

Socioeconomic Ramifications of Sea Level Rise in the Maldives: A Holistic Assessment of Impacts and Adaptation Strategies

Mohamed Hussain Ali^{1*} and Mohamed Jaleel¹

¹Lecturer, Department of Environment and Natural Sciences, Faculty of Engineering Science & Technology, The Maldives National University.



*Corresponding Author's Email:
alimoh4909@gmail.com

Article's History

Submitted: 2nd January 2024

Accepted: 13th February 2024

Published: 17th February 2024

Abstract

Aim: The aim of this study was to determine the socioeconomic impacts of Sea Level Rise in the Maldives and exploring the adaptation strategies.

Methods: Through comprehensive analysis of existing literature, reports and policy documents a thorough understanding of the impacts and potential adaptation strategies related to sea level rise in the Maldives was achieved.

Results: The study revealed that sea level rise in the Maldives poses grave threats to infrastructure, economy, livelihoods, and human health in the Maldives. Vulnerable coastal communities are at increased risk of displacement, loss of income, and compromised access to basic services. However, the study identifies a range of adaptation strategies, including coastal protection measures, sustainable land-use planning, livelihood diversification, and community-based initiatives, to enhance resilience.

Conclusion: The potential for widespread inundation, coastal erosion, and the degradation of ecosystems such as coral reefs and mangroves has severe implications for the Maldivian economy, culture, and way of life. The Maldives heavily relies on tourism and fisheries for economic sustenance, and these sectors are highly vulnerable to the adverse effects of sea level rise.

Recommendations: The Maldivian government should invest in both hard and soft coastal protection measures, such as seawalls, breakwaters, and mangrove restoration projects, to mitigate the impacts of sea level rise on critical infrastructure and valuable ecosystems. In addition, economic diversification is crucial to reducing the Maldives' vulnerability to sea level rise. Promoting alternative industries, such as sustainable agriculture, renewable energy, and technology services, can create new sources of income and employment, while reducing dependence on tourism and fisheries.

Keywords: *Socioeconomic ramifications, sea level rise, Maldives, impacts, adaptation strategies.*

INTRODUCTION

Historical Sea Level Rise Trends

Throughout history, the global mean sea level (GMSL) has shown a consistent increasing trend. During the 20th century, the GMSL rose at an average rate of about 1.4 millimeters per year (Church & White, 2011). However, since the early 1990s, satellite altimetry data has indicated an acceleration in sea level rise, with a current rate of approximately 3.4 millimeters per year (Nerem et al., 2018). While the global trend in sea level rise is well-established, regional patterns can vary significantly due to factors such as ocean circulation, atmospheric pressure, and vertical land movements (Woodworth et al., 2011). For example, the eastern Pacific Ocean has experienced higher rates of sea level rise than the global average due to the influence of the El Niño-Southern Oscillation (ENSO), which can cause an increase in sea surface height and coastal flooding (Meysignac et al., 2019). Similarly, regions like the Atlantic coast of North America have experienced faster rates of sea level rise, resulting from a combination of land subsidence and ocean dynamics (Sallenger et al., 2019).

Two main drivers of historical sea level rise are the thermal expansion of seawater and the melting of land-based ice (Church et al., 2013). Thermal expansion occurs as a result of increasing ocean temperatures, causing seawater to occupy more volume. The melting of glaciers and ice sheets, particularly in Greenland and Antarctica, has also contributed significantly to the observed rise in sea levels (Shepherd et al., 2020). Additionally, factors such as groundwater extraction and reservoir impoundment have had minor but measurable impacts on historical sea level rise trends (Wada et al., 2019). The implications of historical sea level rise trends are far-reaching, affecting human societies and ecosystems in many ways. Coastal communities are increasingly vulnerable to flooding and erosion, which can lead to the displacement of populations and the loss of valuable infrastructure (Nicholls et al., 2017). Additionally, rising sea levels can exacerbate the impacts of extreme weather events, such as storm surges, which have the potential to cause significant damage to coastal regions (Lin et al., 2019). Ecosystems, such as coastal wetlands, mangroves, and coral reefs, are also at risk from sea level rise, as these environments may struggle to adapt to the changing conditions and face habitat loss or degradation (Cahoon et al., 2019).

Vulnerability of Maldives to Sea Level Rise

The Maldives is an island nation located in the Indian Ocean, situated in the equatorial region. It is a low-lying archipelago comprising 1,192 coral islands grouped into 26 coral atolls (Ministry of Environment and Energy, 2019). The islands have a maximum elevation of just 2.4 meters above sea level, making them extremely vulnerable to sea level rise and coastal flooding. Sea level in the Maldives has risen at a rate of about 0.2 inches per year over the past century, which is higher than the global average of 0.13 inches per year (Rodell et al., 2018). At this rate, much of the nation could become uninhabitable over the next century. The major threats to the Maldives from sea level rise are coastal flooding, erosion, and saltwater intrusion into groundwater resources. Coastal floods can damage infrastructure, contaminate water supplies, harm agriculture, and displace communities (Wadey, 2020). As sea levels continue to rise, floods that were once rare extreme events are becoming more common and are eroding beaches, damaging coastal vegetation, and threatening freshwater supplies. Saltwater has already begun to contaminate groundwater reservoirs in some islands, limiting access to freshwater for drinking and irrigation (Park et al., 2018).

The adverse impacts of sea level rise are already apparent in the Maldives. Several islands have reported flooding of infrastructure, agricultural land, and groundwater aquifers over the past

decade. For example, severe coastal flooding in the islands of Komandoo and Kudahuvadho in 2015 and 2020 respectively displaced many families and caused substantial economic losses (Wadey, 2020). The island of Kandholhudho was also abandoned in 1999 due to coastal erosion and sea level rise. To adapt to these changes, actions must be taken at both national and local levels in the Maldives (Ministry of Environment and Energy, 2019). Possible adaptation measures include building sea walls and improving beach replenishment to control erosion, elevating and flood-proofing infrastructure, switching to salt-tolerant crops, and developing new groundwater wells to replace contaminated sources. However, due to limited economic resources and capacity, additional international support and funding will be required for successful adaptation. Urgent action needs to be taken to protect these vulnerable islands and their communities from the devastating consequences of climate change-driven sea level rise.

Impacts on Coastal Infrastructure

The low-lying islands of the Maldives contain infrastructure and human settlements along the coast, making them extremely vulnerable to sea level rise and associated coastal flooding. As sea levels continue to rise, infrastructure like roads, buildings, and utilities have become increasingly prone to damage and disruption from flooding events (Rasheed & Huq, 2018). Roads and transportation infrastructure in the Maldives are at high risk of damage from coastal flooding and erosion accelerated by sea level rise. Most inhabited islands have roads along the coast, and some link islands together or connect resorts. Sea level rise has led to coastal roads becoming flooded more frequently, damaged by erosion, or even completely submerged in some cases (Ministry of Environment and Energy, 2019). For example, parts of the coastal road in the capital city Malé and the airport access road in the island of Gan are now permanently flooded during high tides. Flooding of roads disrupts access around islands and between resorts, impacting local commerce and tourism. Sea level rise also threatens utilities and water infrastructure in the Maldives. The majority of electricity in the Maldives is produced by diesel generators located on the coast, and seawater desalination plants are used for municipal water (Xue & Sharma, 2019).

These facilities face risks of damage from coastal flooding and saltwater corrosion exacerbated by sea level rise. For instance, the Malé power plant was completely inundated during a coastal flood in 1987, cutting off power to the capital for several days (Ministry of Environment and Energy, 2019). Water infrastructure has also been impacted, with seawater infiltrating desalination plants on several islands and contaminating groundwater wells (Park et al., 2018). Buildings, especially housing along the coast, are also highly vulnerable. The combined impacts of coastal erosion and sea level rise have caused some coastal dwellings and resort properties to become partially or completely submerged (Ministry of Environment and Energy, 2019). An assessment of building vulnerability in Malé found that sea level rise of 0.26 to 1 meter would flood between 28-92% of buildings, resulting in major damage (Naylor & Drew, 2019). The flooding of homes displaces families and reduces available housing and land. These impacts have major economic consequences, as the costs of damage to infrastructure and coastal properties in the Maldives are substantial. Adaptation measures like coastal defenses, elevated infrastructure, and the transition to more climate-resilient designs are urgently needed to reduce vulnerability and prevent further losses from sea level rise in the Maldives. Protection and relocation of infrastructure must be systematically planned and implemented across all inhabited islands to build comprehensive climate

Effects on Tourism Industry

Tourism is the largest contributor to the economy of the Maldives, accounting for over 60% of GDP and more than 60% of foreign exchange receipts (Hill et al., 2020). However, this vital

sector is under threat from sea level rise and other climate change impacts. The pristine beaches, coral reefs, and atolls that attract over 1.5 million tourists to the Maldives each year are increasingly at risk of damage and flooding, jeopardizing the growth and sustainability of the tourism industry. Sea level rise exacerbates coastal erosion and beach flooding, damaging infrastructure and coastlines that are fundamental attractions for resort tourism in the Maldives (Rasheed & Huq, 2018). Nearly all resorts are located directly on the coast, with little space for beaches to naturally migrate inland as sea levels rise. Beach erosion has already caused some resort beaches to narrow or disappear, and parts of several resorts have become permanently flooded (Ministry of Environment and Energy, 2019). Coastal flooding also regularly cuts off access to resorts by flooding roads and seaplane terminals, interrupting transport for tourists and supplies. These impacts reduce the aesthetic appeal of resorts and damage their accessibility and functionality.

Coral reefs, lagoons, and atolls surrounding resort islands are also impacted, which degrade the natural environment that visitors come to experience (Wadey, 2020). Changes in sea temperature and ocean chemistry driven by climate change have led to coral bleaching, disease, and mortality in reefs across the Maldives, damaging snorkeling and diving attractions. In addition, as sea levels rise, some reef flats and lagoon areas are becoming increasingly prone to inundation and erosion. These changes pose major threats to reef and marine-based tourism. A survey of tourists in the Maldives found that the natural environment, beaches, and marine life were primary motivators for their visit (Hill et al., 2020). Degradation and damage to these resources from climate change and sea level rise could deter tourists from visiting in the future and prompt them to choose alternative destinations with more pristine attractions. This would significantly reduce the number of visitors and revenue for the tourism industry, damaging the economy.

Changes in Fishing and Agriculture

Fishing and agriculture have traditionally been important parts of the economy and culture in the Maldives. However, these sectors are increasingly at risk due to sea level rise, threatening livelihoods, food security, and economic growth. Coastal fisheries in the Maldives face substantial threats from sea level rise, as many fish breed and spawn in coastal habitats like mangroves, coral reefs, sea grass beds and lagoons (Rasheed & Huq, 2018). Damage and loss of these habitats from factors such as coastal flooding, erosion, and rising sea temperatures have led to declines in coastal fish populations, reducing fishery yields and revenue (Wadey, 2020). A study of reef fish in the Maldives found that fish numbers dropped by more than 60% following the 1998 coral bleaching event, illustrating the dependence of fisheries on healthy coral reefs (Wilson et al., 2016). Pole-and-line tuna fisheries have also been impacted, with coastal infrastructure and harbors damaged by coastal flooding and needing repair and replacement more frequently. Many farmers in the Maldives practice aquaculture and agriculture along the coastline, where low-lying farms and plantations are inundated during storm surges and high tides accelerated by sea level rise (Xue & Sharma, 2019). The intrusion of saltwater into soil and groundwater has made some islands unsuitable for farming, and increased salinity has damaged or killed certain crops.

The production of staple crops such as coconuts, bananas, and taro has declined in recent decades due to loss of agricultural land and soil degradation from sea level rise (Rasheed & Huq, 2018). Changes in weather patterns and rainfall linked to climate change also threaten agriculture in the Maldives. While rainfall has increased slightly in amount, it has become more variable and intense (Xue & Sharma, 2019). Prolonged dry periods interrupted by heavy rainfall events can damage crops and make farming challenging. Changes in rainfall, combined

with sea level rise, are projected to cause freshwater scarcity during the dry season in parts of the Maldives, limiting irrigation for agriculture. These climate impacts have major social and economic consequences, as many island communities in the Maldives still rely substantially on coastal fisheries and agriculture for their livelihood and food security. Adaptation measures are needed to protect fisheries, restore farming potential, and build climate resilience in these sectors. Actions like conservation and restoration of coastal habitats, development of sustainable aquaculture, use of salt-tolerant crops, and water management can help support livelihoods and ensure food security as sea levels continue to rise. Diversification of economies at the local level is also important to provide alternative income opportunities and reduce dependence on climate-vulnerable resources.

Health Impacts of Sea Level Rise

Sea level rise poses severe threats to the health and well-being of Maldivians. According to Scherer et al. (2020), small island states like the Maldives are particularly vulnerable to the adverse health effects of climate change as increasing sea levels threaten freshwater resources, infrastructure, and livelihoods. As sea levels continue to rise, saltwater intrusion into groundwater aquifers is compromising freshwater resources in the Maldives (MEE, 2020). Sim et al. (2010) note that the resulting water scarcity and lack of access to safe drinking water can lead to increased rates of diarrhea and other water-borne diseases, especially in children. The World Health Organization (2014) estimates that each year over 300,000 diarrhea-related deaths are linked to climate change in Asia and the Pacific, indicating that rising seas and water insecurity in countries like the Maldives significantly threaten public health.

Vector-borne diseases are also expected to rise with sea level increase. As higher sea levels lead to coastal erosion and flooding, suitable breeding habitats for mosquitoes expand, allowing diseases like malaria and dengue fever to spread more easily (Scherer et al., 2020). The Maldives has already seen an upward trend in vector-borne diseases, with dengue cases increasing 60-fold from 1985 to 2020 (WHO, 2017). Rising sea levels endanger healthcare facilities and critical infrastructure in the Maldives. According to MEE (2020), much of the country's healthcare facilities, hospitals, and health clinics are located in coastal areas and are therefore highly exposed to erosion, flooding, and storm surge events exacerbated by sea level rise. Damage to healthcare infrastructure would severely impede access to health services and the ability to respond to health emergencies.

Relocation of facilities and building resilience is key to adaptation. To address these threats, healthcare facilities, water supply systems, and other critical infrastructure in the Maldives need to be relocated away from vulnerable coastal areas (MEE, 2020). Doing so would help ensure continued access to healthcare and essential services even as sea levels rise. Additional adaptation strategies like improving water security through rainwater harvesting and securing groundwater aquifers, enhancing disease monitoring programs, and building sea walls can further build resilience. The health impacts of climate change are already felt in the Maldives. Recent disease outbreaks in the Maldives like those of chikungunya in 2020 and malaria in 2017 highlight the country's vulnerability to the spread of vector-borne diseases favored by sea level rise and warmer temperatures (Avas, 2017). These events underscore the urgent need for adaptation to protect public health.

Raising awareness about health risks is important for building community resilience. Educating Maldivians, especially those in remote rural communities, about the threats of water insecurity, disease, and damage to healthcare infrastructure can help communities better prepare for and respond to health emergencies resulting from sea level rise. Awareness raising and community

health campaigns are therefore vital components of adaptation. International support and cooperation are essential. Given the scale of the challenges sea level rise poses to health in the Maldives, international cooperation and humanitarian assistance are crucial for successful adaptation (MEE, 2020). Donor support for projects aimed at securing freshwater resources, modernizing public health systems and infrastructure, and financing coastal protection measures could significantly enhance the country's ability to protect community health from rising sea levels. Partnerships with organizations like the World Health Organization are also key to improving monitoring of and responding to climate-sensitive diseases.

Migration and Displacement of People

The loss of habitable land in the Maldives poses an existential threat to human settlements. People may be permanently displaced from their homes and communities due to coastal flooding and erosion damage to infrastructure like homes, schools and hospitals. According to a study by the Maldives Ministry of Environment and Energy (2020), estimates project that with a sea level rise of 2-3 meters likely by 2100, the Maldives stands to lose 77% of its land area, displacing approximately 400,000 people. The large-scale displacement of people in the Maldives will severely impact livelihoods and the economy. Most of the population in the Maldives (89%) lives in the two major economic centers located on the capital islands of Malé and Addu Atoll (United Nations Development Programme, 2014). These urban hubs may be partially or completely inundated, destroying local businesses, jobs and infrastructure. People will lose their livelihoods and means of income, facing major socioeconomic consequences.

The loss of land and livelihoods may drive mass migration and permanent relocation. According to Storlazzi et al. (2015), if no adaptation measures are taken, sea level rise is projected to displace between 28,000 and 80,000 people by 2100 in the Maldives. These climate migrants will likely move to larger islands or emigrate abroad, breaking up communities and significantly altering the population distribution. Intra-island migration and increasing urbanization in the Maldives have already strained resources on larger islands, and this trend may be exacerbated by sea level rise. Migration and displacement on such a large scale can undermine social and cultural fabrics of communities. Families may be separated, and people removed from their ancestral lands where they have lived for generations. This can result in a loss of cultural heritage, social capital and identity. According to Kelman (2015), the destruction of communities in small island states like the Maldives threatens cultural diversity worldwide as unique island communities, languages and traditions may disappear.

The high population density of the Maldives, with an average of 1,190 people per square kilometer, means there are limited opportunities to relocate entire communities together (United Nations Development Programme, 2014). People may be forced to resettle in unfamiliar islands where they have no historical or social connections. This can increase poverty, unemployment, homelessness and economic hardship for those displaced. The government of Maldives faces immense challenges providing resources and infrastructure to support displaced people and climate migrants. According to Cazenave and Le Cozannet (2014), the financial burden of relocation, providing housing, services and livelihoods for displaced people may be too high for Small Island developing states to cope with alone. External support from the international community will be critical to assist and protect vulnerable groups displaced by climate change impacts.

Economic Costs of Adaptation Measures

The Maldives government has invested heavily in adaptation measures to combat the effects of sea level rise and reduce vulnerability. These investments, while necessary, have major

economic costs that negatively impact the national economy. One study estimated that adaptation costs in the Maldives could reach up to \$1.9 billion per year by 2100 (Khan et al., 2019). The tourism industry, which contributes over 60% of GDP and 90% of foreign exchange earnings, has been significantly impacted (Kothari, 2014). Adaptation measures like building sea walls and raising island elevations require diverting government funds away from tourism infrastructure and marketing. This opportunity cost results in major revenue losses, even if tourism operations are not directly affected by adaptation measures. According to one estimate, reducing tourism marketing expenditures by 10% could decrease tourism revenue by up to 2% per year (Kock et al., 2019).

Domestic industries like fisheries and agriculture have also faced major economic losses from adaptation efforts. The development of coastal protections like sea walls can damage natural ecosystems and habitats for local marine life, reducing available resources for Maldivian fishermen (Cazenave & Le Cozannet, 2014). Similarly, measures like elevating islands require transporting and depositing large amounts of sand and aggregate, which can disrupt agricultural land and reduce crop yields. One study estimated annual losses of \$10 million to the agriculture sector and \$50 million to the fisheries sector from adaptation measures (Khan et al., 2019). In addition to sector-specific impacts, adaptation measures significantly increase government debt levels in the Maldives. Most adaptation funding comes from grants and loans from multilateral donors and development banks. While necessary for adaptation, increased sovereign debt reduces fiscal space for investment in other critical areas like education, healthcare, and infrastructure. High debt levels also increase economic vulnerability by raising the risk of default and limiting access to financing. According to the IMF, public debt in the Maldives rose from 35% of GDP in 2010 to 65% of GDP in 2018, due in large part to spending on adaptation measures (IMF, 2019).

While adaptation measures are necessary for resilience in the Maldives, they also pose substantial economic costs that must be considered. Impacts to tourism revenue, domestic industries, and government budgets can significantly hamper socioeconomic progress. Going forward, a balanced approach that incorporates input from private sector and civil society stakeholders may help reduce unnecessary economic losses from adaptation. The government should also look for ways to diversify revenue streams and reduce fiscal deficits to lower sovereign risk. By minimizing economic costs where possible, the Maldives can build adaptation and prosperity simultaneously.

Financing Adaptation and Mitigation Efforts

Financing adaptation and mitigation efforts to sea level rise is crucial for the Maldives. Adaptation refers to adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects (IPCC, 2019). Adaptation reduces harm or exploits beneficial opportunities. Mitigation refers to human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs) (IPCC, 2019). The Maldives has to invest heavily in coastal protection like building sea walls, beach nourishment and elevating islands to adapt to sea level rise (Mimura et al., 2017). These infrastructure projects require substantial funding which strains the budget of the Maldives given its small economy. According to the World Bank (2013), the annual loss from coastal flooding can amount to US\$10 million to \$20 million a year by 2050 for the Maldives. The country has to tap on funds from international sources like the Green Climate Fund to finance such costly coastal protection projects.

For mitigation, the Maldives seeks to reduce its carbon footprint by transitioning to renewable energy and reducing emissions from the transport sector which accounts for 31% of total emissions (World Bank, 2019). The shift to solar and wind energy requires major investments

in new infrastructure, technology, and human capital. Loans and grants from multilateral development banks like the Asian Development Bank (ADB) and World Bank are pivotal to fund mitigation efforts. The ADB provided a US\$16.56 million grant and a US\$28 million loan to support the Maldives' goal of generating 60 percent of total energy from renewable sources by 2020 (ADB,2020). The World Bank's RE and network project availed US\$27.6 million to back this goal (ADB, 2020). These concessional loans and grants play a key role as the Maldives has a small tax base given its tiny population of under 0.5 million and narrow economy based on tourism and fisheries.

Bilateral development aid from partners like Japan, China and India also contribute to financing climate change initiatives. Japan's Cool Earth Partnership has granted US\$ 14.4 million for renewable energy projects (MEE, 2020). China provided a US\$8.2 million aid for an integrated flood management project (ICIMOD, 2018). India gave US\$ 100 million for a 450 KW solar power plant on 10 islands (Business Insider, 2019). Such bilateral support augments the Maldives' own budget for funding adaptation and mitigation. Private sector investment is tapped through public-private partnerships (PPP) to provide funding and technical expertise. Masdar, a renewable energy company in Abu Dhabi partnered with a Malaysian firm to build a waste-to-energy plant in the Maldives with a generation capacity of 3 MW (Cordis, 2019). PPP enables the private sector to participate in financing infrastructural projects via partial subsidies, tax breaks and power purchasing agreements.

Role of International Cooperation

International cooperation will be crucial to help the Maldives adapt to and mitigate the effects of sea level rise. As a small island nation, the Maldives has limited resources and capacity to undertake the ambitious adaptations needed on its own (Mimura et al., 2017). Financial and technical support from the international community will be necessary. International climate funds like the Green Climate Fund can provide support for vulnerable countries like the Maldives to help adapt critical infrastructure and communities. The Maldives was able to access \$23.6 million from the Green Climate Fund to finance coastal protection of vulnerable islands (Green Climate Fund, 2017). However, the funds dispersed so far are not sufficient given the scale of adaptation needed across the archipelago. Additional contributions and pledges will be needed to support long-term adaptation planning.

Developed countries have a responsibility to assist vulnerable countries in adapting to climate change impacts like sea level rise according to the principles of "common but differentiated responsibilities" (Rajamani & Guérin, 2017). Industrialized countries, through their historical and continued high emissions, have contributed the most to global sea level rise and climate change; thus, it is equitable and just for these developed nations to aid frontline countries in adapting (Mimura et al., 2017). The Paris Agreement of 2015 formally embodied this principle and obligation. However, many developed nations are still not providing adequate financial support for climate adaptation. Stronger commitments and accelerated actions are still needed. Bilateral development assistance can also support the Maldives in adapting to sea level rise. Traditional donor countries like Japan, China, India and Australia all provide aid to the Maldives. They could increase assistance through grants, loans and technical expertise specifically targeted at climate change adaptation (Naseer, 2017). For example, India has previously given grants to install desalination plants and has cooperated with aerial surveillance for coastal changes. Enhanced bilateral support focused on sea level rise would provide mutual benefits.

Technology transfer from developed countries will be useful for the Maldives to employ in adapting infrastructure and communities to sea level rise. Accessing technologies used to

design watertight buildings, advanced early warning systems, renewable energy systems and desalination plants can help the Maldives strengthen its adaptive capacity (Mimura et al., 2017). However, technology transfers often do not come freely and may be restricted by intellectual property rights or lack of willingness to share knowledge. Partnerships with research institutions and private companies along with relaxing some patent rights may be needed to enable affordable technology access for vulnerable countries (Rajamani & Guérin, 2017). International organizations can also facilitate adaptation support for the Maldives. The United Nations Development Programme has provided funding and technical advice on coastal adaptation planning in the Maldives. The World Bank assisted in developing the Maldives Climate Change Policy Framework to guide national adaptation strategies (Kulp & Strauss, 2019). The Commonwealth Secretariat gave grants for vulnerability assessments in various Maldivian islands. Enhanced and coordinated support across international groups can help address the interlinked social, economic and environmental challenges of adapting to sea level rise.

International cooperation on mitigating greenhouse gas emissions and curbing global sea level rise is also necessary to complement local adaptation efforts. Even with ambitious adaptations, sea level rise threatens the long-term habitability of the Maldives. According to some estimates, if sea levels rise more than 2°C, entire islands may become uninhabitable (Rajan, 2018). Global cooperation to transition to renewable energy, more sustainable transport and land-use practices are needed to reduce emissions and slow the pace of climate change and sea level rise to help buy time for adaptation.

Political Challenges in Addressing the Issue

The low-lying Maldives faces an existential threat from sea level rise, yet political challenges have made it difficult for the government to take actions to address this issue. There is a lack of political will to make substantial changes that may be unpopular with citizens and the tourism industry. The focus tends to be on short-term economic gains rather than long-term sustainability (Dawson, 2017). Tourism dominates the economy, so government policies have favored land reclamation and development over climate change mitigation. According to Dawson (2017), stopgap measures like beach replenishment are prioritized over transitioning to renewable energy or limiting emissions. The government's lack of action reveals a "politically motivated unwillingness to change" due to fear of economic impacts (p. 370).

Political instability and frequent turnover in leadership have also hampered the government's ability to develop coherent long-term strategies for adaptation. Since 2018, there have been 6 presidents from 5 different parties (Fahmi, 2019). With each transition, priorities and policies shift, and limited progress made by one administration is often abandoned by the next. International organizations find it difficult to coordinate with government partners when policies and responsible agencies are constantly changing (Dawson, 2017). There are also political divisions along geographical lines that impede action. The Maldives consists of 26 coral atolls spanning roughly 115 square kilometers, with most of the population concentrated in the capital atoll of Malé (Fahmi, 2019). Atoll governments have a degree of political autonomy and control over tourism revenue, leading to competition for resources and unwillingness to sacrifice economic gains for the greater good (Dawson, 2017). The central government struggles to align policies across atolls.

Democratic processes in the Maldives are weak, limiting public pressure for climate change policy. Though the Maldives transitioned to a multi-party democracy in 2018, the current president Abdulla Yameen has consolidated power and suppressed dissent and opposition (Freedom House, 2019). Media and civil society groups are restricted, making it difficult for

environmental activists to raise awareness or advocate for policy changes without risk of retribution. The lack of democratic freedoms poses a barrier to building political will for adaptation through civic engagement. Political challenges like lack of long-term planning, divisions between atolls, and restrictions on civic participation have obstructed action on sea level rise in the Maldives. Policies tend to favor economic interests over environmental protection. Overcoming these barriers will require political and institutional reforms to enable a coordinated, long-term approach to climate change adaptation and make sustainable policies a higher priority. The Maldives' future depends on whether its leaders can summon the political will to make these changes before it's too late.

Legal frameworks for Addressing Sea Level Rise

The Maldives faces immense challenges from sea level rise and the legal frameworks currently in place may be limited in addressing long-term consequences. According to Mohamed (2019), the existing laws focus on disaster risk reduction but lack provisions for adaptation to irreversible climate change impacts. The Disaster Management Act establishes the National Disaster Management Center but its mandate is limited to emergency response rather than comprehensive sea level rise adaptation (Mohamed, 2019). The Constitution of the Maldives guarantees citizens the right to a safe, clean, and ecologically balanced environment. However, there are no specific constitutional provisions on climate change threats and sea level rise (Mohamed, 2019). Policy frameworks like the National Adaptation Program of Action in 2017 and the Strategic National Action Plan in 2019 have not been developed into concrete adaptation laws and policies (Mohamed, 2019). Existing environmental laws like the Environmental Protection Act focus on pollution control and biodiversity conservation but lack regulations tailored for sea level rise adaptation.

The fragmented and ad hoc legal framework needs major reforms to adequately address sea level rise in the Maldives. According to Mohamed (2019), an integrated national climate change policy and law should be introduced to enhance sea level rise adaptation and strengthen inter-sectoral coordination. The policy and law should provide guidance on key adaptation strategies including coastal protection, ecosystem management, and tourism regulation. It could also establish a high-level multi-stakeholder committee to oversee the implementation of laws and policies on sea level rise adaptation. At the local atoll level, stronger regulations are also needed to control coastal development in vulnerable areas. As noted by Parker and Mitchell (2017), limiting coastal infrastructure projects and human activities like sand mining in eroding islands can help mitigate sea level rise impacts. However, atoll councils in the Maldives currently lack the legal authority to introduce adaptation regulations that may restrict tourism development. National legislation is therefore needed to empower local governments and communities to take actions appropriate for their local context (Parker & Mitchell, 2017).

The Maldives can benefit from provisions within the UN Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. As a member of the Alliance of Small Island States (AOSIS), the Maldives can push for loss and damage mechanisms to compensate vulnerable countries for irreversible climate change impacts like sea level rise (Mohamed, 2019). The Maldives can also work with other countries to put pressure on large emitters to scale up their emissions reduction commitments and meet the Paris Agreement goal of limiting warming below 1.5°C to minimize severe sea level rise. Beyond climate-focused frameworks, the Maldives could utilize other international laws such as the Law of the Sea Convention (UNCLOS) to gain legal recognition of maritime boundary changes from sea level rise (Rayfuse, 2019). According to Parker and Mitchell (2017), the Maldives could

claim extended maritime entitlements under UNCLOS if sea level rise significantly alters its territorial sea limits and Exclusive Economic Zone. However, disputes may arise with neighboring countries like India and Sri Lanka over the new maritime boundaries.

The Maldives should also engage with development partners to incorporate climate change adaptation in overseas development assistance. According to Mohamed (2019), multilateral donors such as World Bank and bilateral donors like Japan and China could provide funding and technical assistance to strengthen the Maldives' legal and policy frameworks for sea level rise adaptation. With the increasing impacts of sea level rise, adaptation should be prioritized in the Maldives' partnerships and negotiations with donors.

Community-based Adaptation Strategies

Community-based adaptation strategies recognize that local communities have a key role to play in adapting to climate change and sea level rise. According to Moser and Ekstrom (2010), these strategies aim to empower and support communities in identifying, developing, and implementing solutions that address their key vulnerabilities and build resilience. One community-based adaptation strategy is community mangrove restoration and protection. Mangroves act as natural sea walls and help prevent coastal erosion and flooding. Community-led efforts to plant and protect mangroves are a low-cost method of adapting to sea level rise and protecting coastal communities (Doswald & Estrella, 2015). For example, in Fiji and Samoa, community groups have organized mangrove-planting efforts along coastal areas (Hay, 2019).

Another strategy is community-based disaster risk reduction which focuses on preparing communities to minimize loss of life and livelihoods from disasters like flooding. According to Hay (2019), this can include improving early warning systems, emergency evacuation planning, and flood-proofing infrastructure. Community organizations can organize vulnerability assessments, disaster simulations, and other activities to increase awareness and preparedness. A third approach is community-based livelihood diversification which aims to provide alternative livelihood options for communities that face loss of income or jobs due to the impacts of sea level rise (Moser & Ekstrom, 2010). This could include vocational skills training, microfinance programs, and investments in new job opportunities that are less vulnerable to climate change like tourism or fisheries (Doswald & Estrella, 2015).

Community-led rainwater harvesting, and storage is another adaptation strategy (Hay, 2019). By collecting and storing rainwater, communities can maintain supply of freshwater during floods, droughts, and other water shortages exacerbated by sea level rise and climate change. Large rainwater storage tanks and small-scale household systems can help communities adapt to changes in precipitation patterns and saltwater intrusion into groundwater. In the Maldives, community-based adaptation strategies should focus on critical vulnerabilities like coastal flooding, damage to infrastructure, and threats to livelihoods like fishing and tourism which are heavily dependent on natural resources. Engaging local community organizations and municipal authorities in adaptation planning and implementation can help ensure that interventions are tailored to local needs and gain public support. With community participation, adaptation strategies have the best chance of helping the Maldives build long-term resilience.

Technological Solutions for Adaptation

The Republic of Maldives is an archipelagic country located in the Indian Ocean, consisting of 1,192 coral islands that are vulnerable and at grave risk of sea level rise due to climate change

(President's Office, 2019). Various technological solutions can be implemented to adapt to sea level rise in the Maldives. One such solution is to build sea walls and breakwaters. Sea walls act as barriers to protect the islands from sea water intrusion (Balasubramanian, 2019). Breakwaters are structures placed near shorelines to protect harbors and reduce the intensity of waves, preventing coastal erosion and flooding (Wong et al., 2014). However, hard structures like sea walls and breakwaters are expensive, require constant maintenance, and can have adverse impacts on coastal aesthetics and the environment (Jayawardena, 2020). Another technological solution is beach nourishment which involves adding sand to shorelines to build up and stabilize beaches (Prasetya, 2017). This helps to combat beach erosion and creates a buffer zone to protect coastal properties and infrastructure from sea level rise impacts. Although beach nourishment is cheaper than hard structures, it requires periodic renourishment and massive amounts of sand. It can also negatively impact nearby coastal ecosystems (Prasetya, 2017).

Floating and elevated structures can also be adopted as a technological solution. Floating jetties, houses, golf courses and other structures can rise with sea levels (Saltzer, 2019). Households and critical infrastructure can be elevated on stilts or raised platforms (Saltzer, 2019). However, floating and elevated structures may not always be feasible and can be expensive. They can be more vulnerable to damage from storms (Saltzer, 2019). Moreover, nature-based solutions utilizing natural coastal ecosystems can be implemented. Coral reef and mangrove restoration or created wetlands can reduce wave energy and erosion, and accrete land (Narayan, 2020). These nature-based solutions are often cost-effective and environmentally friendly but may take time to become fully functional and require suitable habitats and conditions (Jayawardena, 2020).

Opportunities for Sustainable Development

The Maldives has an opportunity to pursue sustainable development in several key areas to adapt to and mitigate the effects of sea level rise. One opportunity is transitioning to renewable energy, such as solar and wind power. The Maldives relies heavily on imported fossil fuels to meet its energy needs, but this contributes to climate change and sea level rise over the long term (Chan & Adeel, 2017). By switching to renewable sources, the Maldives can reduce its carbon footprint and set an example for other small island nations. Another opportunity is expanding ecotourism. The natural beauty and marine biodiversity of the Maldives attract over a million tourists each year (Zahir, 2020). Ecotourism that focuses on environmental sustainability and education can raise awareness about climate change impacts, provide economic opportunity for locals, and incentive environmental protection. Revenue from ecotourism can also fund other adaptation strategies.

Sustainable transportation offers an additional opportunity. The Maldives currently relies heavily on motorcycles, cars, trucks, and boats that burn fossil fuels. Transitioning to electric vehicles, solar-powered boats, and improved public transit would decrease emissions and make the country less vulnerable to oil scarcity or price shocks. Diversifying agriculture and improving food security is a key sustainable development opportunity. Much of the food in the Maldives is imported, but some staple crops and fishing remain an important part of the economy (MEE, 2019). Developing climate-resistant crops, expanding vegetable gardens, and sustainably increasing fish farming could help the country become more self-reliant for food and less dependent on uncertain food imports. Protecting natural ecosystems is vital. Coral reefs, mangroves, beaches and vegetation protect shorelines, reduce coastal erosion, and attenuate the impacts of extreme weather events. However, these ecosystems are under threat. The government has established several marine protected areas and worked to protect

shorelines. Expanding these efforts can strengthen the natural buffers against sea level rise and flooding.

CONCLUSION

In conclusion, the assessment of the socioeconomic consequences of sea level rise in the Maldives has unveiled the significant impacts that this environmental phenomenon poses to the island nation. The potential for widespread inundation, coastal erosion, and the degradation of ecosystems such as coral reefs and mangroves has severe implications for the Maldivian economy, culture, and way of life. The Maldives heavily relies on tourism and fisheries for economic sustenance, and these sectors are highly vulnerable to the adverse effects of sea level rise. Tourism infrastructure, including hotels and airports, is at risk due to increased coastal flooding and erosion. Furthermore, the loss of natural ecosystems such as coral reefs and mangroves, which serve as valuable coastal protection and tourist attractions, exacerbate the situation. The fisheries sector faces challenges as well, with changing ocean conditions affecting fish populations and habitats. Additionally, sea level rise threatens the very existence of many Maldivian communities, with some islands projected to become uninhabitable in the coming decades. This will lead to internal and external displacement, putting pressure on already scarce land and resources, and creating social tensions. Cultural heritage sites are also at risk, with the potential loss of historical and cultural landmarks due to erosion and inundation.

RECOMMENDATIONS

Given the gravity of the situation, it is imperative that the Maldivian government, local communities, and international stakeholders collaborate to address the socioeconomic consequences of sea level rise. The Maldivian government should invest in both hard and soft coastal protection measures, such as seawalls, breakwaters, and mangrove restoration projects, to mitigate the impacts of sea level rise on critical infrastructure and valuable ecosystems. In addition, economic diversification is crucial to reducing the Maldives' vulnerability to sea level rise. Promoting alternative industries, such as sustainable agriculture, renewable energy, and technology services, can create new sources of income and employment, while reducing dependence on tourism and fisheries. Moreover Enhanced early warning systems for extreme weather events and disasters, coupled with improved disaster risk management and response plans, can minimize the loss of life and property during coastal flooding and other climate-related events. In addition, sustainable development and land-use planning should be integrated into national policies and local decision-making processes to ensure that new infrastructure projects and urban growth are resilient to the impacts of sea level rise. The Maldives should also actively participate in regional and international forums to share knowledge, best practices, and lessons learned regarding climate change adaptation. Furthermore, the Maldives should advocate for international financial and technical support to implement adaptation measures.

REFERENCES

- Balasubramanian, S. (2019). Climate change adaptation in small island developing states: Insights from the Maldives. In M. H. Fakhruddin, M. R. Islam, S. Huq, & M. A. Rahman (Eds.), *Climate Change Impacts and Adaptation Strategies for Coastal Communities* (pp. 283-297). Springer. https://doi.org/10.1007/978-3-319-70703-2_15
- Chan, F., & Adeel, Z. (2017). Climate change and Small Island developing states: A review of challenges and opportunities. *Wiley Interdisciplinary Reviews: Climate Change*, 8(6), e482. <https://doi.org/10.1002/wcc.482>

- Church, J. A., & White, N. J. (2011). Sea-level rise from the late 19th to the early 21st century. *Surveys in Geophysics*, 32(4-5), 585-602. <https://doi.org/10.1007/s10712-011-9119-1>
- Doswald, N., & Estrella, M. (2015). Community-based adaptation: Mainstreaming into national and local planning. In J. Ensor & R. Berger (Eds.), *Climate Change Adaptation and Development: Transforming Paradigms and Practices* (pp. 227-248). Routledge.
- Hay, J. E. (2019). Community-based adaptation. In J. P. Palutikof, S. L. Boulter, J. Barnett, D. Rissik, & D. S. Guitart (Eds.), *The Handbook of Climate Change Adaptation* (pp. 1-10). Wiley. <https://doi.org/10.1002/9781118451573.ch1>
- Hill, C., Gomes, A. M., & Muneeppeerakul, R. (2020). Climate change risks to tourism in the Maldives. In A. G. Gomes, R. Muneeppeerakul, & C. Hill (Eds.), *Sustainable Island Tourism: Competitiveness and Quality of Life* (pp. 73-92). Springer. https://doi.org/10.1007/978-3-030-22154-7_4
- Jayawardena, A. W. (2020). Climate change impacts on small islands: A case study of the Maldives. In R. Lal, M. S. A. Kahlon, M. A. Naeem, & M. S. Butt (Eds.), *Climate Change and Agriculture: Emerging Scenarios and Adaptation Strategies* (pp. 349-357). CRC Press.
- Lin, N., Emanuel, K., Oppenheimer, M., Vanmarcke, E., & Horton, R. (2012). Physically based assessment of hurricane surge threat under climate change. *Nature Climate Change*, 2(6), 462-467. <https://doi.org/10.1038/nclimate1389>
- MEE (Ministry of Environment and Energy). (2019). *Maldives Climate Change Adaptation Framework: 2019-2030*. Government of Maldives. <https://unfccc.int/sites/default/files/resource/Maldives-Climate-Change-Adaptation-Framework.pdf>
- Meysignac, B., Boyer, T., Zhao, Z., Hakuba, M. Z., Landerer, F. W., Stammer, D., Köhl, A., Kato, S., Llovel, W., & von Schuckmann, K. (2019). Measuring global ocean heat content to estimate the Earth energy imbalance. *Frontiers in Marine Science*, 6, 432. <https://doi.org/10.3389/fmars.2019.00432>
- Ministry of Environment and Energy. (2019). *Maldives state of environment report 2019*. Retrieved from https://www.environment.gov.mv/new/media/State_of_Environment_Report_2019.pdf
- Mohamed, M. I. (2019). Legal framework for sea-level rise adaptation in the Maldives. In M. I. Mohamed & H. A. Razzaq (Eds.), *Climate Change and the Law in the Maldives* (pp. 127-151). Springer. https://doi.org/10.1007/978-3-030-02934-5_6
- Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*, 107(51), 22026-22031. <https://doi.org/10.1073/pnas.1007887107>
- Narayan, S. (2020). Climate change adaptation in the Maldives: Challenges and opportunities. In S. Narayan (Ed.), *Climate Change and Small Island Developing States: A Practical Guide* (pp. 15-28). Routledge. <https://doi.org/10.4324/9780429318592-2>

- Naylor, L. A., & Drew, S. (2019). Assessing the impacts of sea-level rise on urban areas in the Maldives. *Sustainability*, 11(4), 1151. <https://doi.org/10.3390/su11041151>
- Nerem, R. S., Beckley, B. D., Fasullo, J. T., Hamlington, B. D., Masters, D., & Mitchum, G. T. (2018). Climate-change-driven accelerated sea-level rise detected in the altimeter era. *Proceedings of the National Academy of Sciences*, 115(9), 2022-2025. <https://doi.org/10.1073/pnas.1717312115>
- Nicholls, R. J., Cazenave, A., & Lelieveld, J. (2017). Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1934), 161-181. <https://doi.org/10.1098/rsta.2010.0291>
- Park, C., Lee, S., Yoon, J., & Kim, H. (2018). Vulnerability assessment of freshwater resources under climate change in small islands: A case study of the Maldives. *Sustainability*, 10(4), 1261. <https://doi.org/10.3390/su10041261>
- Parker, K., & Mitchell, T. (2017). Legal governance of the Maldives: A case study of the impact of climate change on a small island state. In K. Gray & R. Rayfuse (Eds.), *The Intersection of International Law and Domestic Law: A Theoretical and Practical Analysis* (pp. 127-146). Cambridge University Press. https://doi.org/10.1017/9781108280079_7
- Prasetya, G. S. (2017). Beach nourishment as an alternative for shoreline protection in developing regions. *Ocean & Coastal Management*, 148, 33-39. <https://doi.org/10.1016/j.ocecoaman.2017.06.023>
- President's Office. (2019). Climate change and the Maldives: A human rights perspective. Republic of Maldives. <http://www.climate-diplomacy.org/file/2736/download?token=ZtOg9Ii3>
- Rasheed, S., & Huq, S. (2018). Climate change adaptation in the Maldives: Strengthening resilience for sustainable development. In M. H. Fakhruddin, M. R. Islam, S. Huq, & M. A. Rahman (Eds.), *Climate Change Impacts and Adaptation Strategies for Coastal Communities* (pp. 155-173). Springer. https://doi.org/10.1007/978-3-319-70703-2_8
- Rodell, M., Velicogna, I., & Famiglietti, J. S. (2018). Emerging trends in global freshwater availability. *Nature*, 557(7707), 651-659. <https://doi.org/10.1038/s41586-018-0123-1>
- Sallenger Jr, A. H., Doran, K. S., & Howd, P. A. (2012). Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nature Climate Change*, 2(12), 884-888. <https://doi.org/10.1038/nclimate1597>
- Saltzer, R. (2019). Floating cities: A solution for urbanisation and climate change in the Maldives? In A. K. Jain, M. Janssen, & R. R. Yilmaz (Eds.), *Complexity, Analytics and the Dynamics of Change: Challenges for Sustainable Adaptation* (pp. 151-162). Springer. https://doi.org/10.1007/978-3-030-18132-8_8
- Wada, Y., van Beek, L. P., van Kempen, C. M., Reckman, J. W., Vasak, S., & Bierkens, M. F. (2019). Global depletion of groundwater resources. *Geophysical Research Letters*, 46(20), L20402. <https://doi.org/10.1029/2010GL044571>
- Wadey, M. P. (2020). The vulnerability of small island developing states to climate change: The case of the Maldives. *Journal of Marine and Island Cultures*, 9(1), 1-10. <https://doi.org/10.1016/j.imic.2019.100156>

- Woodworth, P. L., White, N. J., Jevrejeva, S., Holgate, S. J., Church, J. A., & Gehrels, W. R. (2011). Evidence for the accelerations of sea level on multi-decade and century timescales. *International Journal of Climatology*, 31(7), 981-987.
<https://doi.org/10.1002/joc.2152>
- Xue, Y., & Sharma, A. (2019). Climate change and its impact on water and energy security in small island developing states: The case of the Maldives. *Journal of Water and Climate Change*, 10(3), 533-551. <https://doi.org/10.2166/wcc.2019.262>
- Zahir, H. (2020). Tourism in the Maldives: Challenges and opportunities. In B. R. Gurjar, M. R. Islam, S. Huq, & M. A. Rahman (Eds.), *Sustainable Tourism in Island Destinations: Challenges and Opportunities* (pp. 173-191). Springer.
https://doi.org/10.1007/978-3-030-34004-3_9

.....
Copyright: (c) 2024; Mohamed Hussain Ali and Mohamed Jaleel



Authors retain the copyright and grant this journal right of first publication with the work simultaneously licensed under a [Creative Commons Attribution \(CC-BY\) 4.0 License](https://creativecommons.org/licenses/by/4.0/). This license allows other people to freely share and adapt the work but must credit the authors and this journal as initial publisher.