Climate Change and Its Impact on Coastal Economy of Sri Lanka

K.W.G. Rekha Nianthi,
Department of Geography,
University of Peradeniya,
Sri Lanka

And

Rajib Shaw,
Graduate School of Global Environmental Studies,
Kyoto University,
Japan

Abstract

Current climate change, mainly man-induced, is one of the most serious environmental problems. It is related to greenhouse effect and associated global warming, increasing levels of carbon dioxide and other greenhouse gases. The global warming is expected to lead to increase temperature, more frequent droughts, erratic rainfalls and rise in sea level which may affect Sri Lanka too, particularly its coastal economy, and thus the society as well. Projected sea level rise (SLR) in Sri Lanka is 0.3 m by 2010 and 1.0 m by 2070. Adverse impact of climate change would influence the coastal environment, agriculture, forest, biodiversity, health, energy, human settlements etc. Seal Level Rise (SLR) will inundate the low lying coastal areas in particular. This study shows that significant economic impacts will be seen on the following sectors: land resources (an estimated amount of 1242 million rupees), tourism sectors (affected cost: 201 million rupees and replacement cost of 1174 million rupees in the study area), industries (small industries impact 152 million rupees) and rice and coconut production (64.5 million and 83 million rupees respectively). A balance of economic, environmental and social issues is required to develop pro-active policy measures of SLR. A Coastal Zone Management Plan (CZMP) should incorporate development issues, scale issues and multi-stakeholder issues. Community participation at local level is an important element, which requires capabilities and livelihoods as means and equity and sustainability as principles. Further integrated research and implementation are required for effective CZMP.

Key words: Climate change, Coastal, Sea level, Economic Impacts

1. Introduction

Owing to Sri Lanka's location between 6° and 10° north latitude, the South Asian Monsoon provides unique opportunity to monitor climate change in Sri Lanka and in the tropics region as well. It is now accepted that the earth will experience the effects of climate change due to global warming as a result of the increase of carbon dioxide and other greenhouse gasses in the atmosphere. Climate change does not yet feature prominently within the environmental or economic policy agenda of developing countries. Yet evidences show that some of the most adverse effects of climate change will be in developing countries, where population are most vulnerable and that climate change will affect the potential for development in these countries (Beg et. al., 2002). Studies also indicate that countries in the tropical belt and on the small islands or the countries with long coastal zone would be affected most (IPCC, 2001; Ali, 1996; Munasinghe, 2001). The impact of climate change would manifest in all socio-economic sectors: like agriculture, forest, bio- diversity, health, energy, human settlements etc. Based on Global Climate Change Models (GCCM), it is expected that Sri Lanka too will experience several adverse impacts of climate change due to global warming (Gornitz 1995, Munasinghe 1998). As a tropical Island, Sri Lanka is expected to be affected by global warming especially from the associated sea level rise (SLR).

Sri Lanka has a coastline of 1720 km in length, which provides biologically rich and divers coastal environment with unique ecosystems. This coastal area contains, most important ecosystems such as lagoons, estuaries, mangroves, salt marshes, sand dunes, beaches and coastal marshy wetlands and different water bodies (Figure 1). All these ecosystems will be affected to varying degrees through inundation, coastal erosion or change in ecological systems due to sea level rise (Atlas, 1997).

Coastal area is the densely populated with more than 65 per cent of the total country's population, and developed area in the country and contains the capital city of Colombo and several large cities. The total population in the coastal belt is projected to be 8.4 million in 2010. The commercial capital of Colombo and some of the largest Municipal Councils (MC) come within the coastal zone. There is also a heavy concentration of industries in the coastal zone with over 80 per cent of the industrial units located in and around Colombo alone. Tourism is a major activity in the coastal area. Tourism infrastructure, major commercial ports, fisheries, harbours and anchorage are also located in the coastal area (Figure 2). The main highway and railway are also located close to the coast (Figure 3 and 4). In view of this geographical setting, it is believed that most adverse impact of global climate change (i.e. in the form of sea level rise) shall be felt in the densely populated and highly productive coastal zone of Sri Lanka (Rekha Nianthi 2003a, 2003b, 2005).

Global warming is expected to lead to increase in temperature, more frequent droughts, high intensity rainfall and rise in sea level in Sri Lanka too. Theses anticipated changes in the global context exhibit a significant threat to different economic activities and environment of the coastal area. Analysis of temperature data over the past 100 years indicates, that Sri Lanka has been experiencing a rise in air temperature of around 0.016° Celsius per year since the 1960s. As indicated in the climate change scenario for Sri

Lanka, the effects of climate change for 2010 are marginal + 0.5° C for temperature and the intensities of dry weather and rainfall may increase in Sri Lanka. Climate change scenario developed for year 2070 will be quite significant. Climate change could have insignificant effect even in the year 2010 in Sri Lanka (ADB, 1994).

The low lying coastal areas in particular are sensitive to any change of sea level (CCD, 1986; Madduma Bandara, 1989). Even a small change has potential to bring about significant changes in the coastal area in Sri Lanka. An analysis of tidal records of the Colombo harbour since 1949 indicates an increase in the seal level by about 0.6 mm. for Sri Lanka and the Indian subcontinent (Scheffer, 1992). This would be a direct result of ~~a~~ thermal expansion of water in the Indian Ocean as indicated in the rise of sea surface temperature (Kayane, 1995).

In contrast to the potential threats, not so much work has been done on the climate change impacts and adaptation measures in Sri Lanka, with a few exceptions (Domroes and Schaefer, 2000; Rekha Nianthi, 2003b; Madduma Bandara, and Wickramagamage, 2004). This chapter discusses the current situation of the climate change impacts on coastal environment and economy of Sri Lanka. The chapter also reviews economic evaluation of the impact of sea level rise in the coastal area. Finally, this study highlights development strategies, adaptation and further recommendations and policy options to respond to concerned coastal sectors for climate change in Sri Lanka as part of a specific project conducted by the first author (Rekha Nianthi 2005). This study also incorporates the information from secondary sources like Climate Change in Asia: Sri Lanka County Report (ADB 1994), Commonwealth Scientific and Industrial Research Organization (CSIRO) and Initial National Communication under the United Nations Framework Convention on Climate Change (Natcom 2000).

2. Impact of Sea Level Rise (SLR)

The increasing concentration of greenhouse gases in the atmosphere is causing an increase in the atmospheric temperature. One of the direct and major consequences of an increase in temperature is a rise in sea level. However, sea level change is not a stand alone problem resulted due to climate change. It is also affected by other factors like geological subsidence, sedimentation etc. In case of Bangladesh, an estimate shows that sea level change is 90% due to Sea Level Rise (SLR) and 10% due to subsidence (Ali, 1996).

The scenario of sea level rise in Sri Lanka is 0.3 m. by 2010 and 1.0 m. rise by 2070 (Natcom 2000). Low lying areas is the most direct and obvious consequences of SLR. SLR could also increase the risk of floods. A rise in sea level would lead to increase tidal influence upstream and also increase salinity in open bays, because the increased cross section would slow the average speed at which freshwater flow to the oceans. Some of the other adverse impacts of SLR in coastal areas are: Inundation, shoreline erosion, coastal flooding, salinity of estuaries and aquifers, modify tidal range in rivers and bays, alter frequency and severity of storms. All the above impacts are threatened to ecological balance and to coastal infrastructures. Figure 3 and 4 demonstrates important coastal infrastructures like highway and railway lines, which are vulnerable to SLR. Figure 5 shows the conceptual framework of impacts of SLR on coastal environment (Rekha Nianthi, 2003).

Sea level would induce accelerated erosion too. The primary reason being that with an increase in the sea level, a large area of the beach is wetted and the turbulence generated within the surf zone is brought more landward. The beach profile itself thus moves landward, resulting in a loss of beach space. Any increase in the mean sea level would results in increased tidal prism (the volume of water carried in to bays of lagoons during a tidal cycle). This increase is a direct result of increase in the platform area due to inundation and shoreline retreat. Narrow rivers entrances with flanking sand bars are found at some of the rivers out lets such as Gin Ganga, Bentara Ganga, Kalu Ganga, and Maha Oya in Sri Lanka. A 1.0 m. SLR would tend to destroy the sands bars, resulting in a widening of the inlet. Any increase in the volume of sea water entering an estuary or lagoons would adversely affect the peripheral agricultural crops and lands too (Rekha Nianthi, 2005).

In the 21st Century, global sea level rise will raise flood levels and hence increase flood risk in the coastal areas (Nicholls et al. 1999). The number of people who experiences flooding will also be affected by other factors such as increasing population within the costal flood plain. Coastal population in many countries is increasing rapidly with rapid urban growth of the coastal towns and cities. Therefore, the coastal vulnerability is increasing, and SLR is contributing significantly to this vulnerability.

The other issue is the coastal wetlands, which could also experience substantial losses due to sea level rise. These areas are highly productive and provide a number of important functions such as flood protection, waste assimilation, nursery areas for fisheries, and natural conservation. Therefore, wetland cost has a high human cost. There are three major ways by which SLR can disrupt wetlands viz. inundation, erosion and salt water intrusion. A 1 meter sea level rise could diminish the valuable coastal wetlands systems. An important factor in determining the vulnerability of wetlands to SLR is the tidal range. Coastal wetlands are generally less than one tidal range above mean sea level. Thus rise of sea level by one tidal range would cause all the existing wetlands to submerge. A rise of sea level of 1 m. can therefore, be expected to destroy most of the coastal wetlands in Sri Lanka. For an example, the Muthurajawela marsh represents a large area of brackish water marshes, mangroves swamps and freshwater marshes, merging in to an estuarine system to the northwest. Similarly, the marsh land, mangrove and estuary ecosystem near Balipeta, Galle district is also highly vulnerable to SLR (Figure 6).

Sea level rise would also have adverse impacts on infrastructure in the coastal area. The present coast protection structure such as revetments and sea walls (Figure 7) will be affected by sea level rise, thereby increasing its adverse impacts on the socio economic systems in the coastline areas. Hence coastal wetlands are endangered ecosystems which will be affected by SLR.

3. Economic Cost of Climate Change (ECCC) on Sea Level Rise

Climate change and seal level rise continues to figure prominent on the environmental policy agenda, both nationally and internationally. A key challenge when assessing the impacts of climate change and sea level rise is synthesis, i.e., the need to reduce the complex pattern of individual impacts to a more tractable set of regional and sectoral indicators (Toll et. al., 2000). Many models use physical measures such as number of people affected (Hoozemans et al., 1993), change of total plant growth (White et al., 1998), number of system undergoing change (Alcamo et al., 1995), and so on. Such physical matrices are well suited to measure the impact of natural systems. It is evident that there are several damage calculations in developed countries, which the developing countries lack these calculations until recently.

.

The current paper one of the first attempts in this regard, specifically for Sri Lanka. These estimates help to stress the vital importance of incorporating the dimension of global climate change into national strategies of development and integrating initiatives in to the current plans and programs. In this paper, an economic evaluation has focused on the impacts of the SLR on the coastal region. The economic cost of climate change has been focused on four sectors: Land Resources, Tourists sector, Industries and Crops such as rice and coconut.

3.1 Land Resources: One of the major losses associated with SLR is loss of land resources. The calculation of economic value of land loss would be as: by the 2010 about 30 m beach will retreat based on assumptions. The length of the study area is 285 km. Therefore, total land loss under 30 m. beach retreat is 855 hectares. Under the present sea level loss of land due to erosion in the study area is 11.3 hectares. If this level of average land loss will occur within next 20 years, until 2010. Then the land loss is 11.3*20 = 226 hectares. So the land loss due to SLR is: 855-226=629 hectares. If one perch costs 5000 rupees[1] then the total value of lost land is 1242 million rupees.

3.2 Tourists Sector: Another major loss associated with SLR is loss of tourists sector. Tourists industry plays an important role in Sri Lanka’s economy and it is highly vulnerable to climate change, especially to the SLR. In 1990 the total number of tourists visiting Sri Lanka was 318,000. The amount of foreign exchange earnings from tourists industry was US$ 155.5 million. and employment about 25000 (direct) and 30000 (indirect). About 80% of the total hotel rooms in the country are located in the coastal area and some of them are at risk because most of them are located very close to the sea

[1] 1 US$ = 45.00 Rs

(less than 50 m. in distance). Due to this circumstances, SLR would bring substantial losses to the hotel industry and thereby tourism. By assessing the income lost to the industry or a particular hotel by reduced accommodation facilities the direct losses due to SLR can be estimated as follows:

Total income from tourism in 1990: (155.5 million. US$) = 6997.5 million rupees (1US$ = 45 Rupees in 1990). Total FDI (Foreign Direct Investment) inflows during 2002 were about $246 million US$ and are expected to exceed $300 million in 2003. A significant part of the FDI comes to the tourism sector. 80% major hotels are found within study area, it is assumed that 60% of income of coastal tourism was coming from the study area. This is equivalent to 3358 million rupees, If 6% damage occurs due to SLR cost of damage is 201 million rupees.

The other method of employed to estimate the damage due to SLR is the "**Replacement cost approach"**. The underlying principal of this method is to assess cost of replacing a particular item which is subject to damage. Example: Relocation cost of hotels due to 0.3 m. SLR is 4% damage and 1 m. SLR: damage is : Total room capacity of the country is about: 9472. The study area has about 24% of the total capacity 2310. The estimated figures are based on 4% loss. Total number of rooms fully affected will be equal to 93 and it is distributed under three categories: namely 5 star, 3 star and ordinary as 10%, 50% and 40% respectively. Assuming the cost of replacement of one of these rooms are 3.5 million rupees, 2.4 million rupees and 1.0 million rupee respectively are current price, and the total cost of replacement will be 1174 million rupee.

3.3 Industries: There are several industries located in the coastal area. There are: Organized factory industries, small industries such as coconut and fisheries based industries, Quarrying and mining (sand and coral). According to the Central Bank (1990) the total income from organized factory industries in 1990 was equal to 30,984 million rupees. Percentage income from coastal zones is 66%. Therefore, income share from coastal area is 20,449 million rupees.

As study area contains most of the urbanized and industrialized regions in the country 70% of the income is assumed to be generated within the study area. Therefore in the study area income share (70%*total coastal zone factory income) is 14,314 million rupees. If 4% damage will occur due to 30 m beach retreat (assumptions): the loss of income of factory based industries is 572 million rupees. According to the Central Bank (1990) the total income from small industries is 1907 million rupees. Percentage income in coastal zone is 20%. Therefore the monetary value is 381 million rupees. **Assumptions:** As the highest populated coastal area are located within study area 40% of income from coastal small industries are within study area. Therefore monetary value is 152 million rupees, and loss of income is 6 million rupees.

3.4 Rice and Coconut Production: The impacts of climate change on selected major agricultural crops have been estimated on certain assumptions. The climate related changes take effects while other variables are held constant. Agriculture in the coastal area can be affected by salinity intrusion and loss of land. Although several crops are available in the study area the most vulnerable crops under SLR are rice and coconut as they are the crops found in low lying coastal areas. Therefore, assessment has been done only for theses two crops.

Total value generated by rice lands in the country in 1990 was 15088 million rupees. As the total extent cultivated is 0.857 million hectares, income generated per hectare is 17 605 rupees. Total cultivated extent within the AGA divisions in the study area is 36640 hectare. Therefore total value of rice production in the area is 645 million rupees. **Assumptions:** About 10% damage due to Sri Level Rise (SLR). Therefore income loss due to SLR is 64.5 million rupees.

Total value of production of coconut lands in the country in 1990 was 4852 million rupees. Total cultivated land area (hectare.) 0.25 million hectare. Total cultivated land area in coastal AGA division under study area is 42 810 hectare. If income forms 1 hectare is 19408 rupees. The total value of coconut production within the study area is 830 million rupees. **Assumption:** 10% damage is 83 million rupees. Therefore loss of income due to SLR is 83 million rupees.

4. Specific Issues to Respond to Climate Change and Sea Level Rise

This section attempts to identify the policy options that are available to deal with the manifold impact of these changes, and outlines the strategies that might be adopted. This includes an evaluation of beaches, adaptations for sea level rise and strategies to protect beaches and structures.

Due to the flooding of coastal areas, the coastal resources of Sri Lanka would be affected significantly by SLR. Sri Lanka coastal resources include resorts, national parks, industries, aquaculture, agriculture, mineral sand extraction and fisheries. According to statistics the population is being increased in coastal areas especially, in the Wet zone, which has caused tremendous commercial and industrial growth and has put pressure on the coastal resources. Therefore, the impacts of SLR are of particularly significance in the Western and South-western coastal areas. Therefore, the protection of the coastal resources is absolutely necessary. The SLR scenarios stipulated by the Inter Governmental Panel on Climate Change (Natcom, 2000) are 30 cm. for the year 2010 and 1.0 m. for the year 2070. The strategies for dealing with the impacts of the SLR are discussed in this section.

Beach protection measures are basically based on economic and aesthetic value. Sri Lanka coast are having a predominant sandy beach which is due to the transport of sediment from hinterland by the river systems. Beaches are supplied with materials from rivers, coral reefs and in some cases from adjacent eroding shore fronts. A combination of waves, currents and winds are the natural force which moves this sand along the beach offshore and onshore. The causes that contribute towards erosion can be classified in two ways. One is the natural causes, which include long term changes in climatic conditions, migration of river outlets and rise of sea level. The other one is human activities, sand mining from rivers and coastal destruction of barriers reefs, dredging or reclamation and from improper designed coastal structures.

Recent assessment and studies show that the coastal beach from Maha Oya to Wellamankara is eroding at 3.5 to 4.0 m./year, while the beach from Palliyawatte to Dickowita is eroding at 2.3 m./year. These high rates can be attributed to very large scale mining in both the Kelani Ganga and Maha Oya. The study area in general is subjected to one of the highest erosion prone sectors of the island. Significantly high erosion rates of 3.5 to 4.0 m. are observed in the last few years economically active beaches. A rise in sea level would induce an accelerate trend in erosion, because a larger beach is wetted and the turbulence generated within the surf zone is brought itself moves land-ward, resulting in a loss of beach space. In addition, a number of external factors could change the fundamental wave parameters, such as the effects of global warming increasing the probability of occurrence of extreme events. Sand mining from beaches and estuaries are also an important activity in the study area. The mining of river sand is heaviest from Kelani Ganga and Maha Oya. Excessive mining and inappropriate sand mining operations can contribute to shoreline erosion. Heavy erosion of the coast north of Colombo in recent years has in part been attributed to the high levels of sand mining in the Kelani Ganga. River bed degradation, bank erosion and salt water intrusion are other adverse impacts of increased levels of sand mining.

Coral reefs are natural protectors for sea erosion. The recent Indian Ocean Tsunami has caused varied damages (from almost unaffected to extreme damage) to the coral reefs at different places of Sri Lanka. At some places, it has mechanical breakage, at some places uprooting was observed. The SLR models indicate that sea erosion of low lying coastal areas will increase constantly. By preventing the natural coral reefs surrounding certain coastal areas from being mined, those stretches of beaches can be protected. Wherever, the aesthetic value of the beach is economically important, as a popular recreation area of tourists, replenishment programs where sand is dredged and pumped from the outer and offshore perimeters are an alternative. This method would help maintain the original coasts and preserve the aesthetic beauty. Revetments are quite successful in preventing sea erosion. With rising sea levels, strategically placed revetments will protect large stretches of valuable low lying coastal areas and provide shelter and habitats for a large variety of marine life. So as to minimize the cost on the aesthetic value of the beaches, only area that are of less popularity among the tourists need use this adaptation strategies.

The economically important structures are: the ports, roads, railways, fisheries harbours, and anchorage. Colombo and Galle are the main coast protection ports structures in the west and southwest sides of Sri Lanka. Infrastructure such as power, water and telephone lines that will be affected by the SLR would need to be relocated. The appropriate measures would be dependent upon the economic and social feasibility of the strategies. The major port of Colombo caters to a large amount of container ships. The existing and planned structures in the ports of Galle and Colombo are able to withstand the impact of a 0.3 m. SLR. What is needed is the strategy to adapt to the 2070 scenarios. Railway lines are at risk from 0.3 meters of SLR. Railway lines may have to be moved inland, which may displace economic activities and human habitats. In addition to the SLR impact, the Indian Ocean Tsunami of 2004 significantly damaged the coastal railway, and caused casualty of more than 200 people. Several roads which consist of highway main roads are vulnerable to a 1 m. SLR. The Beruwala fishery harbour needs to be protected from a 1 m. SLR at any cost. Since the fishing industry contributes significantly to the GDP, it is important that the structures should be immediately upgraded to withstand the impact of at least a 0.3 meters SLR by the year 2010.

As a consequence of SLR, increasing salinity of low lying coastal areas is also expected. The effect of salinity on productive agricultural land, wildlife areas and water resources could be devastating. Introducing strips of vegetation that grow on high levels of salt content would reduce the salinity level. The strategies for controlling salinity intrusions at water intakes are two ways: One is locating the intake further upstream at high capital costs. Second is constructing a physical salinity barrier downstream of the present intake. Salinity and flood will extend to other low-lying agricultural areas. In this regards, some strategies are suggested to this issue. There are: further strengthening of protective measures such as salt water exclusion schemes and pumping mechanisms, diversification in to varieties of rice and other crops which are salinity resistant and conversion of these lands to brackish water fisheries.

There are some strategies introduced to protect the wetlands too. The strategy would be to allow the wetlands to function as they are so that SLR will inflict natural changes in the ecosystem. Another one is prevention of dumping water and untreated waste water. Construction of bunts to protect presently dry areas against flooding whenever the adaptive strategies suggested above are not feasible the areas could be converted in to mangroves. Converting theses area in to mangroves is not economically costly and be beneficial for both environmentally and economically in the long term. Fish production could increase manifold as these mangroves are used as breeding grounds for fish.

5. Policy Implications and Way Ahead

Specific policy measures to reduce the impacts of climate change and SLR can not be considered in isolation. Reference should be made to the concept of sustainable development and climate change, as proposed by Munasinghe (2001). There, the concept of "*sustainomics*" was introduced, which focused on trans-disciplinary, integrative, balanced, heuristic and practical framework for development as a sustainable approach. A combination and balance of social, economic and environmental capital is required in this process. Environmental sustainability deals with the overall performance or health of ecological system. Social sustainability seeks to reduce the vulnerability and maintain the health of social and cultural systems. Economic sustainability aims to maximize the flow of income that could be generated while maintaining the stock of assets which yields beneficial outputs. This framework helps decision makers focus on the development, rather than just the magnitude of economic growth. Therefore, the policy related to SLR and economic impacts should go beyond the economic issues, and should include social, cultural and environmental issues for its sustainability.

Yohe and Schlesinger (1998) made estimation of expected economic cost of protection or abandonment in the USA based on three different economic analysis models. However, its policy implications and adaptation measures are lacking in the analysis. Nicholls et al. (1999) stressed on "the commitment to SLR" regardless of the emission policy, and argued that the small islands and countries with long coastal lines should take lead in this endeavour. Beg et al. (2002) suggested the need of integrated policy making with regional, national, and local level government agencies. It requires a holistic approach of different sectorial policy, and integrating it to the coastal zone management issues. Institutional analysis and capacity building of different sectors is a prime requirement in this regard. Also, there is an urgent need to look at the links among different international conventions. Beg et al. (2002) argued that although the economic growth and poverty reduction are the main focus of the developing nation's policy makers, yet climate change mitigation and adaptation can offer these countries the opportunity to revisit the development strategies from a new perspective. This is in line with the suggestions of Munasinghe (2001) for an integrated and holistic policy measure.

The crucial obstacle of climate change, sea level rise and its policy implication lies in the time and scale problems. In most cases, the climate scenario focuses on far-future impacts of 2050, 2070 or 2100, while the needs of policy makers are immediate future, for next 5 years, 10 years. The other problem is regarding the scale of climate scenario. In most cases, it is on regional scale, while the provincial policy makers require scenario in their provinces. These constrain leave us with crude local level climate scenario, and therefore, the implementation at the policy level remains incomplete.

As evident from the above discussion, an effective Coastal Zone Management Plan (CZMP) and policy to reduce the economic impacts of climate change and sea level rise has to be participatory, holistic and local. The local level policy has to be supported by the national and international framework. Agenda 21 can be considered as a good example of local level policy implication, which has a strong binding force from national and international level. Approaching local sustainability is the key issue of policy implementation (Gibbs 2002). A range of spectrum exists from very weak sustainability to very strong sustainability. While very weak sustainability focuses on capital assets, weak sustainability focuses on natural capital use, strong sustainability focuses on ecosystem functions, and very strong sustainability focuses on economic system based on multi-purpose integration. Therefore, it is important that the local level environmental and regulatory issues should be linked to the economic policies and framework. These should be part of the integrated development plans. Meeting the challenge posed by sustainability requires (EC 1998):

- Integrated approaches within strategic frameworks which allow policy instruments to address multiple problems simultaneously,
- Policy interventions at the local level, as opposed to passing on the problem either spatially or temporarily, and
- Policy solutions which lead to changes in individual patterns of consumption and behaviour by individuals

Participation of local communities in the Coastal Zone Management Plan (CZMP) can be regarded as having five dimensions, which are common to citizen participation. These are: collective action, co-learning, cooperation, consultation and compliance (Kanji and Greenwood 2001). Chambers (2005) focused on the classical idea of development through local community participation. He argued on the following four factors as the "web of well-being": *capabilities* and *livelihoods* as means; *equity* and *sustainability* as principles that quality livelihood to become livelihood security, and well-being to become responsible well-being. This is one of the crucial missing link of grass-root policy implementation, and should be kept as a top priority for policy making on CZMP. Figure 8 shows the conceptual plan of the CZMP incorporating the issues described above.

In conclusion, Coastal Zone Management Plan (CZMP) and other alternative polices regards to sea level rise should be revised taking in to consideration the potential impacts on every appearance in the coastal areas. Preparation of a coastal database and examine vulnerability of coastal areas should be done through case studies in scientific as well as socio-base techniques. There are some other issues to be considered in related to SLR and climate change research. These are the needs:

1) To build up a data base related to climate change, need to introduce and provide incentives/disincentives,
2) To consider the cost effective policies,
3) To adopt an integrated approaches,
4) To promote stakeholder collaboration, and
5) To increase the awareness program of climate change to the public in the country.

Research and scientific assessments play a vital role in improving the understanding of the potential impacts of climate change on coastal environment in Sri Lanka, with especial reference to the scale and time. Such investigation will enable the development and assessment of appropriate adaptation strategies for sea level rise. National Action Plans (NAP) approach would also promote integrated impacts studies which would improve the information and data available to decision makers in all sectors of the coastal areas for developing plans and future policies on climate change on coastal environment.

Acknowledgement:
The draft version of this paper was developed when the first author (KWGRN) visited Kyoto University with financial grant (Start-up Research Grant of Kyoto University) to the second author (RS). This support is highly acknowledged.

References

Alcamo J., Krol M., Leemans R. (1995): Stabilizing greenhouse gases: Global and Regional Consequences- Results from the IMAGE 2.0 Model. pp1-10. Bilthoven: RIVM.

Ali A. (1996) Vulnerability of Bangladesh to climate change and seal level rise through tropical cyclones and storm surges: Water, Air and Pollution, 92, 171-179.

Asian Development Bank (1994): *Climate Change in Asia: Sri Lanka Country Report*, Regional study on Global Environment issues, Manila.

Atlas of Sri Lanka (1997): Arjuna`s, Dehiwala, Sri Lanka.

Beg N., Morlot J.C., Davidson O., Afrane-Okesse Y., Tyani L., Deton F., Sokona Y., Thomas J. P., Rovere E., Parisk J., Parikh K., and Rahman A. (2002): Linkages between climate change and sustainable development, Climate Policy, Vol. 2: 129-144.

CCD/DANIDA (1986): *Sri Lanka Mater Plan: Coast Erosion Management*, Coast Conservation Department, Colombo.

Central Bank of Sri Lanka (1990): Industrial Trend and Income, Colombo.

Chambers R. (2005): Responsible well-being: a personal agenda for development: in Ideas for Development, pp. 184-198, Earthscan, London.

Domroes, M. and Schaefer, D. (2000): “Trends of recent temperature and rainfall changes in Sri Lanka” *Proceedings of the International Conference on Climate Change and Variability*, pp.197-204.

EC (1998): European Commission: Sustainable urban development in the EU: A framework for action, communication from the commission to the council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, Brussles: DG XVI, EC.

Gibbs D. (2002): “Approaching local sustainability”: in: *Local economic development and environment*, page 1-25, Routledge Press.

Gornitz V. (1995): Seal-level rise: A review of recent past and near-future trends: Earth Surface Process and LAndreforms, No. 1, pp. 7-20.

Hoozemans F.M.J., Marchand M., Pennekamp H.A. (1993): A global vulnerability analysis: vulnerability assessment for population: Coastal wetlands and rice production and a global scale, second revised version, Delft: Delft Hydraulics

IPCC. Climate Change (2001): Impacts, adaptation, and vulnerability. IPCC, Cambridge University Press, UK. 2001.

Kanji N. and Greenwood L. (2001): Participatory approaches to research and development in IIED: Learning from experiences, IIED, London, October.

Kayane Y. (1995): Hydrological consequences of Global Warming revealed by the Century-long Climatological data in Sri Lanka an South West India. *In the Interim Report of IGBP Activities in Japan 1990-1994*, Science Council of Japan.

Madduma Bandara, C.M. (1989): Coastal change of Crow Island and Its Enviorns, *Coast Conservation Department*, Colombo.

Madduma Bandara, C.M and Wickramagamage, P. (2004): "Climate change and its impact on upper watersheds of the Hill country of Sri Lanka", in Srikantha Herath, Assela Pathirana and Weerakoon S.B., *Proceedings of the International conference on sustainable water resources management: In the changing environment of the monsoon region:* Volume 1, National Water Resources Secretariat, Colombo.

Munasinghe M. (1998): Climate change decision-making: science, policy and economics: International Journal of Environment and Pollution, Vol. 10. No. 2, pp. 23-36.

Munasinghe M. (2001): Sustainable development and climate change: applying the sustainomics trans-disciplinary framework: International Journal of Global Environmental Issues, Vol. 1, No. 1, 15-25.

NARESA (1991): *Natural Resources of Sri Lanka*, Condition and Trends, NARESA, Colombo.

Natcom (2000): Democratic Socialist Republic of Sri Lanka, *Initial National Communication under the United Nations Framework Convention on Climate Change*, State printing corporation, Padukka.

Nicholls R. J., Hoozemans M.J., Marchand M. (1999): Increasing flood risk and wetland losses due to global sea-level rise: regional and global analysis: Global Environmental Change, 9, S69-S87

Rekha Nianthi, K.W.G. (2003a): *Global Warming and Climate Change* (Sinhala language version), Dharshana printers, Kandy, Sri Lanka.

Rekha Nianthi, K.W.G. (2003b): "Recent trends of climate change in Sri Lanka", *The Journal of Geo-Environment*, 3: 37-49, Rajshahi University, Bangladesh.

Rekha Nianthi, K.W.G. (2005): "Climate change and its potential influences on agricultural economy of Sri Lanka". Unpublished Ph.D. Thesis, Dept. of Geography, North- Eastern Hill University, Shillong (India).

Scheffer, H. J. (1992): Future Sea Level Rise, Impact on Coastal stability, *Proceeding of a seminar on causes of coastal erosion in Sri Lanka*, CCD/GTZ Coast Conservation Project, Colombo.

Toll R.S.J., Fankhauser S., Richels R. G., mith J. B. (2000): Hoe much damage will climate change do? Recent estimates: Working Paper SCG-2, 21 pages.

White D.J., Running S.W., Keane R.E., Ryan K.C., Fagre D.B., Key C.H. (1998): Assessing simulated ecosystem processes for climate variability research at glacier national park: Ecological Applications, 8, 805-823.

Yohe G. and Schlesinger M. (1998): Sea-level change: the expected economic cost of protection or abandonment in the US. Climate Change, Vol. 38: 447-472.

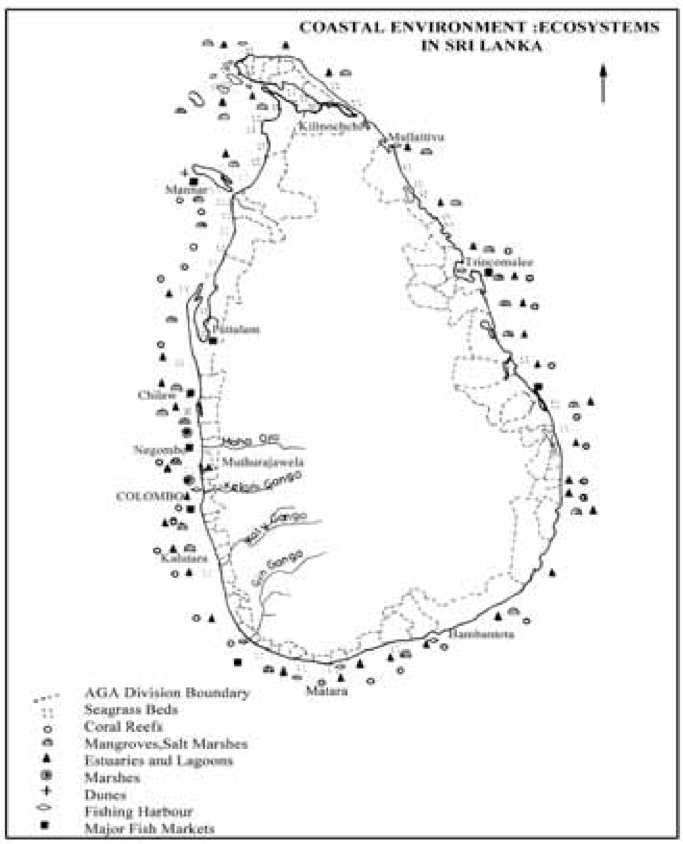

Figure 1: Coastal Eco-systems and Resources of Sri Lanka

Figure 2. High density southern coastline in Sri Lanka which is the hub of economic activities.

Figure 3. Colombo Galle main highway along the southern coast of Sri Lanka, which is highly vulnerable to SLR

Figure 4. Railway line along the southern coast, which is highly vulnerable to SLR.

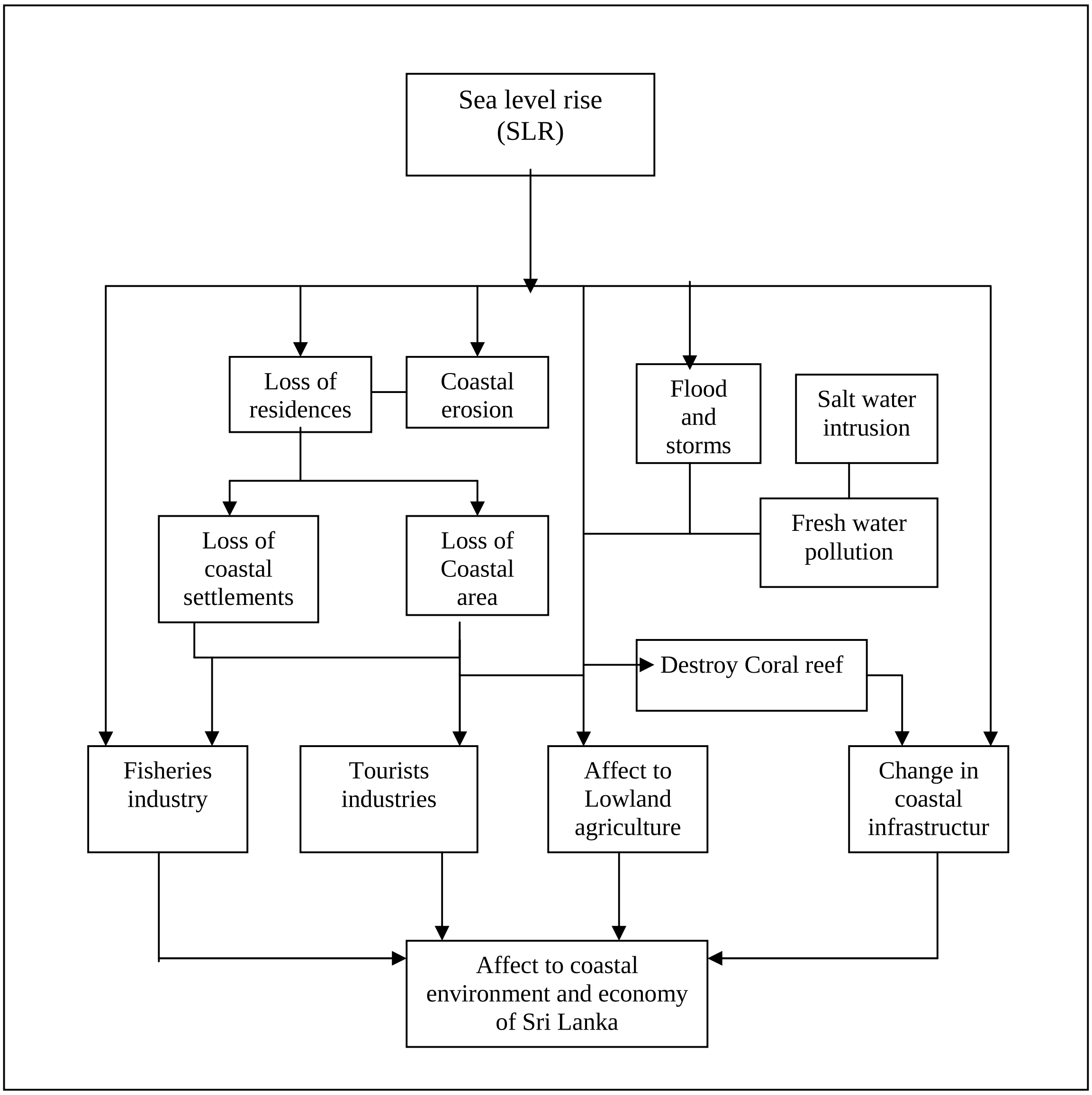

Figure 5. Conceptual framework of seal level rise which will affect the coastal environment of Sri Lanka (Source: Rekha Nianthi, 2003:175)

Figure 6. Marsh land, mangrove and coastal and estuary ecosystem near Balipeta, Galle district of southern Sri Lanka highly vulnerable to SLR.

Figure 7. Sea wall constructed along the coastal zone is vulnerable to SLR.

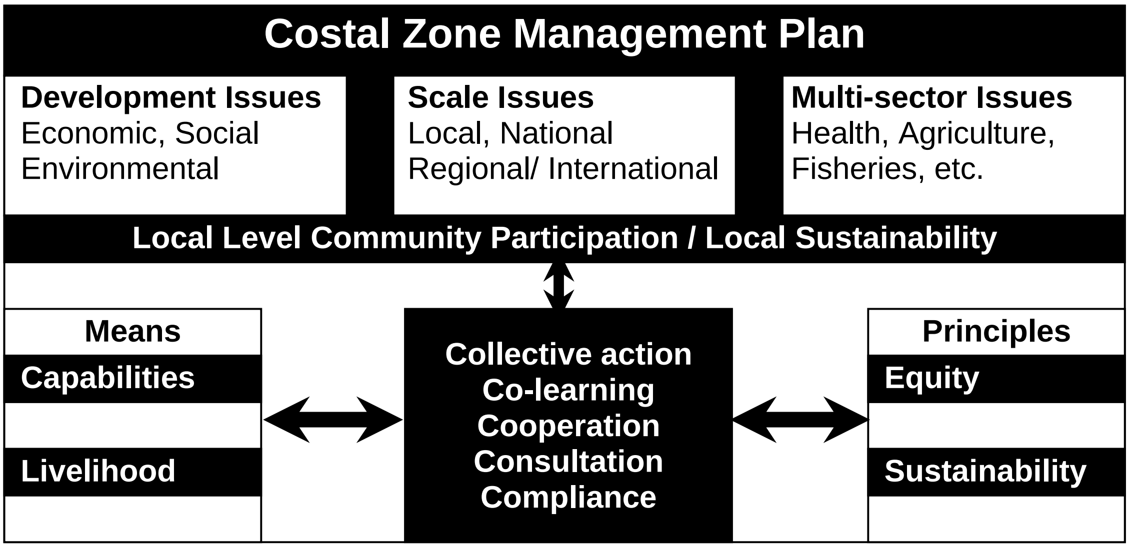

Figure 8. Conceptual framework of Costal Zone Management Plan (CZMP) with specific focus on its local sustainability.