Adam and Anderson 1996).

Tuna movement and abundance in the Indian Ocean is closely linked to the monsoon-driven ocean productivity (Adam 2006). The Somali Basin and the north Arabian Sea is particularly productive during the southwest monsoon which is becoming stronger causing over 300% increase in phytoplankton biomass in the area (Goes J, Thoppil P.G. et al. 2005). These in turn is expected to have profound implications of tuna distribution and abundance in the Indian Ocean (Adam 2006).

As tuna fishery of Maldives is part of the wider Indian Ocean tuna fisheries, climate-induced changes and fishery overexploitation occurring elsewhere may have local repercussions (Adam 2006). The most recent assessments of the tuna stock in Indian Ocean revealed that the bigeye tuna is overexploited and that yellowfin tuna stock is considered to have reached maximum sustainable levels (IOTC 2005).

The method of tuna fishing adds to the vulnerabilities of the fisheries sector. The method that is in use is the pole-and-line which is based on livebait acquired from coral reefs. For every 7-10kg of tuna catch a kilogram of livebait is required which approximates to 21,000t of livebait each year (Adam 2006). As described in other sections coral reefs are highly vulnerable to changes in SST and CO2 concentrations.

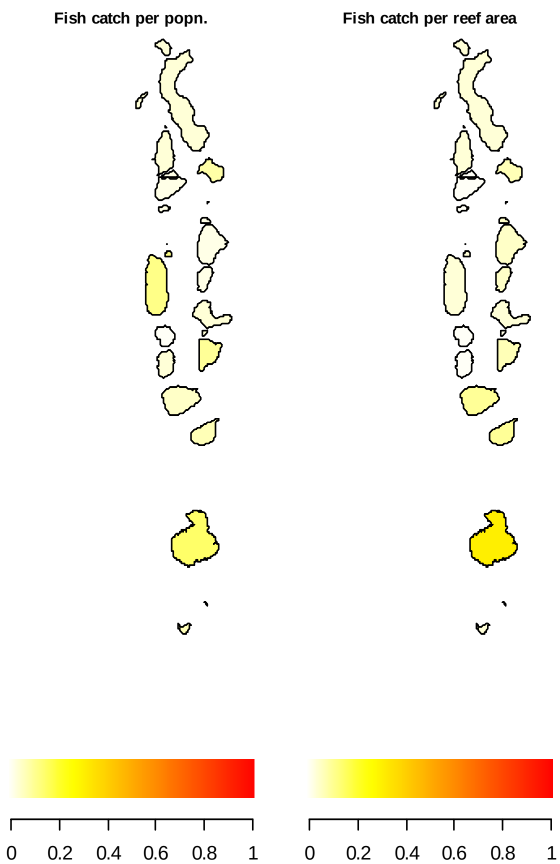

Figure 15 Relative estimates of fish catch by atoll units in terms of population and reef area: per capita catch (tons / person per year, left) and catch per reef area (t / km^2 / year, right).
Note: Reef areas are those reported by Naseer & Hatcher (2004), fish catches are total national landings reported by MoFAMR and populations estimates from Census (2006), Ministry of Planning and National Development.
(Source: (Adam 2006)).

The fisheries catch data shows clear variation in fish catch associated with climatic changes. At present fisheries export revenue is estimated at US$100 million and the capital investments in fisheries are increasing rapidly with the privatization policy of the Government. Estimates of fish catch by atoll shows that certain atolls will feel relatively higher impacts (Figure 15).

Highest catch per capita is seen in Huvadhoo, Meemu, Alifu and Lhaviyani atolls while fish catch per reef area is highest in Huvadhoo, Thaa and Laamu Atolls.

5.5 Human Health

Although the health status of the Maldivian population has improved significantly over the last two decades as described in Chapter Three, there is high morbidity to children and adults from climate related diseases. Flooding associated with increased rainfall and high sea levels coupled with increased surface air temperature is likely to cause higher incidences of vector- and water-borne diseases (IPCC 2001). At present 18% of inhabited islands experience rainfall and/or ocean-induced flooding at least once a year (Shaig 2006).

Even now vector borne diseases such as dengue and scrub typhus are the major public health concerns in the country. Epidemiological data shows changes in the seasonal nature of dengue and continued high prevalence from mid 2005, spreading to the atolls, leading to epidemic proportions. Scrub Typhus which was endemic 60 years ago reemerged in 2002 with mortality rates as high as 10%. Scrub Typhus continue to be prevalent causing significant morbidity (Moosa 2006).

There is also high morbidity caused by water-borne diseases particularly gastroenteritis. From 15,000 cases in 2004 number of cases increased by almost 50% to 21,000 cases in 2005. It is also seen that people in the atolls are more vulnerable to diarrhoeal diseases than in Male’ and this disparity is more pronounced in children under five years. In addition to these climate related factious diseases there has been an increase in the conditions of the skin, subcutaneous tissue and eye that has close linkages to climate change caused by increase exposure to UV radiation (Moosa 2006).

The climate change related vulnerability is further compounded by the high level of malnutrition in children and poor quality of drinking water (Moosa 2006). In 1997 the nutritional situation in the country was worse than Sub-Saharan Africa. In 2005 the forecasts were that one in four children may be underweight in Maldives by 2015. It was also found that the nutritional status of children varies across the atolls. The vulnerability to climate change is exacerbated by local characteristics such as high population congestion, low income levels and, accessibility and quality of healthcare.

5.6 Water Resources

Maldivian islands have a precarious hydrological system. With the predicted sea level rise and during periods of ocean-induced flooding, saltwater may infiltrate the freshwater lens making the lens saline (Shaig 2006). In all the inhabited islands except Male' people depend on groundwater for washing, bathing and other non-potable uses. Thus saltwater intrusion would affect the quality of life for the people in the islands. Saltwater intrusion would also affect soil and vegetation causing impacts on agriculture and terrestrial environment.

At present ninety per cent of atoll households use rainwater as the main source of drinking water. However, 30% of the atoll population reported drinking water shortages in 2004 and there are no measures of how safe the stored rainwater is (MPND 2005). The predicted changes in precipitation have the potential to impact on rainwater harvesting and storage.

5.7 Agriculture and Food Security

Heavy import dependency, limited food storage, ad hoc distribution, and limited agriculture pose severe food security risk to the population. The Maldives imports almost all food items except fresh tuna and coconut. Every year more than 17 million kilograms of rice and flour and 10 million kilograms of sugar are imported (MCS 2006). Long-term and emergency food storage is virtually absent except for warehousing in Male' and nine other islands (STO 2006). Food distribution system is by boat from Male' to islands and the quantity that can be transported across on one trip is very small (MHAHE 2001). Islands face food security problems during high winds and storms on a regular basis. In the month of September 2006 xx islands reported food shortage due to bad weather (Newspaper).

The limited agriculture in the islands could be affected by saltwater intrusion into the aquifer and flooding. The islands with agricultural activities are also those that are more prone to flooding. [VPA III data on food shortage].

5.8 Biodiversity

Maldives is the seventh largest reef system of the world. Corals, the basic ecological component of reefs, are sensitive to changes in temperature, CO2 concentrations and salinity. Maldives experienced extensive coral "bleaching" in 1998 where shallow reefs were affected (Status of coral reefs 2002). Monitoring programs have shown that recovery of both coral cover and species diversity is underway but slow. Communities have changed dramatically in some instances. Large areas of reef flats have been totally denuded by this bleaching incident affecting habitats of reef associated species.

Mass spawning and coral recruitment is cued to environmental conditions. Many reef fish are known to have seasonal spawning cycles which may be disrupted resulting in recruitment failure. In addition, reef fishes have a pelagic larval phase ranging from days to few weeks. Survival of larvae depends on favourable conditions of the pelagic environment (Adam 2006). These factors make coral reefs particularly vulnerable to climate change.

Most reefs of the Maldives appear to be at the point where they are sea level limited and with no potential for upward growth. Reefs appear to be now growing outwards laterally and filling up inside and it is predicted that sea level rise would induce reefs to grow vertically upwards. However, increased SST and CO_2 concentrations may alter the calcification potential of coral reefs resulting in slow growth. If the rates of sea level rise are higher than the rate of vertical reef growth, coral reef may not survive (Naseer 2006).

With damage to coral reef and associated habitat loss, reef fish species which are specialists requiring specific types of habitats within a reef or specific type of food from a reef could be adversely affected (Adam 2006).

6 Identification of Key Adaptation Needs and Prioritisation of Adaptation Activities

This chapter provides firstly, the adaptation needs and options that were identified through three regional stakeholder consultations and secondly an overview of the prioritization of the adaptation activities which includes the criteria that were applied to prioritise the adaptation activities. Details of the process are given in Annex X.

6.1 Adaptation Needs and Options

The adaptation needs and options were identified through three regional stakeholder consultations and the First National Communication of the Republic of Maldives to the UNFCCC (2001).

6.1.1 Land, Beach and Human Settlements

1. Consolidate population and development.
2. Acquire support for the speedy and efficient implementation of Safer Island Strategy.
3. Strengthen land-use planning as a tool for protection of human settlements.
4. Build capacity for coastal zone management.
5. Protect beaches through soft and hard-engineering solutions.
6. Protect house reef to maintain natural defense of islands.
7. Improve building designs to increase resilience.
8. Integrate climate change adaptation into national disaster management framework.
9. Develop flood control measures for islands.

6.1.2 Critical Infrastructure

1. Build coastal protection for airports.
2. Strengthen capacity for planning and design to ensure sustainable infrastructure development.

6.1.3 Tourism

1. Coastal protection and coastal zone management to protect tourist infrastructure.
2. Diversify the tourist product to reduce over-dependency on marine environment.
3. Develop climate change adaptation policy and strategy for tourism.

6.1.4 Fisheries

1. Exploit new species and promote poultry farming as alternative sources of protein to reduce over-dependency on tuna for protein.
2. Improve fish finding and fish harvesting.
3. Establish aquaculture/mariculture as an alternative to natural breeding to reduce the economic and social impacts of changing tuna abundance.
4. Undertake research and disseminate information on fisheries and climate change.
5. Experiment new and alternative species and breeding methods for livebait.
6. Integrated reef fishery management.

6.1.5 Water Resources

1. Acquire appropriate sewage treatment and disposal technologies to protect water resources.
2. Increase safe rainwater harvesting.
3. Acquire solar desalination technologies appropriate for small islands.
4. Undertake rainwater recharging of aquifers to reduce salinisation from saltwater intrusion and storm surge flooding.
5. Protect and preserve natural water catchment areas.

6.1.6 Human Health

1. Strengthen regulatory and institutional capacity for vector control.
2. Streamline the planning of healthcare services and strengthen medical emergency response.
3. Promote healthy islands and healthy buildings.
4. Strengthen the capacity for healthcare delivery.
5. Undertake research on climate change related diseases.

6. Increase nutrition promotion campaigns.

6.1.7 Agriculture and Food Security

1. Develop a national food security strategy.
2. Secure trade agreements with foreign trade partners to ensure food security.
3. Increase local food production through new technologies and strengthen marketing and sale of local food items.
4. Promote traditional food preservation and storage practices for local food.
5. Enforce and strengthen quarantine to prevent pests and diseases.

6.1.8 Biodiversity

1. Provide alternatives to coral and sand as construction materials.
2. Enhance the capacity for waste management to prevent pollution of marine environment.
3. Formulate and implement an oil pollution contingency plan.
4. Acquire appropriate sewage treatment technologies.
5. Establish marine protected areas.
6. Establish an information base on coral reefs and climate change.
7. Undertake monitoring and research to prevent coral diseases and rehabilitate coral reefs.

6.2 Prioritisation of Adaptation Activities

First a set of criteria applicable to the present circumstances in the Maldives was developed to select priority adaptation activities. Secondly, the criteria were prioritised and which was then applied to prioritise the adaptation activities.

6.2.1 Prioritisation Criteria

The following criteria were used to prioritise adaptation activities. The criteria was prioritised using multi-criteria analysis.

Objective 1: Reduce the degree of adverse effects of climate change.

1. Degree to which adverse effects of climate change to natural capital (beach, vegetation, water, coral reefs and related ecosystems) is reduced.
2. Degree to which adverse effects of climate change to produced capital (public infrastructure, utilities such as power, water supply and telecommunications) is reduced.
3. Degree to which adverse effects of climate change to human capital (loss of life, human health) is reduced.

Objective 2: Reduce poverty and promote equality to enhance adaptive capacity.

4. Degree to which disparity between Male' and the atolls is reduced.
5. Degree to which empowerment of women is achieved.
6. Degree to which food security is increased.

Objective 3: Achieve synergy with national development goals and MEAs.

7. Degree to which the economy can be strengthened and diversified.
8. Degree to which employment opportunities can be increased particularly for youth and women.
9. Degree to which the natural environment will be protected.
10. Degree to which people and property can be made safer from damage caused by natural disasters.

Objective 4: Cost-effectiveness.

11. Degree to which adaptation measure is socially accepted.
12. Degree to which the adaptation measure is financial feasible.
13. Degree to which the measure is technically feasible.

6.2.2 Prioritisation of Activities

The adaptation activities were prioritised using an analytical hierarchy process. The list of priority activities and the project profiles developed based on these activities are given in Chapter Seven.

7 Priority Adaptation Activities

[Project profiles to be inserted]

References

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