Climate Change Impact on Coastal Resources in Sri Lanka*

Sea warming and sea level rise may impact strongly on coastal fisheries and agriculture in Sri Lanka, aggravating the poverty of coastal communities. Sri Lanka cannot prevent climate change, but can adopt mitigation/ preparedness strategies. This study, carried out by the National Aquatic Resources Research and Development Agency (NARA) discusses how climate change will impact on coastal resources. It also identifies several activities to overcome the impact of climate change on fisheries and agriculture – such as culture of seaweed, oyster farming, crab fattening, artificial production of marine ornamental fish, value addition to agriculture and fisheries products, and use of fish aggregating devices.

The coastline of Sri Lanka is about 1 760 km long, the third longest in South Asia. A total of 4.6 million people (about one quarter of the population), lives along the coast. Sri Lanka's coastline exhibits considerable geographic diversity; bays, long sandy beaches, lagoons, dunes, bar built lagoons and estuaries.

It supports a unique ecosystem and serves as base for sensitive habitats such as mangroves, coral reef beds and seaweed beds. The coastal zone is extremely sensitive to changes in climate. It is prone to disasters but also acts as a buffer zone against disaster. Fishery is the major livelihood in the coastal zone. Agriculture is important as well.

Coastal fisheries accounts for almost three quarters of the total fisheries production in Sri Lanka. The fishery sector contributed about 1.2 percent of the GDP in 2006 and continues to be an important source of foreign exchange. In 2006, fishery export amounted to 138 million US $. Prawns, mainly from culture (80%) accounted for 14 percent of the export value from fisheries products. The ornamental fish industry based on coral reefs is rapidly expanding since the early 1990s. The coastal zone supports infrastructure for coastal and offshore fisheries, tourism, recreation, and navigation.

Sea level rise has intensified coastal erosion, siltation of estuaries,

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saltwater intrusion into rivers and salination of coastal plains. Increased siltation and reduced fresh water discharge into the coastal zone have enhanced sedimentation on the coastal zone. Anthropogenic activities – such as overexploitation of resources, emission of green house gases, deforestation, ad hoc irrigation, land use changes, sand mining – accelerate the slow processes of climatic change.

A Coastal Zone Management Plan was introduced in Sri Lanka in 1997 to integrate development activities and protect the coastal environment and resources. The Plan has focused primarily on the vulnerability of the coast to erosion. But vulnerability to climate change has not received adequate attention.

Climate system and its components

Climate is an outcome of the exchange of heat and mass between various components of nature. Climate evolves in time under the influence of its own internal dynamics; also by interaction among various components of nature and their physical, chemical and biological properties. The natural components are – atmosphere, hydrosphere (ocean), cryosphere (ice sheets), lithosphere (land) and biosphere. The system is also influenced by external forces such as volcanic eruptions, solar variations, composition change of the atmosphere, land-use change.

Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. In general, 'climate change' is attributable to human activities altering the atmospheric composition, and 'climate variability' attributable to natural causes.

Natural processes and their impacts on climate

Climate change can be classified into 'forcings' and 'feedbacks'. A climate forcing is an energy imbalance imposed on the climate system by natural processes (such as changes in solar energy output, volcanic emissions) and anthropogenic effect (such as emissions of greenhouse gases, aerosols, and their precursors). A climate feedback is an internal climate process that amplifies or dampens the climate response to an initial forcing.

Various hypotheses have been formulated for long-term climate change. But no generally accepted explanation fits all observed characteristics. Some of the hypotheses are:

- Change in Earth's orbit, thus variations in solar radiation (20, 40 & 100 kyr);
- Isostatic readjustments;
- Transition between steady states;
- Non-linear transfer from 20 & 40 kyr;
- Slow CO_2 feedback; and
- Inter-planetary dust.

Over the last 400 000 years the Earth's climate has been unstable, with very significant temperature changes. These changes suggest that climate may be quite sensitive to internal or external climate forcings and feedbacks. But during the last 10 000 years, temperatures have been less varying. Based on the incomplete evidence available, it is unlikely that global mean temperatures have varied by more than 1°C in a century during this period. Records indicate a strong correlation between carbon dioxide content in the atmosphere and temperature.

Geological data indicates that global average sea level may have risen at an average rate of about 0.5 mm/ yr over the last 6 000 years. At an average rate of 0.1 to 0.2 mm/ yr over the last 3 000 years, global warming will lead to a sea level rise of 110 to 880 mm.

Anthropogenic impacts on the climate

Human activities add to nature's influences on climate. Human impacts on the climate system include increasing concentrations of atmospheric greenhouse gases (*e.g.,* carbon dioxide, chlorofluorocarbons and their substitutes, methane, nitrous oxide, etc), air pollution, increasing concentrations of airborne particles, and land alteration.

Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30 percent, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15 percent. These increases have enhanced the heat-trapping capability of the earth's atmosphere.

While some gases, such as carbon dioxide and methane in the upper atmosphere, create the greenhouse effect associated with global warming, other pollutants, such as sulfur dioxide and nitrogen oxides in the lower atmosphere cool the earth's surface by reflecting sunlight.

Coastal bio-physical features and resources

Sri Lanka's coastal region comprises 74 administrative divisions. They contain about:

- 23 percent of the islands 65 610 km^2 land area, 25 percent of the population, including 65 percent of the total urban population, 70 percent of the tourist hotels, 62 percent of the industrial units and 285 sq. km of lands gazetted as municipal and urban lands;
- Habitats that are vital for ecological functions, maintaining biodiversity and economic activities, especially the coastal and marine fishery; and
- A large number of high priority archeological, historical, religious and cultural sites, as well as scenic and recreational sites.

The coastal fishery accounts for about 68 percent of the coastal and marine fishery, which together provides 88 percent of the total fish production in Sri Lanka. Agricultural lands comprise around

17 percent of the coastal zone, while home gardens comprise about 20 percent.

Fisheries and aquaculture: The Sri Lankan fishery is dominated by coastal fishing. Coastal fisheries are broadly defined as fishing activities taking place in the area of the continental shelf or the fisheries conducted within a day (24 hrs). However, in general, fishing activities within the area of the sea extending up to 40 km from the coast are considered as the coastal fishery. At present, coastal fisheries accounts for 48 percent of the total fish production (with about 121 360 metric tonnes) while offshore and inland and aquaculture contribute 38 and 14 percent respectively.

More than 1 337 fishing villages are scattered along the coastline of Sri Lanka and some 128 400 households live in these villages. The fisheries directly employ over 143 150 fishermen. It is estimated that around 15 percent of the marine landings are from reef fisheries.

The coastal zone is heavily used for fish landings. Sri Lanka has some 752 minor fish landing sites scattered along the coast besides 10 main fishery harbours and 19 anchorages. The total marine fishing family population amounts to 626 940. It is estimated that more than a million people from the coastal community depend on fisheries for their livelihood. The fisheries sector contributes more than SLR 14 440 million foreign exchange through export of marine and aquaculture products.

Mineral resources: Coastal areas contain several types of quaternary deposits among which are sands, sandstone, quartz, gravels, red earth and inland coral deposits. Among the important minerals in coastal areas are heavy mineral sands (Kokilai to Pulmodi, Kuderamali, Trincomalee, Beruwala and Hambantota), Silica sand (Madampe-Nattandia, Vallipuram), salt (Puttalam, Mannar, Elephant Pass and Hambantota). Miocene limestone (Puttalam, Mullithevu,

Jaffna Peninsula), iron ore (Ratgama), and moonstones (Ambalangoda), peat (Muthurajawela). Possible resources include placer deposits, petroleum, gas and shale. As of 1997, US $ 330 million worth of heavy mineral placer deposits were identified on the shallow waters off Beruwala.

Sensitive habitats: Several species of marine mammals and sea turtles and also large numbers of wader birds frequent the coastal lagoons of Sri Lanka. Nearly 50 seabird species have been recorded on the west coast of the Island.

Mangroves cover the near-shore areas of many coastal water bodies. They stabilize the shoreline; their stems and roots trap fine sand and soil particles, forming an erosion-resistant layer. By inhibiting wave damage they provide the coast with buffer against the sea's forces and control runoff, thereby reducing siltation in estuaries and sea grass beds. Mangroves are a major source of food and nutrients to estuarine, lagoons and near shore coastal waters and provide a nursery for the early stages of commercially important crustaceans and fish. Mangroves are widely harvested for subsistence but also for commercial purposes.

Coral and sandstone reefs are common along the coast of Sri Lanka. Coral reefs dissipate wave energy and thus enhance coastal stability by containing erosion. Sandstone reef habitats dissipate wave energy and thus enhance coastal stability by containing erosion and provide habitats for variety of flora and fauna. The most extensive coral reefs in Sri Lanka are the patchy coral reefs in the northwestern coastal and offshore waters, occurring within the Gulf of Mannar, west of the Kalpitya peninsula and on the western and eastern coastal areas.

***Seagrass*:** beds comprise a highly productive habitat that supports many commercially important organisms. They serve as breeding and feeding grounds of marine organisms, and are the main habitat of the endangered dugong. Prominent seagrass beds are found in Gulf of Mannar, Palk Bay and Palk Strait and in several basin estuaries and lagoons. Seagrass beds bind sediment and stabilize the coast against erosion.

Quantifying changes on climatic variables in Sri Lanka

The forecasts for global sea level rise in this century vary considerably, but the Inter-governmental Panel on Climate Change (IPCC) has provided a central estimate of 0.2 m and 0.5 m rise by the years 2050 and 2100 respectively. By 2100 a general shoreline retreat of 25 m is expected, corresponding to an average retreat of 0.25 m per year. However, coastal erosion is controlled by winds, waves, surges, geomorphology and geology. In critical areas coastal erosion rate may vary from 1-13 m/year.

The surface temperature record, as compiled by Jones *et al*., 1997 offers the most convincing evidence of sea surface warming. The global temperature record from 1870 falls into four periods. The first (1870-1910), when urban development and heating standards were modest, shows no definite trend. The second, from 1910 to 1945 showed a temperature increase of about 0.5°C. The third, from 1946 to 1975, showed a fall of about 0.15°C. This

period coincides with the expansion of the aviation industry, with removal of many weather stations to airports, and an expansion of the system to rural areas. The period after 1976 – characterized by rapid expansion of human population, motor traffic and economic wealth – shows a rise of about 0.5°C.

Meteorology

In general, cyclones are generated in the Bay of Bengal during October and November. The mean annual occurrence of cyclones is 0.2, indicating a return frequency of cyclones every five years. Globally, climate change has shown increasing frequency and intensity during the last three decades; however, the trend in Sri Lanka is opposite.

It is believed that human-induced climate change, rather than naturally occurring ocean cycles, may be responsible for the recent global increases in frequency and strength of hurricanes. During the period from 1901 to 1995, 13 cyclones hit the Sri Lankan coasts.

Climate-induced environmental changes

Earth is a warm, wet planet. History provides clear evidence that a warm wet world is optimal for organisms. Ability to cope with the changing climate, habitat and resource is essential for the survival of species. Mobile and adaptable species are the most likely survivors.

Sea level rise induced by climate change and inflow of surface runoff and river inflow may change the physio-chemical characteristics of coastal waters, generating an adverse impact on the coastal fishery and aquaculture. It can cause inundation of low-lying areas, shoreline retreat, saltwater intrusion into coastal water bodies and rivers and sandbar formation at the mouths of water bodies and rivers. The major issues/ problems can be listed as following;

- Enhanced erosion;
- Salination/ salt water intrusion into low lying coastal plains;
- Ecosystem changes (*e.g.* conversion of brackish water into hypersaline water);
- Closing of river mouth – reduced water exchange, accumulation of pollution;
- Tourism – loss of beaches;
- Destruction of sensitive habitats; and
- Destruction/ damage to archeological/ historical, religious and cultural sites.

Biological environment

Seawater rise associated with climatic change means less food, offspring and oxygen for fish populations in addition to changes in rainfall patterns, currents and sea levels. Hotter temperatures are expected to stunt the growth of some fish, resulting in fewer offspring. Normally, fish metabolism speeds up as temperature rises, and insufficient food supplies could slow their growth and reproduction rates. Sudden fish kills have been observed in some enclosed water bodies such as Berai Lake in Colombo during unusually hot days.

Sensitive habitats are fragile, thus vulnerable to climatic changes. Most of the sensitive habitats in Sri Lanka are in different degrees of degradation owing to climatic changes and anthropogenic effects, resulting in decline of resources.

Impact of climate changes on coastal communities

The biological and socio-economic implications of salination and saltwater intrusion on marine and coastal ecosystems caused by sea level rise are extensive. These include reduced biological diversity and productivity, declining land values and reduced revenues from tourism, fisheries and other development activities. Saltwater intrusion into groundwater means less freshwater, including water for drinking, in coastal areas.

Sand mining on the coast increases coastal erosion. River sand mining leads to erosion of river banks and deepening of river beds. The latter leads to intrusion of salt water into rivers, endangering water supply schemes.

Coastal erosion results in loss of beach and landscape quality, damage to private houses, public buildings, hotels and infrastructure. Sea level rises could lead to difficulties for shore-based communities: for example, many major cities such as Galle, Matara and Hambantota already need storm-surge defenses, and would need more if sea level rise accelerates.

Presently, coastal erosion is managed by installing coast protection structures, using setback

Coastal erosion, associated with sea level rise, exerts a profound impact on the beach seine fishery, which contributes about 5 percent of the total fish production, and requires fairly large tracts of beach area for net-hauling and drying.

lines, avoiding development on erosion-prone coasts, and enforcing regulatory mechanisms. The recommendations in this regard are:

- Stop sand mining on beaches and rivers;
- Stop coral mining;
- Promote vegetation and mangrove culture; and
- Promote offshore sand mining.

Fisheries and fishing communities

The impact of temperature rise on fish populations is not adequately known because of lack of long- term research monitoring on the subject. But with coastal fishery resources under pressure because of overfishing, climate changes will likely aggravate the situation to the stage of no recovery.

Larger-scale sea fisheries production is not under immediate threat due to climatic changes. The fisheries most sensitive to climate change are among those most affected by human interventions – such as those in dams, wetlands, coastal areas, manipulated habitats and areas affected by population growth.

Coastal agriculture and farming community

Traditionally, agriculture has been the mainstay of the Sri Lankan economy. It has also provided about 35 percent of the employment and 21 percent of the national output. Almost 72 percent of the population engages directly or indirectly in agricultural activities.

Climate changes predicted as a result of increases in greenhouse gases are likely to impact farming systems. The changes are sea level rise, higher tropical surface temperatures, increased tropical cyclone frequency and severity, and changes in cloud cover and precipitation.

Rising sea levels inundate coastal farmlands, enhance salt-water intrusion, make coastlines retreat and force shifts to more salt-tolerant activities like shrimp farming. Changes in precipitation reduce returns on existing water resources, reduce plant propagation and aggravate plant disease patterns.

The possible impacts of climate change on farming systems include:

Changes in weather pattern*:* The IPCC has stated that the global average surface temperature has increased since 1861. In Sri Lanka the data analyzed for more than 100 years from 14 meteorological stations across Sri Lanka recorded a temperature increase of 0.01°C - 0.036 °C y^{-1} during the last 30 years.

During the same period, rainfall had decreased by 10 to 35 mm across Sri Lanka, except on the northwest coast, where the rainfall had increased by 9 to 17 mm. Precipitation, evaporation and transpiration patterns are not stable or predictable. Flood control, drainage, and irrigation infrastructure have to evolve with change. As sea level rises, low-lying coastal plains, particularly Jaffna Peninsula, are prone to inundation, saline groundwater intrusion and drainage congestion.

Sri Lanka was devastated by the December 2004 tsunami along 1 200 km (68%) of its 1 770 km costal belt. At some places, marauding seawaters intruded 2-3 kilometers inland, damaging most seawater-sensitive crops – not only farm fields, but also thousands of small home gardens where the rural folk grow vegetables and fruit trees. Irrigation and drainage canals within 200 m of the coastline were severely damaged.

Proposed actions and recommendations

Coastal planning should take into account the impacts of climate change – especially sea level rise, higher temperatures, prolonged droughts, severe rainfall, cyclones and storm surges. Integrated coastal zone management is essential for coastal zone planning, management, monitoring and evaluation. It requires close coordination with government agencies and communities. Needed action:

Mariculture/ aquaculture

- Expand aquaculture to increase and stabilize seafood supplies, help stabilize employment, and carefully augment wild stocks (Batticaloa, Kalpitya, Chilaw). Introduce aquaculture, mariculture and fish farming. Potential areas for mariculture are Gulf of Mannar, Koddiyar Bay in Trincomalee, Jaffna and Hambantota.
- Promote culture of seaweed, clams, spiny lobsters. sea cucumber, oysters, bivalves, Cobia (*Rachycentron canadum*), Pompano (*Trachinotus blochii*), Giant trevally (*Caranx ignobilis*), Rabbit fish (*Siganus janus*) – Kalpitya, Rekawa, Batticaloa, Trincomalee.
- Encourage Graciliaria (seagrass) and Eucheumia farming in the open sea and in abandoned shrimp ponds – Dutch Bay, Muttur, Kinnya.
- Promote oyster farming and crab fattening activities – Rumassala, Trincomalee Bay,
- Introduce artificial production of marine ornamental fish in selected coastal districts — Negombo, Beruwala, Chilaw, Bentota, Weligama.

Infrastructure

- Develop resources and facilities for culture fisheries development activities, verification studies, testing feeds. Set up a computerized information system linking major markets, exporters and producers.

Technology transfer

- Transfer technologies for culture of fisheries and seaweeds to communities.
- Introduce fish aggregating devices.
- Set up pilot projects for the culture of Asian seabass, grouper in cages, mud crabs and molten crabs in concrete tanks, mollusks culture in cages and oyster farming.

Socio-economics

- Develop production strategies for culture fisheries.
- Improve market access for marine products including suitable methods of processing and value addition.

- Strengthen the trader-export value chain.
- Promote family/ small-scale farmer approach.
- Strengthen fishery cooperative societies, and increase the participation of women in their activities.
- Increase fish production through the development of small-scale community based production units.
- Promote entrepreneurship development and provide access to technology, technical expertise, information systems, credit and extension services.

Public awareness

- Improve public awareness about fish handling to reduce fish spoilage and improve the quality of fish. This will make possible higher prices for fishers and better living standards.
- Promote awareness on sophisticated methods of fish processing including dry processing and vacuum- packing, through training and better processing facilities.
- Promote habitat conservation.

Management

- Strengthen community participation in the management of coastal habitats.
- Strengthen research on management systems and aquatic systems, leading to innovation.
- In coastal areas, integrate the management of fisheries with other uses of coastal zones.
- Monitor health problems (*e.g.* algal blooms, cholera) that could be aggravated by climate change and harm fish stocks and consumers.

Research Requirements

- Evaluate the potential impact of sea level rise and beach erosion on infrastructures, harbours, anchorages and beach landings.
- Identify erosion trends and formulate appropriate mitigation measures.
- Identify untapped potential for mariculture and aquaculture.
- Carry out biological studies on culture species.
- Identify constraints to increasing volumes and prices of seaweed.

Further reading:

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