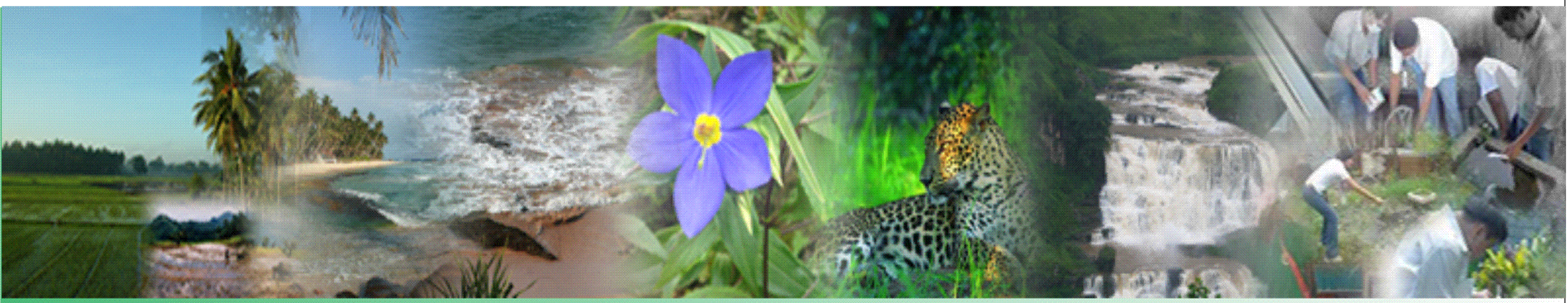
Ministry of Environment and
Renewable Energy
Sri Lanka



Technology Needs Assessment And Technology Action Plans For Climate Change Adaptation

Technology Needs Assessment

2011

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Sri Lanka being an island nation subjected to tropical climatic influences is highly vulnerable to climate change impacts. We are already experiencing significant climatic imbalances manifested through increasing average temperatures, drastic variations in rainfall patterns and extreme climatic events such as heavy rainstorms, flash floods, and extended droughts and weather related natural disasters in various forms and severity. These extreme and sometimes unseasonal events affect not only the human lives and properties but also have long term impacts on the ecosystems as well.

"*Mahinda Chinthana* – Vision for the Future", the Government of Sri Lanka's Ten Year Development Policy Framework assigns a very high priority to the management of the environment and the natural resources sector including addressing climate change impacts. In keeping with the Government's overall vision on tackling climate change impacts, the "National Climate Change Policy (NCCP) for Sri Lanka" identifies the paramount need of undertaking appropriate actions for climate change adaptation in order to build resilience of the country to face the adverse impacts of climate change. The NCCP emphasizes the importance of exploring technologies and best practices already available in the country and globally, and select nationally appropriate innovative technologies, disseminating, and implementation to the extent possible with sound monitoring mechanisms.

The Government and my Ministry in particular recognizes that the Technology Needs Assessment (TNA) Project implemented in collaboration with Global Environment Facility (GEF), United Nations Environment Programme (UNEP), UNEP-Risoe Center (URC) and the Asian Institute for Technology (AIT),as the first comprehensive national exercise undertaken towards addressing our climate change concerns. Thus, the TNA Report provides an assessment of the priority technology requirements and action plans for climate change adaptation activities in food, water, coastal, health and biodiversity sectors. I am convinced that this exercise has been a nationally driven process involving local expertise and knowledge supplemented by international experiences.

In fulfillment of the Government's firm commitment towards taking appropriate national actions for tackling climate change related issues and also collaborative obligations to the international community in this context, I have great pleasure in presenting the **Sri Lanka's National Report on Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation** to the policy makers, potential investors, technology developers, scientists and all other stakeholders who are actively participating in sustainable development efforts of the country. I also recommend this report for consideration and emulation of the world community and invite them to be partners in achieving our economic, environmental and social development goals.

Susil Premajayantha, MP

Minster of Environment and Renewable Energy

Government of Sri Lanka

PREFACE

Sri Lanka ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 1993 and acceded its Kyoto Protocol in September 2002. In keeping with the obligations of the UNFCCC, the Government of Sri Lanka submitted its Initial National Communication in 2000 and submitted the Second National Communication in 2012. Over the last two decades, Sri Lanka has made a significant progress towards improving the national policy framework and strengthening the legal and institutional capabilities to facilitate implementation of obligations under the UNFCCC and Kyoto Protocol. These timely actions demonstrate the Government's firm commitment in addressing country's environmental and climate change related issues.

Although Sri Lanka is a low greenhouse gases emitter, it is highly vulnerable to adverse impact of climate change. Analysis of past records suggests that air temperature throughout the island has been on a rising trend during the last century. The future scenarios predict higher levels of emissions and possibility of adverse climate change impacts, if no mitigatory and adaptation actions are undertaken now.

The TNA explores country needs for the reduction of greenhouse gas emissions and adaptation technologies. It also re-affirms the will of the Government along with the international community to contribute to the joint efforts in addressing the climate change threat. It is envisaged that this process will open up access to funds, create an enabling environment for the transfer of priority technologies which will improve the climate resilience of the most vulnerable sectors in the country.

I would like to take this opportunity to extent my gratitude to the Global Environment Facility (GEF) for funding and the United Nations Environment Programme (UNEP) and the UNEP Risoe Center (URC) for implementing this project in collaboration with the Asian Institute of Technology (AIT). A record of appreciation is also extended to the members of the TNA committee, Sectoral working Groups and all other experts who have contributed to this national exercise.

B.M.U.D Basnayake
Secretary
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ACKNOWLEDGMENTS

This report on Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation was the outcome of the project on Technology Needs Assessment (TNA) on Climate Change Adaptation and Mitigation for Sri Lanka conducted by the Climate Change Division of the Ministry of Environment and Renewable Energy from June 2011 to April 2013.

The TNA project in Sri Lanka was funded by the Global Environment Facility (GEF) and technically supported by United Nations Environment Programme (UNEP) and the UNEP Risoe Center (URC) in collaboration with the Asian Institute of Technology (AIT). First and foremost, my appreciation goes to the GEF, UNEP, URC and AIT for their financial and technical supports.

I wish to take this opportunity to express my sincere gratitude to Hon. Susil Premajayantha, Minister of Environment and Renewable Energy, Hon. Anura Priyadarshana Yapa, Former Minister of Environment, Mr. B.M.U.D. Basnayake, Secretary, Ministry of Environment and Renewable Energy and Mr. Gamini Gamage, Additional Secretary (Environment and Policy) of the Ministry of Environment and Renewable Energy for their leadership, directions and guidance provided to conduct this project successfully.

My appreciation is extended to the members of the TNA committee, sectoral working groups and all other experts who contributed to this project. I am grateful to the various governmental, non-governmental and private sector personnel who took time out of their busy schedules to meet with our consultants and to provide data and information.

I am thankful to all the consultants of the TNA project, namely Mr. H.M. Bandaratillake, Team Leader and sector experts Dr. (Mrs.) S.M. Wijesundara (Food Sector), Dr. N.P. Sumanaweera (Health Sector), Prof. (Ms.) Hema M.K.K. Pathirana (Water Sector), Prof. (Ms.) P.R.T. Cumaranatunga (Coastal Sector), and Mr. Shamen Vidanage and Ms. Manishka De Mel representing International Union for Conservation of Nature (IUCN) (Biodiversity Sector).

My special thanks is also extended to the staff of the Climate Change Division of the Ministry of Environment and Renewable Energy, particularly to Ms. Anoja Herath, Coordinator of the TNA project, Ms. Nirosha Kumari and Ms. Surani Pathirana, Environment Management Officers of the Ministry of Environment and Renewable Energy.

Finally, on behalf of the Ministry of Environment and Renewable Energy I would like to thank all those who contributed to make this project realistic. Without their supports this project would never be success.

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Stakeholder Participation

TNA Committee	– Annex A1
Workshop Participants	– Annex A2

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP- Risoe Centre (URC) in collaboration with the Asian Institute for Technology (AIT), for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein are a product of the National TNA team, led by the Secretary, Ministry of Environment and Renewable Energy, Government of Sri Lanka.

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ABREVIATIONS

ADB	Asian Development Bank
AIT	Asian Institute of Technology
CBF	Community Based Fishery
CBSL	Central Bank of Sri Lanka
CCD	Coast Conservation Department
CCS	Climate Change Secretariat
CWSSP	Community water supply and sanitation project
CZMP	Coastal Zone Management Plan
DOA	Department of Agriculture
DZ	Dry Zone
GDP	Gross Domestic Production
GEF	Global Environment Facility
GHG	Green House Gas
IAS	Invasive Alien Species
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
MCDA	Multi Criteria Decision Analysis
ME	Ministry of Environment
MOH	Ministry of Health
MSL	Mean Sea Level
NDMC	National Disaster Management Centre
NEM	North East Monsoon
NTFP	Non-Timber Forest Products
PA	Protected Area
REDD	Reducing Emissions from Deforestation and (Forest) Degradation
RO	Reverse Osmosis
RWH	Rain Water Harvesting
SWM	South West Monsoon
TAP	Technology Action Plans
TFS	Technology Fact Sheet
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
WZ	Wet Zone

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Executive Summary

This report describes the Technology Needs Assessment (TNA) for climate change adaptation in Sri Lanka that was undertaken between June 2011 and December 2011. In line with its obligations as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), the Democratic Socialist Republic of Sri Lanka has undertaken a number of actions since ratifying the Convention in 1993 and acceding to the Kyoto Protocol in September 2002. Sri Lanka submitted the Initial National Communication on Climate Change (INC) to the 6th Session of the Conference of Parties (COP6) in 2000. The GHG inventory for 2000 and Second National Communication (SNC) was completed in 2011. Over the last two decades the country has made a significant contribution towards the improvement of national policy, strengthening of legal and institutional capabilities thus creating an enabling environment for implementation of the obligations under UNFCCC and Kyoto Protocol. Some of these policy interventions include development of National Environmental Policy (2002), National Climate Change Policy (2012), National Climate Change Adaptation Strategy (NCCAS) (2010) and Sri Lanka Strategy for Sustainable Development (2007). The National Advisory Committee on Climate Change (NACCC) was established in 2008 and subsequently in 2012 restructured as the National Expert Committee on Climate Change.

Under the UNFCCC, developing countries are encouraged to assess and report their technology needs for climate change adaptation and mitigation; and developed countries have committed to assisting with the technology transfer. The TNA process in Sri Lanka has followed the guidelines and procedures as recommended by UNDP/UNFCCC Handbook for Conducting Technology Needs Assessments for Climate Change (November 2010), Organizing the National TNA Process: An Explanatory Note (2010) and guidelines provided by the Asian Institute of Technology (AIT). The focus of the assessment has been on technologies that support Sri Lanka's economic development in a sustainable manner, in line with the National Development Policy Framework of Sri Lanka ("*Mahinda Chintana : Idiri Dakma*" – Vision for a New Sri Lanka, (2010) and vulnerability to climate change. The methodology adopted in the TNA was a stakeholder-driven process to identify and assess environmentally sound technologies that will, within national development objectives, reduce the impact of climate change and the rate of greenhouse gas emissions in Sri Lanka. The process of conducting the TNA was initiated by the Ministry of Environment with establishment of the National TNA Committee which mandated the Project Coordinator, National Consultants and sectoral stakeholder working groups to manage the process.

As the initial step of the TNA process, the priority sectors for adaptation and mitigation were identified in consultation with the National TNA Committee. The priority sectors thus identified for adaptation were **Food, Health, Water, Coastal and Biodiversity**. This prioritization was followed by preparation of a list of potential technologies for each sector in consultation with sectoral stakeholder working groups and other sector experts. Thereafter this list was prioritized by using the Multi Criteria Decision Analysis (MCDA) process at stakeholder consultation workshops for each sector. The process was involved in; a) selecting basic criteria for evaluation, b) deciding on sub-criteria associated with each basic criterion and c)

weighting the criteria and sub-criteria. Then the Performance Matrix was constructed based on the criteria and weighted scores followed by Benefit/Cost analysis which helped determining the most preferred, prioritized technologies.

Food Sector: The food sector in the current TNA included agriculture, livestock and fishery sub-sectors. Given the significant contribution made by the food sector to the Sri Lankan economy as a determinant of economic growth and as a source of employment to the nation's work force, its ability to adapt to climate change impacts becomes critical for continued economic growth. Several climatic parameters such as changing temperature and rainfall regime, availability of irrigation waters, sea level rise, intrusion of saline water, coastal flooding etc. are seen as directly or indirectly contributing to the success of crop production in the country. The climatic parameters which are critical for food production such as the quantum of rainfall received and the rainfall pattern has shown a declining trend and high variability respectively with incidences of increased extreme weather events. Changes in the diurnal variation of temperature, soil temperature and pest populations due to changes in climate factors are likely to exert a significant impact on crop production. The combined effect of changes in climatic parameters such as those contributing to land degradation is another dimension of serious negative consequences of climate change.

The current TNA carried out an analysis of various technology options for climate change adaptation in Sri Lanka with a view to understand the relative importance or potential contribution of each of them in negating or lowering the adverse impacts on the food sector. Through an extensive consultative process, a list of all potent technologies available in the food sector to face the challenge of climate change was compiled. The MCDA process constituted a scheme which took into account 19 different benefit characteristics from Environmental, social, and economic spheres in conjunction with the cost of implementation for ranking the identified adaptation technologies. The final benefit/cost analysis ranked **(1) Sustainable culture-based fisheries, (2) Sustainable land management and (3) Crop diversification and precision farming, as the most promising technologies.** Any technology with high cost of implementation was the key factor for not considering such technologies for selection.

Health Sector: Climate change has the potential for causing both direct and indirect adverse impacts on the health sector. Injury, high incidence of communicable diseases, mental illnesses, health effects due to high or low temperatures of the environment, diseases of the respiratory system etc. can be considered as direct impacts while food, water & rodent borne diseases due to contamination or scarcity of water in protracted droughts, crop failure leading to food shortage which contributes to macro nutrient & micronutrient deficiency, nutritional disorders and loss of live stock causing similar effects are perceived as some major indirect impacts. There is a fair possibility to alter the health of the people due to the effects of climate change. It is imperative to develop policies, legislation, strategic plans and administrative structures conducive to implement adaptation related activities at all levels of the health care system. Adaptation technologies aiming at minimizing the adverse health effects are needed.

At the first sectoral stakeholder meeting nine (09) potential adaptation technologies were identified and Technological Fact Sheets (TFS) were developed accordingly. These technologies were prioritized at a subsequent meeting using Multi Criteria Decision Analysis (MCDA) and first three technologies were selected as implementation priorities following the cost-benefit analysis. These selected technologies were; **(1) Technology for early warning systems and networking for information exchange on extreme events and other climate change related events, (2) Transfer of knowledge and skills to health personnel and (3) Management of Health Care waste.** Although there are other aspects of health services that requires attention for strengthening, this TNA is being recognized by all involved in the activity as an excellent opportunity to address these areas.

Water Sector: The freshwater ecosystems in Sri Lanka constitute surface water, groundwater, and overlapping waters. Surface water includes rivers, villus, man-made reservoirs, minor tanks etc. There are 103 distinct natural river basins that cover almost 90% of the island. Out of them nine are major rivers. More than 90% of the small tank systems are clustered into cascades and these tank network systems have been built in water scarce areas particularly in the Dry Zone by ancient kings mainly for agricultural purposes. The vast ancient reservoirs, small and large tanks and canals built by ancestors are being supplemented by many recent irrigation projects such as Victoria, Randenigala and Kotmale reservoirs. At present, certain rivers and lakes in Sri Lanka are polluted with industrial wastes. Excessive sand mining and over exploitation of ground water have resulted sea water intrusion in certain areas of the country. High concentrations of nitrate ions and bacterial contamination have been reported in tube well water from the Jaffna peninsula. High concentrations of fluoride ions are found in eastern and north-central dry zone, especially in the Districts of Anuradhapura and Polonnaruwa. The national policy on water supply envisages ensuring access to safe drinking water to all residents by 2025.

Air temperature in Sri Lanka has increased by $0.45^{0}C$ over the last 22 years, suggesting a rate of $0.2^{0}C$ increase per decade[1] and possible impacts predicted on the water sector due to climate change are severe droughts, floods, sea level rise etc. It has been predicted that, by 2050, the amount of rainfall received from the north-east monsoon which at present is the major source of water for the dry zone of Sri Lanka will be reduced by 34% while that received from the south-west monsoon will be increased by 38%. This would make the dry zone districts more vulnerable to droughts and the wet zone districts to floods and landslides. Prominent change due to low rainfall will be the increase of the area falling within the dry zone. Due to such droughts, surface water availability and per capita water availability will be decreased. The floods due to increase in rainfall intensity will reduce ground water recharge and also would affect quality of surface water, sediment generation and transport of sediments. Studies on the sea level rise have shown an increasing trend of sea water intrusion in certain coastal areas. As a result salinity of surface water and ground water in such areas will be increased.

[1] Department of Meteorology, Sri Lanka, 2010

Through an extensive consultative process seven (07) adaptation technologies were selected based on one or several factors such as the impacts of climate change, rainfall, economic, environmental and social benefits. Out of these adaptation technologies, the most preferred three were selected by using MCDA approach and the selected three technologies in order of priority are; **(1) Restoration of minor tank net works, (2) Rainwater harvesting from rooftops, (3) Boreholes/tube wells as a drought intervention for domestic water supply.**

Coastal Sector: Sri Lanka's coastal zone is highly variable in its morphology & ecology and it constitutes many sensitive ecosystems such as, coral reefs, mangroves, sea grass beds, sand dunes, lagoons, estuaries, etc. which has been subjected to many changes in the past due to natural phenomena and anthropogenic activities. The impacts of climate change on the coastal zone are expected to be largely site specific due to the influence of local factors. The potential impacts of climate change are many and varied, but from a human perspective, the five most important effects of climate change in the coastal zone are; a) increased probabilities of coastal flooding and inundation b) coastal erosion c) rising water tables d) saltwater intrusion into surface & groundwater and e) biological effects. The expected most important impacts on coastal zone of Sri Lanka due to climate change are Sea Level Rise (SLR) of about 0.5 m by 2050, coastal inundation, coastal erosion, loss of coastal terrestrial habitats, saltwater intrusion, changes in coastal biodiversity and changes in coastal morphology.

In consideration of the development programmes undertaken and the current socioeconomic status of the country, nine (09) most important climate change adaptation technologies needed for the coastal sector were identified in consultation with the sectoral stakeholder working group. Thereafter considering the Cost and benefits such as, economic (employment, foreign exchange earnings & protection for infrastructure); social (income, education & health) and environmental (land reclamation and reduction of GHG, land loss due to sea level rise & inundation), above selected adaptation needs were prioritised using the MCDA approach. Accordingly, (**1) Sand dune rehabilitation, (2) Restoration of mangroves and (3) Restoration of coral reefs by transplanting were** identified in order of priority.

Biodiversity Sector: Sri Lanka has a varied climate and topography which has resulted in a rich biodiversity distributed within a wide range of ecosystems. It is one of the most biologically diversed countries in the Asian region and falls within the 34 biodiversity hotspots identified in the world. In the context of its predominantly agriculture-based economy and the high dependence on many plant species for food, medicines and domestic products, conservation of biological diversity is of special significance to Sri Lanka.

The biodiversity sector in Sri Lanka has been identified as one of the most vulnerable sectors to climate change. Sri Lanka is vulnerable to the risk of sea level rise and increased frequency of storms that can bring major impacts on coastal biodiversity. Additionally, analysis of climate data indicate a change in rainfall regimes, and a trend for increasing air temperature, which in turn will have impacts on the country's biodiversity.

Through an extensive consultative process with members of the sectoral stakeholder working group, a list of eleven (11) potent technologies available in the biodiversity sector to minimize the vulnerability to climate change were identified as suitable adaptation options. Out of these adaptation options, the most preferred five (05) technologies were selected using MCDA approach. The first five technologies were selected as implementation priorities and they in order of priority are; **(1) Restoration of degraded areas inside and outside the protected area network to enhance resilience, (2) Increasing connectivity through corridors, landscape/matrix improvement and management, (3) Improve management, and possibly increase extent of protected areas, buffer zones and create new areas in vulnerable zones, (4) Focus on conservation of resources and carryout special management for restricted range, highly threatened species and ecosystems, (5) Ex-situ conservation for highly threatened species and possible re-introduction.**

CHAPTER 1

Background and Introduction

1.1 Background

Sri Lanka ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 1993. The primary objective of this multilateral agreement is to achieve the stabilization of Greenhouse Gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic activities from interfering with the climate system. In terms of Articles 4.1(c), (j) and 12 of the Convention, countries are periodically required to submit reports to the UNFCCC on strategies, plans and programmes regarding their attempts to address climate change. In order to fulfill these requirements, Sri Lanka submitted the Initial National Communication to the 6th Session of the Conference Of Parties (COP 6) in 2000. In September 2002, the Government of Sri Lanka acceded to the Kyoto Protocol. Over the last two decades Sri Lanka has made a significant contribution towards the improvement of national policy and strengthening of legal and institutional capabilities for implementation of the obligations under UNFCCC and Kyoto Protocol.

Some of these institutional initiatives include establishment of the Climate Change Secretariat (CCS) within the Ministry of Environment (ME) to serve as a node for the implementation of UNFCCC decisions including the preparation of the National Communications & GHG inventories, and establishment of the Designated National Authority (DNA) for the CDM under the Kyoto Protocol (KP). In addition, the ME has been instrumental in establishing two CDM Centres at University of Moratuwa and University of Peradeniya in order to involve the University system in promoting CDM activities in the country, particularly in the areas of energy and agriculture respectively. Besides these, the Centre for Climate Change Studies (CCCS) has been established within the Meteorological Department (MD) for undertaking research on climate change including analysis of data collected by the MD and make projections of climate change based on IPCC findings and assist scientists in other institutes in carrying out impact studies in their relevant sectors. Furthermore, National Capacity Needs Self Assessment on Climate Change (NCSA) and other related assessments have been carried out by the ME in 2007[2].

The recent policy and legal initiatives undertaken towards meeting the obligations of the UNFCCC include creation of a new environment related policies such as National Environmental Policy (2003), National Climate Change Policy (2012), National Land Use Policy (2007), National Forest Policy (1995), National Policy on Wildlife Conservation (2000), National Watershed Management Policy (2004), National Air Quality Management Policy (2000), National Policy on Wetlands (2006) etc and the new amendments to the Forest and Wildlife laws (Forest Ordinance & Fauna and Flora Protection

[2] ME, 2007, Thematic Assessment Report on Climate Change

Ordinance)[3]. In addition, recently developed strategies such as *Haritha* (Green)[4] Lanka Action Plan, National Climate Change Adaptation Strategy and Sri Lanka Strategy for Sustainable Development, demonstrate the importance that the Government places on environmental and climate change related issues. Besides, the National Council for Sustainable Development was formed in 2009[2] under the chairmanship of the President of the Democratic Socialist Republic of Sri Lanka to provide leadership and guidance for sustainable development in the country. The Council is charged with the responsibility of producing an integrated policy, and overseeing and guiding the implementation of the *Haritha* Lanka Action Plan to ensure the sustainability of social and economic development programmes while safe guarding the environmental integrity of the country.

1.2 Objectives of the Technology Need Assessment (TNA)

The Technology Needs Assessment is carried out to identify measures and practices that might be implemented in different sectors of a country to reduce GHG emissions and vulnerability to climate change and to contribute to overall development goals. It provides multiple benefits at the country level, including the identification of barriers for deployment and diffusion of technologies and facilitate in removing of policy and legal gaps leading to improvement of enabling environments, increasing the capacity of local institutions and experts, and raising public awareness of climate change issues.

The main objective of the Climate Change Technology Needs Assessment is to identify and assess environmentally sound technologies that have synergy between reducing the impact of climate change and the rate of GHG emissions in Sri Lanka within national development objectives. The TNA represents a set of country driven activities that identify and determine the most appropriate mitigation and adaptation priority technologies for Sri Lanka. By adopting a consultative process, it identifies the barriers to technology transfer and measures to address these barriers through a sectoral analysis.

The Specific Objectives of the TNA are to;

a. Define priority sectors for which technologies are needed to sustain national development projects and programmes in light of the UNFCCC and potential impacts of climate change.

b. Identify suitable technologies that contribute to climate change adaptation in the relevant sectors.

c. Prioritize the identified technologies, their cost-effectiveness, and barriers to implementation.

d. Develop an enabling framework for the development and diffusion of prioritized technologies for relevant sectors.

e. Develop project proposals for priority technologies for relevant sectors to mobilize resources for implementation of the programme.

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[3] Ministry of Environment, 2011, Sri Lanka

[4] National Action Plan for *Haritha* (Green) Lanka Programme, 2009, National Council for Sustainable Development, Presidential Secretariat, Sri Lanka

1.3 National Circumstances

Sri Lanka is an island nation in the Indian Ocean, located about 80 km to the southeast of the Indian sub-continent, lying between 5°55’ and 9°50’ North latitudes and between 79°42’and 81°53’ East longitudes. It comprises a mainland of area 65,610 km^2, including 2,900 km^2 of inland water bodies and several small islands with only six islands having area more than 1,000 ha located off the northwest coast. The mainland has a maximum length of 435 km in N-S direction and maximum width of 240 km in E-W direction. The south-central part of the country is mountainous, while the rest of the country is mostly flat undulating land. The country has a coast line of about 1,585 km, comprising sandy beaches and sand dunes, dotted with many lagoons, estuaries, marshes, mangroves and deltas. There are altogether 103 rivers spread around the country[5].

The climate of the country depends largely on the monsoon wind pattern. The annual mean surface air temperature of the island has an average value of about 27 °C, with the values varying between 35 °C in the lowlands and about 15°C in the highlands. The country receives rainfall over 2,500 mm annually in the south-west quadrant during the south-western monsoon period, while receiving below about 1,750 mm annually during the north-eastern monsoon period. Based on the rainfall, the country is divided into three climatic zones – wet, dry and the intermediate zones, with the dry and intermediate zones covering the major portion of the country. During the two inter-monsoon periods, there is rainfall spread over the entire country. The annual average rainfall received over the country is about 1,860 mm.

Sri Lanka gets affected by many extreme events annually including floods, landslides, droughts and occasional cyclones, causing much damage to property and to human lives. Efforts are being made to minimize the damage through improved monitoring systems providing real time rainfall information from landslide prone areas and also improving mechanisms for information dissemination to people in threatened areas. The government has recently established a separate Ministry on Disaster Management to coordinate work on disaster relief and related work.

Wide variation in population density exists across the districts in Sri Lanka. Colombo is overwhelmingly the most densely populated district with 3,729 persons per square kilometer, which is nearly 11 times higher than the national average. According to the 2001 Census of Sri Lanka population density stands at 300 persons per square kilometer whilst 72% of the population lived in rural areas, 22% in urban areas and 6% in plantation estates. The mid-year population estimates in Sri Lanka for year 2010 was 20.65 million people with a population density of 329 persons per square kilometer and it is one of the most densely populated countries of the world[6]. The population growth rate is around 1.1 per cent at present and it is projected that the population will reach the 25 million mark by the middle of the century.

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[5] ME, 2011, Second National Communication on Climate Change, Ministry of Environment, Sri Lanka

[6] Department of Census and Statistics, 2011

Sri Lanka's economy is based mainly on the service sector which has contributed 59% to the GDP in 2010, with the industrial and agricultural sectors contributing 29% and 12% respectively. The GDP (at current price) in 2010 has been Rs 5,602 billion (US$ 49.5 billion) with an average annual real growth rate of 8.0% in 2010. The per capita GDP (current price) has grown from about US$ 800 in 2001 to US$ 2,399 by 2010[7]. Sectors that have brought revenue to the country were industrial production, agriculture, fisheries, and tourism, mineral exports including gem stones, among others.

The human development indicators show values that are exceptionally high for a developing country. The life expectancy at birth is 74 years and the adult literacy rate, 91.4 per cent. Infant mortality is low (18.57 deaths/1,000 live births), and 93 per cent of the population have access to advanced health care. The Human Development Index (2010) is 0.658, approaching the level of developed countries, demonstrating a high quality of life. Sri Lanka is a multi-ethnic secular state. The major ethnic groups in the country are Sinhalese (73.9%), Tamils (18.2%) and Moors (7.1%). The majority of the population is Buddhists (69.3%), and the other major religions are Hinduism (15.5%), Muslims (7.6%), and Christians (7.6%)[8].

Sri Lanka has carried out its Second National Greenhouse Gas (GHG) Inventory for 2000 in accordance with the revised 1996 IPCC Guidelines (RIG, 1996) and reported in the Second National Communication in Climate Change (2011)[7]. Based on this inventory, the total aggregate emission was 20,798 GgCO_{2Eq} which comprised 65% from the energy sector, 22.6% from the agriculture sector, 9.8% from the waste sector, 2.4% from the industry sector and 0.2% from the land use change and forestry sector as shown in Table 1.1. With the uptake of 6,254 GgCO_{2Eq} from the land use change and forestry sector, the total net emission had been 14,544 GgCO_{2Eq}. The composition of this quantity was 45.8% of CO_2, 46.9% of CH_4 in CO_{2Eq} and 7.3% of N_2O in CO_{2Eq}. Transport, Energy, Agriculture, Industry and Waste are the highest GHG.

[7] Economic and Social Statistics of Sri Lanka, 2011, Central Bank of Sri Lanka

[8] CBSL, 2011, Economic and Social Statistics of Sri Lanka, 2011, Central Bank of Sri Lanka

Table 1.1 Summary of GHG Emissions/Removals during 2000[9]

Sector	CO_2 Gg	CO_2 Removals Gg	CH_4 $GgCO_{2Eq}$	N_2O Gg $Co_{2\ Eq}$	Total Gg_{Eq} (Net)	Percentage of total
Energy	10,430.01		881.37	251.10	**11,562.48**	**61.4%**
Ind. Processes	492.40				**492.40**	**2.6%**
Agriculture			3,887.94	821.50	**4,709.44**	**25.0%**
LUCF-Emissions	10.34		35.07		**45.41**	**0.2%**
Waste			2,033.22		**2,033.22**	**10.8%**
Total-Emissions	10,932.75		6,837.60	1,072.60	**18,842.95**	**100.0%**
LUCF-Removals		-6,253.99			**-6,253.99**	
Total-Net	**10,932.75**	**-6,253.99**	**6,837.60**	**1,072.60**	**12,588.96**	

Source: ME, 2011, Second National Communication on Climate Change

Sector Vulnerability Profiles and National Climate Change Adaptation Strategy (NCCAS) for Sri Lanka: 2011 – 2016[10], developed by the Ministry of Environment in 2010 have identified the following five key sectors as the most vulnerable sectors in the Sri Lankan context:

- Agriculture and Fisheries
- Water
- Health
- Urban Development, Human Settlements & Economic Infrastructure
- Biodiversity and Ecosystem Services

1.4 National Sustainable Development Strategies

The concept of sustainable development is not new to Sri Lanka, though the term itself has come into prominence only recently. The natural resource conservation had been an integral part of the ancient civilization of Sri Lanka and much evidence to this effect is available in ancient chronicles of Sri Lanka such as Mahawamsa[11]. Our ancestors have had a long tradition of living in harmony with nature in the course of harnessing natural resources for more than 2500 years.

After the Rio summit in 1992, the government of Sri Lanka began to follow a more focused and comprehensive policy towards sustainable development. The nation is committed to ensuring environmental sustainability by 2015 as part of its commitment to achieving the Millennium Development

[9] ME, 2012, Second National Communication in Climate Change, Ministry of Environment, Sri Lanka

[10] ME, 2010, National Climate Change Adaptation Strategy for Sri Lanka: 2011 – 2016, Ministry of Environment, Sri Lanka.

[11] The great historical chronicle of Ceylon (Sri Lanka) composed in the late 5th or early 6th century.

Goals. Realizing the need to strike a balance between environmental conservation and economic development, the Government of Sri Lanka in 2003, enunciated the National Environmental Policy with the vision *"to achieve a healthy and pleasant environment sustaining nature for the well being of people and the economy".* The policy ensures a sound environmental management within a framework of sustainable development in the country and provides the direction for the necessary measures to conserve and manage Sri Lanka's environment and natural resources. Successive National Environmental Action Plans (NEAP), recently developed Climate Change Policy and strategies such as *Haritha* Lanka Action Plan, National Climate Change Adaptation Strategy and National Sustainable Development Strategy of Sri Lanka provides a broad environmental policy framework for sustainable development in the country.

Although Sri Lanka has made substantial progress in economic development over the past few decades, significant challenges to sustainable development still prevails. These challenges have been broadly identified as poverty, land degradation, realization of social well being, sustainability of water supply, sound ecosystem management and clean environment, energy security, heritage and culture and good governance.

Although overall population below the national poverty line has decreased over the last two decade from 26% (1993) to 8.9% (2009/10) along with the growth in per capita incomes, there are wide regional disparities within the country[12]. Further, poverty in the 7 poorest districts has increased during the last decade though national per capita income rose during this period; while urban poverty halved, poverty in the estate sector increased 50%. Over half the population is below the minimum level of dietary energy consumption, and there is a higher prevalence of under nutrition in rural and estate sectors than in urban areas. Food security in terms of availability, accessibility and affordability is uncertain notably in the estates.

The major environmental issues faced by Sri Lanka at present include land degradation, pollution and poor management of water resources, impacts of large scale deforestation in the past, loss of biological diversity due to non-sustained extraction of resources that exceed the recuperative capacities of ecosystems and species, air pollution, declining availability of fresh water, coastal erosion, degradation of marine and coastal habitats, inadequate facilities for solid waste disposal in urban areas, traffic congestion in the main cities, and increasing loss of agricultural productivity[13].

At the same time, Sri Lanka needs to accelerate economic growth in order to meet the rising expectations of a growing population, about 15% of which is still below the poverty line[14], and on the other hand, there is a need to be judicious in resource use in view of the alarming rate at which the resource base is being depleted.

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[12] Department of Census and Statistics, 2011

[13] Sri Lanka Environmental Outlook Report, 2010

[14] Department of Census and Statistics, 2011

The Sri Lanka Strategy for Sustainable Development (SLSSD) which was developed by the Ministry of Environment and Natural Resources in 2007[15] aims to meet the country's various development needs as well as its development challenges, and to mainstream environmental considerations in policy-making and policy implementation. According to SLSSD, Sri Lanka's vision for sustainable development is *"Achieving sustained economic growth that is socially equitable and ecologically sound, with peace and stability"*.

The SLSSD seeks to achieve this vision through eradication of poverty, ensuring competitiveness of the economy, improving social development, ensuring good governance, and a clean and healthy environment. These five goals prioritize the challenges that have to be addressed in the path to achieving sustainable development.

Following are the general strategies adopted in the path to sustainable development:

i. Creating an economy for sustainable development
ii. Strengthening institutional structure for sustainable development
iii. Creating a policy framework for sustainable development
iv. Creating a regulatory framework for sustainable development
v. Creating a knowledge base for sustainable development

The SLSSD recommended establishing an implementation mechanism known as the "National Council for Sustainable Development (NCSD)" through a parliamentary bill as a policy making, approving and monitoring body under the leadership of His Excellency the President of Sri Lanka. Based on this recommendation, The Cabinet of Ministers of the Government approved the decision to establish the National Council for Sustainable Development (NCSD) chaired by His Excellency the President of Sri Lanka in 2008 and to formulate the *Haritha* (Green) Lanka Programme. The *Haritha* (Green) Lanka Programme was thus developed in 2009 and it aims to mainstream the subject of 'Environment into the national development planning process in the country. The NCSD is responsible for overall management and coordination of the programme. Ministry of Environment acts as the Secretariat and the Ministry of Plan Implementation monitors progress of the programme.

1.5 National Climate Change Policies and Actions

The UNFCCC defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over a comparable time period"[16]. Climate change has been heralded as a

[15] Sri Lanka Strategy for Sustainable Development, 2007, Ministry of Environment and Natural Resources, Sri Lanka
[16] UNFCCC, 1992, United Nations Framework Convention on Climate Change, *(Sri Lanka became a party to the UNFCCC in 1993)*

threat to the global society. It has become a subject of intense interest to public policy decision makers internationally. As a small island nation, Sri Lanka falls into the UNFCCC and IPCC's category of 'vulnerable' small island nations under serious threat from various climate change impacts, such as sea level rise and severe floods and droughts (UNFCCC 1992; IPCC 2001)[17]. These threats are considered to have significant negative consequences on various sectors within Sri Lanka (ME, 2011). Climate change puts extra burdens on the social and economic challenges that the poorest already face, emphasizing and increasing their vulnerabilities due to the dependence of their livelihoods on climate sensitive natural resources and their weak social protection structures. By directly eroding the resources that poor people depend on for their livelihoods, climate change makes it easier for people to fall into poverty and harder for the poorest to escape from it.

Sri Lanka, being a developing country in the tropical region with significant poor population, and located in a disaster prone region, is highly vulnerable to climate change in terms of physical as well as socio-economic impacts. Although Sri Lanka's GHG emissions are negligible compared to those of developed or larger developing countries, analysis of past records in Sri Lanka have highlighted that air temperature in the island has been rising throughout the country during the last century with a temperature increase of 0.016ºC per year between 1961 and 1990 whilst the highest increase of minimum temperature being about 2.0 C at Nuwara Eliya. Night time annual average temperatures have increased in a faster rate than that of the daytime, up to a maximum of 0.02 ºC per year. Analysis of rainfall data reveals that the variability has been increasing in the past in most parts of the island resulting in water scarcities in the dry zone of Sri Lanka. Extreme weather events such as high intensity rainfall followed by flash floods and landslides, and extended dry periods resulting in water scarcity are now becoming common occurrences in the country.

Therefore urgent action towards implementing adaptive measures is imperative in order to build resilience of the country to enable facing the adverse impacts of climate change, while actively involving in the global efforts to minimize the greenhouse gas emissions within the framework of sustainable development. Sri Lanka has to address these challenges considering the global scenario of decreased financing for infrastructure development, increased volatility to energy markets, problems related to food security, trade, commerce and industrial development together with the climate change challenges.

As climate change is a complex issue requiring action by a varied group of stakeholders, lately the necessity of a national agenda to face this challenge has been conceived. In this context, the Government of Sri Lanka has developed a policy framework on the basis of UNFCCC guidelines that addressed the need for the nation to engage in climate change mitigation and adaptation measures. This

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[17] IPCC, 2001, (Intergovernmental Panel on Climate Change), Climate Change 2001: Impacts, Adaptation, and Vulnerability: Summary for Policymakers, a Report of Working Group II of the Intergovernmental Panel on Climate Change.

policy framework namely, “National Climate Change Policy for Sri Lanka” was developed in 2012 with a view to provide directions for all the stakeholders to address the adverse impacts of climate change efficiently and effectively.

1.5.1 National Climate Change Policy for Sri Lanka

The national climate change policy is aimed at mainstreaming climate change issues within the overall national effort towards sustainable development and it creates the conditions necessary to overcome the major gaps existing at present. See the box for highlights of the National Policy.

SRI LANKA NATIONAL CLIMATE CHANGE POLICY

Vision : A future where climate change will have no adverse consequences on Sri Lanka.

Mission: Addressing climate change issues locally while engaging in the global context.

Goal : Adaptation to and mitigation of climate change impacts within the framework of sustainable development

Objectives:

- Sensitize and make aware the communities periodically on the country’s vulnerability to climate change.
- Take adaptive measures to avoid/minimize adverse impacts of climate change to the people, their livelihoods and ecosystems.

It is an essential pre-requisite to proceed from the present position the country is in now, as far as climate change is concerned. Success of such a national agenda would largely be determined by the effectiveness of measures taken to overcome the main gaps existing at present.

1.5.2 Actions taken by Sri Lanka to counter Climate Change Impacts

Since ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, a number of actions has been taken by the Government of Sri Lanka towards complying with its obligations under the Convention[18].

[18] Herath. A, 2008, Climate Change and Energy in Sri Lanka, Ministry of Environment and Natural Resources, Sri Lanka

These actions include *inter alia*, Ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1993; Acceding the Kyoto Protocol (2002); Preparation of the Green House Gas (GHG) Inventory (1994); Preparation of the Initial National Communication on Climate Change (2000); Undertaking Research Studies on Climate Change; Establishment of the Centre for Climate Change Studies- CCCS (2001); National Capacity Self Assessment for the Implementation of the three Rio Conventions –NCSA (2004-2006); Establishment of Clean Development Mechanism (CDM) under the Kyoto Protocol; Establishment of the Sri Lanka Carbon Fund (2008); Establishment of the National Advisory Committee on Climate Change (2008); Establishment of the Climate Change Secretariat (2008), formulation of National Climate Change Policy for Sri Lanka (2011) and preparation of the National Climate Change Adaptation Strategy (2010).

In addition, issues related to climate change and ozone layer depletion has been integrated into the formal education system of the country by incorporating them in school curricula and some Universities offering separate modules on climate change in their environmental science streams. Government agencies having responsibilities of managing the environment, climate and allied fields have been conducting training and awareness programs in schools and universities with the view to update the students on climate change and its impacts. The Air Resource Management Centre (Air Mac) of the Ministry of Environment is involved with conducting training programs for government officers, technical officers of Vocational Training Institutes and Automobile Engineering Training Institutes and technicians of garages on reduction of vehicular emissions *vis a vis* control of GHG emission.

The GEF Enabling Activity (Phase II) Project, Strengthening Capacity for Climate Change Adaptation Project, Capacity Development of Clean Development Project Promotion in Sri Lanka, Preparation of Second National Communication on Climate Change Project, are some of the significant project interventions in the recent past through which institutional capacity of respective agencies has been strengthened to enable complying with the national obligations of the Climate Change Convention. As the need for information exchange has been recognized as a priority, actions towards networking of climate change related institutions in Sri Lanka in this regard is in the process of development.

1.5.3 Goals of National Climate Change Adaptation Strategy for Sri Lanka (NCCAS)

Although Sri Lanka's contribution to global warming is insignificant, its vulnerability to climate change appears to be very high. Hence, Sri Lanka has recognized the need for climate change adaptation in order to achieve its economic development goals as articulated in the Mahinda *Chintana* policy framework while ensuring environmental sustainability. In view of this, the Ministry of Environment in 2010 developed the National Climate Change Adaptation Strategy (NCCAS) defining a prioritized framework for action and an investment plan for the period 2011- 2016 with the overall goal of systematically moving the country towards a climate change resilient future. In order to achieve this goal NCCAS has identified the following strategic thrust areas for action.

- Mainstream Climate Change Adaptation into National Planning and Development
- Enable Climate Resilient and Healthy Human Settlements
- Minimize Climate Change Impacts on Food Security
- Improve Climate Resilience of Key Economic Drivers
- Safeguard Natural Resources and Biodiversity from Climate Change Impacts

1.6 TNA Relevance to National Development Priorities:

In the recent years, the population pressure has brought in wide range of environmental problems in Sri Lanka. Land degradation, pollution and poor management of water resources, impacts of past large scale deforestation, loss of biological diversity, coastal erosion, increasing scarcity of water for agriculture, inadequate facilities for waste disposal in urban areas, wide range of issues in the transport sector and increasing loss of agricultural productivity are some of such major issues faced with. Besides these environmental issues, inequalities in income distribution and access to essential services in different districts, in increasing income disparities and malnutrition are the significant economic and social challenges prevalent at present[19].

In spite of these challenges, Sri Lanka has already made an impressive progress towards meeting the Millennium Development Goals in key areas of human development such as education and health. Being a developing country, graduating to the middle income country status is remarkable achievement despite the severe social and economic setbacks of the 2004 Asian Tsunami and long years of civil conflict.

The Government's new National Development Framework ("*Mahinda Chintana: Idiri Dakma*" - Vision for a New Sri Lanka, (2010) aims at accelerating growth, with particular emphasis on equitable development, recognizing that there has been a perpetuation of income disparities both among income earners and across geographic regions. It focuses on three main areas: (i) achieving more equitable development through accelerated rural development; (ii) accelerating growth through increased investment in infrastructure; and (iii) strengthening public service delivery.

In view of this, Sri Lanka needs to accelerate economic growth in order to meet the rising expectations of a growing population, about a quarter of which is still below the poverty line. Therefore, a sustainable high level of economic growth must be ensured without causing irreversible damage to the environment. The country's national development framework and SLSSD seeks to achieve this vision through eradication of poverty, ensuring competitiveness of the economy, improving social development, ensuring good governance, and a clean and healthy environment.

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[19] ME, 2007, Sri Lanka Strategy for Sustainable Development, Ministry of Environment and Natural Resources, Sri Lanka

Simultaneously, the TNA aims to reduce GHG emissions and vulnerability to climate change in priority sectors of Sri Lanka and to contribute to overall national development goals. It provides multiple benefits at the country level, including the identification of barriers for deployment and diffusion of technologies and facilitate in removing of policy and legal gaps leading to improvement of enabling environments, increasing the capacity of local institutions and experts, and raising public awareness of climate change issues.

The TNA process starts with an identification of a country's development and sustainability priorities with particular attention to GHG emission reduction potentials and adaptation needs in the context of the appropriate country scenarios on climate change. The priority sectors and technologies are identified on the basis of the GHG emission reduction potential, contribution from low carbon technology investments and vulnerability to climate change impacts. Accordingly, five (05) priority sectors have been identified for climate change adaptation. These sectors are; **Food, Health, Water, Coastal Resources and Biodiversity**. The process aims at providing opportunities for achieving both, the country's development goals and sustainable development through protection against climate change impacts and mitigation of climate change.

Two main objectives expected from the TNA process:

- To meet Sri Lanka's national development priorities, and
- To maximize the sustainability outcomes of the country, particularly through GHG emission reduction and protection against projected climate change damage.

CHAPTER 2

Institutional arrangement for the TNA and the stakeholders' involvement

2.1 TNA team, national project coordinator, consultants, etc

The Sri Lankan TNA has followed the guidelines from the UNDP/UNFCCC Handbook for Conducting Technology Needs Assessments for Climate Change (November 2010), Handbook for Conducting Technology Needs Assessments for Climate Change (2009) and Organizing the National TNA Process: An Explanatory Note, 2010[20]. Overview of the institutional arrangements involved in the TNA process proposed by UNDP/UNFCCC Handbook for Conducting Technology Needs Assessments for Climate Change is shown in Figure 2.1.

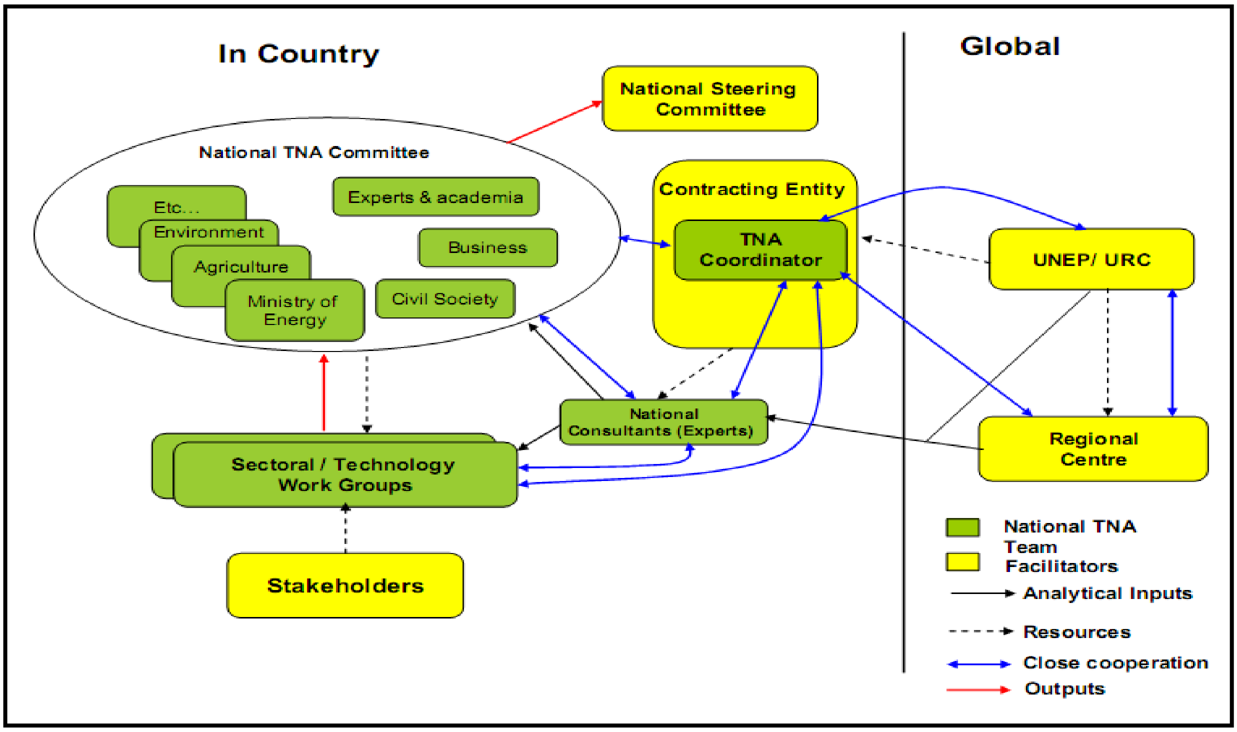

Figure 2.1 Institutional Arrangements for the TNA Project

Based on the guidelines proposed by the UNDP/UNFCCC Handbook, following initial steps were taken in forming institutional arrangements for the implementation of the TNA project:

- Identification and establishing the lead agency for TNA project implementation

[20] S. Dhar, j. Painuly, I. Nygaard, 2010, Organizing the National TNA Process: An Explanatory Note, UNEP Risoe Centre, Denmark.

- Exploring objectives and scope of the Project through a consultation meeting
- Identification of relevant stakeholder agencies and personnel for the TNA Committee
- Identification of a core team involving the lead technical institutions and representing participants, and other technical experts for all the sectors.
- Appointment of the TNA Coordinator and National Consultants
- Define a process for stake holder consultation by establishing the TNA committee and Technical Sectoral Stakeholder Working Groups for all the priority sectors.

Accordingly, setting up of the National TNA team was the first operational task undertaken in the TNA process. The **Ministry of Environment (ME)** being the focal point for UNFCCC and Kyoto Protocol was designated as the lead agency responsible for the TNA process. The **National TNA Team** comprised of the inter-ministerial **National TNA Committee**, **Project Coordinator**, **National Consultants** and **Sectoral Technical Working Groups**. The "National Advisory Committee on Climate Change", the highest level multi-stakeholder decision making body of the Ministry of Environment, functioned as the **National Steering Committee** for the Project. This Committee comprised of senior officers from all relevant line Ministries, members from Non-Governmental Organizations and the private sector. The Climate Change Secretariat is located in the ME and it also serves as the chair to the National Advisory Committee on Climate Change.

TNA Committee: The TNA Committee that included senior representatives from relevant Ministries led the TNA process. The Committee chaired by the Secretary of the Ministry of Environment comprised of 21 members. *(List of members of the National TNA committee is provided in Annex A1).* The composition of the National TNA team remained flexible to enable including any other members as required during the TNA process. Members of the National TNA Committee were those who are familiar with national development objectives and sector policies, overall insights of climate change, and potential climate change impacts and adaptation needs for Sri Lanka. This National TNA committee functioned as a Task Force overseeing the TNA process and it provided the leadership for project implementation. As agreed at the initial TNA meeting, the specific responsibilities of the TNA committee included the following;

1. Identify national development priorities and priority sectors for the Technology Need Assessment.
2. Decide on composition and constitution of sectoral technical workgroups.
3. Review and approve technologies and strategies for mitigation and adaptation as recommended by sectoral workgroups.
4. Review and approve the TNA Report, Report on Barrier Analysis and Enabling Framework (including a roadmap of policies that will be required for removing barriers and creating the enabling environment), and National Technology Action Plan for mitigation and adaptation and Project ideas for all sectors.

The Project Coordinator: A senior officer attached to the Climate Change Secretariat with adequate scientific background, facilitation skills and familiar with the climate change negotiations and activities functioned as the Project Coordinator who was vested with the responsibility of managing the overall TNA process while providing vision and leadership for the overall exercise as the focal point. This included facilitation of communication with the National TNA Committee and Consultants, coordination and communication with sectoral technical working groups and stakeholders, recruitment and coordination with Consultants, formation of networks, information acquisition, preparation of Work Plans and monitoring of the progress of the Project etc. Facilitation of TNA activities including administrative support, organization of TNA Committee meetings, organization of technical stakeholder working group meetings and workshops as well as implementation of the Work Plan of the Project was through the Project Secretariat under directions of the TNA Coordinator.

National Consultants: A Team of five (05) national experts and a Team Leader provided the required technical expertise for the adaptation component of the Project. The responsibility of each expert included identification and prioritization of technologies, carryout barrier analysis, enabling framework & market assessment and preparation of draft Technology Action Plans (TAP) & draft project ideas for their respective area of expertise. The Team Leader functioned under the overall guidance of the TNA Committee and the Project Coordinator. The responsibility of the Team Leader included providing overall guidance to sector experts, preparation of that consolidated Technology Needs Assessment (TNA) reports for Mitigation and Adaptation.

Sectoral Technical Working Groups: Functioning of Sectoral Technical Working Groups is discussed under the section on “Stakeholder Engagement Process”.

2.2 Stakeholder Engagement Process

The stakeholder involvement is very crucial to the TNA process as it reflects national response to climate change technology, and implementation of activities at all levels. In order to ensure widest possible stakeholder participation in the TNA process, five (05) technical stakeholder working groups were established on sectoral basis. These stakeholder working groups represent Food, Health, Water, Coastal Resources and Biodiversity Sectors. The stakeholders for the technical working groups have been identified from the relevant organizations and institutions as recommended by the UNDP/UNFCCC Handbook (2010). The stakeholders in the working groups included representatives of the Government departments with responsibility for policy formulation & regulation, private & public sector industries, technology distributors, users & suppliers, organizations involved in the manufacture, import & sale of technologies and other relevant institutions such as universities, research organizations & relevant NGOs. The Sector Working Groups were mandated with the responsibility of taking decisions with regard to the technologies appropriate for respective sectors, undertake barrier analysis, market assessment and enabling framework for relevant sectors, and contribute to development of TAP and project ideas.

As recommended by the UNDP/UNFCCC Handbook, following steps have been followed in the stakeholder involvement process;

- Identification of stakeholders for sectoral working groups.
- Define the goals and objectives of working groups.
- Clarification of stakeholder roles.
- Establishment of an ongoing process for stakeholder engagement.
- Involvement of stakeholders in each stage of the process.

The goals, objectives and the working arrangements of the participatory process was discussed and agreed with all sectoral stakeholder working groups at the **National Inception Workshop**. At this meeting objective of the TNA Project and purpose of stakeholder participation was also discussed and agreed. The main purpose of the stakeholder participation is to get their involvement throughout the TNA process for selecting priority sectors, technology identification and prioritization, barrier analysis, market mapping and development of enabling framework, Technology Action Plans (TAPs), project ideas etc, as they will be intimately involved in implementation of recommended technologies. Therefore, an ongoing arrangement has been established to get continuous and adequate involvement of stakeholders at each stage of the TNA process.

The roles and responsibilities of stakeholder working groups have been discussed during the inception workshop. Each sectoral stakeholder working group included around 15-20 persons representing related organizations in the respective sectors. The compositions of the sectoral working groups were flexible with the provision for including additional members depending on the requirement. The Project Coordinator together with the consultants facilitated the sectoral working group discussions ensuring maximum output from the deliberations. *(The compositions of the Sectoral Technical Stakeholder Working Groups are provided in Annex A 2).*

CHAPTER 3

Sector Prioritization

3.1 Development Priorities and Overview of Priority Sectors

3.1.1 Development Priorities in Sri Lanka

The sector prioritization process for adaptation started from identification of development and sustainability priorities of Sri Lanka, with particular attention to vulnerability of different sectors to climate change. The following are the main criteria adopted for selecting and prioritizing sectors for the climate change adaptation;

- Contribution to the development priorities of the country
- Contribution to minimize vulnerability to climate change
- The market potential
- Access to/availability of technologies in the sector.
- Other criteria appropriate to national circumstance

The Development Policy Framework of the Government of Sri Lanka – "Sri Lanka Emerging Wonder of Asia: *Mahinda Chintana* – Vision for the Future" – presents Sri Lanka's economic policy strategies, actions and the roadmap for the next six years[21].

The economic development philosophy of *Mahinda Chintana* is that economic growth alone would not bring prosperity to the society but social, cultural, religious and environmental development are equally important. The development goals of the Government will be achieved by transforming the country to a modern, knowledge-based, environmentally friendly and well connected rural-urban network that benefits all citizens of the country through equitable access to development[22].

The main strategies as stated in this policy framework are;

- A Prosperous Country: A Land of Plenty
- Enterprises with Strength to Conquer the World
- Developed Road Network and Transport System
- Focus on Modern Education and Knowledge Systems
- A Healthy Society

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[21] Sri Lanka Emerging Wonder of Asia: *Mahinda Chintana* – Vision for the Future, 2010, Department of National Planning, Ministry of Finance and Planning, Sri Lanka.

[22] Annual Report, 2010, Ministry of Finance and Planning, Sri Lanka.

- Comforts, Convenience and Satisfactory Lifestyle
- Shared Values and Rapid Development

The development priorities identified based on the above strategic directions in the policy framework are as follows;

- Agriculture: feeding the nation
- Fisheries and Aquatic resources
- Self reliance in Livestock industry
- Irrigation: Water is our heritage and Life and
- Water services Perspective
- Healthy Society
- Housing for All – Prosperous and healthy Lifestyle
- Environment
- Modern Education and Knowledge Systems
- A Modern Economy Through Science and Technological Innovations
- Electricity for everybody, everyday
- Industry sector: Towards Global Competitiveness
- Developed Road Network and Transport System

3.1.2 Overview of Priority Sectors

Climate change vulnerabilities cut across many sectors in the economy, and threaten to compromise the significant achievements the country has recorded in the last 20 years in increasing incomes and reducing poverty, as well as country's ongoing development drive. Investments currently being deployed for the ongoing development efforts are also at risk due to climate change. The sector vulnerability profiles developed for Sri Lanka in 2010[23] has identified following sectors where climate vulnerabilities are expected to be critical. These sectors include;

- Agriculture and Fisheries
- Water
- Health
- Urban Development, Human Settlements & Economic Infrastructure
- Biodiversity and Ecosystem Services

The overview of the relevant key sectors is given below:

a) Agriculture and Fisheries Sectors:

Agriculture plays a major role in the economy as source of income for the majority of rural poor, source of national growth, provider of opportunities for private investment, and a driver of agriculture related industries. In 2010, the agriculture sector contributed 11.90% to the national GDP[24]. The sector provided

[23] ME, 2010, National Climate Change Adaptation Strategy for Sri Lanka- 2011 to 2016

[24] CBSL, 2010

direct employment to 31.3% of the total labor force in 2009. Furthermore, it is estimated that the agriculture-related activities provide the major source of employment and livelihood for nearly 72% of the Sri Lankan population. In national income statistics, agriculture is defined as including crop production, animal husbandry, fisheries and forestry. The contribution to the GDP from agriculture sector comes predominantly from crop production which accounted for 77% in 2010. In comparison, the contributions from livestock, forestry and fisheries sectors were 7.1%, 5.7% and 10.5% respectively[21]

Aquaculture has emerged as one of the key strategic sectors in view of the increasing demand for fishery products, and potential for income diversification and increasing utilization capacity of scarcely used or degraded lands. Reservoir based fresh water fishery provides significant contribution to food and nutritional security of the rural areas of the country. With the development of inland fishery, per-capita fish consumption in the land-locked regions such as Anuradhapura and Polonnaruwa districts has exceeded the average national per-capita fish consumption. This has been primarily achieved especially through culture-based fishery (CBF) in medium size perennial reservoirs and small village tanks.

b) Water Sector:

In Sri Lanka there are 103 distinct natural river basins that cover approximately 90% of the island[25]. River basins originating from the wetter parts of the up country are perennial while many of those in the dry zone are only seasonal. According to the Agrarian Services Act No. 58 of 1979*,* tanks having an irrigated command area of less than 80 ha (1 ha = 2.47 acres) are categorized as small or minor tanks. More than 90 percent of the small tank systems are clustered into cascades and these tank network systems have been built in water scarce areas by ancient kings mainly for agricultural purposes.

Water is mainly used for domestic, irrigation, hydropower generation and industrial purposes. Protected wells, deep & tube wells, protected springs and pipe borne municipal supplies are considered as safe drinking water sources and water from unprotected wells, rivers, tanks and canals are considered as unsafe. According to Mahinda Chinthanaya policy framework, 90% of people will have access to safe drinking water by year 2016. It further envisages 100% of urban population, 90% of rural population and 80% of estate sector to have access to safe drinking water by year 2016.

c) Health Sector:

In general the Health sector has a well established preventive and curative care network throughout the country despite the fact that there are differences between the different geographical areas, especially with regard to the adequacy of human resources in the public health service sector. Although the public hospitals are satisfactorily equipped to provide communicable disease prevention services, their impact in controlling such diseases appear to be minimal.

There are 1,042 Government hospitals in the country with 13,280 doctors and 26,629 nurses and other related staff[26]. In addition there are 147 Private Hospitals mainly in urban centers. There are 316 Medical

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[25] Imbulana K.A.U.S.,*etal,* 2010

[26] Ministry of Health, 2010

Offices of Health areas in the island. The preventive care services provided by the public health officials include Maternal and Child health, immunization, nutrition supplementation, health education, sanitation, communicable disease prevention and many other related services.

Many communicable diseases are under control and diseases such as Malaria and Japanese Encephalitis are almost eradicated. However, recently Dengue has achieved an epidemic level resulting nearly 20,000 persons have been affected in 2011out of which 155 have died of complications due to dengue. The main reason is irregular precipitation pattern and collection of clean water in an around the human dwellings. Therefore, climate change and related extreme weather events is likely to have both direct and indirect impacts on health of the people.

d) Biodiversity and Ecosystem Services:

Sri Lanka has a varied climate and topography, which has resulted in rich biodiversity, distributed within a wide range of ecosystems. The biodiversity of the country is recognized as being globally important. Sri Lanka along with the Western Ghats of India has been identified as one of the 34 biodiversity hotspots in the world[27]. Biodiversity provides a multitude of ecosystem goods and services to people of the island, including watershed services, regulation of climate, carbon sequestration and supply of non-timber forest products such as rattan, wild foods, fruits, medicinal plants etc., among many others.

The biggest threats to the Protected Area System and biodiversity in general come from encroachments, conversion to other land uses, illegal extraction of natural resources, shifting cultivation, forest fires, haphazard development projects, poaching, pollution, gem mining, siltation and sedimentation in coastal and marine ecosystems, sewage and solid waste disposal, development of aquaculture and illegal sand/coral mining. However, it is estimated that about 15% of the islands forests and scrublands lie within the country's Protected Area (PA) system[28], while some marine protected areas have also been set up in addition to these terrestrial areas.

The Sector Vulnerability Profile (SVP) for the biodiversity sector (which is a supplementary document to Sri Lanka's National Climate Change Adaptation Policy) has looked at the impact of climate change on this sector. It states that, as an island nation, Sri Lanka is vulnerable to the risk of sea level rise and increased frequency of storms that can bring major impacts on coastal biodiversity. Additionally, analysis of climate data indicates a change in rainfall regimes, and a trend of increasing air temperature, which can also have impacts on the country's biodiversity.

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[27] Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. & Kent, J. 2000. Biodiversity hotspots for conservation priorities.*Nature* 403, 853–858

[28] Ministry of Environment (1999).*Biodiversity conservation in Sri Lanka: a framework for action*. Colombo, Sri Lanka.

3.2 Process and Criteria of Prioritization

In the process of prioritizing the sectors, the development and sustainability priorities, potential for applying adaptation technologies and their vulnerability to climate change were deliberated with the stakeholder groups and the TNA committee.

The steps undertaken by the stakeholders for prioritization of sectors are summarized in Table 3.1. The list of the stakeholders participated in the deliberations is provided in Annex A2.

Table 3.1: Strategic Choice of Priority Sectors for Adaptation

Steps	Description	Development Priorities(Step 1) / Most Vulnerable Sector(Step 2) / Prioritized Sectors(Step 3)
Step 1	Identifying Development Priorities	Agriculture, Fisheries & Aquatic resources, Livestock development, Water, Healthy Society, Housing for all, Healthy Lifestyle,. Environment, Education and Knowledge Systems, Modern Economy Through Science and Technological Innovations, Electricity for everybody, Industry sector: Towards Global Competitiveness , Developed Road Network and Transport System
Step 2	Identification of Sectors with high vulnerability to climate change (*Identification was primarily based on the Sector Vulnerability Profiles*)[20]	Agriculture & Fisheries, Water, Health, Urban Development, Human Settlement & Economic Infrastructure and Biodiversity & Ecosystem Services[29] *(Ref: Sector Vulnerability Profiles)*
Step 3	Prioritizing sectors in terms of development priorities, and vulnerability to climate change	Food, Health, Water, Coastal Resources and Biodiversity Sectors.

Accordingly, five (05) priority sectors were identified in the context of the national development priorities identified in the policy framework "*Mahinda Chintana*–Vision for the Future" vis-a-vis sustainable development goals of Sri Lanka, vulnerability of potential sectors to climate change based on the vulnerability profiles,. In view of its cross sectoral significance to fisheries and biodiversity, coastal sector was selected although it has not been recognized as highly vulnerable to climate change in the sector vulnerability profiles.

[29] ME, 2010, National Climate Change Adaptation Strategy for Sri Lanka- 2011 to 2016

The sectors thus prioritized and subsequently endorsed by the National TNA committee are;

- Food
- Health
- Water
- Coastal
- Biodiversity

3.3 Current status of technologies in the Selected Sectors

3.3.1 Current status of technologies in the Food Sector

Technological advancements and utilization of improved technologies in agriculture is strong in certain areas such as genetic improvement of crop species, particularly rice and in pest & disease control. Scientific methods of crop protection and integrated pest management technologies have been made popular through farmer education by the national extension service. Also, Sri Lanka is widely known for development and operation of integrated irrigation systems based on water harvesting in man-made reservoirs and by river diversions.

However, further development of technologies for improved efficiency in irrigation water management is an urgent need. Other high priority areas for climate change adaptation in the food sector include conservation & management of land & water resources, preserving the genetic resilience of crop varieties & animal breeds, strengthening the resilience of inland aquaculture and development of more-resilient varieties of crops to counter adverse effects of climate change.

Some of the technologies used at present in the Food Sector of Sri Lanka:

- Plant and animal breeding
- Pest and disease control including promotion of bio-pesticides and integrated pest management
- Promoting precision farming and traditional varieties of crops
- Conservation of plant and animal genetic resources
- Conservation of crop wild relatives
- Ex-situ conservation of plant genetic resources
- Surface water harvesting
- Soil and water conservation
- Reduction of land degradation in agriculture areas
- Protecting agriculture from alien and invasive species
- Promoting quality seeds and planting material
- Promotion of organic and bio-fertilizers
- Promotion of organic farming
- Development and improvement of post harvest technologies

- Irrigation and water management
- Promotion of inland aquaculture

Note on Technology Selection for the present TNA: Prioritization of adaptation technologies in the food sector has been done with the primary concern of sustaining the current levels of food production from the ill effects of Climate Change in the short to medium term. The other important consideration was the cost of technology. Despite the fact that these selected technologies have been in existence for some time and requires minimal financial inputs for implementation, such technologies have not been utilized for full potential due to various operational/institutional constraints i.e. precision farming and traditional varieties of crops; soil and water conservation.

The short and medium term technologies which are proven and readily available, but not fully utilized at present were selected whereas, some of the newer technologies that are costly i.e. solar-powered drip irrigation solutions and technologies taking a longer period to produce results such as development new varieties, breeding of new animals were not selected.

3.3.2 Current status of technologies in the Health Sector

There are many issues related with the application of the technologies available and such issues impede achievement of the expected outcomes in times of need. Some of the issues are purely financial and some are non-financial, and still some others are both financial and non-financial. However, the main issue is that the adverse health effects of climate change are not yet perceived as a priority in the health sector. The current focus is on disasters and emergencies. Therefore, the resources; financial as well as non-financial, such as equipment, human resources, training, are provided when there is a disaster or an emergency. In addition, technologies are expensive hence; acquisition and sustainability of such technologies are not feasible. There is an acute shortage of qualified trainers; the attitude of health personnel is also not conducive towards climate change adaptation activities. A paradigm shift in approach at the top policy making level and subsequent diffusion down to the grass root level shall make a difference over time. However, a brief description of technologies implemented by the health sector in Sri Lanka is given below.

- Transfer of knowledge & skills to Preventive & Hospital Health care workers
- Mobile services including, Clinical, laboratory, water quality surveillance, in times of extreme events
- Disease prevention activities: Surveillance (active & passive), identification of cases, isolation, vector monitoring, health education, food sanitation/waste management. Immunization, prophylactic measures. Routine work conducted by public health staff.
- Early warning on communicable diseases: Active collection of data, implementation of outbreak control mechanisms. Supported by Ministry of Health and World Health Organization

- Development of National Climate change Adaptation Strategy for Sri Lanka (2010-2016) with an objective of Enabling Climate Resilient & Healthy Human Settlements. The interventions are directed at 1) Mobilization of stakeholders for climate change adaptation of settlements 2) Improve planning to include climate change considerations 3) ensure adequate quality and quantity of water for settlements 4) Combat climate change-related health concerns in settlements 5) Increase awareness on vulnerabilities and adaptation of settlements.

Note on Technology Selection for the present TNA: It is necessary to point out that, all three technologies prioritized in the Health Sector are not new technologies in reality. A minimal to substantial instigation has been accomplished in all three prioritized technologies in the country since the Asian tsunami and even before. Bomb blasts occurring in many populated and during rush hours in the urban and sub-urban areas prompted the government to take precautionary actions by establishing an entity to train personnel from different sectors as early as 1995. The trained group was supposed to train the personnel in their respective working districts. The Author is one of the trained persons from the health sector. The training included basic four phases of a disaster and how to prepare plans, report writing etc. The emphasis was on natural disasters like floods, cyclones, landslides, epidemics and droughts etc. The accidents and events like lightning, animal attacks and tsunami were not included.

The training of trainers were done after the tsunami at the National Institute of Health Sciences, Kalutara and the participants prepared a set of training manuals to train Public Health Staff in the Districts. The Environmental and Occupational Directorate in conducting a training programme for public health staff, in which climate change and health is one component.

There is a well established early warning system throughout the island to early detection of communicable diseases, where the information from the periphery is relayed to the Epidemiology Unit of the Ministry of Health. The epidemiology unit then takes necessary action to contain the disease.

Health Waste Care Management is done in a prescribed way in larger institutions, especially large public and private hospitals in urban areas.

Current inputs for *Transfer of knowledge and skills to Health Personnel* are satisfactory though it is not substantial. While the main focus is on Emergency/Disaster management, some training is being provided for hospital workers and preventive health staff. However, absence of proper cohesion between the two groups real life situation sometimes become chaotic. There is little or no emphasis on the effects on human health due to climate change. There is also an acute shortage of trainers and absence of measures to retain the available personnel.

Considerable technological inputs are being made available for *Early Warning Systems and networking for information exchange on Extreme Weather events and other climate change related events.* However, the main emphasis is on Emergencies/Disasters only. The emphasis on health related climate change issues are not adequately addressed. Networking between principal stakeholders is lacking. There is no focal point or structure available in the Ministry of Health to address climate change related issues. Lacks regular information exchange is resulting poor awareness and knowledge at all levels from policy makers to general public.

Due to these reasons, stakeholders identified *"Transfer of knowledge and skills to Health Personnel"* and *"Early Warning Systems"* as technologies under the present TNA.

3.3.3 Current status of technologies in the Water Sector

Following are the currently used adaptation technologies in the water sector;

- Diversification of water supply by rainwater harvesting from rooftops for drinking and household uses,
- Restoration of minor tank networks (cascade systems)
- Harvesting of surface runoff – unlined ponds and lined ponds
- Tube wells and Boreholes
- Major tanks
- Wells
- Desalination of brackish water by reverse osmosis

Note on Technology Selection for the present TNA: Most of these current technologies have been selected as technologies to be considered under the present TNA due to reasons discussed in this section. Although most of the technologies have been in use in the past, they have not yielded satisfactory results due to multifaceted issues. All the three technologies prioritized in the Water Sector under in the present TNA have been implemented in Sri Lanka since time immemorial.

The tradition of management, repair and maintenance of minor tank systems by farmers has been in existence for nearly 1500 years. Considering the importance of rural development in the Dry Zone, there have been numerous small tank rehabilitation projects and efforts, but most of them have achieved poor results as such work has been focused on individual tanks without considering the cascade hydrology. For example, ad hoc raising of bunds and spillways of minor tanks in recent development programs has seriously disrupted the delicately balanced hydrology between the respective tanks within a cascade.

There are no public health regulations for construction, maintenance and testing the quality of rain water collected in Rainwater harvesting systems in Sri Lanka. As a result, collection of domestic roof top rain water for drinking has caused direct health concerns due to biological and chemical contamination and indirect health issue due to disease causing insect vector breeding in the tanks. Many roof top rain water harvesting systems in Sri Lanka have become failures due to lack of proper maintenance of roof top rainwater harvesting systems.

Most of the boreholes have been installed in the past without giving due consideration to major factors affecting sustainability. It is estimated that 40% of the tube wells constructed in the last decade are abandoned due to contamination with iron/ manganese/ fluorides. Contamination of ground water due to bacteria, NO_3^- and salt intrusion also has been reported.

In the proposed adaptation technologies under the present TNA Project, steps have been proposed to overcome those issues and problems identified in the past.

3.3.4 Current status of technologies in the Coastal Sector

In coastal management in the country both “hard” and “soft” structural solutions are applied depending on the level of vulnerability and level of protection required. They are applied separately or in combination, depending on the specific conditions of the site.

Hard defences are the traditional approach to coastal defence. It utilises structures which provide a solid barrier between the land and sea and resist the energy of the tides and waves, thus preventing any land/sea interaction from taking place. Examples of hard defences include seawalls, sea dikes, revetments, armour units and breakwaters. Hard defences such as dikes & revetments are used in Sri Lanka to protect certain coastal belts which are severely affected by coastal erosion (e.g Hikkaduwa of Southern Sri Lanka) and break waters are the commonly used structures in harbours and coastal cities which needs protection from wave action, storm surges and inundation (harbours in Colombo, Galle & Hambantota and cities of Colombo & Galle are the best examples). Although hard defense mechanisms provide quick solutions against coastal erosion and inundation, they can impede the recreational use of beaches and can be costly to construct and maintain. In addition, hard structures do not protect the natural beauty of the coastal environment and they change the natural balance of coastal ecosystems.

On the other hand the soft defences have not been widely used or non-existent as defence mechanisms against coastal erosion along the coastal belt of Sri Lanka, although they need less financial inputs when compared to construction of hard structures. Mangrove replanting programmes where mangrove habitats are destroyed due to establishment of prawn farms have shown that it is the best possible method to protect and stabilize the coastal belts adjacent to lagoons and estuaries, against coastal erosions. The coastal habitat restoration studies carried out after 2004 tsunami event have proved that coral transplanting could be implemented for restoration of reefs which have been degraded due to natural phenomena such as *El Ninno* and anthropogenic activities such as coral mining and destructive fishing practices. Furthermore, it was evident that the coastal belts of south eastern coast (Hambanthota) where the sand dune vegetation is not disturbed by anthropogenic activities suffered no damage or less damage during the 2004 tsunami incident. Underwater observations before and after tsunami incident in the southern coastal belt (Weligama) indicated that sea grass beds suffered very little or no damage during tsunami.

Note on Technology Selection for the present TNA: The rehabilitation of sand dunes and restoration of mangrove vegetation are not new technologies for Sri Lanka. These technologies have existed over last several decades in small scale and more emphasis have been provided after 2004 tsunami disaster. Currently, rehabilitation of sand dunes involves planting Whistling Pine (*Casuarina equisetifolia*), which was proved to be a failure during tsunami in 2004as these plantations could not offer adequate protection to coastal infrastructure. The programme under the present TNA, proposes to select the economically important plants (medicinal plants, *Pandanus* sp. etc.) which are most suitable to the selected sites and plant them with community participation, in order to uplift the socio-economic status of the coastal communities, while encouraging them to deviate from unsustainable, sand dune destructive activities.

Mangrove rehabilitation is a currently widely practiced activity, but planting mangrove vegetation is done in a very haphazard manner. At present in Sri Lanka, mangrove replanting is carried out without a proper zonal plans and the natural propagation of mangrove plants. In certain places plants are selected for replanting without considering the natural biodiversity and composition. Therefore, present proposal under TNA project suggests that mangrove replanting should be carried out by preparing zonal plans and considering the diversity and distribution of plants which were existed in the past prior to destruction. In addition to the replanting programmes, community should be provided some training to use the mangroves for economic activities/cottage industries, and nature tourism activities in a sustainable manner.

3.3.5 Current status of technologies in the Biodiversity sector

The current technologies adopted in the biodiversity sector are summarized below:

- Restoration of degraded areas inside and outside the protected area network through aided natural restoration, agro-forestry, analogue forestry as appropriate to enhance resilience and monitoring of such restored areas
- Increasing connectivity through corridors, landscape/matrix improvement and management (includes altitudinal and other movement) by establishing forest corridors, corridors/linkages in aquatic environments (fish ladders,). Strengthen management of corridors, and promote environmentally friendly land uses that will facilitate connectivity.
- Managing and monitoring invasive alien species (IAS) by methods such as creating awareness on IAS, eradication or minimizing identified invasive species, prevention by enforcing legislation such as quarantine & imports related legislation and monitoring programs.

- Reducing other stresses on species and ecosystems such as, minimizing pollution of air water& soil, removing encroachments, stop illegal logging/clearing, prevent habitat fragmentation, prevent over exploitation of aquatic and terrestrial species, stop poaching and enforcement of laws.
- Adaptive management and monitoring programs of species and ecosystems. ie, fieldwork and research to identify on the ground changes, monitoring the effectiveness of management techniques.

- Improve management, and increase extent of protected areas, buffer zones and create new areas in vulnerable zones. ie, creating management plans and its implementation, capacity building of relevant authorities, monitoring conservation activities, identifying areas to establish new protected areas, zoning protected areas.
- Focus conservation resources and carryout special management for restricted ranges, highly threatened species and ecosystems. ie, use red list to identify critical species, species management plans for highly threatened/critical species, monitoring of threatened species, in situ conservation programs targeted at species, habitat enrichment, re-introduction of species, ex-situ conservation etc.
- Reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources management and incorporating climate change adaptation considerations (ensuring implementation).
- Ex-situ conservation for highly threatened species and possible reintroduction through, improving the status of zoological and botanical gardens, establishment of seed banks with a focus on endemic and threatened species, plant propagation etc.

Note on Technology Selection for the present TNA: The proposed technologies under the present TNA are not entirely new to Sri Lanka; most of those technologies are being implemented by the Department of Wildlife Conservation and Forest Department for several decades. In most cases they have been implemented in isolated pockets of forests or protected areas, and community participation in planning and implementation has been very minimal. As a result most of these programmes were not successful. i.e, Restoration of degraded areas is a programme annually implemented in the past, however, in most cases appropriate tree species have not been selected, and community participation is very marginal in such programmes. Moreover, some of the existing technologies are yet to be implemented in a comprehensive manner, and are relevant in the climate context and vital for biodiversity adaptation.
Some of those technologies, which are considered ‘existing’ technologies were chosen for the present TNA for following reasons:

- The selection of technologies for the present TNA was based on a comprehensive literature review that included international peer reviewed journal articles, international books and current publications.
- The technologies selected were based on what’s appropriate rather than whether they were ‘new’ or ‘existing’ technologies.

CHAPTER 4

Technology Prioritization for the Food Sector

4.1 An overview of possible adaptation technology options in Food Sector

Food sector which includes agriculture (Rice, Fruits & Vegetables, Other Field Crops, Sugar Cane, Tea, Coconut, Export Agricultural Crops etc.), Livestock (Dairy, Poultry etc.) and Fishery is one of the most vulnerable sectors to climate change impacts in Sri Lanka[30]. Changing climate and weather patterns suggest high potential of negative impacts on food production, food security and natural resources in the country. The impending vagaries of climate change such as intense, uncertain, highly variable rainfall pattern and temperature, sea level rise, combined with deterioration and dwindling of natural resources emphasize the necessity of sustainable climate change adaptation technologies to increase the productivity, stability and resilience of the food sector. Please see Annex C 1 for Paddy area vulnerability with drought and flood exposure.

4.1.1 Technologies Identified

With a view to utilize technological approaches that can be quickly harnessed for developing adaptation technologies to reduce vulnerability to climate change, 09 adaptation options were identified as priority technologies for consideration. The identification of technologies was guided by factors such as the adequacy of information available on the proposed technology, the probability of success or failure of the technology, cost, potential risks and the level of confidence of the sector specialists in the choice of the proposed technology. The technologies thus identified fall under the broad categories of crop/livestock/fishery management, sustainable water use and management, capacity building of stakeholder organization and sustainable land management.

The adaptation technology options identified are as follows;

1. Sustainable Land Management
2. Crop Diversification & Precision Farming
3. Ecological Pest and Disease Control
4. Rain Water Harvesting

[30] ME, 2010, Sector Vulnerability Profile: Health, Supplementary Document to: The National Climate Change Adaptation Strategy for Sri Lanka, 2011 to 2016, Ministry of Environment, Sri Lanka.

5. Solar-powered Drip Irrigation
6. Development of Appropriate Breeds
7. Development of Appropriate Varieties
8. Responsive Agricultural Extension
9. Sustainable Culture-Based Fisheries

All the technologies identified are currently available in Sri Lanka. Of the proposed technologies, Rain Water Harvesting, Solar-powered Drip Irrigation, Responsive Agricultural Extension and Sustainable Culture-Based Fisheries are proposed for short term implementation while the other technologies are to be implemented on long term basis.

Adaptation Technology	Scale of Implementation	Benefits
1. Sustainable Land Management	Large Scale	- Increased agricultural productivity and food security - Creation of employment - Cost of reservoir de-silting and other off-site costs reduced - Increased profitability from farming leading to reduced cost of commodities - Improved livelihoods and social sustainability - Land degradation and downstream sedimentation & siltation reduced - Reduced contamination of soil and surface and ground water - Reduced GHG emissions - Minimize non point source pollution - Secured bio diversity and improve ecosystem sustainability
2. Crop Diversification & Precision Farming	Large Scale	- Increases crop yield, quality and reduced production costs due to efficient use of farm inputs and labor - Ensure productivity and food security - Minimized health problems from environmental pollution resulting from indiscriminate resource use - Increased returns on investments and improving attractiveness of farming, particularly to youth, through adoption of high-tech methods. - Prevents soil degradation in cultivable land. - Reduction of chemical use in crop production - Efficient use of water resources and other natural resources

		- Demand driven fertilizer management systems will ensure conservative use of fertilizer contributing to reduced GHG emission - Facilitate bio diversity conservation
3. Ecological Pest And Disease Control	Small Scale	- Lowers costs of pest & disease management over time - Increases value of produce - Increased Environmental Quality - Reduced health risks
4. Rain Water Harvesting	Small Scale to Large Scale	- Increase profits by reducing crop damages during water scarcity - Secure ground water quality/quantity - Reduced land degradation - Increase job opportunities - Promote investments by lowering risks - Specially improved rural lively hood
5. Solar-powered Drip Irrigation	Small Scale	- Reduced costs of production and higher prices enabled realizing better incomes - Year round gainful employment for the farm family labor. - Use of solar energy provides local and global benefits through the reduction of pollutants and emission of green-house-gases. - Lowered water withdrawal from ground water resources, prevents depletion of ground water table and pollution from infusion of saline and other contaminants. - Reduced use of agricultural chemicals such as weedicides and pesticides minimizes adverse environmental impacts and biodiversity loss. - Drip technology also reduces soil degradation from top-soil erosion associated with flood irrigation - Increase yields and profitability - Increase availability of food - Reduce price fluctuations of vegetables and fruits
6. Appropriate Breeds	Large Scale	- Ensured food security - Productivity and profitability - Increase employment opportunities in production sector and value chain increased - Environmental health improved due to increase of disease resistance
7. Appropriate Varieties	Large Scale	- Ensured food security - Increased productivity and profitability

		- Increased employment opportunities - Reduced environmental damage by avoiding pest control chemicals
8. Responsive Agricultural Extension	Large Scale	- Increased overall efficiency of resource use - Improved public awareness and education - Promote rural development and resource conservation
9. Sustainable Culture-Based Fisheries	Large Scale	- Ensured food security - Create new employment opportunities in the fish value chain - No ecosystem damage - Minimal use of external resources for fishery production

Table 4.1: Overview of adaptation benefits of the proposed Technologies

4.2 Criteria and Process of Technology Prioritization

The Multi Criteria Decision Analysis (MCDA)[31] approach was employed for prioritization of potential adaptation technologies. This approach provided opportunity to assess technologies across a range of development and sustainability criteria.

Multi Criteria Decision Analysis (MCDA):

4.2.1 Determination of Criteria and Weightings

The criteria applied for evaluation of technologies included cost of technologies, and economic, social, and environmental benefits. The scoring system adopted to evaluate the technological options is given in Table 4.2 Accordingly; each option was given a total score on a scale of 0 -100 by using the weight factor assigned for each criterion. The Weight Factor for each criterion was set by apportioning 100 points on the basis of their relative importance. . The each criterion was measured qualitatively based on the impact of the respective option (Rank 1-5). The criterion decided and weightings are provided in Table 4.2 below.

[31] Multi-Criteria Analysis: A Manual, 2009, Department of Communities and Local Government: London

Table 4.2: Criteria and Weighting Factors

Category		Criteria	Weight Factor
Cost (30)		Cost of Technology	30
Benefits (70)	Economic (35)	Impact on Food Security	10
		Effect on Employment generation	5
		Effect on Farmers income/Poverty reduction	10
		Impact on Energy use	5
		Impact on New markets/enterprises/Industries	5
	Social (15)	Household labour involvement	1
		Gender equity	1
		Impact on Rural Development	5
		Livelihood improvement	4
		Community participation	1
		Health benefits	3
	Environmental (20)	Impacts on ground water quality/quantity	3
		Impact on surface water quality/quantity	3
		Impact on Soil Erosion/Runoff & Sedimentation	5
		Impact on Soil Quality/health	2
		Effect on biodiversity conservation	2
		Quality of Watershed functions	2
		Impact on air pollution	1
		Effect on GHG Emissions	2

4.2.2 Construction of Scoring Matrix: As described in the MCDA manual, the Scoring Matrix was constructed based on the above criteria and weight factors (See Annex B 1 for weighted scores, costs and benefits of technologies) and the results are given in Table 4.3 below.

Table 4.3: Results of the MCDA

Technology	Cost of Technologies (US $ M)	Benefits	Rank
1. Appropriate Varieties	0.82	36.20	5
2. Appropriate Breeds	2.95	42.00	8
3. Sustainable Land Management	0.27	36.00	(3)
4. Drip Irrigation	0.32	31.00	4
5. Rain Water Harvesting	5.45	32.40	9
6. Crop Diversification & Precision Farming	0.68	46.70	(2)
7. Ecological Pest & Disease Management	0.25	19.40	6
8. Responsive Agricultural Extension	0.55	16.00	7
9. Sustainable culture-based fisheries	0.15	50.90	(1)

The Figure 4.2 shown below, illustrates the benefits, estimated as (total score- weighted cost), and plotted against the costs and the results were used in determining the most preferred, technologies. Accordingly, option Nos. 9, 6 and 3 were selected as the most preferred technologies in order of priority.

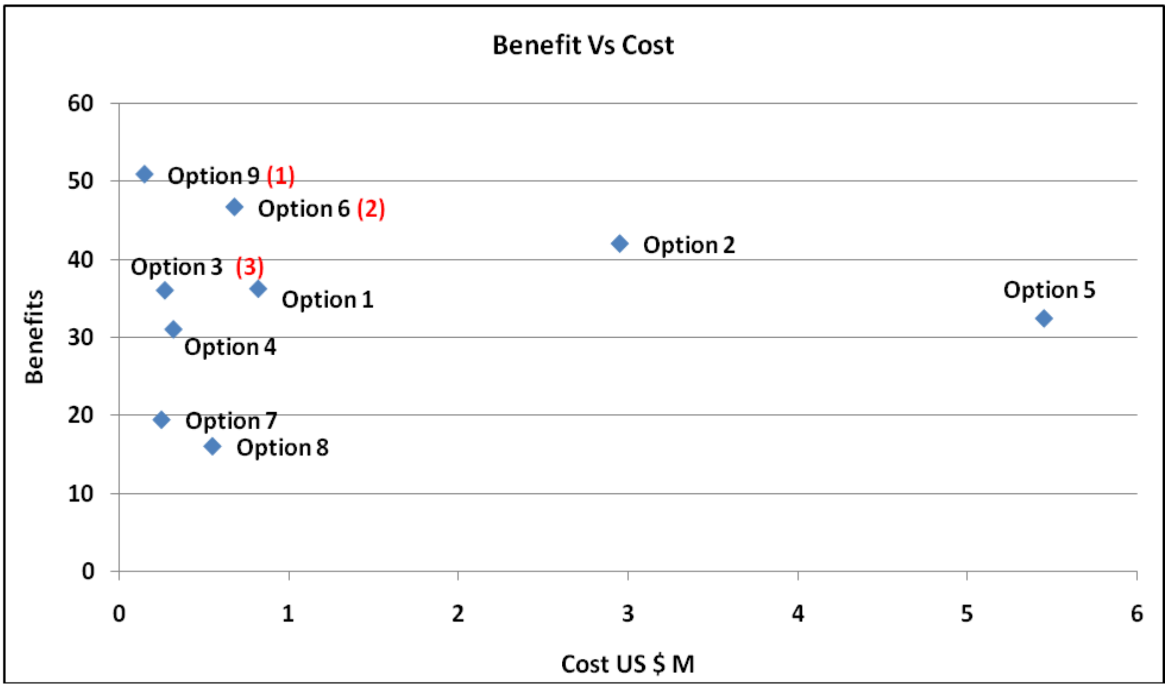

Figure 4.1: Plot of Benefit Vs Cost for identified technology options

4.3 Results of the Technology Prioritization

Ranking of technological options, from most cost effective to least cost effective, based on the results of the multi-criteria analysis is given below:

1. **(Option 9) - Sustainable Culture-based fisheries**
2. **(Option 6) - Crop diversification and precision farming**
3. **(Option 3) - Sustainable land management**
4. (Option 4) - Drip Irrigation- Solar powered
5. (Option 1) - Appropriate varieties
6. (Option 7) - Ecological pest and disease management
7. (Option 8) - Responsive agricultural extension
8. (Option 2) - Appropriate Breeds
9. (Option 5) - Rainwater harvesting –Minor tank restoration

Despite their high potential for reducing vulnerability effects from climate change, the results of the MCDA analysis (Fig 4.2) suggests that relatively high cost technologies such as the development of appropriate animal breeds *(Option 2),* appropriate crop varieties *(Option 1),* and rain water harvesting through minor tank restoration *(Option 5),* were not favored by the ranking adopted.

Considering the tendency to disfavor high cost interventions, and to verify the robustness of results, a sensitivity analysis was carried out by lowering the weights assigned to cost of adaptation options by 10% (to 20%) and economic benefits increased by that amount. This did not alter the results of the analysis in a significant manner.

Table 4.4: Summary Table for Prioritized Technologies

No	Technology	Scale of Application *(Small, Medium or Large Scale)*	Time Scale *(Short, Medium or Long term)*	Benefits *(Output from MCDA)*	Estimated total lifetime Cost (US $ M)
1	Culture-based fisheries Crop diversification and precision farming	Medium Scale	Medium term	50.83	0.150
2	Crop diversification and precision farming	Large Scale	Long term	45.67	0.682
3	Sustainable land management	Large Scale	Long term	35.5	0.273

4.4 Summary Account of Recommended Technologies:

1. Culture-based fisheries Crop diversification and precision farming

Technology:

Use advances in fish breeding and management to develop fish culture under diverse environmental conditions.

Summary:

Reservoir fisheries, especially culture-based fisheries (CBF) in medium size perennial reservoirs and small village reservoirs are highly vulnerable to the climate change impacts. Unexpected rainfall changes and changes in annual rainfall pattern in recent past have significant impacts on the water retention of the reservoirs. Hence, an effective methodology is needed to predict water availability in seasonal reservoirs enabling CBF farmers to adapt to changes in monsoonal rainfall pattern.

As climate change has direct influence on artificial breeding of fish, alternative techniques and/or improvement of existing technologies is needed. Study of different techniques for successful breeding of introduced and local fish species suitable for aquaculture is a major requirement in the finfish aquaculture in the country under the scenario of climate change.

A combination of hard and soft technologies would be appropriate depending on local factors. Prediction of water availability in reservoirs with climate change impacts; Identification of alternative means of fingerling stocking; Development of techniques to identify climate change impacts on fish breeding; Improving breeding techniques to overcome climate change influences; Effective knowledge dissemination and capacity building are some of the appropriate technologies to overcome these problems. *(See section 4.1.1 for more details on benefits).*

2. Crop diversification and precision farming

Technology: Redesign cropping patterns based on forty six agro-climatic zones of the country to enable cultivating the most appropriate crops/varieties for the respective zone in order to effectively and optimally utilize the natural resources, inputs, agrochemicals and stabilize the productivity.

Summary:

Rainfall pattern & intensity and over & inappropriate use of water would adversely affect the availability of ground water. Increasing air temperature can directly affect productivity in certain ecosystems. Further, it can increase the incidence of pest and disease outbreaks. Sea level rise will cause shifting of coastal non-saline and inundation boundaries further inland. Therefore, the existing cropping patterns and systems would lose their level of productivity and economic viability. Therefore, it will become necessary to critically review and re-design alternative integrated farming systems at ecosystem level.

Precision farming can compliment crop diversification in securing a sustainable agricultural system. It reduces use of water, fertilizer, pesticide, and labor, and assures quality produce. In livestock production, precision farming can increase productivity through regulation of micro-environment, improving feed and fodder production, and assuring timely veterinary care.

The crop diversification systems would involve modest costs in land re-design. Precision farming also could add new costs for developing information systems and monitoring. It involves judicious combining of low and high technology progressively integrated over time.

Development costs and adoption costs for different units of precision farming techniques can be enumerated separately. The estimated total implementation cost works out to Rs. 75.0 million. *(See section 4.1.1 for more details on benefits).*

3. Sustainable land management:

Technology: Integrated use of land management technologies that promote soil & water conservation and preserving the overall health of the soil.

Summary:

Land degradation is one of the critical environmental problems in the country and sustainable management of land is of high national priority. Some major results of land degradation are heavy soil lose, high sediment yields, soil fertility decline, landslides, salinization, alkalinization, acidification including both desertification and formation of acid sulphate soils, iron toxicity development, nutrient accumulation, water logging and indiscriminate disposal of waste. Presently, the rate of soil erosion in the hilly regions of the country is 100 tons/ha/yr. Sustainable land management techniques facilitate increased productivity of land and agricultural activities.

Adoption of appropriate corrective measures to address negative impacts of poor land management practices is considered long overdue. The technology proposed is highly appropriate in the current situation and become more so with the effects of climate change.

Synergetic and additive outcomes of the Sustainable Land management assure conservation of natural resources and sustainable agricultural productivity. All of these efforts would directly contribute in increasing the nation's ability to withstand against the negative impacts of climate change. Benefits will be widespread with producers as well as consumers benefitting from the technology adoption. *(See section 4.1.1 for more details on benefits)*

CHAPTER 5

Technology Prioritization for the Health Sector

5.1 An overview of possible adaptation technology options in the Health Sector

5.1.1 The Health Sector Vulnerability profile

Ensuring equity in health care through easy access to high quality and modern health care services especially for lower income groups and the most vulnerable people in the country has become the focus of the government's agenda for the health sector. Under the *Suva Sewana* Programme announced in the Mahinda *Chintana*, the government is committed to ensure high quality free health services.

Sri Lanka is vulnerable to climate change related factors such as extreme situations of temperature changes and rainfall patterns. These conditions will influence the prevailing ecosystem equilibrium with changes in hydrology and agriculture, which will influence microbial contamination pathways. Transmission dynamics of vectors which are common in Sri Lanka are vulnerable to change depending on environmental factors such as temperature, rainfall regimes, sanitation, etc. The broad categories of health outcomes anticipated due to climate change are increased incidents of morbidity and mortality through air pollution, water and food borne diseases, vector and rodent borne diseases and impacts of food and water shortages.

Climate change impacts in Sri Lanka are particularly significant in the following areas[32]:

- Vector borne diseases–essentially mosquito borne diseases
- Rodent borne diseases
- Food and water borne diseases
- Nutritional status
- Other environment related disorders

In Sri Lanka many communicable diseases are under control and diseases such as Malaria and JE is almost been eradicated. Recently Dengue has reached an epidemic level, affecting nearly 28,000 persons in 2011 out of which 185 have died of complications of dengue[33]. The main reason is irregular rainfall patterns and resultant collection of clean water in an around the human dwellings. Improper

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[32] ME, 2010, Sector Vulnerability Profile: Health, Supplementary Document to: The National Climate Change Adaptation Strategy for Sri Lanka, 2011 to 2016, Ministry of Environment, Sri Lanka.

[33] Epidemiology Unit of the Ministry of Health, Sri Lanka

storage systems to overcome water shortages and inappropriate solid waste disposal are other reasons for mosquito breeding and spread of Dengue.

The available adaptation technologies fall within three categories;

1 New Technologies ie. introduction of new vaccines, drugs and insecticides
2 Relatively new technologies being disseminated in developing Countries e.g. well equipped mobile laboratories; Computer based information and reporting systems.
3 Well established technologies needs to be assessed for sustainability and for further improvements.

In Sri Lankan context, it is ideal to support all the above, but when considering use of a particular technology it is imperative to assess its potential risks against the benefits.

5.1.2 Technology Identification

Following nine (09) adaptation technology options were considered for the Health sector as priority technologies.

1. Transfer of knowledge and skills to Health Personnel
2. Diagnostic facilities to detect water borne diseases
3. Technology to detect, prevent and control water borne diseases
4. Technology for Early Warning Systems and net-working for information exchange on extreme events and other Climate Change related events
5. Research to identify the magnitude of diseases and other aspects affecting human health due to climate change
6. Drinking water quality improvement through continued surveillance during and after extreme weather events
7. Technology to improve urban health inputs to adapt to climate change and extreme weather events related adverse health impacts
8. Technology to enhance adaptability of the people to overcome traumatic effects due to climate change related extreme events.
9. Technology for management of health care waste

5.2 Criteria and process of technology prioritization

The methodology used to prioritize the technologies was Multi Criteria Decision Analysis (MCDA) Approach. This approach provided opportunity to assess technologies across a range of development and sustainability criteria. As described in the MCDA manual, the chronological order of events of the MCDA are; establish the decision context; identify the objectives and criteria; scoring; weighting; combining weight and scores for each technology; examine results and sensitivity analysis.

The nine (09) technologies identified at the initial stakeholder consultations were considered for evaluation.

5.2.1 Multi Criteria Decision Analysis (MCDA)

Determination of Criteria and Weightings

The criteria for evaluating potential technologies were selected through a stakeholder consultation and the criteria included cost of technologies, and economic, social, & environmental benefits. The scoring system adopted to evaluate the technological options is given in Table 5.1. Accordingly, each option was given a total score on a scale of 0 -100 by using the weight factor assigned for each criterion. The Weight Factor for each criterion was set by apportioning 100 points based on their relative importance.

Table 5.1: Criteria and Weighting Factors Identified for the Health Sector

Category		Criteria	Weight Factor
Cost (25)		(US $) for implementation of the Technology	25
Benefits (75)	Economic (5)	Minimal energy use for Technology	5
	Social (52)	Access to Services	12
		Long-term health benefits	25
		Local & Multi-sector involvement	9
		Employment Generation	6
	Environmental (18)	Minimize Eco-system Degradation	8
		Impact on Pollution	10

5.2.2 Scoring Matrix: The Scoring Matrix was constructed based on the above criteria and the results of the MCDA are given in Table 5.2 below. (See Annex B 2 for weighted scores, costs and benefits of technologies

Table 5.2: Results of the MCDA

Technology	Cost $ US	Benefits	Rank
1.	50,000	69.00	(2)
2	50,000	29.20	8
3	112,500	32.00	9
4	50,000	71.00	(1)
5	55,000	35.40	4
6	50,000	32.00	5
7	36,000	28.00	7
8	43,750	29.70	6
9	62,500	43.90	(3)

The Figure 5.1 below illustrates the Benefits plotted against the Costs. The Benefit Vs Cost plot helped determining the most preferred technologies. Based on the results of the analysis, option Nos. 5, 1 and 2 were selected as the most preferred technologies in order of priority. Then a sensitivity analysis was carried out by changing the weights assigned to cost of technologies and social criterion. However, this did not show any significant change to the above results.

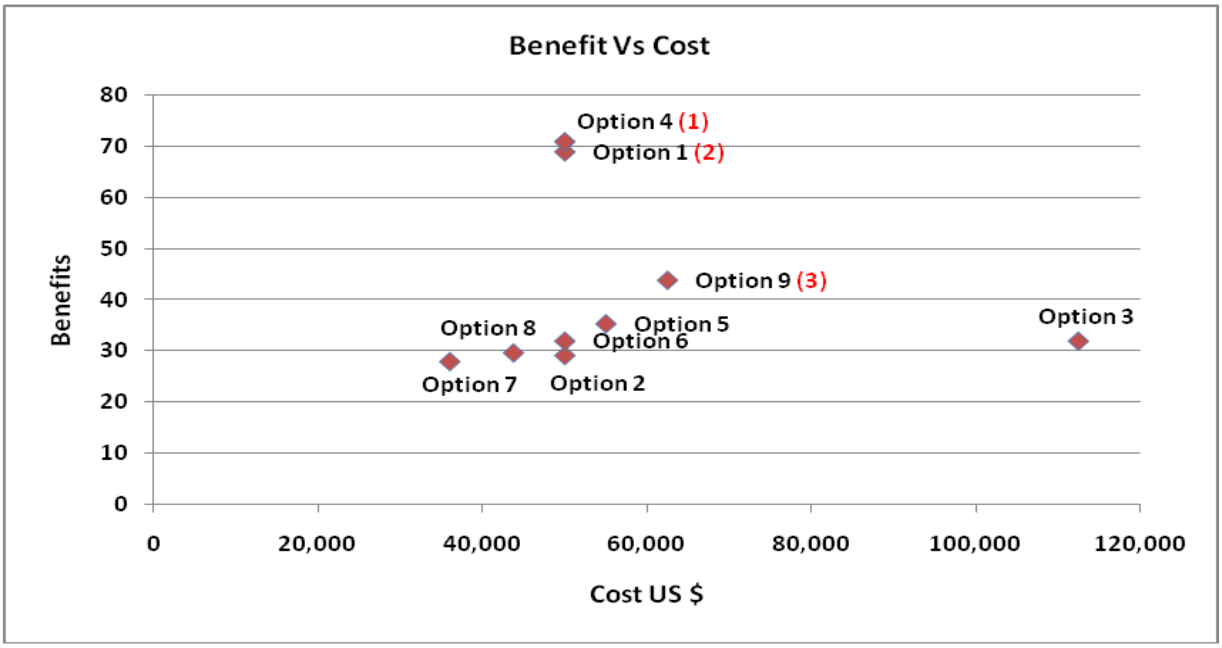

Figure 5.1: Benefit Vs Cost Plot for Identified Technology Options

5.3 Results of the Technology Prioritization

The results of the Multi-Criteria Decision Analysis ranked the identified technologies in order of priority as shown below.

1. ***(Option 4)*** **Early Warning Systems and net-working for information exchange on extreme events and other Climate Change related events**
2. ***(Option 1)*** **Transfer of knowledge and skills to Health Personnel**
3. ***(Option 9)*** **Management of Health Care waste**
4. *(Option 5)* Research to identify the magnitude of diseases and other aspects affecting human health due to climate change.
5. *(Option 6)* Drinking water quality improvement through continued surveillance during and after extreme weather events
6. *(Option 8)* Technology to enhance adaptability of the people to overcome traumatic effects due to climate change related extreme events
7. *(Option 7)* Technology to improve urban health inputs to adapt for climate change and extreme weather events related adverse health impacts
8. *(Option 2)* Diagnostic facilities to detect water borne diseases
9. *(Option 3)* Technology to detect, prevent and control water borne diseases

Accordingly, technological options 4, 1 and 9 were rated as preferred priority Technologies for the Sector.

Table 5.3: Summary Table for Prioritized Technologies

No	Name of the Technology	Scale of Application *(Small, Medium or Large Scale)*	Time Scale (Approx number of years)	Potential Mitigation (GHG emission reduction) in the Time Scale	Benefits *(Output from the MCDA)*	Estimated total lifetime Cost $ US
1.	Early Warning Systems and networking for information exchange	Large	3	NA	71	50,000
2.	Transfer of knowledge and skills to Health Personnel	Large	3	NA	69	50,000
3.	Management of Health Care waste	Medium	3	NA	44	62,500

5.4 Summary Account of Recommended Technologies

1) Technology for Early Warning Systems and net-working for information exchange on extreme events and other Climate Change related events

Technology: Generation and sharing of information using early warning systems and networks.

Adaptation needs: Use Early Warning Systems and networking between different agencies for information sharing on extreme events and other climate change related events in order to contain adverse health effects.

The risk knowledge gained following risk assessments help to develop preventive mechanisms and further enhance Early Warning Systems and networking among different agencies. Systems with monitoring and predicting capabilities provide time estimates of the potential risk faced by communities, economies and environment. Communication networks are needed for delivering warning messages to the potential locations to be affected in order to alert local and regional governmental agencies. Coordination, good governance and appropriate action plans are key points in effective early warning.

The technology diffusion will contribute to climate change adaptation through;

- Providing sufficient time for health personnel to prepare action plans based on contingency plans to minimize and respond to expected impacts.
- Provide Health and administrative authorities to make preparations along with the support of NGOO, UN agencies, private sector and community organizations.
- Engaging the general public at individual, family, community and country level in adaptation activities.

2) Transfer of knowledge and skills to Health Personnel

Technology: The technology shall include providing training to enhance knowledge on adverse health effects of climate change & adaptability and development of skills to enable undertaking adaptation actions for selected categories of Public Health and hospital based health personnel.

Adaptation needs: Improvement of knowledge and skills among health personnel shall improve their capabilities in implementing adaptation activities by the general public through community networks. Although there is substantial ability to manage mass casualty incidents, knowledge on climate change related health consequences and skills to manage outcomes of such events are not adequately developed in curative care institutions. The health personnel should be provided with complete knowledge and skills on full circle of disaster management including preparedness, mitigation, response, early recovery, sustainable development and documentation as appropriate to the respective category of personnel.

The transfer of knowledge to the general public through the skilled health personnel will help to adapt and minimize the adverse impacts of climate change such as vector borne & food borne diseases, injuries and effects of extreme weather events like floods, landslides, drought, thunderstorms, lightning etc. As the services provided to the community by the health personnel are administered and monitored at district level, the program would be implemented at district level. The transfer of knowledge from the district level to the lower levels of public health care i.e. through Medical officer of Health area to Public Health Inspector range down to Public health Midwife area and to the communities in the villages will be facilitated so as to improve adaptation modalities towards minimizing adverse effects of climate change on the health sector.

Formulation of Hospital Disaster Management Teams and Development of a Hospital Emergency Plan will enable improving the effectiveness and the efficiency of activities undertaken at a time of disaster.
Skills to perform pre-determined tasks, accurately and timely by different categories of staff of a hospital and to succeed in synchronization with others according to the plan shall be improved through participatory planning, documentation and sharing of plans, and testing the plan by conducting drills and simulations. The plans shall be reviewed on the outcome of the drills and simulations and the lessons learned shall be recorded for future reference.

Social benefits of this programme would be: The enhanced opportunities for the participation of community leaders and volunteers in the implementation programs will enable achieving desired outcomes. Continued involvement of the general public will depend on the enthusiasm of the health workers and non-tangible incentives gained by them through the success of interventions. Technology transfer will improve the food and personnel hygiene at the household level, ability to prevent communicable diseases, injuries during extreme events and improve health seeking behavior.

Economic benefits: Active participation of the public in economic development activities at individual, family and community level will be ensured. Capital requirement for intervention is minimal.

Environmental benefits: GHG emissions are minimal. The technology will enhance reduction of pollution by human activities and the technology itself has no direct impact on environment.

3) Management of Health Care waste:

The objective of this technology is to transfer knowledge and skills related to better health care waste management to health care personnel.

Adaptation needs: Improper management of health care waste contributes to pollution of soil, water and air leading to health hazards. As the climate change effects and related extreme events are on the increase, current haphazard hospital waste management practices has to be replaced with proper systems to minimize the adverse health effects.

This technology contributes to climate change adaptation by minimizing the adverse impacts on environment (air, water, soil, animals, plants and land), thereby reducing the effects on human health and wellbeing, and also reducing the disturbances to public security and order.

Implementation: It has been well conceived is an urgent need for proper HCWM to minimize the adverse effects on humans and the environment. In the absence of proper HCWM system, the impacts of climate change and extreme events would be greater than that of under normal circumstances. Participation of both the public and private sector, which are catering to the health services of the country need to be ensured while resources from NGOs, UN agencies and bilateral and multilateral donors are sourced for successful implementation.

CHAPTER 6

Technology Prioritization for the Water Sector

6.1 An overview of possible adaptation technology options for the Water Sector

6.1.1 Brief Overview of the Water Sector

Water is the most essential ingredient for the sustenance of all living organisms. The total renewable water resources available in the freshwater ecosystems of Sri Lanka is estimated at 49 km^3 as surface water, 8 km^3 as groundwater, and a further 7 km^3 as overlapping water. Surface water includes rivers, villus[34], man-made reservoirs, minor tanks etc. In Sri Lanka there are 103 distinct natural river basins that cover nearly 90% of the island[35]. Mahaweli River *(Ganga*) is the longest river and it covers about 16% of the island's total area. It is the only perennial river which passes through the dry Zone of the country. The collective length of the all 103 rivers is about 4,560 km[21]. The vast ancient reservoirs, small and large tanks and canals built by ancestors are supplemented today with many recently built irrigation and hydropower reservoirs. More than 90% of the small tank systems are clustered into cascades and these tank network systems have been built in water scarce areas by the ancient kings mainly for agricultural purposes.

There are six main types of groundwater aquifers in Sri Lanka. They are shallow karstic aquifers, coastal sand aquifers, deep confined aquifers, lateritic aquifers, alluvial aquifers and shallow regolith aquifers in the hard rock region. In addition to these main aquifers, a large number of small groundwater pockets can be found throughout the country.

In Sri Lanka, water is mainly used for domestic, irrigation, hydropower generation and industrial purposes. Water from protected wells, hand pumps, tube wells, protected springs and pipelines are considered as safe drinking water sources and water from unprotected wells, rivers, tanks and canals are considered as unsafe.

Adaptation technologies already in use in Sri Lanka have been designed primarily in response to decrease in surface water availability and per capita water availability. These adaptation technologies are

[34] Villus are wetland ecosystems also known as freshwater marshes found in the low lying areas where rivers flow and incidence of frequent flooding is common. These areas have a perennially high fluctuating water table. Flooding and rain water accumulation suppress tree growth in such areas, but encourage some types of grasses, and other aquatic plants.

[35] Imbulana K.A.U.S, *et al* 2010, "Sri Lanka Water Development Report"

important in order to protect health, wellbeing and economic development during the periods of water scarcity. Diversification of water supply by rainwater harvesting from rooftops for drinking and household uses, household drinking water treatment and safe storage, harvesting of surface runoff rainwater, restoration of minor tank networks and desalination of brackish water are some of the solutions used when there is a water scarcity. The Community Water Supply and Sanitation Project (CWSSP), Lanka rainwater-harvesting forum and certain other organizations facilitate rain water harvesting programs in Sri Lanka. When there is a scarcity of surface water, demand for ground water increases, and Boreholes/tube wells are used to extract ground water in such situations. Please see Annex C 2 for Drinking water sector vulnerability to flood exposure and sea level rise.

6.1.2 Identified Adaptation Technologies in the Water sector

Seven (07) potential adaptation technologies were identified as priority technologies through stakeholder consultations and the technologies so identified are of three types as given below;

- Technologies identified in response to risk of flooding due to increase in rainfall intensity.
- Desalinization of surface water and ground water due to sea water intrusion as a result of sea level rise
- Technologies identified for resilience to water quantity and quality degradation.

The identified technology options are as follows;

1. Rainwater harvesting from rooftops for drinking and household uses
2. Surface runoff rainwater harvesting
3. Household drinking water treatment and safe storage
4. Boreholes/tube wells as a drought intervention for domestic water supply
5. Solar distillation
6. Restoration of minor tank networks
7. Desalination of brackish water by reverse osmosis

6.2 Criteria and process of technology prioritization

6.2.1 An overview of possible adaptation technology options and their adaptation benefits

As indicated in the table 6.1, all the adaptation technologies identified fit into one or more typologies because their ability to contribute to one or more aspect of climate change adaptations. The six typologies are:

- Diversification of water supply
- Ground water recharge
- Preparation for extreme weather events

- Resilience to water quality degradation
- Storm water control and capture
- Water conservation

Table 6.1: Typologies of the seven adaptation technologies

Technology	Typology					
	Diversification of water supply	Ground water recharge	Preparation for extreme weather events	Resilience to water quality degradation	Storm water control and capture	Water conservation
1. Rainwater harvesting from rooftops	√	√		√	√	√
2. Boreholes/tubewells			√			
3. Surface runoff rainwater harvesting	√	√			√	√
4. Restoration of minor tank networks	√	√			√	√
5. Household drinking water treatment and safe storage				√		
6. Desalination of brackish water by Reverse osmosis	√			√		
7. Solar distillation				√		

The suitable areas/regions for implementation of the proposed technologies are shown in table 6.2 below.

Table 6.2: Suitable areas/regions for implementation of the proposed technologies

Technology	Area/Region
1. Rainwater harvesting from rooftops	Whole country as required
2. Boreholes/Tube wells	Areas where suitable bed rock geology is available for installation
3. Surface runoff rainwater harvesting	Dry zone and major cities
4. Restoration of minor tank networks	Dry zone – cascade systems
5. Household drinking water treatment and safe storage	Areas where safe drinking water is not available
6. Desalination of brackish water by Reverse osmosis	Areas where fresh water is contaminated with saline water
7. Solar distillation	Island wide

6.2.2 Multi Criteria Decision Analysis (MCDA)

The methodology used to prioritize the technologies was Multi Criteria Decision Analysis (MCDA) Approach.

a) Determination of Criteria and Weightings

Determination of Criteria and Weightings being the first step of MCDA process, the evaluation criteria were identified through a stakeholder consultation and the criteria selected included cost of technologies, and economic, social, & environmental benefits. Then, each technological option was given a score against each criterion based on the preference of the respective technology (i.e. the least preferred option getting the lowest score). The weightings assigned for each criterion subdivided into twelve (12) sub-criteria selected using the social, economic and environment importance of the adaptation technologies are given in the Table 6.3 below.

Table 6.3: Criteria Adopted to Prioritize the Adaptation Technologies

<table>
<tr><th>Major Criteria</th><th colspan="3">Sub divisions of criteria selected (Weight factor)</th></tr>
<tr><td>Costs (20%)</td><td colspan="3">Cost/m^3 of water (20%)</td></tr>
<tr><td rowspan="13">Benefits (80%)</td><td rowspan="3">Economic (8%)</td><td colspan="2">Employment (4%)</td></tr>
<tr><td colspan="2">Investment (2%)</td></tr>
<tr><td colspan="2">Low GHG release (2%)</td></tr>
<tr><td rowspan="6">Social (54%)</td><td colspan="2">Continuous water supply (15%)</td></tr>
<tr><td colspan="2">Health (20%)</td></tr>
<tr><td rowspan="3">Education</td><td>Awareness (5%)</td></tr>
<tr><td>School/University (5%)</td></tr>
<tr><td>Research (5%)</td></tr>
<tr><td colspan="2">Income (4%)</td></tr>
<tr><td rowspan="3">Environmental (18%)</td><td colspan="2">Impact on ground water (6%)</td></tr>
<tr><td colspan="2">Impact on surface water (6%)</td></tr>
<tr><td colspan="2">Minimizing flooding (6%)</td></tr>
</table>

The most suitable adaptation technologies for the water sector were selected by prioritizing the seven adaptation technologies by using MCDA.

6.2.3 Scoring Matrix: The Scoring Matrix was constructed based on the above criteria and weight factors (See Annex B 3 for weighted scores, costs and benefits of technologies). Benefits were calculated using the formula "Benefit = Total score – Weighted score of costs". The cost and the benefits of the selected technologies are given in the Table 6.4 and Figure 6.1 illustrates the Benefits plotted against the Costs. The subsequent sensitivity analysis did not change the results of this analysis to a significant level.

Table 6.4: Costs and benefits of the selected technologies and the order of priority with respect to the MCDA

Adaptation Technology	Cost US $ /m^3	Benefit	Rank
(Option 1) Roof top rainwater harvesting	1.88	57.57	**(2)**
(Option 2) Surface runoff rain water harvesting	1.5	36.51	5
(Option 3) Household drinking water treatment and safe storage	15.03	55.34	7
(Option 4) Boreholes/Tubewells	1.16	47.34	**(3)**
(Option 5) Solar distillation	3.22	38.97	6
(Option 6) Restoration of minor tank networks	0.12	52.84	**(1)**
(Option 7) Desalination by RO	4	47.97	4

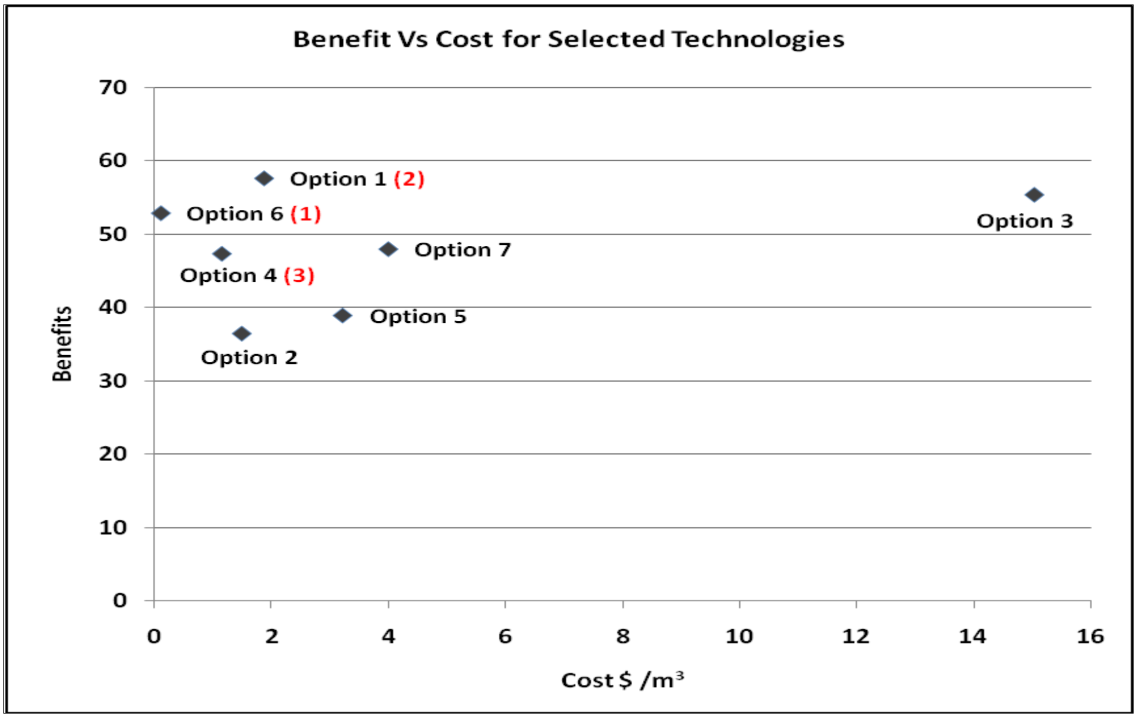

Figure 6.1: Benefit Vs Cost Plot for Selected Technologies

6.3 Results of Technology Prioritization

As per the above MCDA results, the three technologies which received the highest rating in order of priority are; (1) Restoration of minor tank net works *(Option 6);* (2) Rainwater harvesting from rooftops *(Option 1)*; (3) Boreholes/tube wells as a drought intervention for domestic water supply *(Option* 4). Accordingly they are recommended for implementation.

The Multi-Criteria Decision Analysis ranking of the identified technologies in order of priority are as follows:

1. **Restoration of minor tank networks**
2. **Rainwater harvesting from rooftops for drinking and household uses**
3. **Boreholes/tube wells as a drought intervention for domestic water supply**
4. Desalination of brackish water by Reverse Osmosis
5. Surface runoff rain water harvesting
6. Solar distillation
7. Household drinking water treatment and safe storage

Table 6.5: Summary Table for Prioritized Technologies

No	Name of the Technology	Scale of Application *(Small, Medium or Large Scale)*	Time Scale (Approx number of years)	Potential for adaptation in sub sector in the Time Scale	Benefits *(Output from the MCDA)*	Estimated total lifetime Cost US $/m^3
1.	Restoration of minor tank networks	Large	3	High	52.84	0.12
2.	Roof top rainwater harvesting	Small	3	High	57.57	1.88
3.	Boreholes/ Tubewells	Small	2	High	47.34	1.16

6.4 Summary Account of Recommended Technologies

1) Restoration of minor tank networks

Dry zone receives around 1000 mm rainfall during the Maha season (N-E Monsoonal rains during October – February) and about 500 mm in the Yala season (S-W Monsoonal rains during April – July) with a distinct dry season from May to September. The annual average evaporation in the dry zone is between 1,700 mm and 1,900 mm, which exceed the average annual rainfall, implying water stress in the dry zone[21]. The irrigation water demand in the Yala season is greater than that of the Maha season for the dry zone. Further, due to climate change, dry zone will be vulnerable to droughts. Therefore, it is imperative to implement technologies which augment supply of irrigation water to the dry zone.

There are a number of important but abandoned minor tanks in the dry zone (table 9) and restoration of such tanks would be an additional water source. Ad hoc raising of bunds and spillways of minor tanks in recent development programs, have seriously disrupted the delicately balanced hydrology between the respective tanks within a cascade. It is necessary to study the total hydrological relationships between all the bigger tanks within a cascade before rehabilitating individual tanks. When restoring minor tanks it will be useful to follow the procedures/instructions given by Panabokke *et al*[36].

2) Roof top rainwater harvesting for drinking and household uses

Rainwater harvesting means collection, preservation and maximizing utility of rain water. Many countries in the developed world including Australia, Hawaii, Germany, Japan, USA, Singapore etc. also make use of rain water. Harvesting of rainwater from roof tops can be done at household level and also in other places such as hospitals, schools, housing complexes etc. Incorporation of RWH into household water practices would indirectly contribute to the economic development by saving money and time while serving as an adaptation technology for climate change.

A study on the rainfall pattern for the period from 1960 to 2001 has shown that the length of dry spells is increasing all over Sri Lanka[37]. The same study (Ratnayake U.R., *et al* 2005) has also shown that the daily rainfall intensities have increased and therefore rain water from roof tops could be harvested within a short period of time. Rainwater could be harvested during the rainy season and the rainwater storage can provide short term security against such dry periods. Present rain water harvesting system should be expanded to other areas in the country.

3) Boreholes/tube wells as a drought intervention for domestic water supply

Groundwater has become very popular among many farmers in the dry zone as a supplementary source for cultivating short-term crops during the frequent dry seasons experienced due to the changes in the rainfall patterns. In addition, groundwater is also used as a drinking water source. The borehole efficiency (high efficiency means both high yield and high success rates) changes with the bedrock geology.

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[36] Panabokke C, Sakthivadivel R, Weerasinghe A.D. "Evolution, present status and issues concerning small tank systems in Sri Lanka, IWMI.

[37] Ratnayake U.R., and Herath G.,(2005)"Changes in water cycle: effect on natural disasters and ecosystems", Proceedings of the workshop on Sri Lanka National Water Development report

CHAPTER 7

Technology Prioritization for the Coastal Sector

7.1 An overview of the Sector, Projected impacts of Climate Change and Possible Adaptation Technology options in the Coastal Sector

7.1.1 Possible impact of climate change on the coastal sector

Climate change effects such as sea temperature changes & sea level rise (SLR), increased frequency & magnitude of tropical storms and other extreme events will have negative impacts on ecosystems due to coral bleaching, saltwater intrusion, flooding, erosion and also on human well-being by loss and/or reduced productivity in goods and services provided by ecosystems. Sensitive ecosystems such as coral reefs, sand dunes, sea grass beds and mangroves are not only economically and ecologically important to Sri Lanka but they act as buffers against wave action, storm surge, and tidal variations and sometimes against severe conditions such as tsunami which was evident during the 2004 tsunami. While global mean sea level rise is important, the local or relative sea level is the dominant factor in determining impacts on the coast. Climate change may also cause increases in both extreme wave heights and in the intensity of storms, which can be uncertain especially in the tropics where storms may become more intense but less common.

Sri Lanka being an island with 25% of its population living in coastal areas, coastal communities both rural and urban are at risk from the effects of rising sea levels, increasing temperatures, disasters such as floods and droughts and salt water intrusion[38]. Apart from the population density in the coastal regions, 62% of industrial units and more than 70% of tourist infrastructure are located on Sri Lanka's coastal areas[39]. "The coastal zone accounts for about 43% of the nation's GDP, so impacts on coastal settlements translate into substantial impacts on the nation's economy"[40]

Large tracts of Sri Lanka's coastal belt are already pressured by a host of human induced environmental threats including pollution, coral & sand mining, erosion and depletion of mangroves and these will be further exacerbated by climate change[41]. Tourism, fisheries and agriculture play a substantial role in

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[38] Jayatilake, A. 2008, Climate Change due to Global Warming: A Global Challenge in Sri Lanka Perspective. Economic Review, 2008

[39] ME b, 2010, Climate Change Vulnerability in Sri Lanka - Sector Vulnerability Profile: Water.

[40] ME a, 2010, Climate Change Vulnerability in Sri Lanka - Sector Vulnerability Profile: Urban Development, Human Settlements and Economic Infrastructure.

[41] Pallewatta, N, 2010, Impacts of Climate Change on Coastal Ecosystems in the Indian Ocean Region

livelihoods of coastal communities and are directly or indirectly exposed to coastal vulnerability that in turn increases the effects on poor communities that rely on these enterprises.

Coastal zone of Sri Lanka is defined as the area lying within a limit of 300 m landwards of the Mean High Water Line and a limit of 2 km seawards of the Mean Low Water Line and in the case of rivers, streams, Lagoons or any other body of water connected to the sea either permanently or periodically, the landward boundary shall extend to a limit of 2 km measured perpendicular to the straight base line drawn between the natural entrance points thereof and shall include water of such rivers, streams and lagoons or any other body of water so connected to the sea.

Coastal Zone Management Project, Coast Conservation Departmen (Olsen et.al 1992)

Expected impacts of climate change to Coastal Sector:

- Sea Level Rise (SLR) of about 0.5 m by 2050
- Coastal inundation
- Coastal erosion
- Loss of coastal terrestrial habitats
- Saltwater intrusion
- Changes in coastal biodiversity
- Changes in coastal morphology

7.1.2 Identified Adaptation Technologies in the Coastal Sector

Nine (09) adaptation technologies were identified through stakeholder consultations considering the important physical and biological properties of different coastal districts and their socioeconomic importance. The identified technologies are as follows;

1. Restoration of coral reefs as soft defense mechanisms
2. Replanting of sea grasses as a soft defense mechanism
3. Sand dune rehabilitation as a soft defense mechanism
4. Beach nourishment
5. Restoration of mangrove habitats
6. Construction of dikes
7. Floating mariculture for sea weeds
8. Floating mariculture for fish
9. Construction of groins & sea walls (revetments)

In addition to above, establishment of salt water barriers, flood hazard mapping and flood warning systems also was considered important. However, these were not taken into consideration for want of detailed information which was not readily available. Table 7.1 depicts the current status of application of the technologies selected.

Table 7.1: Current Degree of Application of Selected Adaptation Technologies

Technology	Current degree of application			
	Not applied	Low	Medium	High
1. Restoration of coral reefs		X		
2. Replanting of sea grasses		X		
3. Rehabilitation of sand dunes	X			
4. Restoration of mangroves				X
5. Beach Nourishment		X		
6. Construction of dikes			X	
7. Floating mariculture for sea weeds	X			
8. Floating mariculture for fish	X			
9. Construction of groins & sea walls				X

7.2 Criteria and process of technology prioritization

7.2.1 Adaptation benefits of the Identified Technologies: An overview of identified technology options and their adaptation benefits are given in table 7.2 below;

Table 7.2: Overview of Possible Adaptation Technology Options and their Adaptation Benefits

No	Technology	Adaptation Benefits
1.	**Restoration of coral reefs**	Ensure ecosystem services to tourism, fisheries and shoreline protection. This natural reef building mechanism provides a protection from expected sea level rise.
2.	**Replanting of sea grasses**	Sea grass beds provide coastal zones with a number of ecosystems related goods and services such as, fishing grounds, wave protection, oxygen production and protection against coastal erosion. Sea grass meadows account for 15% of the ocean's total carbon storage. They slowdown the water current, maintaining water clarity by trapping sediments to allow light penetration and providing shade and habitats for small marine species. They are very useful for forming a protective belt against possible coastal erosion that may occur due to sea level rise and also for removal of CO_2.
3.	**Sand dune rehabilitation**	Dune vegetation are capable of withstanding to the harsh conditions prevail in the coastal environments and the unstable conditions of the substratum on which they are anchored. They are well adapted to the strong winds and waves in this environment, although the sand is loose and porous and the substrate keeps shifting constantly.

4.	**Beach nourishment**	Beach nourishment is primarily used in response to shoreline erosion, while it provides flood reduction benefits as well. It helps to dissipate wave energy; when waves run up a beach and break, they lose energy and this interaction will be of different extents depending on the beach profile, shapes and gradients.
5.	**Restoration of mangrove habitats**	Mangroves perform essential functions in terms of coastal flood and erosion management. They induce wave and tidal energy dissipation and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilize shore sediments, thus reducing erosion. Mangrove ecosystems played a vital role in buffering the force of the tsunami waves and in protecting the human inhabitations.
6.	**Construction of dikes**	The primary function of sea dikes is to protect low-lying, coastal areas from inundation by the sea under extreme conditions. These structures have a high volume which helps to resist water pressure, sloping sides to reduce wave loadings and crest heights sufficient to prevent overtopping by flood waters. Dikes are widely used to protect low-lying areas against inundation in many countries including Sri Lanka.
7.	**Floating mariculture for sea weeds**	Seaweed farming is a profitable coastal activity which helps to improve the socio-economic standard of coastal communities. In addition, it will help to reduce dissolved CO_2 levels in sea water which is important for reduction of GHG. This is a farming system which does not need the addition of fertilizers or nutrients as they are freely available in the marine environment. Seaweed is harvested throughout the world as a food source as well as an export commodity for the production of agar and alginates such as Carrageenan for a range of products including ice cream, yoghurt, pet food, beauty treatments etc. It is also used in the preparation of drugs and in agriculture and horticulture as an organic fertilizer and a soil dressing.
8.	**Floating mariculture for fish**	Provide protection against salt water intrusion into fresh water source which causes reduction of availability of fresh water for aquaculture. Therefore, fish and shrimp culture is protected.
9.	**Construction of groins & sea walls**	Prevent erosion due to sliding of soil as a result of high wave action and coastal flooding. They could be coupled with soft barriers such as artificial reefs and sea grass plots.

7.2.2 Multi Criteria Decision Analysis (MCDA)

Multi-Criteria Decision Analysis (MCDA) was carried out to prioritize the 9 adaptation technologies in order to select the most suitable 3 adaptation technologies for the coastal sector.

a) Determination of Criteria and Weightings

The evaluation criteria to be applied were identified through a stakeholder consultation. These criteria included cost of technologies, and economic, social, & environmental benefits. In deciding the criteria, adequate considerations were given to socio economic importance of the coastal sector and also to secure the maximum benefit out of the selected adaptation technologies. Then, each option was given a score against each criterion, considering the preference. The weightings for each criterion were allocated taking into account the relative importance of the criterion. Twelve criteria were selected using the social, economic and environment importance of the selected adaptation technologies and they are given in the Table 7.3 below.

Table 7.3: Criteria Adopted to Prioritize the Adaptation Technologies

<table>
<tr><th>Major Criteria</th><th colspan="3">Sub divisions of criteria selected (Weight Factor)</th></tr>
<tr><td>Costs (25%)</td><td colspan="3">Cost/m^2 of land area covered (25%)</td></tr>
<tr><td rowspan="12">Benefits (75%)</td><td rowspan="3">Economic (15%)</td><td colspan="2">Employment (5%)</td></tr>
<tr><td rowspan="2">Investment/ Long-term benefits</td><td>Foreign exchange earnings (5%)</td></tr>
<tr><td>Protection for infrastructure (5%)</td></tr>
<tr><td rowspan="6">Social (30%)</td><td colspan="2">Income (10%)</td></tr>
<tr><td rowspan="3">Education</td><td>Improve awareness ((5%)</td></tr>
<tr><td>Opportunities for research-based education (3%)</td></tr>
<tr><td>Improve environmental sensitivity (5%)</td></tr>
<tr><td colspan="2">Health (7%)</td></tr>
<tr><td rowspan="4">Environmental (30%)</td><td colspan="2">Reduction of GHG (7%)</td></tr>
<tr><td colspan="2">Reduction of land losses due to SLR (10%)</td></tr>
<tr><td colspan="2">Reduce inundation (5%)</td></tr>
<tr><td colspan="2">Land reclamation (8%)</td></tr>
</table>

7.2.3 Scoring Matrix: The Scoring Matrix was constructed based on the above criteria and weight factors to evaluate how the different technologies rate against various criteria. (See Annex B 4 for weighted scores, costs and benefits of technologies). Benefits were calculated by using the formula "Benefits = Total Score – Weighted Score of Costs" The cost and the benefits of the selected technologies are given in the Table 7.4. Figure 7.1 shown below illustrates the Benefits plotted against the Costs. The sensitivity analysis carried out by changing the weights assigned to cost of technologies and criterion did not show any significant deviation from the original results.

Table 7.4: Costs and benefits of the selected technologies and the order of priority

No	Technology Options	Cost US $/m^2	Benefits	Order of priority
1.	Restoration of coral reefs	14.30	54.17	**(3)**
2.	Replanting of sea grasses	22.94	36.99	6
3.	Sand dune rehabilitation	2.13	56.54	**(1)**
4.	Restoration of Mangroves	10.50	52.22	**(2)**
5.	Beach Nourishment	25.56	39.16	5
6.	Construction of dikes	37.50	39.65	7
7.	Floating mariculture for sea weeds	31.00	32.20	8
8.	Floating mariculture for fish	50.59	29.85	9
9.	Construction of groins & sea walls	22.5	44.65	4

7.3 Results of technology prioritization

The results of the Multi-Criteria Decision Analysis ranked the identified technologies according to order of priority as shown below.

1. **Sand dune rehabilitation**
2. **Restoration of Mangroves**
3. **Restoration of coral reefs**
4. Construction of groins & sea walls
5. Beach Nourishment
6. Replanting of sea grasses
7. Construction of dikes
8. Floating mariculture for sea weeds
9. Floating mariculture for fish

According to the order of priority, the three technologies which received the highest degree of priority are (1) Sand dune rehabilitation; (2) Restoration of Mangroves; (3) Restoration of coral reefs.

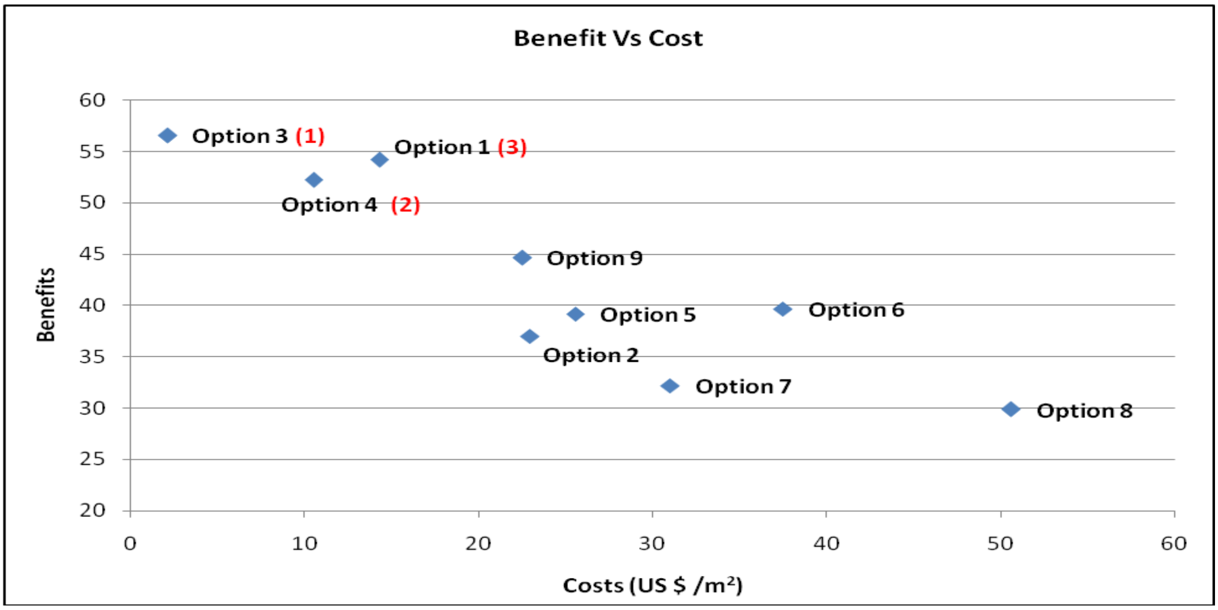

Figure 7.1: Benefit Vs Cost Plot for Identified Technology Options

Table 7.5: Summary Table for Prioritized Technologies

No	Name of the Technology	Scale of Application *(Small, Medium or Large Scale)*	Time Scale (Approx number of years)	Potential for adaptation in the Time Scale	Benefits *(Output from the MCDA)*	Estimated total lifetime Cost/ ha US $
1.	Sand dune rehabilitation	Large scale	3 years	High	61.54	21,300
2.	Mangrove restoration	Large scale	3 years	High	55.56	15,950
3.	Restoration of Coral reefs	Small scale	3years	Medium	55.50	429,000

7.4 Summary Account of Recommended Technologies

1) Sand dune Rehabilitation as a soft defense mechanism

Sand dune vegetation has the ability to withstand the harsh conditions prevail in the coastal environment and the unstable conditions of the substratum on which they are anchored. Sand dune plants grow in areas where the temperature is high and the winds and waves are strong.

These plants have developed specialized adaptabilities which enable them to withstand to these conditions. They are adapted to stand against the strong winds and waves in this environment, although the sand is loose and porous and the substrate keeps shifting constantly. Therefore, plants closest to the sea have lateral roots and shoots growing in along the surface. These roots and shoots form a dense mat on the surface as seen in Goat's Foot (*Ipomoea pescaprae*) and Spinifex (*Spinifex littoreus*).

Further inland, where dunes are more stable, plants grow more upright. Dune plants also have adaptations to prevent desiccation. On clear, sunny days, the temperature in sand dunes can rise to as much as 50°C and fresh water is also lacking. Because of this, sand dune plants have developed xerophytic characteristics. The outer layer of leaves is very thick and leaves are often reduced to spiny projections (as seen in Spinifex) or rolled up (as seen in Goat's Foot) to minimize water loss. Dune plants such as *Pandanus* sp. have effectively provided protection in certain areas in the Hambantota District where natural dune vegetation has not been affected by human interference. Replanting of dune vegetation may not only serve as a soft defense for harsh wave action and storm surges but also will act as traps for GHG.

2) Mangrove Restoration

One of the most commonly restored wetland ecosystems for coastal protection is mangroves. Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion control. They induce wave and tidal energy dissipation[42] and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilize shore sediments, thus reducing erosion. Wetland restoration reestablishes these advantageous functions for the benefits of coastal flood and erosion protection. Techniques have been developed to reintroduce mangrove vegetation successfully to areas where they have previously existed and to new areas with mix results. Mangrove ecosystems have played a vital role in buffering the force of the tsunami waves and in protecting the human inhabitations, most of the mangrove areas have been lost due to indiscriminate clearing and reclamation for industrial, urban, tourist resorts, roads, aquaculture ponds, and fishing ports development.

Observations indicate that a mature mangrove plantations help reducing the costs of dike maintenance by 25-30% provided that the width of the mangrove stand is at least comparable to the characteristic wavelength of incident waves[43]. In contrast to hard defenses, wetlands are capable of undergoing 'autonomous' adaptation to SLR, through increased accumulation of sediments to allow the elevation of the wetland to keep pace with changes in sea level[44]. Coastal wetlands also provide a number of important ecosystem services including water quality improvement and climate regulation. They are valuable locations for sediment, contaminant, carbon and nutrient accumulation and they also provide

[42] Brampton, A.H. (1992) Engineering significance of British salt marshes in Allen, J.R.L. and Pye, K. (eds.).

[43] Tri, N.H., Adger, W.N. and Kelly, P.M. (1998) Natural resource management in mitigating climate impacts: the example of mangrove restoration in Vietnam.

[44] Nicholls, R.J. and Klein, R.J.T. (2005) Climate change and coastal management on Europe's coast in Vermaat, J.E. et al.(eds.). Managing European Coasts: Past, Present and future

vital breeding and nursery ground for a variety of birds, fish, shellfish and animals. They also function as a sustainable source of timber, fuel and fiber for the coastal communities.

3) Restoration of Coral Reefs as soft defense mechanism

Coral reefs are underwater structures made from calcium carbonate secreted by corals which are biologically classified as Cnidarians (coelenterates). Corals are marine organisms belonging to Class *Anthozoa* of Phylum *Cnidaria* typically living in compact colonies of many identical individual "polyps". The group includes the important reef builders that inhabit tropical oceans and secrete calcium carbonate to form a hard skeleton. Coral forming organisms construct the reef by secreting hard skeletons of aragonite (a fibrous, crystalline calcium carbonate). Reefs grow best in warm, shallow, clear, sunny and agitated waters. Coral reefs often called “rainforests of the sea” and they form some of the most diverse ecosystems on Earth[45]. (http://en.wikipedia.org/wiki/Coral reef)

Coral reefs deliver ecosystem services to tourism, fisheries and shoreline protection. The annual global economic value of coral reefs has been estimated at $US375 billion. Healthy tropical coral reefs grow horizontally from 1 to 3 cm (0.39 to 1.2 in) per year, and grow vertically anywhere from 1 to 25 cm (0.39 to 9.8 in) per year; however, they grow only at depths shallower than 150 m (490 ft) due to their need for sunlight, and cannot grow above sea level (Hatta, et.al., 1999). As an adaptation for expected sea level rise due to climate change, this natural reef building mechanism continued during the evolutionary process should be artificially enhanced by providing hard substrata attached with relevant samples of temperature tolerant live corals to produce artificial coral reefs. Transplanting of corals on concrete blocks and tiles has been successfully implemented by a group of marine scientists at University of Ruhuna. Due to the utilization of dissolved CO_2 in water to construct the exoskeleton, corals can be considered not only as a soft defense mechanism against wave action, but also as a system having potential for reducing GHG.

[45] Garrison, T. (1995). Tropical Oceans in Oceanography: An introduction to Marine Science. Wordsworth Publishing Company, New York

CHAPTER 8

Technology Prioritization for the Biodiversity Sector

8.1 An overview of the sector, projected impacts of climate change and trends of including adaptations to the adverse effects of climate change

8.1.1 Background and Sri Lanka's Biodiversity

Sri Lanka is one of the most biologically diverse countries in Asia. Despite its small size of 6,570,134 hectares Sri Lanka has a varied climate and topography, which has resulted in rich biodiversity, distributed within a wide range of ecosystems. In fact conservation of these resources has been an integral part of Sri Lanka's ancient civilization as stated in ancient chronicles such as the *Mahawamsa*[46]. King Devanampiyatissa established one of the world's earliest wildlife sanctuaries during 247 to 207 BC during the advent of Buddhism to the country, a philosophy that respects all forms of life[47].

Sri Lanka's biodiversity is considered to be the richest per unit area in the Asian region with regard to mammals, reptiles, amphibians, fish and flowering plants; overtaking several mega diversity countries such as Malaysia, Indonesia and India[48]. The biodiversity of the country is recognized as being globally important. Sri Lanka along with the Western Ghats of India has been identified as one of the 34 biodiversity hotspots in the world[49]. Biodiversity provides a multitude of ecosystem goods and services to people of Sri Lanka, including watershed services, regulation of climate, carbon sequestration, and supply of non-timber forest products such as rattan, wild foods, fruits, & medicinal plants, among many others. It is estimated that about 15% of the islands forests and scrublands lie within the country's Protected Area (PA) system[50], while some marine protected areas have also been set up in addition to these terrestrial areas. Conservation of country's biodiversity is recognized in national planning, and is highlighted in several policies, legislations and programs set up to protect the country's biodiversity. The Mahinda *Chintana*, national policy framework for Sri Lanka, *Haritha* (Green) Lanka Action Plan,

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[46] The great historical chronicle of Ceylon (Sri Lanka) composed in the late 5th or early 6th century.

[47]Forest Department Manual Sri Lanka. 2008. Forest Department, Sri Lanka.

[48]NARESA 1991, Natural Resources of Sri Lanka: Conditions and Trends. Natural Resources, Energy and Science Authority of Sri Lanka, Sri Lanka

[49] Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403, 853–858

[50] Ministry of Environment (1999). *Biodiversity conservation in Sri Lanka: a framework for action*. Colombo, Sri Lanka.

Biodiversity Action Plan for Sri Lanka and the National Physical Planning Policy and Plan[51] are prominent among them.

Despite all these efforts, Sri Lanka's biodiversity remain threatened. While some critical areas are not included in the protected area system, even some of those within the system still face serious threats. The biggest threats to the protected area system and biodiversity in general come from encroachments, conversion to other land uses, illegal extraction of natural resources, shifting cultivation, forest fires, haphazard development projects, poaching, pollution, gem mining, in coastal and marine ecosystems siltation and sedimentation, sewage and solid waste disposal, development of aquaculture and illegal sand/coral mining. According to the latest IUCN Red List in 2007 for Sri Lanka, of the 677 vertebrate species 233 (33%) have been classified as Nationally Threatened. Of this, 138 (62%) are endemic to the country. Many plant species in the country are also facing threat. The Red List assessed about 35% (1,099) of indigenous angiosperm flora and found that 61% of these species are threatened, of this 412 (61%) are endemic[52].

8.1.2 Climate Change and Biodiversity

Climate change will no doubt be a threat to Sri Lanka's biodiversity. It is unlikely that all impacts of climate change on biodiversity are preventable. However, it is recognized that genetically diverse populations of species, and species rich ecosystems, have much greater potential to adapt to climate change. Conservation of biodiversity and maintenance of ecosystem structure and function may, therefore, be one of the most practical climate change adaptation strategies that Sri Lanka can adopt to conserve the country's natural heritage[53].

The Sector Vulnerability Profile (SVP) for the biodiversity sector (which is a supplementary document to Sri Lanka's National Climate Change Adaptation Policy) has looked at the impact of climate change on this sector. It states that, as an island nation, Sri Lanka is vulnerable to the risk of sea level rise and increased frequency of storms that can bring major impacts on coastal biodiversity. Additionally, analysis of climate data indicate a change in rainfall regimes, and a trend for increasing air temperature, which can also have impacts on the country's biodiversity. It states that the impact of climate change on biodiversity and possible areas for adaptation are still speculative.

Some of the impacts relating to climate change are salinization of low lying areas due to sea level rise, storm surges and salt water intrusion, loss of coastal land due to sea level rise and increased coastal erosion, loss of coastal wetland area, adverse impacts to mangroves, coral reefs and sea grass beds and

[51] Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

[52] IUCN Sri Lanka & the Ministry of Environment and Natural Resources (2007), The Red List of threatened fauna and flora of Sri Lanka, Colombo, Sri Lanka, xiii+148pp

[53] Ministry of Environment, 2010 Op. Cit.

associated marine organisms, and changes in salinity of lagoons and estuaries. It is expected that there will be changes in coastal and marine systems, species and ecosystem services due to global warming and ocean acidification. This will impact coral reefs, other shell forming organisms and associated species and fish stocks, rising ocean temperatures and El Nino events that will systematically bleach and impoverish coral reef systems, and there will be an increased spread of marine invasive species.

It is expected that climate change will cause changes in onset of flowering/fruiting and flushing in terrestrial plants and breeding and reproduction in animals having implications on species survival, and ecosystems. Forest ecosystems and species in fringe areas between the major climatic zones are expected to be most vulnerable to impacts of climate change. Elevated carbon dioxide level can cause changes in forest structure while species loss can occur due to structural and compositional changes in habitats and deterioration of ecosystem services.

8.1.3 Adaptation Technologies Identified

Twelve (12) adaptation technologies *cum* strategies were identified as technologies/strategies for the biodiversity sector.

The technology options identified are as follows;

1. Restoration of degraded areas inside and outside the protected area network to enhance resilience.
2. Modeling the impact of climate change on biodiversity to predict changes for conservation and management.
3. Increasing connectivity through corridors, landscape/matrix improvement and management.
4. Protecting refuges which are less vulnerable to climatic changes.
5. Managing and monitoring invasive alien species (IAS).
6. Reducing other stresses on species and ecosystems.
7. Adaptive management and monitoring programs of species and ecosystems.
8. Focusing on conservation of resources and carrying out special management for restricted range, highly threatened species and ecosystems.
9. Improving management of existing protected areas, increasing extent, creating buffer zones and new areas in vulnerable zones.
10. Reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources and incorporating climate change adaptation considerations (ensuring implementation).
11. Ex-situ conservation for highly threatened species and possible reintroduction.

8.1.4 An Overview of Possible Adaptation Technology Options and their Adaptation Benefits

The identified technologies/strategies have various benefits for conserving biodiversity and adapting to climate change. Table 8.1 below gives a brief introduction to the technology and its benefits *(please see Fact Sheets in Annex C 5 for more details).*

Table 8.1: Introduction and benefits of identified technologies

1. Restoration of degraded areas inside and outside the protected area network to enhance resilience This will enable restoring degraded areas inside and outside the Protected Area network to enhance resilience to better withstand the impact of climate change. Some of its benefits are highlighted below. • Not a 'new technology' as such and in- country capacity exists. • Beneficial for carbon sequestration, which would contribute to climate change mitigation. • Restoration will ensure that ecosystem services are maintained for local communities and the larger population. • Create income generating opportunities such as direct involvement in restoration activities, community conservation, payments for ecosystem services, REDD and ecotourism. • Job creation, as restoration will require manpower. • Need for policy or legislative reforms will not arise.
2. Modeling the impact of climate change on biodiversity to predict changes for conservation and management This will enable forecasting impacts of climate change on biodiversity in order to undertake appropriate conservation and management measures. Some of its benefits are highlighted below. • Most climate change adaptation strategies will required to be based on prediction and provides ability for better future planning, even though such predictions may not be totally accurate. • Adaptation strategies could be made effective if based on climate models and existing data. • It will ensure that climate change adaptation strategies are planned and executed so as to minimize the impacts on biodiversity. • Sustainability of biodiversity and associated ecosystem services will be ensured while making them more resilient thereby benefiting those communities dependant on ecosystem services for livelihoods. • Integration of such a technology in climate change adaptation strategies would allow ecosystems to be more resilient, and damage to ecosystem services are minimized.
3. Increasing connectivity through corridors, landscape/matrix improvement and management It is an important mechanism to connect fragmented areas, as many Protected Areas are isolated from each other. Increased connectivity through corridors will provide for landscape/matrix improvement and management. Some of its benefits are highlighted below. • There are legal provisions for such corridors in wildlife legislation and are referred to as 'jungle corridors' hence no legal reforms are required.

- There will be benefits associated with ecosystem services for the larger population.
- The enhancement of the landscape will also increase the opportunities for conservation related jobs and income.
- Local employment opportunities resulting from restoration, monitoring or conservation requirements.
- Accrued benefits from ecotourism, community conservation and sustainable utilization of NTFP, REDD etc.
- Environmental benefits include maintaining genetic diversity, allowing migration for species with large home ranges, seed dispersal, carbon sequestration and other ecosystem services.
- It will also allow ecosystems to be resilient to the changing climate as they are better conserved.

4. Protecting refuges which are less vulnerable to climatic changes

This technology will focus on protecting those refuges which are less vulnerable to climate change. Some of its benefits are highlighted below.

- The main benefits would be the provision of a stable climate and habitat for biodiversity conservation in a changing climate to ensure its viability.
- There will be a multitude of environmental benefits associated with ecosystem services. These include carbon sequestration, maintaining biodiversity, regulating the microclimate etc.
- Potential benefits to local communities from community conservation initiatives, REDD, payment for ecosystem services etc.
- Direct employment benefits from the establishment, conservation and monitoring of the refuges.

5. Managing and monitoring invasive alien species (IAS)

Will focus on managing and monitoring invasive alien species as climate change exacerbate the spread of invasive or non-native species, which include plants, animals, and pathogens. Some of its benefits are highlighted below.

- Enabling legislative and policy environment already exists in the country for management of IAS.
- IAS have the potential to destroy biodiversity, especially native species and can also impact agriculture thus controlling will also be beneficial to the agricultural sector.
- Employment opportunities due to increasing personnel requirement for monitoring, enforcement and removal of IAS.
- Supplementary incomes from ecosystem services, community conservation, REDD etc.
- The IAS being one of the leading causes of biodiversity loss, it will ensure sustainability of biodiversity and minimize degradation.

6. Reducing other stresses on species and ecosystems

This technology aims at reducing or removing other non-climatic stresses on species and ecosystems giving species the maximum flexibility to evolve responses to climate change. Some of its benefits are highlighted below.

- Reducing stresses on biodiversity will ensure that ecosystem services are minimally impacted and will provide food, watershed services, control erosion, regulate disease etc.
- A well conserved protected area or environment will attract more tourism and visitation, benefiting local livelihoods.

- Increased conservation and monitoring activities will require manpower thus creating employment opportunities.
- Improved ecosystem services could provide income through the sustainable collection of NTFP, microclimate and pest control benefiting agriculture etc.
- This technology will maintain viability and resilience of biodiversity, and better adapted to impacts of climate change.
- Enhanced ecosystem services such as carbon sequestration and other environmental services.

7. Adaptive management and monitoring programs of species and ecosystems

This technology focuses on adaptive management and monitoring programs of species and ecosystems. Monitoring is essential to observe climate change impacts and associated ecosystem responses and adjusts management strategies accordingly. Some of its benefits are highlighted below. Partnership based adaptive management is important as it will allow field managers help to test and refine ideas progressively in order to be effective during the uncertainties of climate change.

- Adaptive management would minimize impacts of climate change and would increase resilience, which will be important for maintaining ecosystem services benefiting a large group of people.
- Additionally there will be increased job opportunities for conservation activities, while local communities could benefit from community conservation, payment for ecosystem services, ecotourism etc.
- Early action could minimize potential irreversible damages well in advance of impacts becoming severe.
- Such preventative and early action will cost less than intervening when considerable impact has occurred.

8. Focusing on conservation of resources and carrying out special management for restricted range, highly threatened species and ecosystems

This will focus on conservation of resources and carrying out special management practices for restricted range, highly threatened species and ecosystems vulnerable to climate change to minimize species loss and extinction. Some of its benefits are highlighted below. This mechanism will ensure that biodiversity is conserved in a sustainable manner, preventing threats of extinction.

- It will ensure that ecosystem services are maintained – which will benefits a large group of people.
- Income generation from ecotourism and visitation to conservation facilities/areas where there are targeted programs for threatened species.

9. Improving management of existing protected areas, increasing extent, creating buffer zones and new areas in vulnerable zones

These efforts will provide for improved management of existing Protected Areas, expansion, creating buffer zones and new areas in vulnerable zones. Some of its benefits are highlighted below. Local communities will benefit from ecotourism related activities and community conservation programs, REDD, payments for ecosystem services etc.

- Benefits from ecosystem services such as micro-climate regulation, watershed services, erosion and flood control, carbon sequestration etc.

10. Reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources and incorporating climate change adaptation considerations (ensuring implementation). Involves in reviewing and undertaking reforms if necessary, to existing laws, regulations, and policies relating to biodiversity conservation and natural resources management in order to incorporate climate change adaptation considerations. It is also of utmost importance to ensure that these revised laws and policies are implemented. Some of its benefits are: • Benefits from sustainability and increase of resilience of biodiversity and ecosystem services – resulting from implementation of appropriate laws and policies. • The review and amendment process itself will not generate income, but its implementation could include income generation options such as payments for ecosystem services, community conservation, REDD etc. • Preparedness and having such legislation and policies will ensure the smooth implementation of climate change adaptation strategies. • It will be attractive to donors, as the fundamentals have been set in place for adaptation.
11. Ex-situ conservation for highly threatened species and possible reintroduction This will entail carrying out ex-situ conservation for highly threatened species and reintroducing them to the wild if possible. The main environmental benefit would be that this mechanism would contribute to the viability of threatened biodiversity, and genetic diversity. Other benefits are; • Certain ex-situ conservation programs, especially those associated with zoological gardens, botanical gardens and aquaria can generate significant income from foreign tourists and local visitors. • Zoological Gardens, botanical gardens and aquaria provide excellent learning platforms for students of all ages and adults • They also provide information on threatened species and importance of conservation, and play an important role in obtaining support for biodiversity conservation in general.

8.2 Criteria and process of technology prioritization

8.2.1 Multi Criteria Decision Analysis (MCDA)

The methodology used to prioritize the technologies was Multi Criteria Decision Analysis (MCDA) Approach. The criteria and the weightings for selected criteria were determined through stakeholder consultations.

b) Determination of Criteria and Weightings

The criteria included cost of technologies, and economic, social, & environmental benefits. These major criteria were sub-divided and the weightings for each criterion and its sub-divisions were apportioned taking into account the relative importance. Seven (07) criteria were selected using the social, economic and environment importance and the respective weight factors are given in the Table 8.2 below.

Table 8.2: Criteria Adopted to Prioritize the Adaptation Technologies

<table>
<tr><th>Major Criteria</th><th colspan="2">Sub divisions of criteria selected</th><th>Weight Factor</th></tr>
<tr><td>Costs 10%)</td><td colspan="2">Annual investment in Rs Million (Government and Public)</td><td>10%</td></tr>
<tr><td rowspan="6">Benefits (90%)</td><td>Economic 10%)</td><td>Job creation/opportunities – Potential of the activity to create employment opportunities.</td><td>10%</td></tr>
<tr><td rowspan="2">Social (30%)</td><td>Ecotourism and Conservation benefits (payments for ecosystem services, REDD etc) - The contribution of the strategy for ecotourism development (benefits accrued by the local communities and the State).</td><td>20%</td></tr>
<tr><td>Improve awareness, research opportunities</td><td>10%</td></tr>
<tr><td rowspan="3">Environmental (50%)</td><td>Overall contribution to saving biodiversity (effectiveness/impact) – Degree of contribution to biodiversity conservation in the medium to long term (eg: protecting one species vs a larger group; small impact to survival vs major impact)</td><td>15%</td></tr>
<tr><td>Addresses conservation urgency, including threatened species – Potential benefits of an urgent/essential conservation issue is being addressed (E.g.: a highly threatened ecosystem or Red List species)</td><td>15%</td></tr>
<tr><td>Enhancing ecosystem services (general) - Contribution to enhancing ecosystem services (E.g.: Contribution of restoration to ecosystem services vs ex-situ conservation)</td><td>20%</td></tr>
</table>

8.2.2 Scoring Matrix: The Scoring Matrix was constructed based on the above criteria and weight factors to evaluate how the different technologies rate against various criteria. (See Annex B 5 for weighted scores, costs and benefits of technologies).

8.3 Results of Technology Prioritization

During stakeholder consultation process it was noted that for a natural resource based sector like biodiversity, benefits were relatively more important when compared with other sectors (although costs were considered according to the MCDA). Hence, environmental and ecotourism & conservation benefits were given relatively high weight factor in the MCDA process (Table 8.2). In prioritizing technologies those options that had the highest level of benefits per unit cost were given the highest priority. The benefit/cost ratio was also calculated and those options shown to have the highest benefit/cost ratios were prioritized and the top five technologies selected had the highest B/C ratios, indicating the highest returns per unit cost. The costs and benefits of selected technologies based on the MCDA and performance matrix are given in Table 8.3 and Figure 8.1 below.

Since it was considered important to include species level interventions as well, five main technologies were selected instead of selecting three options. These five technologies were recognized as the most important adaptation strategies for the biodiversity sector to counter climate change challenges.

As shown in Table 8.3 and Figure 8.1, technological option numbers 1,3,8,9 and 11 have the potential to provide high level of benefits as well as highest C/B ratios upon which the final selection was made. The sensitivity analysis carried out subsequently by changing the weights assigned to cost of technologies and environmental criterion, did not show a significant deviation from these results.

Table 8.3: Costs and benefits of the selected technologies and the order of priority

No.	Technology	Benefits	Annual Costs (US $ mill/year)	Priority
1.	Restoration of degraded areas inside and outside the protected area network to enhance resilience	85.00	0.91	**(1)**
2.	Modeling the impact of climate change on biodiversity to predict changes for conservation and management	30.00	0.59	10
3.	Increasing connectivity through corridors, landscape/matrix improvement and management	75.00	0.82	**(2)**
4.	Protect refuges which are less vulnerable to climatic changes	53.33	0.77	6
5.	Manage and monitor invasive alien species (IAS)	41.67	0.77	8
6.	Reduce other stresses on species and ecosystems	49.17	0.73	7
7.	Adaptive management and monitoring programs of species and ecosystems	41.67	0.82	9
8.	Focus on conservation of resources and carryout special management for restricted range, highly threatened species and ecosystems	69.17	0.91	**(4)**
9.	Improve management, and possibly increase extent of protected areas, buffer zones and create new areas in vulnerable zones	70.83	0.82	**(3)**
10.	Review and modify existing laws, regulations, and policies relating to biodiversity and natural resources and incorporate climate change adaptation considerations	6.67	0.14	11
11.	Ex-situ conservation for highly threatened species and possible reintroduction	64.17	0.91	**(5)**

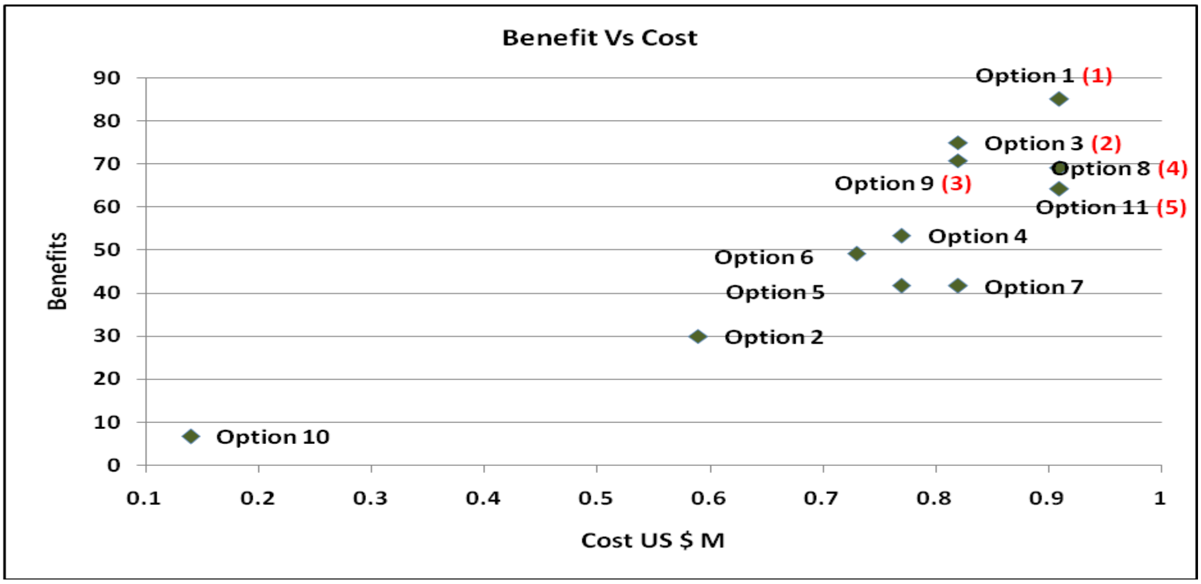

Figure 8.1: Benefit vs. cost plot for selected technologies

The five (5) technologies thus selected are given below in order of priority.

The 5 technologies which received the highest priorities are as below:

1. Option1: Restoration of degraded areas inside and outside the protected area network to enhance resilience.
2. Option 3: Increasing connectivity through corridors, landscape/matrix improvement and management
3. Option 9: Improve management, and possibly increase extent of protected areas, buffer zones and create new areas in vulnerable zones
4. Option 8: Focus on conservation of resources and carryout special management for restricted range, highly threatened species and ecosystems
5. Option 11: Ex-situ conservation for highly threatened species and possible reintroduction.

Upon conclusion of selecting the technologies, further consultations were held in order to deliberate on further details of technologies/sub-strategies under consideration.

Table 8.4: Summary table for Prioritized Technologies for the Biodiversity Sector

No.	Technology	Scale of Application (small, medium or large scale)	Time Scale (short, medium or long term	Benefits (outputs from the MCDA)	Estimated total annual cost (US $ million)
1.	Restoration of degraded areas inside and outside the protected area network to enhance resilience	Medium-large scale	Long-term	85.00	0.91
2.	Increasing connectivity through corridors, landscape/matrix improvement and management	Medium-large scale	Long-term	75.00	0.82
3.	Improve management, and possibly increase extent of protected areas, buffer zones and create new areas in vulnerable zones	Medium scale	Long-term	70.83	0.82
4.	Focus on conservation of resources and carryout special management for restricted range, highly threatened species and ecosystems	Medium-large scale	Long-term	69.17	0.91
5.	Ex-situ conservation for highly threatened species and possible reintroduction	Medium scale	Long-term	64.17	0.91

8.4 Summary Account of Recommended Technologies

The prioritized technologies/strategies are summarized below (in order of priority), including the sub-technologies and strategies identified by the stakeholders.

1) Restoration of degraded areas inside and outside the Protected Area network to enhance resilience.

Restoration of degraded areas inside and outside the Protected Area network to enhance resilience will allow biodiversity to better withstand the impact of climate change. Resilience can be defined as *the capacity of a system to absorb disturbance and reorganize, while undergoing change so as to retain* *essentially the same function, structure, identity, and feedbacks*.[54] Although some areas are legally declared as Protected Areas, they are degraded due to illegal activities such as encroachments for settlement and clearing, and logging. However, there are other areas outside the existing PA network which could be considered important for conservation as at present or in the event of species shift their range as a result of climate change. Restoration will require selecting suitable native species and recreating the former conditions of the ecosystem. Some ecosystems that can be restored include forests, wetlands, coastal areas, coral reefs etc. In Sri Lanka forest[55], aquatic[56], reef and coastal areas have been restored in the past. Therefore, restoration is not a new technology, Some of these technologies are currently in place, and has been so for several decades.

There are several international experts who endorse this strategy as an essential climate change adaptation strategy for biodiversity in papers published in peer-reviewed journals.[57,58] Additionally several Policies, Action Plans and Strategies in Sri Lanka have identified this as essential for biodiversity conservation (see Fact Sheet 1 for more details.).

Some mechanisms/sub-technologies suggested by stakeholders includes the following (not in order of priority):

a) Mapping and modeling to identify ecosystems and species (aquatic and terrestrial) that are highly vulnerable to climate change.
b) Device appropriate technologies for natural/aided restoration within protected areas in highly vulnerable areas as identified in the mapping and modeling.
c) Facilitate regeneration in areas outside protected areas as identified in mapping and modeling.
d) Monitoring restoration inside and outside the Protected Area network.
e) Aided natural restoration within protected areas.
f) Identify suitable scientific methods of restoration.
g) Creation of analogous ecosystems outside protected areas.

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[54]Walker B.H, Holling C.S, Carpenter S.R, Kinzig AS. 2004. Resilience, adaptability and trans-formability. *Ecology and Society* 9(2): 5

[55]Ashton, M.S., Gunatilleke, C.V.S., Singhakumara, B.M.P. and Gunatilleke, I.A.U.N. 2001. Restoration pathways for rainforest in south west Sri Lanka: a review of concepts and models, *Forest Ecol. Manage.* 154 (2001), pp. 409–430

[56]MDG SriLanka. 2009. *Ensure environmental sustainability.* Available online from: http://www.mdg.lk/ images/flash/learningzone.swf

[57]Mawdsley, et al. 2009. Op. Cit.

[58] Heller, N.E. & Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

2) **Increasing connectivity through corridors, landscape/matrix improvement and management (includes altitudinal and other movement)**

Increasing connectivity in the broader landscape is vital for conserving biodiversity during climate change[59]. It is an important mechanism to connect fragmented areas, as many protected areas are isolated from each other. With climate change, corridors become important as they will allow migration of species, whose range will change to the changing climate[60,61]

This strategy involves the protection of areas and regions that would be essential for climate-induced wildlife movements[62]. Technologies that can be used include movement corridors for terrestrial species, while unblocked streams and rivers are important movement corridors for aquatic species[63]. In the case of forests, a system of corridors could be designed utilizing existing patches or augmenting with restoration and other restoration mechanisms, creating an opportunity for short or long term migration. There are provisions for such corridors in wildlife legislation and are referred to as 'jungle corridors'[64]

Papers published in peer-reviewed journals[65,66]by international experts have endorsed this as an essential climate change strategy for biodiversity. Additionally several Policies, Action Plans and Strategies in Sri Lanka have identified this as essential for biodiversity conservation (see Fact Sheet 3 for more details.). Some mechanisms suggested by stakeholders include the following (not in order of priority):

a) Mapping of existing Corridor network using existing knowledge and identification of proposed Corridors through climate modeling and mapping.
b) Establish a Corridor network (existing and new corridors).
c) Strengthen management of existing corridors.
d) Design and map a system of Corridors to allow gene flow.
e) Management Plans for Corridors (especially in watershed areas).
f) Promoting organic agriculture to support livelihoods among local communities.
g) Reduce pressures and threats to Corridors.
h) Establish special Corridors in selected areas while protecting existing corridors.

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[59]Mawdsley, et al. 2009. Op. Cit.
[60]Mawdsley, et al. 2009. Op. Cit.
[61]Hannah, L and Hansen, L. 2005. Chapter 20 – Designing Landscapes and Seascapes for Change. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press
[62]Allan, J. D., M. Palmer, and N. L. Poff. 2005. Climate change and fresh- water ecosystems. Pages 274–290 in T. E. Lovejoy and L. Hannah, editors. Climate change and biodiversity.Yale University Press, New Haven, Connecticut.
[63]Mawdsley et al., 2009. Op. Cit.
[64]The Fauna and Flora Protection Ordinance No. 2 of 1937 and Amendment Act No. 49 of 1993.
[65]Mawdsley, et al. 2009. Op. Cit.
[66]Hannah, L and Hansen, L. 2005. Chapter 20 – Designing Landscapes and Seascapes for Change. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press

3) **Improve management, and possibly increase extent of protected areas, buffer zones and create new areas in vulnerable zones**

Protected Areas are a conservation tool to conserve biodiversity by protecting species and ecosystems. This strategy will focus on effectively managing established protected areas and will also entail increasing the extent of terrestrial and aquatic habitats, which have been identified as a climate change adaptation strategy[67]. Conservationists often favor protected areas as they aim to provide a safe haven and minimize impacts from humans and other threats. Protected areas have various purposes and levels of protection.[68] In Sri Lanka these vary from Strict Natural Reserves where access is strictly limited to Sanctuaries, which may contain private land[69]. It is vital to ensure that these areas possess a good representation of biodiversity. Effective management of existing protected areas is important as creating new areas is challenging due to high pressure for lands in a developing country. However there are numerous areas that are earmarked as proposed reserves, which can be included into the Protected Area network. Creating new protected areas or expanding existing areas does not require advance technologies.

This strategy has been accepted as an essential climate change adaptation strategy for biodiversity internationally[70]. In addition at national level, this strategy has been included in Policies, Strategies and Action Plans related to climate change adaptation essential for biodiversity conservation (see Fact Sheet 9 for more details.). Some mechanisms suggested by stakeholders include the following (not in order of priority):

a) Enhance the capacities of the relevant authorities to manage highly vulnerable protected areas/corridor network.
b) Promote private individuals/organizations to purchase and manage habitats for conservation.
c) Increase extent of protected areas and buffer zones
d) Identify the species or ecosystems that can be accommodated within anthropogenic ecosystems
e) Identify and research the forms of adaptive management for native species.
f) Promote the purchase of forests for its conservation.

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[67] Mawdsley, et al. 2009. Op. Cit.

[68] IUCN. 2011.IUCN Protected Area Management Categories http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/

[69] The Fauna and Flora Protection Ordinance No. 2 of 1937 and Amendment Act No. 49 of 1993.

[70] Mawdsley, et al. 2009. Op. Cit.

4) **Focus conservation resources and carryout special management for restricted range, highly threatened species and ecosystems**

This technology involves investing resources in the maintenance and continued survival of species that are likely to become extinct as a result of global climate change[71]. Thus it would target species that need special attention, with high vulnerability to climatic changes.

Recent studies have shown the ecological changes in the phenology and distribution of plants and animals are already occurring, and have been linked to local and regional climate change. Range-restricted species, show severe range contractions, and certain such species have gone extinct. Tropical coral reefs and amphibians have been most negatively affected[72]. The Sri Lanka Red List[73] identifies threatened species, and their locations. Thus this can be used to identify and target specific species that may require additional conservation intervention. Globally the IUCN Red List is already being used to identify species at risk with climate change[74].

Attention has been drawn internationally on the need for focusing conservation resources and carryout special management for restricted range, highly threatened species and ecosystems as a climate change adaptation strategy for biodiversity[75,76]. Additionally, several Policies, Action Plans and Strategies in Sri Lanka have identified this as essential for biodiversity conservation (see Fact Sheet 8 for more details.). Some mechanisms suggested by stakeholders include the following (not in order of priority):

a) Device specific species Management Plans for vulnerable species.
b) Implement a regular monitoring program for identified vulnerable species.
c) Establish a database incorporating details of identified vulnerable species.
d) Develop a tropical register for all remnant patches
e) Conduct translation from ecosystems cited for destruction.
f) Build a database of people in particular taxa and encourage research in such restricted ranges.

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[71]Mawdsley, et al. 2009. Op. Cit.

[72]Parmesan, C. 2006, Ecological and evolutionary responses to recent cli- mate change. Annual Review of Ecology, Evolution and Systematics 37:637–669.

[73]IUCN Sri Lanka and the Ministry of Environment and Natural Resources (2007) The 2007 Red List of Threatened Fauna and Flora of Sri Lanka, Colombo, Sri Lanka. xiii+148pp.

[74]IUCN. 2009. Climate change and species.
http://www.iucn.org/about/work/Programs/species/our_work/climate_change_and_species/

[75]Mawdsley et al. 2009. Op. Cit.

[76] Heller, N.E. & Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

5) Ex-situ conservation for highly threatened species and possible reintroduction

Ex-situ conservation refers to conservation activities that occur outside the usual habitat of a species. Often this approach focuses on captive maintenance programs for species that would otherwise become extinct due to climate change. Such an approach would generally be a last resort for species[77]. Zoological Gardens, captive breeding centers, seed banks etc are some example of such conservation activities, and therefore not considered as a new technology. However some advanced facilities may be necessary for certain species. Zoological Gardens and breeding centers have long been carrying out captive breeding, especially for keystone mammals. Sperm and egg banks would be rather extreme forms of this strategy, but may be necessary[78]. Often such activities are carried out as insurance against future or unexpected threats that will make in-situ conservation difficult. Ex-situ conservation is usually not favored where in-situ conservation is possible, but its importance as an insurance mechanism is recognized. In some situations, ex-situ conservation will need to be carried out until global warming is reversed may be the only chance of survival for some species. Ex-situ collections should have sufficient diversity to allow adaptation[79].

Several international experts published in peer-reviewed journals[80]endorsing this strategy as an essential climate change adaptation strategy for biodiversity. Several national Policies, Strategies and Action Plans in Sri Lanka have also identified this as essential for biodiversity conservation (see Fact Sheet 11 for more details.). Some mechanisms suggested by stakeholders include the following (not in order of priority):

a) Establishing a program for captive breeding/propagation of the species selected for ex-situ conservation.
b) Implement a re-introduction program that will enhance/establish wild populations that would ensure their long-term survival.
c) Monitoring of captive breeding/propagation and the re-introduction programs and optimizing them.
d) Provide provisions in wildlife legislation and policies.
e) Identify species' potential new habitats.
f) Establish seed-banks and in-vitro gene banks for flora.

[77]Mawdsley, et al. 2009. Op. Cit.
[78]Mawdsley et al. 2009. Op. Cit.
[79]Noss, R. F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology 15:578–590.
[80]Mawdsley et al. 2009. Op. Cit.

CHAPTER 9

Summary/Conclusions

Although Sri Lanka is a low net emitter of greenhouse gases, it is highly vulnerable to climate change in terms of physical as well as socio-economic impacts. There is irrefutable evidence that Sri Lanka is affected by the global climate change impacts. The analyses of climate data indicate a significant trend in increasing air temperature over the four decades from 1960 to 1990. At the same time, the future scenarios predict higher levels of emissions and greater potential for adverse climate changes impacts unless timely mitigatory and adaptive actions are undertaken.

Sri Lanka being a developing country party to the UNFCCC it is required to undertake a Technology Needs Assessment (TNA) with respect to climate change to explores country needs for the reduction of greenhouse gas emissions and adaptation technologies for the vulnerable sectors. The TNA was carried out from June to December 2011 for most vulnerable sectors to climate change in Sri Lanka. The sectors considered include **Food, Health, Water Coastal and Biodiversity** sectors. Following were identified as the high priority adaptation technology options for these sectors;

Food Sector:

(1) Culture-based fisheries.
(2) Sustainable land management.
(3) Crop diversification and precision farming.

Health Sector:

(1) Early Warning Systems and Net-working for information exchange on extreme events and other Climate Change related events
(2) Transfer of knowledge and skills to health personnel
(3) Management of Health Care waste

Water Sector:

(1) Restoration of minor tank net works.
(2) Rainwater harvesting from rooftops.
(3) Boreholes/tube wells as a drought intervention for domestic water supply.

Coastal Sector:

(1) Sand dune rehabilitation.
(2) Restoration of Mangroves
(3) Restoration of coral reefs by transplanting corals.

Biodiversity Sector:

(1) Restoration of degraded areas inside and outside the Protected Area network to enhance resilience.
(2) Increasing connectivity through corridors, landscape/matrix improvement and management
(3) Improve management, and consider increasing the extent of protected areas, buffer zones and create new areas in vulnerable zones
(4) Focus on conservation of resources and carryout special management for restricted range, highly threatened species and ecosystems
(5) Ex-situ conservation for highly threatened species and possible re-introduction.

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ANNEXES

ANNEX - A

ANNEX A1

NATIONAL TNA COMMITTEE

1. Secretary, Ministry of Environment – Chairman
2. Addl. Secretary (Environment & Policy), Ministry of Environment
3. Director (Policy Planning), Ministry of Environment
4. Director (Air Resources Management & International Resources), Ministry of Environment
5. Director (Biodiversity), Ministry of Environment
6. Director (Sustainable Environment), Ministry of Environment
7. Director (Climate Change), Ministry of Environment
8. Director General, Department of External Resources , Ministry of Finance & Planning
9. Director General, Department of National Planning, Ministry of Finance & Planning
10. Secretary, Ministry of Agriculture
11. Secretary, Ministry of Water Supply and Drainage
12. Secretary, Ministry of Fisheries and Aquatic Resources Development
13. Secretary, Ministry of Health
14. Secretary, Ministry of Economic Development (Tourism)
15. Secretary, Ministry of Transport
16. Secretary, Ministry of Power and Energy
17. Secretary, Ministry of Industry and Commerce
18. Secretary, Ministry of Disaster Management
19. Secretary, Ministry of Local Government and Provincial Council
20. Secretary, Ministry of Technology and Research
21. Director, Industrial Technology Institute of Sri Lanka

ANNEX A 2

STAKEHOLDER WORKSHOP PARTICIPANTS

WORKSHOP PARTICIPANTS

SECTOR PRIORITISATION

1. Mr. Samitha Midigaspe - Chief Engineer, Ceylon Electricity Board, Colombo.
2. Mr. Rohitha Gunawardane – Head Env Division , Ceylon Electricity Board, Colombo.
3. Mr. H.M.U.K.P.B. Herath – Director, National Aquaculture Development Authority of Sri Lanka
4. Dr. Nirmalie Pallewatte - Head - Department of Zoology, University of Colombo
5. Dr. Siril Wijersundara - Director General, Department of Botanical Gardens, Peradeniya
6. Mr. R.A.S. Ranawaka - Senior Engineer (R &D), Department of Coast Conservation
7. Dr. Terney Predeep Kumara - Head, Dept of Oceanography & Marine Geology, University of Ruhuna
8. Dr.(Mrs.) A.P Bentota - Additional Director, Oil Crops Research & Development Institute, Department of Agriculture
9. Dr. S.P. Nissanka - Head, Department of Crop Science, University of Peradeniya
10. Ms. Sujeewa Fernando - Environment Management Officer, Ministry of Health
11. Ms. Sarojini Jayasekara - Deputy Director, Central Environmental Authority, Battaramulla
12. Ms. R.D.S. Gunarathna - Asst. Director, Ministry of State Resources & Enterprise Development
13. Mr. Roshan Salinda - Project Manager, Green Movement of Sri Lanka, Nugegoda
14. Mr. Wijaya Samarasinghe - Director/Planning, Sri Lanka Railway Department
15. Mr. R.S.C. George, Deputy General Manager , National Water Supply and Drainage Board
16. Dr. Tanuja Ariyananda - Executive Director, Lanka Rain Water Harvesting Forum
17. Mr. K.M. Viraj J Priyanjith - Asst. Director, Ministry of Private Transport Services

FOOD SECTOR

1. Ministry of Agriculture - Executive Coordinator (NRM)
2. Ministry of Export Crop Promotion - Director General / Head, Climatology
3. Ministry of Livestock and Rural Development - Secretary
4. Ministry of Fisheries and Aquatic Development - Director General (Technical)
5. Department of Agrarian Development - Commissioner General
6. NRMC, Department of Agriculture - Addi. Director,Natural Resource Management
7. Sri Lanka Council for Agricultural Research Policy(SLCARP) - Executive Director
8. Department of Agriculture – Director General
9. Field Crops Research and Development Institute (FCRDI) - Director
10. Tea Research Institute – Director
11. Coconut Research Institute - General Manager
12. Coconut Development Board - General Manager
13. Practical Action of Sri Lanka - Director
14. Oil Crops Research & Development Institute - Director
15. Hadabima Authority - Executive Officer
16. Horticultural Crop Research & Development Institute - Director
17. Oxfam - Senior Programme Manager
18. NARA - Head/ Environmental Studies Division
19. Prof. Upali Amarasinghe, University of Kelaniya
20. Dr. S.P. Nissanka, Head, Department of Crop Science, University of Peradeniya
21. Prof. Pradeepa De Silva, Head, Department of Animal Science, University of Peradeniya
22. Dr. W.M.H.K. Wijenayake, Department of Aquaculture and Fisheries, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka.

HEALTH SECTOR

1. Ministry of Health – Director/ Envt. & Occupational Health
2. Centre for Environment Justice -
3. Urban Development Authority – Director General
4. NASTEC - Director
5. Central Environmental Authority – Director General
6. Waste Management Authority –Western Province – Mr. R.P. Samarakkody/ Director
7. National Waste Management Supporting Centre, (MLG&PC) - Director
8. Sri Lanka Anthropological Association - Chairman
9. WHO – WHO Representative
10. Faculty of Medicine, Defense University of Sri Lanka - Dean
11. Faculty of Medicine, University of Peradeniya - Dean
12. National Science Foundation – Chairperson
13. Dr.Danister L. Perera , Ayurveda,244/2, Galle Road, Ratmalana.

WATER SECTOR

1. Ministry of Irrigation and Water Supply
2. Ministry of Water Supply and Drainage
3. Department of Irrigation
4. National Water Supply and Drainage Board
5. Water Resources Board, Gregory's Avenue, Colombo-7
6. Head, Irrigation & water management & agriculture relation division
   Hector Kobbekaduwa Agrarian Research & Training Institute
7. Sarvodaya, Sri Lanka (NGO)
8. Practical Action of Sri Lanka - Director
9. Water Care Engineering (pvt) Ltd,73F, Kandy Road, Dalugama,Kelaniya
10. International Water Management Institute (IWMI),Battaramulla
11. DSWRPP project (Dam safety & water resources planning project),Colombo 10
12. Mr. Mahinda Panapitiya,106/3, Kandy Road, Mudungoda (Community Reprsentative).
13. Prof. Dhammike Dissanayake,Dept. of Chemistry, Faculty of Science,University of Colombo,
14. Prof. N.T.S. Wijesekera / Dr. P.P. Gunaratne,Dept. of Civil Engineering
    University of Moratuwa.
15. Dr. R. A. Maithreepala, Dept. of Limnology, Faculty of Fisheries, Aqualculture & Marine Sciences,University of Ruhuna.
16. Dr. D.A.L. Leelamani,,Dept. of Agronomy,Faculty of Agriculture,Universoty of Ruhuna.
17. Dr. Tanuja Ariyananda, Lanka Rain Water Harvesting Forum, Kirilepona, Colombo 5
18. Mr. G.B. Samarasinghe/Mr. S.H. Kariyawasam, Dept. of Meteorology, Colombo.
19. Mr. Bandu Liyanagama, Ad. Director of Water Management, Mahaweli Authority of Sri Lanka
20. Mr. R.S.C. George, DGM, National Water Supply & Drainage Board, Rathmalana
21. Eng. S. Liyanagama, 900 2/13, Udawatta road, Malabe

COASTAL SECTOR

1. Ministry of Fisheries and Aquatic Development – Director General
2. Department of Coast Conservation - Director General
3. Disaster Management Center - Director General
4. National Building Research Organization - Director General
5. Department of Meteorology - Director General
6. NARA/NAQDA - Director General
7. Practical Action - Director
8. Dr. Terney Pradeep Kumara (Head/Dept. of Oceanography & Marine Geology, Faculty of Fisheries & Marine Sciences & Technology, University of Ruhuna.
9. Dr. Tilak P.D. Gamage (Dean/Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna.
10. Dr. R.A. Maithreepala & Dr. H.B. Asanthi (Dept. of Limnology, University of Ruhuna).
11. Dr. Mala Amarasinghe (Dept. of Botany, University of Kelaniya)

BIODIVERSITY SECTOR

1. Ministry of Environment, Battaramulla
2. Ministry of Land and Land Development
3. Ministry of Fisheries and Aquatic Resources
4. Forest Department
5. Department of Land Use Policy Planning
6. Department of Coastal Conservation
7. National Aquaculture Development Authority of Sri Lanka
8. Department of Fisheries & Aquatic Resources
9. Central Environmental Authority
10. Mr. N. Mawilmada – ADB, Sri Lanka Resident Mission
11. Mr. Shamen Vdanage, IUCN, Colombo, Sri Lanka
12. Wildlife and Nature Protection Socity
13. Young Zoologist Association
14. Green Movement of Sri Lanka
15. Environmental Foundation
16. Rainforest Rescue International
17. Galle Wildlife Conservation Society (Madura De Silva)
18. Centre for Environmental Justice
19. Munasinghe Institute for Development (MIND)
20. Mr. Bathiya Kekulanda – Practical Action - Practical Action Sri Lanka, 5 Lionel Edirisinghe Mawatha, Kirulapone, Colombo 5
21. Green Movement of Sri Lanka – The Green Movement of Sri Lanka, No. 9, 1st Lane, Wanata Road Gangodawila, Nugegoda
22. Dr. Nirmalie Pallewatte - Head - Department of Zoology, University of Colombo
23. Dr. Mayuri Wijesinghe - Zoology, University of Colombo
24. Dr. Siril Wijersundara - Director General, Department of Botanical Gardens
25. Dr. Nissanka - University of Peradeniya

ANNEX - B

MATRIX OF WEIGHTED SCORES

Matrix of Weighted Scores, Costs and Benefits – Food Sector (Annex B 1)

Technology Options	Cost US $ M	Weighted Scores								
		Weighted Cost	Environmental							
			Ground Water Quality/ Quantity	Surface Water Quality /Quantity	Soil Erosion /Runoff & Sedimentation	Soil Quality/ Health	Biodiversity Conservation	Watershed Functions	Air Pollution	GHG Emissions
1. Appropriate Varieties	0.82	26.00	2.00	2.00	0.00	0.00	1.00	0.00	0.00	0.00
2. Appropriate Breeds	2.95	14.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00
3. Sustainable Land Management	0.27	29.00	2.00	3.00	5.00	2.00	1.00	2.00	1.00	2.00
4. Drip Irrigation	0.32	29.00	2.00	2.00	5.00	1.00	0.00	0.00	1.00	2.00
5. Rain Water Harvesting	5.45	0.00	3.00	3.00	5.00	1.00	1.00	1.00	0.00	0.70
6. Crop Diversification & Precision Far	0.68	27.00	2.00	2.00	3.00	1.00	2.00	2.00	1.00	2.00
7. Ecological Pest & Disease Manage	0.25	29.00	3.00	2.00	3.00	1.00	1.00	0.00	1.00	0.70
8. Responsive Agricultural Extension	0.55	28.00	2.00	2.00	3.00	1.00	1.00	0.00	1.00	0.70
9. Sustainable culture-based fisheries	0.15	30.00	2.00	2.00	0.00	0.00	2.00	0.00	0.00	0.70

Technology Options *(As above)*	Weighted Scores												Benefits
	Social						Economic					Total Score	
	Household labour involvement	Gender equity	Rural Dev	Livelihood improvement	Health benefits	Community participation	Food Security	Employment generation	Farmers income /Poverty reduction	Energy use	New markets/ enterprises/ Industries		
1.	0.70	0.00	5.00	0.00	0.50	0.00	10.00	2.50	10.00	0.00	2.50	62.20	36.20
2.	1.00	0.50	5.00	4.00	0.50	1.50	10.00	5.00	10.00	0.00	2.50	56.10	42.00
3.	1.00	0.50	5.00	0.00	0.00	1.50	10.00	0.00	0.00	0.00	0.00	65.00	36.00
4.	0.00	0.50	5.00	0.00	0.00	0.00	10.00	0.00	0.00	5.00	2.50	60.00	31.00
5.	0.70	0.50	5.00	4.00	1.00	1.50	0.00	0.00	0.00	5.00	0.00	32.40	32.40
6.	0.70	0.50	5.00	0.00	0.50	0.00	10.00	2.50	10.00	0.00	2.50	73.70	46.70
7.	0.70	0.50	0.00	0.00	1.00	3.00	0.00	0.00	0.00	0.00	2.50	48.40	19.40
8.	0.30	0.50	2.50	0.00	0.50	1.50	0.00	0.00	0.00	0.00	0.00	44.00	16.00
9.	0.70	1.00	5.00	4.00	0.50	3.00	10.00	5.00	10.00	0.000	5.00	80.90	50.90

Matrix of Weighted Scores, Costs and Benefits - Health Sector (Annex B 2)

Option No	Cost $ US	Weighted Scores									Benefits
		Weighted Cost	Environmental		Social				Economic	Total Score	
			Minimize Eco-system Degradation	Impact on Pollution	Access to Services	Long-term health benefits	Local & Multi-sector involvement	Employment Generation	Energy use for Technology		
1	50,000	25.00	7.20	9.00	12.00	25.00	9.00	1.80	5.00	94.00	69.00
2	50,000	16.00	1.20	2.50	6.00	12.50	3.60	0.90	2.50	45.20	29.20
3	112,500	0.00	3.20	4.00	4.80	12.50	4.50	0.90	2.00	31.90	31.90
4	75,000	10.00	7.20	9.00	12.00	25.00	9.00	4.20	4.50	80.90	70.90
5	55,000	15.00	3.20	3.00	3.00	15.00	6.30	2.40	2.50	50.40	35.40
6	50,000	16.00	3.20	4.00	7.20	10.00	4.50	0.90	2.00	47.80	31.80
7	15,750	25.00	3.20	4.00	4.80	10.00	3.60	0.60	1.50	52.70	27.70
8	43,750	18.00	3.20	4.00	6.00	10.00	3.60	0.90	2.00	47.70	29.70
9	62,500	13.00	5.60	7.00	7.20	17.50	3.60	1.50	1.50	56.90	43.90

1. Transfer of knowledge and skills to Health Personnel; 2. Diagnostic facilities to detect water borne diseases; 3. Technology to Detect, Prevent and Control water borne diseases; 4. Technology for Early Warning Systems and Net-working for information exchange on Extreme events and other Climate Change related events; 5. Research to identify the magnitude of diseases other aspects affecting human health due to climate change; 6. Drinking water quality improvement through continued surveillance during and after extreme weather events; 8.Technology to improve urban health inputs to adapt for climate change and extreme weather events related adverse health impacts; 8.Technology to enhance adaptability of the people on Psychological effects due to climate change; 9. Technology for management of health care waste

Matrix of Weighted Scores, Costs and Benefits - Water Sector (Annex B 3)

1. *Rainwater harvesting from rooftops for drinking and household uses; 2. Surface runoff rainwater harvesting; 3. Household drinking water treatment and safe storage; 4. Boreholes/tube wells as a drought intervention for domestic water supply; 5. Solar distillation; 6. Restoration of minor tank networks; 7. Desalination of brackish water by reverse osmosis*

Option	Cost/m^3 US$	Weighted Score														Benefits
		Weighted Cost	Environmental			Social						Economic			Total Score	
			Impacts on Underground water	Impacts on surface water	Minimizing flooding	Continuous Water Supply	Health	Awareness	Schools/ University	Research	Income	Employment	Investment	Low GHG release		
1	1.88	17.64	4.50	4.50	6.00	15.00	10.00	5.00	5.00	0.00	2.67	2.00	1.00	2.00	75.31	57.67
2	1.50	18.14	6.00	4.50	6.00	7.50	0.00	3.34	0.00	2.50	2.67	2.00	1.00	1.00	54.65	36.51
3	15.03	0.00	3.00	3.00	3.00	15.00	20.00	3.34	2.50	2.50	0.00	2.00	0.00	1.00	55.34	55.34
4	1.16	18.60	0.00	3.00	3.00	15.00	10.00	3.34	2.50	2.50	4.00	2.00	1.00	1.00	65.94	47.34
5	3.22	15.68	1.50	1.50	3.00	0.00	20.00	1.65	2.50	2.50	1.32	2.00	1.00	2.00	54.65	38.97
6	0.12	20.00	6.00	6.00	6.00	7.50	10.00	3.34	2.50	2.50	4.00	2.00	2.00	1.00	72.84	52.84
7	4.00	15.87	0.00	0.00	3.00	15.00	20.00	1.65	2.50	2.50	1.32	0.00	2.00	0.00	63.84	47.97

Matrix of Weighted Scores, Costs and Benefits - Coastal Sector (Annex B 4)

1-Coral reef rehabilitation; 2Rrestorastion and establish new seagrass beds; 3-Sand dune restoration without beach nourishment; 4-Mangrove restoration; 5-Beach nourishment; 6-Dike construction; 7-Floating mariculture- seaweed farming; 8-Floating mariculture- fish farming; 9-Groins & Sea walls

Option No.	Cost/m^2 US$	Weighted Score														Benefits
		Weighted Cost	Economic			Social					Environmental				Total score	
			Employment opportunities	Increase Foreign Exchange	Protect infrastructure	Income	Awareness	Research-based Education	Environ Sensitivity	Improve Health	Reduction GHG	Reduce land loss due to SLR	Reduce Inundation	Land Reclamation		
1	14.3	18.72	1.63	3.35	3.35	10.00	5.00	3.00	5.00	3.50	7.00	5.34	1.67	5.33	72.89	54.17
2	22.94	14.26	1.63	0.00	3.35	3.33	5.00	3.00	5.00	0.00	7.00	5.34	1.67	1.67	51.25	36.99
3	2.13	25.00	3.33	3.35	3.35	6.67	5.00	3.00	5.00	3.50	7.00	8.00	3.34	5.00	81.54	56.54
4	10.5	20.68	3.35	3.35	3.35	6.67	5.00	3.00	5.00	3.50	7.00	5.34	3.34	3.34	72.90	52.22
5	25.56	12.90	1.63	5.00	3.35	6.67	0.00	0.00	0.00	7.00	3.50	5.34	1.67	5.00	52.06	39.16
6	37.5	6.75	1.63	3.35	0.00	6.67	0.00	3.00	0.00	3.50	3.50	8.00	5.00	5.00	46.40	39.65
7	31	10.11	3.35	3.35	0.00	10.00	5.00	0.00	0.00	3.50	7.00	0.00	0.00	0.00	42.31	32.20
8	50.59	0.00	3.35	5.00	0.00	10.00	5.00	3.00	0.00	3.50	0.00	0.00	0.00	0.00	29.85	29.85
9	22.5	13.39	1.63	3.35	5.00	6.67	0.00	3.00	0.00	3.50	3.50	8.00	5.00	5.00	58.04	44.65

Matrix of Weighted Scores, Costs and Benefits - Biodiversity Sector (Annex B 5)

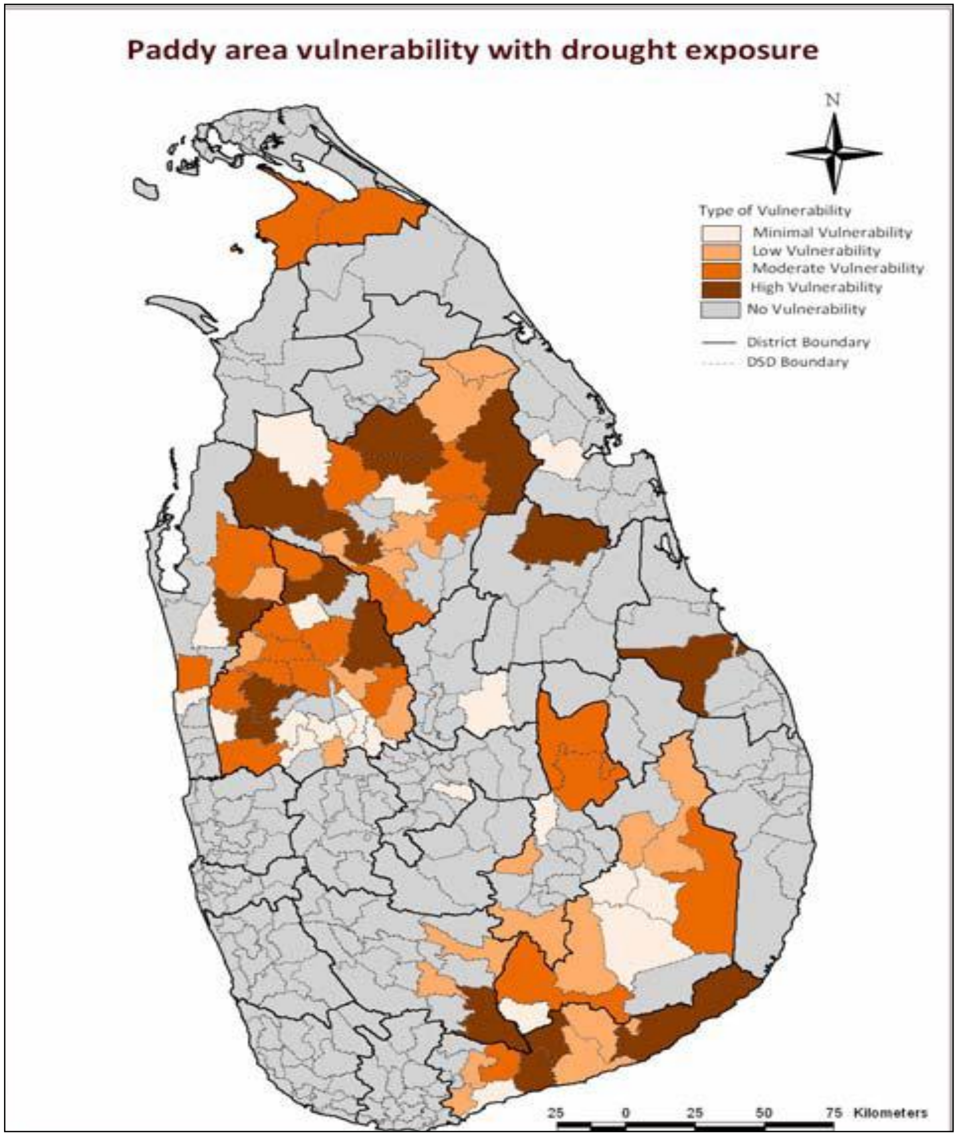
Option No	Annual cost Us $ million	Weighted Scores								Benefit
		Weighted Cost	Environmental			Economic	Social		Total Score	
			Overall contribution to saving biodiversity (impact)	Addresses conservation urgency, incl threatened species	Enhancing ecosystem services (general)	Job creation/opportunities	Ecotourism and conservation benefits	Improve awareness, research opportunities		
1.	0.91	0.00	15.00	15.00	20.00	10.00	20.00	5.00	85.00	85.00
2.	0.59	4.12	7.50	7.50	0.00	5.00	5.00	5.00	34.12	30.00
3.	0.82	1.18	15.00	15.00	20.00	5.00	15.00	5.00	76.18	75.00
4.	0.77	1.76	7.50	7.50	13.33	5.00	15.00	5.00	25.00	53.33
5.	0.77	1.76	7.50	7.50	6.67	10.00	5.00	5.00	43.43	41.67
6.	0.73	2.35	15.00	7.50	6.67	5.00	10.00	5.00	51.52	49.17
7.	0.82	1.18	7.50	7.50	6.67	5.00	10.00	5.00	42.85	41.67
8.	0.91	0.00	15.00	7.50	6.67	10.00	20.00	10.00	69.17	69.17
9.	0.82	1.18	7.50	15.00	13.33	10.00	20.00	5.00	72.01	70.83
10.	0.14	10.00	0.00	0.00	6.67	0.00	0.00	0.00	16.67	6.67
11.	0.91	0.00	7.50	15.00	6.67	5.00	20.00	10.00	64.17	64.17

1.Restoration of degraded areas inside and outside the protected area network; 2.Modeling the impact of climate change on biodiversity to predict changes for conservation and management; 3.Increasing connectivity through corridors landscape/matrix improvement and management; 4.Protecting refugia which are less vulnerable to climatic changes; 5.Managing and monitoring invasive alien species (IAS); 6.Reducing other stresses on species and ecosystems; 7.Adaptive management and monitoring programs of species and ecosystems; 8.Focusing on conservation of resources and carrying out special management for restricted range, highly threatened species and ecosystems; 9.Improving management of existing protected areas, increasing extent, creating buffer zones and new areas in vulnerable zones; 10.Reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources and incorporating climate change adaptation considerations; 11.Ex-situ conservation for highly threatened species and possible reintroduction

ANNEX - C

MAPS

Figure C 1: Paddy area vulnerability with drought and flood exposure (Annex C 1)



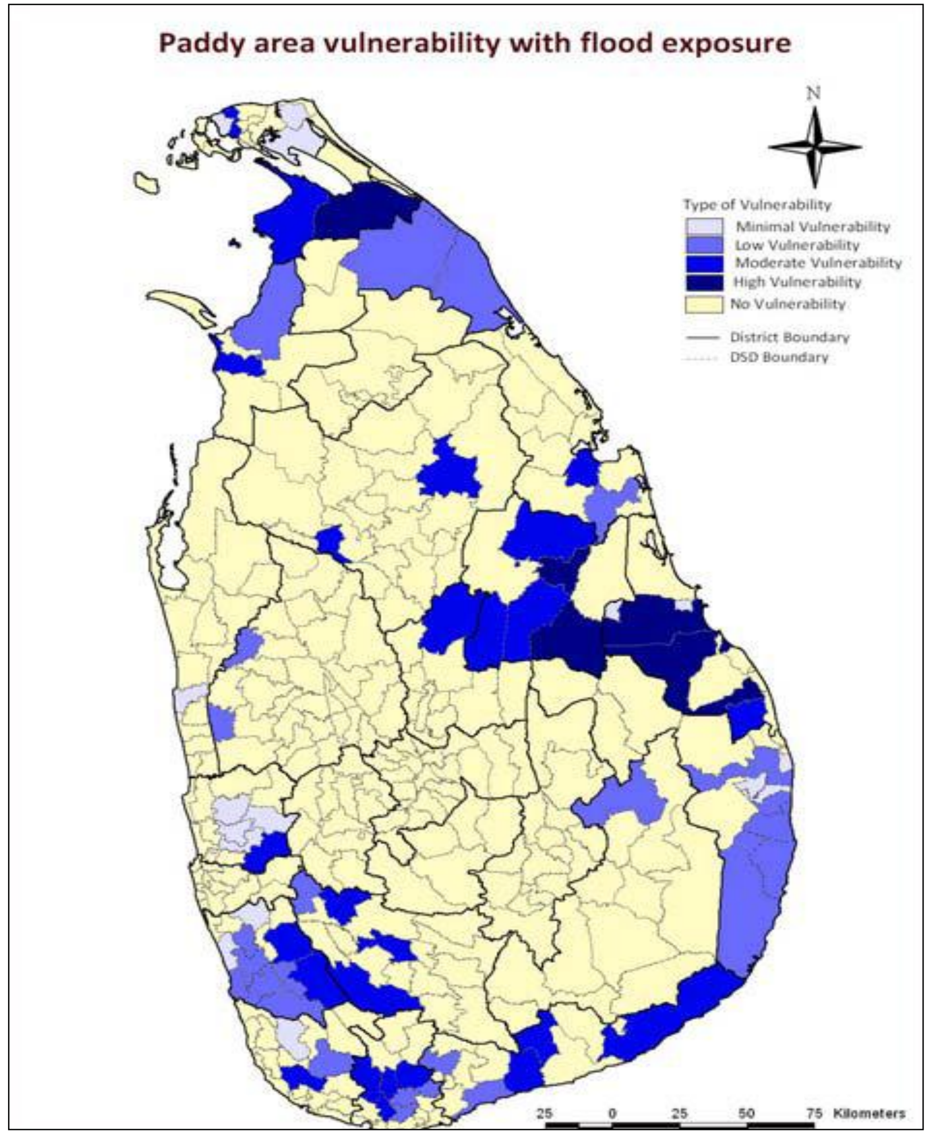
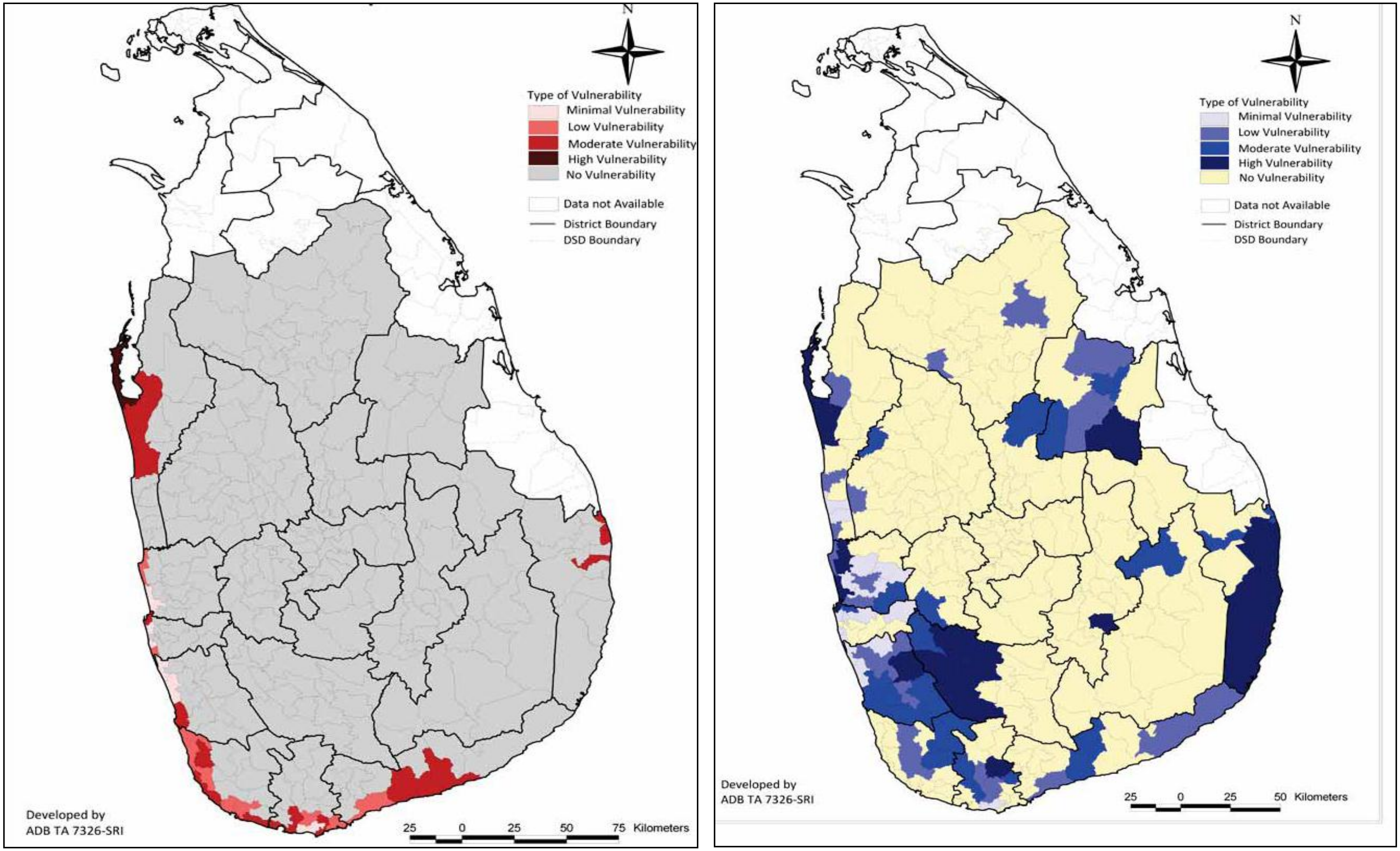


Figure C 2: Drinking water vulnerability to flood exposure and sea level rise (Annex C2)



ANNEX - D

TECHNOLOGY FACT SHEETS (TFS)

Technology Fact Sheets (TFS)

Food Sector

Technology Fact Sheet 1

Appropriate Varietal development

1. *Sector:*	Food
2. Technology Characteristics:	Adaptation
2.1Technology Name:	**1. Appropriate Varietal development**
2.2 Introduction: *low/high tech.* *Brief introduction to the technology*	The development of new varieties is a technology aimed at building resistance to diseases, pest organisms and environmental stresses accentuated by climate change, thereby enhancing productivity of crops and quality, health and nutritional value of crops. The development of modern varieties is carried out by Plant Breeders in the Agricultural Research organizations in state & private companies and help selecting, recommending and introducing varieties better adapted to local climatic conditions. Although there are thousands of traditional and modern high-yielding varieties of crops in existence only a small number of these are multiplied and distributed by the seed producing agencies, whereas famers themselves continue to produce and exchange other varieties preferred by them due to their abilities to adapt to climatic conditions, quality or other reasons. These lesser-used varieties serve as a gene pool to develop new varieties with the characteristics that show better adaptation. Biotechnology offers a more direct approach to breed varieties to tolerate stress by utilizing the gene technological processes to directly detect and transfer genes of interest from other plant or organisms into the crop of interest. By allowing transfer of genes of interest across crops or species that do not normally breed (genetically modified), biotechnology greatly enhances the breeder's ability to produce new varieties with desired characteristics. However, genetic modifications involving complex, multiple gene transfers required for producing tolerance to stresses caused by climate change impacts would still be a challenging task.
2.3 Technology Characteristics/Highlights:	• Requires advance technology (genome mapping, marker development)

Few bullet points, ie. low/high cost; advance technology; low technology.	• High cost intervention (Manages large amounts of experiments and time consuming) • Hard technology due to heavy dependence on equipment, tools and laboratory and other structures • Requires more collaboration and technical assistance from advanced countries with highly-developed systems of scientific research • Even with genetic modification, breeding for tolerance for climate change impacts such as flood/drought resistance, salinity tolerance will require longer term investments in research
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Capacity building is required both at the institutional level, i.e. for increasing research capability, and the organizational level, i.e. for extension of research findings. International collaboration and technical assistance from more advanced systems of research and development outside the country will be necessary. Also, much of the resident capacity for genetic modification lies with multinational companies and commercial research organizations.
3. Operations and maintenance	
3.1 Endorsement by Experts:	Selecting cultivars with traits appropriate for different climatic and environmental conditions has always been the basic process of identifying new varieties. Breeding has tremendously expanded the scope of producing new varieties by facilitating to move beyond the existing genetic pool. Biotechnology and genetic engineering permits making even more dramatic and rapid changes in the breeding process. Varietal development reinforced by advances in biotechnology would be the most potent technology for strengthening adaptation to emerging climate change impacts.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	The development of new cultivars of crops or breeds of animals that are highly adapted to specific conditions at different locations is an approach that is followed by breeders to increase productivity even at present. The specific conditions that define local conditions are combinations of natural and biological factors determined by the local microclimate. In general breeding for such high levels of specificity and the management of such processes is complex and expensive process. But climate change makes breeding varieties with

	higher abilities to tolerate extreme, hostile environments even more justifiable.
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	Varietal development is important to protect the ability of current production systems to provide food supplies for everyone. If food supplies are threatened, prices will rise affecting food security of large segments of poor populations.
4. ***Costs***	
4.1 Cost to implement adaptation options: *Cost measures*	Rs. 30 million per variety developed using the biotechnological techniques of breeding.
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Molecular breeding so far has not been proven to be either faster or cheaper than conventional breeding although the incremental knowledge gained is expected increase productivity of it over time. Rapid pace of changes occurring due to climate change will require increasing the current level of effort three-folds (300%) to sustain innovation required to stay abreast with change. Therefore, additional costs can be roughly estimated to be double what is spent at present on varietal development programs.
5. ***Development Impacts, indirect benefits***	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	- Ensured food security - Increased productivity and profitability - Increased employment opportunities
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	- Reduced rural poverty. - Helped rural development - Improved livelihood of the farmers
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants, Ecosystem degradation etc*	- Reduced environmental damage by avoiding pest control chemicals - Secure bio diversity
6. ***Local context***	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	None.

6.2 Status: *Status of technology in the country*	Sri Lanka has developed technologies for varietal development over a long period and the capacity to achieve breakthroughs is very high.
6.3 Timeframe: *Specify timeframe for implementation.*	Ten to 15 years.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	The technology is highly acceptable as seen by the adoption rates for new varieties of crops.

Technology Fact Sheet 2

Appropriate Breeds Development

1. ***Sector:*** *To be written by sector expert.*	Food
2. ***Technology Characteristics:***	Adaptation
2.1Technology Name:	**2. Appropriate Breeds Development**
2.2 Introduction: *low/high Brief introduction to the technology*	Both contribution of certain animals to the climate change and extent to which their productivity is affected by the climate change are need to be addressed. The existing genotypes of agricultural animals are to face the direct and indirect consequences in changing environmental conditions through appropriate technological interventions. Reduction of methane emission to ease the GHG effect, building resistance to diseases, pests and environmental stresses to enhance the productivity of animals and quality, health and nutritional value of products could be the main focus. Therefore, the development of appropriate breeds to produce cross breeds as per the national breeding guidelines suitable for different agro-climatic zones with special reference to high lactation yield, environmental adaptability and resistance to diseases thereby enhancing productivity and health of the of dairy cattle while improving the quality of the products
2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	• Requires advanced technology (genome mapping, biotechnological approaches and involvements) • High cost intervention (Manages large amounts of experiments and time consuming) • Hard technology • Integrated approach in implementation along traditional method
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Building of resource capacities is required in both at the institutional level, i.e. for increasing research output, and at the organizational level, i.e. for facilitating research and for extension of research findings.

3. Operations and maintenance	
3.1 Endorsement by Experts:	Existing farms in the Up Country and the Dry Zone selected for the purpose needs to be strengthen while expanding holding capacity
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	Improvement of genotypes for better resilience and capacities for a given general and specific environmental context is an approach that is followed by breeders to increase productivity. The specific conditions are combinations of natural and biological factors determined by the local microclimate. In general breeding for such high levels of specificity and the management of such processes is complex and time consuming process. Hence the technological innovations are very much required
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	Breed improvement is important to ensure uninterrupted food supply and nutritional security under changing climate scenarios. This would also ensure the preserve the sustainability of current production systems of small-holder low input set-up in which majority of the rural farmers find their living. Hence the interventions will benefit large number of people. Further, the technological interventions will ensure the sustainable utilization of indigenous categories where most the adaptation characteristics are preserved through non-directional selection after generations of domestication.
4. *Costs*	
4.1 Cost to implement adaptation options: *Cost measures*	Rs. 325 million for the improvement of a large ruminant breed. The cost varies according to the type of candidate animal considered in breed improvement The cost involves the application of advanced molecular tools and traditional breeding process in establishing improved breeding stock/s
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Proper implementation of the breed structure is necessary with necessary extension and other veterinary and veterinary support services. The continues supply of breeding materials and the improved management conditions necessary to obtain the expected production standards are the key factors to be looked after in implementing the adaption option.
5. *Development Impacts, indirect benefits*	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	Employments - More people are attracted for farming. - Job opportunities in value chain

	- Jobs in service providing and extension arms Investments - Infra-structure - Service sector - Human capacity building - Improvements in resources and facilities
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	Income - Generated at rural level, during value addition - Expansion of services at the laboratory levels. Education - Human resource development in the industry - Improved education at rural level with the better income generation Health - Improvement of health of rural people as a result of increased income levels of small-holder sector
5.3 Environmental benefits: *Reductions in GHG emissions,* *Local pollutants,* *Ecosystem degradation etc*	- Low GHG emission - Reduced costing of environment as a result of improved productivity and high adaptability. - Low release of pollutant to the environment as a result of reduced usage of chemicals and drugs
6. *Local context*	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	- Slow process of implementation 99% farmers are at small-holder low input system. - High cost involvement - Low affordability by rural farmers
6.2 Status: *Status of technology in the country*	
6.3 Timeframe: *Specify timeframe for implementation.*	Molecular approach in identifying genes needs 2-3 year screening of different genotypes Inserting genes by crossing (long process) or gene manipulations (short process) and stabilizing in a population by selection and breeding 4-5 generation - 10 – 15 years
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Yes.

Technology Fact Sheet 3

Sustainable Land Management

1. ***Sector:***	Food
2. ***Technology Characteristics:***	Adaptation
2.1Technology Name:	**3. Sustainable Land Management**
2.2 Introduction: *low/high Brief introduction to the technology*	Land is a limited natural resource on which agriculture and livestock activities are carried out. It is interconnected with other natural resources, which are also essential for human life, such as the air, water, fauna and flora. If the land is well managed, the effects of agriculture on the environment will be acceptable and, conversely, if it is badly managed agriculture will deteriorate other natural resources. Land degradation is among the most environmental problems in the country and sustainable management of land is of high national priority. Land degradation is occurring in several ways; those are heavy soil loses, high sediment yields, soil fertility decline, landslides, salinization, alkalinization, acidification including both desertification and formation of acid sulphate soils, iron toxicity development, nutrient accumulation, water logging and indiscriminate disposal of waste. The most significant of theses are heavy soil losses and high sediment yields, thus soil erosion should receive the highest attention. Presently, soil erosion in the hilly regions of the country is 100 tons/ha/yr. Sustainable land management techniques facilitate to increase land and agricultural productivity.
2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	• Medium cost intervention (application of different measures are costly and labour consuming) • Soft technology
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Capacity building is required at the institutional level and the organizational level for extension of research findings carried Field demonstrations
*3. **Operations and maintenance***	
3.1 Endorsement by Experts:	Land degradation is taking place due to inadequate attention to

	sustainable land management practices and the effects of climate change would aggravate the situation further. The quality of land directly affects the level of food production. Therefore, the adoption of sustainable land management should receive high priority.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	Climate change exacerbates land degradation, which is already happening at an alarming scale, through alteration of spatial and temporal patterns in temperature, rainfall, solar radiation, and winds. Appropriate corrective action to address negative impacts of poor land management practices are considered already overdue. The technology is highly appropriate in the current situation and become more so with the effects of climate change.
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	Synergetic and additive outcomes of the Sustainable Land management assure conservation of natural resources and agricultural productivity. All of these directly increase the nation's vulnerability to withstanding the negative impacts of climate change. Benefits will be widespread with producers as well as consumers benefitting from the technology adoption.
4. ***Costs***	
4.1 Cost to implement adaptation options: *Cost measures*	Rs. 30.00M
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Severity of CC impacts changes the sensitivity of vulnerability and areas affected. To carry out the adjustments, additional cost will be required to implement the adaptation option. .
5. ***Development Impacts, indirect benefits***	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	• Increased agricultural productivity • Creation of employment • Lowered reservoir de-silting and other off-site costs
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	▪ Increased food security ▪ Increased profitability from farming ▪ Reduced food costs to consumers ▪ Improved livelihoods and social sustainability
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,*	• Decreased land degradation • Reduced downstream sedimentation and siltation • Reduced contamination of soil and surface and ground water

Ecosystem degradation etc	• Reduced GHG emissions • Minimize non point source pollution • Improve ecosystem sustainability
6. ***Local context***	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	▪ Large investment costs may discourage adoption. ▪ Long gestation periods for the benefits to materialize may serve as a barrier to farmers with short term planning horizons.
6.2 Status: *Status of technology in the country*	Knowledge in the country on the adverse impacts of land degradation and technology measures to minimize impacts is high. The issue concerns more with poor adoption of technology than on the availability of appropriate technologies.
6.3 Timeframe: *Specify timeframe for implementation.*	Immediate commencement and continuation through lifetime of land utilization.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Technology is acceptable and non-controversial. However, the adoption rates are poor due to long-term investment nature of the technology, which requires measures to incentivize the adoption.

Technology Fact Sheet 4

Drip Irrigation for Sustainable Water use and Management- Solar-Powered

1. *Sector:*	Food
2. *Technology Characteristics:*	
2.1Technology Name:	**4. Drip Irrigation for Sustainable Water use and Management- Solar-Powered**
2.2 Introduction: *low/high Brief introduction to the technology*	Water is a scarce resource and due to CC impacts, its consequences will be aggravated more than in the past. Drip irrigation is a supportive technique that can be used to increase water use efficiency and reduce evaporation, runoff, and deep percolation. It also improves irrigation uniformity. Drip irrigation, not only saves water but also saves fertilizer by allowing water to drip slowly to the plant roots, either onto the soil surface or directly onto the root zone. Application of fertilizers through the drip irrigation system increases fertilizer use efficiency and thereby increases 2-3 fold times production and productivity. Adaptation of this technology promotes Sustainable Management of Energy, Water, Land, and Labor. A majority of small farmers who cultivate highlands in the dry zone of Sri Lanka, operate holdings that are too small for use of mechanized technology and benefit from scale-economies. Also these farmers face serious shortage of irrigation for year round cultivation using traditional lift-irrigation systems and experience capital shortage to adopt expensive new technologies. Through the use of an innovative combination of small-capacity drip-irrigation technology with solar-powered water pumping and fertigation units that save capital and on-farm labor requirement, will completely redefined the small-scale highland farming in the dry zone. Use of an innovative combination of small-capacity drip-irrigation systems with solar-powered water pumping and fertigation units that save capital and on-farm labor requirement, will completely redefined the small-scale highland farming in the dry zone of the country.

2.3 Technology Characteristics/Highlights: *Few bullet points, i.e. low/high cost; advance technology; low technology.*	• High cost (Potentially high initial cost) • Advance technology (adoption requires • Hard Technology
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Capacity building is required both at the institutional level, i.e. for increasing research capability, and the organizational level, i.e. for extension of research findings and to carryout field demonstrations.
3. <u>Operations and maintenance</u>	
3.1 Endorsement by Experts:	To increase water use efficiency and productivity water saving technologies along with energy saving methods must be introduced specially to the OFC and Vegetable growers in the dry zone. Although over 18,000 "agro-wells" have been constructed in the dry zone to encourage dry-season cultivation with shallow groundwater irrigation, reliability of water supplies from them during the peak drought months has been poor. This has resulted in non-cultivation or crop loss during the dry months. By increasing the 'effective capacity' of agro-wells through the withdrawal of well water for irrigation at a rate compatible with the dry-season recharge, farming can be done without fear. Large scale implementation of drip irrigation technology can be contributed to improve the efficiency of significant investments already undertaken in the dry zone.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	Advantages of this technology non-related to adaptation can be reaped even in the current climate thereby making its early adoption economically and socially desirable. Under conditions of increased water stress resulting from climate change the benefits of the technology rises quite significantly.
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	The scale of the drip irrigation technology is highly flexible making it appropriate for use by small or large farmers.

4. *Costs*	
4.1 Cost to implement adaptation options: *Cost measures*	Rs. 35.00 M as a soft technology.
4.2 Additional costs to implement adaptation option, compared to "business as usual":	This is a relatively new technology requiring full development of facilities.
5. *Development Impacts, indirect benefits*	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	• Reduce risk and increase yields (by 2-3 fold) and profitability • Reduced costs of production and higher prices enabled realizing greater incomes • Reduce price fluctuation of vegetables and other field crops by introducing off season cultivation • Easy to install and Low maintenance
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	• Newest Agro Knowledge and Technologies and bring about progressive farmers • Because of the solar powered technology, (unattended operation) saves time used for application of water, fertilizer and weeding • Women can take the responsibility for operation and management • Improve personal hygiene • Facilitated gainful employment of the farm family labour throughout the year. • Facilitated women participation in farming through the operation of the system and carrying out regular maintenance operations. • The time spent overall decreased as a result of less time spent on irrigating crops and participating in weeding, fertilizer and other practices. Time saved was used mostly (70%) for more housework and partly (30%) for entertainment or spent with family.
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,* *Ecosystem degradation etc*	• Use of solar energy being one of the most environmentally benign forms of energy replacing fossil fuel based pumps have local and global benefits through the reduction of pollutants and emission of green-house-gases and generate CDM credits. • Lowered water withdrawal from ground water resources,

	particularly during more sensitive dry months, drip technology prevents depletion of ground water table and pollution from infusion of saline and other contaminants. • Increased use efficiency of chemical fertilizer through fertigation prevents resource waste and development of water pollution problems such as eutrophication which is a worsening environmental problem in some parts of the country. • Reduced use of agricultural chemicals such as weedicides and pesticides minimizes adverse environmental impacts such as pollution of water bodies, biodiversity loss. • Drip technology also reduces soil degradation from top-soil erosion associated with flood irrigation. This can also be a contributing factor to water resource degradation and silting of reservoirs.
6. *Local context*	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	To be effective drip irrigation systems require periodic maintenance. No matter how clean the water looks, a water quality analysis should be completed to determine if precipitates or other contaminants are present that could affect operation of the irrigation system.
6.2 Status: *Status of technology in the country*	The Filtration system included with the drip system alone is not always adequate to solve all water quality problems. Chemical treatment is often required to prevent emitter plugging due to microbial growth and/or mineral precipitation. Otherwise, implementation of solar powered drip irrigation technology is a sustainable system to increase water use efficiency
6.3 Timeframe: *Specify timeframe for implementation.*	Life time
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Yes

Technology Fact Sheet 5

Rain Water Harvesting

1. ***Sector:*** *To be written by sector expert.*	Food
2. ***Technology Characteristics:***	Adaptation
2.1Technology Name:	**5. Rain water harvesting**
2.2 Introduction: *low/high Brief introduction to the technology*	Irregular nature of the rains and droughts makes raising crops difficult due to the unavailability of water at correct time in required quantities. Increase water availability and efficient water use for crop production would be one of the most important adaptations for the country. Rainwater harvesting (RWH) is a valuable potential resource for agricultural production. Rainwater harvesting is a method of inducing, collecting, storing and conserving local surface runoff for agricultural production. Storage tanks include water pans, dugouts, tanks, reservoirs and dams. During the 3-6th century, the dry zone was studded with thousands of tanks of varying capacities to collect rain water. There are around 35,000 minor irrigation tanks distributed across the country and 12,000 tanks distributed across the undulating landscape in the dry zone. These tanks are not randomly located but occur in the form of distinct cascades each made up of 4-10 small tanks situated within a single small catchments (meso-catchment) varying in extent from 100-1000 ha, and impound surface relief water of a watershed for irrigation and domestic purposes. These small tanks were an integral part of the eco-system and played a dominant role in the socio-economic and cultural aspects of the village leading to a prosperous rural sector by providing irrigation to about 185,000 ha. However, cultivable extents from these small tanks have decreased gradually with siltation. CC is projected to increase the variability and intensity of rainfall with occurrence of extreme events becoming more frequent. Therefore storage and use of rain water reduces the risk and uncertainty due to water shortage for production and it also encourages farmer to diversify their enterprises, such as increasing production, selection of new hybrid varieties, purchasing larger livestock.

2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	High cost involvement Hard Technology
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Sri Lanka has a rich tradition of practicing RWH technology in the dry zone with the help of an intricate network of small and large reservoirs and adoption of community water management principles. The expansion of technology to harvest water is relatively uncomplicated, but the institutional arrangements for water extraction have to be modified to match changing demands and modified community structure. Operation and maintenance of water conveyance and delivery structures have been very challenging to carry out. Improved technology such as water-control structures and institutional arrangements such as water-users' association to manage and operate large irrigation systems have to be put in place, supported by enabling legislation. There are also potential negative consequences and rising of conflicts as downstream communities may be affected adversely by diversion of water flows. Large dams also increase the risk of safety to installations located downstream. Increased local capacity to assess and manage risks from such events must be built up.
3. Operations and maintenance	
3.1 Endorsement by Experts:	Most of the RWH minor tanks in the country, lost their capacities due sedimentation and poor management. Best adaptation measure to increase crop production, fresh water fishery and livestock under CC, is the rehabilitation of these tanks and increase the water holding capacity and introduction of proper management system.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	The use of different forms of RWH technology is complementary to the current practice of irrigation for agriculture and would strengthen system resilience. It has other advantages such as greatly reducing land erosion and flood inflow to major rivers. It contributes greatly to stabilization of declining ground-water resources, assuring water supplies for domestic and other community uses.
3.3 Size of beneficiaries group: *Technology that provides small*	RWH benefits large sectors of populations over big regions as agriculture is the dominant occupation in some areas of the

benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	country.
4. ***Costs***	
4.1 Cost to implement adaptation options: *Cost measures*	As a pilot project RS. 600 M was estimated to restore 250 minor irrigation tanks to collect rain water for irrigation. Costs of practicing RWH will be higher as the construction of reservoirs and minor irrigation tanks for water impounding and delivery and control structures for water conveyance demand heavy engineering works.
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Costs are location specific and vary by the scale of the project. Large reservoirs and networks of small rural tanks have different cost structures depending on the local geography.
5. ***Development Impacts, indirect benefits***	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	• Increase job opportunities • Makes investments more attractive by lowering risk of crop failures • Raise profits
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	• Improve livelihoods of the community through economic benefits from increasing access to irrigated food production • quality of life from strengthening of domestic water supply
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,* *Ecosystem degradation etc*	• Reduced ecosystem degradation- silting, changes of microclimate • Increase ground water table • Reduced runoff/erosion
6. ***Local context***	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	• The cost of storage systems is a barrier to popularize the technology. • Lack of national policy on rain water harvesting
6.2 Status: *Status of technology in the country*	Rain water harvesting has been practiced since, ancient times, especially in the dry zone agriculture.

6.3 Timeframe: *Specify timeframe for implementation.*	3-4 Years
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	The technology has high local acceptability.

Technology Fact Sheet 6

Crop Diversification & Precision Farming

Sector: *To be written by sector expert.*	Food
2. ***Technology Characteristics:***	Adaptation
2.1Technology Name:	**6. Crop Diversification & Precision Farming.**
2.2 Introduction: *low/high Brief introduction to the technology*	Increasing population and income growth demands more food and agricultural production. Increasing productivity in specific ecosystems is the only option as the pressure for agriculture lands is increasing. Further, decrease natural resources due to excessive and inappropriate usage and climate change would alter the ecosystem composition. Hence diversification of crops and precision farming with intensification would be needed to face emerging threats while maintaining the growth of agriculture production. Rainfall pattern and intensity and over- and inappropriate use would deplete available ground water. Increasing air temperature can directly affect productivity in certain ecosystems. Further, it can increase pest and disease outbreaks. Sea level rise shifts coastal non-saline and inundation boundaries further interior to the island. Therefore, the existing cropping patterns and systems would lose their productivity and economic viability. It will become necessary to critically re-design alternative integrated farming systems at ecosystem level. These changes must be tested and demonstrated in the farm in order to effectively utilize the natural resources and also to stabilize the production and profitability. Precision farming can compliment crop diversification in securing a sustainable agricultural system. Precision farming could match agricultural inputs and practices based on exact need of crops grown in specific eco system to minimize usage while improving the accuracy and efficiency of inputs. Precise application of inputs ‘as needed and where needed’ ensures avoiding overuse or under use of inputs protecting soil health and environment. Also, it reduces levels of water, fertilizer, pesticide, and labour use, and assures quality produce. In livestock production, precision

	farming can increase productivity through regulation of micro-environment, improving feed and fodder production, and assuring timely veterinary care.
2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	• The technology envisages a modest cost: crop diversification may involve modest costs in land re-design; precision farming could add new costs for developing information systems and monitoring • It involves judicious combining of low and high technology progressively integrated over time • Some precision techniques could develop as proprietary products with high initial costs initially lowering their affordability
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	The development suitable packages would require collecting and processing large amounts of data, broadly across large areas of land and also at the individual farm level. Research and extension systems will have to develop capacity to manage such processes. Institutional innovation to integrate publicly-funded R&D outputs with commercial products in the sphere of precision farming techniques would become necessary.
3. Operations and maintenance	
3.1 Endorsement by Experts:	Changing cropping and farming systems have been practiced by farmers throughout the history to respond to demands for new products, overcome challenges to crop production due to varying weather and biotic environment, and improve incomes from farming. Scientifically designed recommendations for diversifying existing cropping patterns and farming practices would be acceptable by farmers. Sustainability concerns have raised interest in crop diversification and integrated farming away from the modern 'industrial' farming methods and the precision farming techniques have found high acceptability in supporting crop management towards improving efficiency of scarce resource use and reducing pollution from agriculture. Therefore, the technology should receive quick acceptance of scientists, policy makers and practitioners alike.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but*	Negative consequences of the adaptation option are minimal as concern towards increasing sustainability of agriculture has already endorsed many of the elements associated with the package. The recommendations have the potential to be progressively incorporated to farming over time somewhat

may have costs and consequences under the current climate.	cushioning the costs of adoption.
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	The technology is innately suitable for large-scale adoption. In fact, some elements of the technology must be adopted as a general practice for optimum results and unit costs of certain precision farming techniques would significantly lower with widespread use by farmers. Also, some elements of the technology package have the public-good nature requiring state patronage in its expansion.
4. ***Costs***	
4.1 Cost to implement adaptation options: *Cost measures*	Costs will be affordable as many components can be incorporated incrementally. Not all components will be relevant in the case of different combinations of crops and livestock enterprises. Thus it may be appropriate to enumerate costs from crop budgets for individual enterprises or enterprise mixes. Development costs and adoption costs for different units of precision farming techniques can be enumerated separately. Rs. 75.0 M is estimated as total implementation cost.
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Additional costs to implement adaptation option will be estimated from costs of combining or introducing new techniques to the existing farming systems.
5. ***Development Impacts, indirect benefits***	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	- increases crop yield, quality and efficient use of farm inputs and labour would reduces cost of production - Ensure productivity and food security
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	• Minimized health problems from environmental pollution , resulting from indiscriminate resource use • Increased returns to resource use and improving the attractiveness of farming, particularly to youth, through adoption of high-tech methods.
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,* *Ecosystem degradation etc*	• Prevents soil degradation in cultivable land. • Reduction of chemical use in crop production • Efficient use of water resources and other natural resources • Reduce GHG emission as demand driven fertilizer management systems emit low NOx and other gases

6. ***Local context***	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	There will be no barriers to implement this technology and policy directions are in place at present to support it.
6.2 Status: *Status of technology in the country*	Some technological advancements are needed in the area of precision farming in particular.
6.3 Timeframe: *Specify timeframe for implementation.*	3-4 years
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Yes

Technology Fact Sheet 7

Ecological Pest and Disease Control

1. ***Sector:*** *To be written by sector expert.*	Food
2. ***Technology Characteristics:***	
2.1Technology Name:	**7. Ecological Pest and Disease Control**
2.2 Introduction: *low/high Brief introduction to the technology*	Climate change will severely affect agricultural production and the livelihood of farmers by unpredictably changing the abundance of insect pests and diseases along with their existing and potential natural enemies. Ecological pest control is an approach to increasing the strengths of natural systems to reinforce the natural processes of pest and disease regulation and improve agricultural production. Ecological controlling of pests and diseases relies on the biodiversity of the agro-ecological system, i.e. the greater the diversity of natural enemy species, the lower the density of the pest population. Following principles of Integrated Pest & Disease Management (IP&DM), this practice envisages use of multiple tactics in a compatible manner to maintain populations of disease-causing organisms at levels below those causing economic injury while providing protection against hazards to humans, animals, plants and the environment. Encouraging natural control mechanisms, it maximizes use of natural and cultural processes and methods, including host resistance and biological control with the least possible disruption of agro-ecosystems. Chemical pesticides are used only where and when these natural methods fail to keep pests below damaging levels. EP &DM is a biotechnology belonging to the denominated 'clean' technologies which combines the life cycle of crops, insects and implicated fungi, with natural external inputs (i.e. bio-pesticides) that allows a better guarantee of good harvesting even in difficult conditions of pests and diseases that emerge with the temperature and water level changes (increase of relative atmospheric humidity and runoff) typical of climate change. Thus, it is a biotechnology for facing uncertainty caused by climate change. EPM contributes to climate change adaptation by

	providing a healthy and balanced ecosystem in which the vulnerability of plants to pests and diseases is decreased. Key components of the EPM approach involve simultaneous engagement of Crop Management (selecting appropriate crops for local climate and soil conditions), Soil Management (maintaining soil nutrition and pH levels to provide the best possible chemical, physical, and biological soil habitat for crops), and Pest management (using beneficial organisms that behave as parasitoids and predators) technologies.
2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	EP&DM is a low-cost technology due to non- or minimal-use of expensive pest control chemicals. However, it is knowledge intensive as practice of EP&DM requires a good understanding of interactions between crop, soil and pest dynamics.
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Requirements of capacity building and knowledge transfer are modest for the implementation of this adoption system as it is a natural control system that relies on strengthening ecological processes.
3. Operations and maintenance	
3.1 Endorsement by Experts:	Disruption to crop production from extreme meteorological events, such as spells of high temperature, heavy storms, floods and droughts are directly observed. Some other changes such as organic matter depletion from higher temperatures, lowered water retention, weed and pest proliferation and population dynamics of disease casing organisms are not so directly observed. In addition, increased atmospheric carbon dioxide is expected to alter the nutritional makeup of crops, thereby affecting the severity of attack from insects and disease organisms. If warmer and longer growing seasons occur, fungal diseases could do well, but only if there is enough moisture to support them. Both enhancement and reduction in disease severity under elevated CO_2 has been reported. Elevated CO_2 would increase canopy size and density of plants, resulting in a greater biomass production and microclimates may become more conducive for rusts, mildews, leaf spots and blights development. As well as increase in temperature with sufficient soil moisture may increase evapo-transpiration resulting in humid microclimate in crop canopy and may lead to incidence of diseases favoured under warm and humid conditions. There is considerable

	information on the effects of increased UV-B on crops and continued exposure to enhanced UV-B radiation lowers the level of antifungal compounds in foliar parts. Aphids are expected to have increased survival with milder winter temperatures, and higher spring and summer temperatures will increase their development and reproductive rates and lead to more severe disease. Recently in Sri Lanka there are some diseases such as Rambutan powdery mildew, cucurbit yellowing syndrome etc. has become epidemic level and it is difficult to control by using conventional disease control methods. Therefore adverse environmental conditions may be the cause for this condition and as solutions crop models can be tested in our conditions such as agronomic practices and biological disease control methods.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	Technology is widely applicable across all current and future scenarios and has no costs and consequences in the current climate.
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	Technology will be widely applicable across all range of crops and farming systems bringing benefits to a majority of producers.
4. ***Costs***	
4.1 Cost to implement adaptation options: *Cost measures*	Rs. 27.00 M is estimated as a total implementation cost including research and development.
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Due to extreme weather events, if new pest and diseases will come across to the environment, additional cost will be imposed for research and development, capacity building and also for extension work.
5. ***Development Impacts, indirect benefits***	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	- Lowers costs of pest control over the long-term - Increased product value

5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	- Does not cause human health problems - Promote healthy living - Reduce risk to humans
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,* *Ecosystem degradation etc*	- Preserve ecosystem health and integrity - Protect biodiversity - Sustained surface and ground water quality
6. *Local context*	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	There will be no barriers to implement this technology.
6.2 Status: *Status of technology in the country*	Some of the techniques are practiced at the Organic farming and home garden cultivations. For commercial level implementation, new technologies must be developed. Therefore, research and development is necessary to adapt the technology.
6.3 Timeframe: *Specify timeframe for implementation.*	Life time
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Very well accepted. People are ready to pay more for healthy food.

Technology Fact Sheet 8

Responsive Agricultural Extension

1. ***<u>Sector:</u>*** *To be written by sector expert.*	Food
2. ***<u>Technology Characteristics:</u>***	
2.1Technology Name:	**8. Responsive Agricultural Extension**
2.2 Introduction: *low/high Brief introduction to the technology*	Rural incomes and development are severely impacted by climate change due to the natural resource-base of agriculture industry. Agricultural extension is the service that provides access to knowledge and information required by clients to increase productivity and sustainability of production systems to improve their livelihoods and quality of living. Therefore, agricultural extension systems must gear them to respond to pressures arising from climate change, of which the severity of impact may be disproportionately high in less-favoured areas. Such areas may also be facing greater challenges in terms of required adaption response. Institutional arrangements for providing localized crop and livestock solutions are not in favour of such challenging circumstances where the transaction costs tend to be high with customary service arrangements. Often private service providers tend to ignore needs of low-potential groups in marginal areas. Furthermore, the type of knowledge and information required by rural clients may well extend beyond traditional boundaries of providing agricultural extension. Traditional extension arrangements form an agent-client relationship which is often effective only under somewhat primal situations. Therefore innovative, cost effective extension solutions are required to address needs in such areas. The role of rural extension services and technical capacities of such organizations must be geared to meet needs of such communities. Links between state and non-state actors and target communities should be strengthened with capacity building and appropriate incentives. Community structures and institutes such as producer groups, water users' associations, produce marketing and processing groups should be made partners of

	rural extension and training networks operated by state and non-state entities. Approaches such as use of Community-based extension agents, Farmer field schools, User groups/Associations have been employed under different situations with varying degrees of success. The most appropriate model for a locality is informed by the background and conditions specific to the locality and discovered following some analysis. What is required to install this capacity within extension organizations depend on the extent of training and capacity building activities undertaken. At the same time, building capacity of rural communities to identify, select and implement appropriate strategies in response to impact of climate variability would permit effective interaction between extension agents and target communities, transforming it to be a truly responsive system. Sometimes, institutional arrangements within the target community may assume the form of an organization directly linked to a resource impacted by climate change as in the case of a water-user group, and in other occasions a more generic one in the form of a producer group for a dominant commodity. Opportunities for implementation of responsive extension scheme should factor in social, economic and environmental factors specific to the community or resource under consideration. Financing of such extension systems have often had significant demands for financing, requiring access to development funding from donor partners.
2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	The technology rests on activities geared to capacity building and stakeholder organization. Primary interventions are in the form of institutional and organizational arrangements underpinned by knowledge development and transfer.
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Major requirement in the adoption of this technology relies on improving upon institutional and organizational arrangements for delivery and transfer of knowledge.
3. Operations and maintenance	
3.1 Endorsement by Experts:	
3.2 Adequacy for current climate: *Are there negative consequences of the*	Being an institutional innovation mechanism, the technology poses no negative consequences.

adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	Responsive Agricultural Extension is important to protect the ability of current production systems to provide food supplies of everyone. If food supplies are threatened prices will rise affecting food security of large segments of poor populations.
4. *Costs*	Rs. 60.00 M
4.1 Cost to implement adaptation options: *Cost measures*	Rs. 20.00 M
4.2 Additional costs to implement adaptation option, compared to "business as usual":	Electronic Media, Mass propaganda etc; Rs. 40.00 M
5. *Development Impacts, indirect benefits*	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	- Increase efficiency of resource use overall - Promote rural development and resource conservation
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	- Encouraged community participation - Support livelihood improvement - facilitate rural development
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,* *Ecosystem degradation etc*	- improved biodiversity conservation - Increased Quality of Watershed functions - Reduced ecosystem degradation
6. *Local context*	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	Requires high quality trained human resources on CC impacts and adaptation measures
6.2 Status: *Status of technology in*	Agricultural Extension is a ongoing process. But the knowledge

the country	on Climate change and extreme weather events and adaptation options should be introduced to the public.
6.3 Timeframe: *Specify timeframe for implementation.*	Life time
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Yes

Technology Fact Sheet 9

Culture-based fisheries

1. ***Sector:*** *To be written by sector expert.*	Food
2. ***Technology Characteristics:***	Adaptation
2.1Technology Name:	**9. Culture-based fisheries**
2.2 Introduction: *low/high Brief introduction to the technology*	Reservoir fisheries provide significant contribution to food and nutritional security of the rural areas in the interior regions of the country. Government statistics indicated that per-capita fish consumption in Anuradhapura and Polonnaruwa districts, where reservoir fisheries activities are successfully established are above the national per-capita fish consumption. Reservoir fisheries, especially culture-based fisheries (CBF) in medium size perennial reservoirs and small village reservoirs are highly vulnerable to the climate change impacts. Unexpected rainfall changes and changes in annual rainfall pattern in recent past have significant impacts on the water retention of the reservoirs. As CBF activities are depend on the two monsoons, changes in rainfall pattern creates uncertainty of maintaining required amount of water for the aquaculture. Hence, an effective methodology is needed to predict water availability in seasonal reservoirs enabling CBF farmers to adapt to changes in monsoonal rainfall pattern. Fish species that are used for the CBF is exotic and fish seed have to produce in hatcheries through artificial breeding. Fingerling availability for stocking at correct time of reservoir filling cannot be assured as induced breeding of major carps community-based fingerling rearing procedure are dependent on gonadal maturity cycles of fish, which are usually related to monsoonal rainfall. This will create fingerling scarcity in the correct time of stocking. Also it caused difficulties in stocking required combination of fish species at correct time period. The rural farmers should therefore develop a resilience capacity to climate change. As such, alternative means of stocking of fish fingerlings reared by rural

	communities should be sought. As climate changes has direct influences on artificial breeding of fish, alternative techniques and/or improvement of existing technologies is needed. Study of different techniques for successful breeding of introduced and local fish species suitable for aquaculture is a major requirement in the finfish aquaculture in the country under the scenario of climate change.
2.3 Technology Characteristics/Highlights: *Few bullet points, ie. low/high cost; advance technology; low technology.*	A combination of hard and soft technologies would be appropriate depending on location features. • Prediction of water availability in reservoirs with climate change impacts. • Identify alternative means of fingerling stocking. • Develop techniques to identify climate change impacts on fish breeding. • Improve breeding techniques to overcome climate change influences. • Effective knowledge dissemination and capacity building
2.4 Institutional and Organizational Requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Two-way communication between farmers and other stakeholders should be improved. Good management practices on irrigation and other water uses in reservoirs should be adapted. Capacity building on relevant institutions to forecast future climate change incidences and identify strategies and improve resilience capacities in vulnerable communities is needed. Identify new techniques to overcome fingerling scarcity due to climate change and disseminate knowledge through effective knowledge transfer strategy.
3. <u>Operations and maintenance</u>	
3.1 Endorsement by Experts:	The approach suggested to implement adaptation to threats to coastal fishery resources relies on protecting and nurturing the resilience of the natural ecosystem and lessening the pressure on the natural system by adopting commercial aquaculture operations. The coastal ecosystem, being a biological system, will invent its own adaptation mechanisms and creating a foundation for long-term resilience and continuity of ecosystem services. Measures aimed at protecting or minimizing external climate change impacts on the coastal ecosystem thus assure some services in the short term, but more importantly a basis for continuation of them to the future as well. Aquaculture on the

	other hand by lowering the pressure on the coastal habitats to respond to market demands for valuable fishery products leaves more breathing space for the system to recover by allowing the harvesting effort to be kept under natural limits for renewal.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	There are no significant negative impacts associated with the technology if the best management practices are adopted. Serious environmental issues have been reported with aquaculture under poor management including severe economic damage from failure to adopt good hygiene, for example. An effective system of monitoring and regulation can overcome such situations.
3.3 Size of beneficiaries group: *Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.*	• Majority of rural people will benefit trough sustainable CBF, and it ensure the nutritional security as well as food security. • Aquaculture farming communities in rural communities and paddy farming communities • People involving in community based fry to fingerling rearing activities. • Government fish hatcheries and extension arm of the Ministry of Fisheries (i.e. National Aquaculture Development Authority)
4. ***Costs***	Prediction of water availability and developing a model • Data collection (available climate data, fish production in reservoirs, satellite images, and other related information from farmer communities) **3 million SL rupees** • Developing a model **2 million SL rupees** • Develop breeding techniques for Climate change influences **5 million SL rupees** • Knowledge dissemination and capacity building **2.5 million SL rupees** • Miscellaneous **1 million SL rupees**
4.1 Cost to implement adaptation options: *Cost measures*	Costs will be estimated for different individual or packages of technological interventions. Measures adopted will vary by location and the economic value of resource to be protected at each location.
4.2 Additional costs to implement adaptation option, compared to "business as usual":	As the CBF is to be developed as a new initiative the full cost of implementation would be required.

5. ***Development Impacts, indirect benefits***	
5.1 Economic benefits: **Employment -** *Jobs* **Investment -** *Capital requirements*	Create new job opportunities: identification of suitable technologies to overcome climate change induced impacts will ensure the sustainability of CBF in reservoirs. It will create new job opportunities for rural communities. (i.e. Doing CBF, Fingerling production, product development, marketing etc.)
5.2 Social benefits: **Income -** *Income generation and distribution* **Education -** *Time available for education* **Health -** *Number of people with different diseases.*	• Additional income for paddy farming communities in rural areas. • Make available low cost protein source for rural communities in affordable price. • Secure the food security and nutritional security of rural communities • Use of available resource for additional income generation. • Effective use of new technologies developed for sustainable CBF. • Capacity building in government and community level. • Reduce the uncertainty of CBF due to climate change impacts.
5.3 Environmental benefits: *Reductions in GHG emissions, Local pollutants,* *Ecosystem degradation etc*	• No formulated food or other inputs are used in CBF therefore available natural food items are used by the stocked fish species. • No GHG emission in CBF. • No local pollutants and ecosystem degradation. • Minimum use of power. • Zero impacts on indigenous/endemic aquatic fauna
6. ***Local context***	
6.1 Opportunities and Barriers: *Barriers to implementation and issues such as the need to adjust other policies.*	There are no serious policy barriers to the introduction of the technology in the country. The technology has acceptance as a means to increase production from reservoirs. However, given the multi-functional nature of irrigation reservoirs, some protocols will have to be developed on adjudicate water allocation priorities.
6.2 Status: *Status of technology in the country*	Basic knowhow about the technology is available in the country. However, the challenge to develop systems that can meet the evolving nature of CC adaptation would require continuous research and development.
6.3 Timeframe: *Specify timeframe for implementation.*	The project will require 5 year implementation period for completion.

6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	The technology will be attractive to all categories of stakeholders as it creates new opportunities for income generation, reduces stress on the natural resources that are heavily exploited and allow greater integration of resource use at the production level.

Technology Fact Sheets (TFS)

Health Sector

HEALTH SECTOR

Technology Fact Sheet-01

Transfer of knowledge and skills to Health Personnel

Sector	**Health**
Adaptation needs	Knowledge and skills among health personnel need to be improved for adaptation activities to be undertaken by the general public through community networks
Technology name	Training on knowledge and skills of selected categories of public health personnel in preventive(Field based) and Curative (Hospital Based) care on adverse health effects of climate change and adaptability
How this technology contributes to adaptation	The transfer of knowledge to the general public by the skilled public health personnel will help to adapt or to minimize the adverse health effects of climate change; vector borne and food borne diseases, injuries and the effects of extreme weather events like floods, landslides, drought, thunderstorms and lightning etc. Training on climate change related health events will enhance early detection and management of vector borne and food borne diseases which will be helpful in surveillance and outbreak control activities. In a situation of high temperature related dehydration or other complications can be attended. Manage and control respiratory conditions due to presence of allergens and other particles in the atmosphere due to air pollution. Furthermore, the training will enhance the ability of the health personnel to reduce the chances of patients getting complications. In situations of extreme events the injured will be attended skillfully and timely preventing further complications and disabilities. Formulation of Hospital and Community Based (led by field health staff) Disaster Management Teams and Development of a Hospital Emergency Plan will improve the effectiveness and the efficiency executing activities / tasks related to the needs of the time. The health personnel should be provided with complete knowledge and skills on full circle of disaster management including preparedness,

	mitigation, response, early recovery, sustainable development and documentation as appropriate to the category of personnel.
Background/Notes, of the technology option sourced from Climate Techwiki, Seminars etc.	Annual Health Bulletin/Epidemiological Reports/Hospital Mortality and Morbidity reports/Community Health Workers. The state of the evidence on programmers, activities, costs and impact on health outcomes of using community health workers: Evidence and Information for Policy .Department of Human Resources for Health, World Health Organization, Geneva, January 2007
Implementation assumptions, How the technology will be implemented and diffused across the sector	An awareness programme on Climate Change and the effects on health is ongoing at present. However, awareness by itself will not help to improve capacity. The number of participants per programme is limited and needs further improvement of the contents. This shall be done at district level as the services are monitored at that level basically. From there it shall diffuse to the lower levels of public health care and to the community. The categories and numbers have to be increased. Skills to carry out Tasks by the staff and to work according to a planned manner will be implemented through improving planning, monitoring and other related activities A monitoring component will be inserted to the existing monitoring mechanisms to assess the progress These will be further elaborated in detailed project proposals.
Cost	2000 $ US (per programme)

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	The participation of community volunteers and leaders will be high leading to favorable outcomes. Direct income generation will be low as per the technology alone Continued involvement of the general public will depend on the enthusiasm of the health workers and non-monetary incentives gained. The technology transfer will improve the household food and personnel hygiene, ability to prevent communicable diseases, and injuries during extreme events and improve health seeking behavior

Country economic development priorities	active participation of the public at individual, family and community levels in economic development activities ensured, capital requirement is minimal
Country environmental development priorities	GHG emissions are minimal The technology will enhance reduction of pollution by human activities. The technology itself has no direct impact on environment
	Costs
Capital cost	-
Operational & Maintenance costs	$US 500/ annum per facility
Daily Supply capacity per facility	Ongoing and continuous
Up-scaling potential	The possibility of covering 80 % of the selected categories of within three years

	Local context
Opportunities/ Barriers	Ample opportunities are available in the public health sector. It is important to include Private Sector and NGOO as most of them are involved in related activities. Attrition of the number health volunteers over time. Loss of interest by when there is no emergency.
Country status	Ongoing activity. Needs curriculum revision. More categories shall be included.
Timeframe	Mid 2012 - end of 2015

Technology Fact Sheet-02

Diagnostic facilities to detect water borne diseases

Sector	*Health*
Adaptation needs	Rapid screening facilities to identify selected pathogens responsible for water borne diseases
Technology name	Rapid testing diagnostic facilities to detect pathogens for water borne diseases: Microbiological/ morphological analysis(Conventional), Molecular Diagnostic methods (Antibody/Nucleic acid based)
How this technology contributes to adaptation	Water borne diseases occur when surface water or water from poorly functioning water distribution systems which are contaminated with disease causing microorganisms are used by humans for drinking and for other purposes. Usually the pathogens are (protozoa, bacteria or viruses). Common diseases are Watery diarrhea, Cholera, Typhoid and Paratyphoid Enteric Fevers, Shigellosis, Giardiasis, Viral Hepatitis etc. The technology will enable early detection of pathogens responsible for speedily spreading water borne diseases as well as pathogens in water sources for confirmation. Ensure prevention of major outbreaks and complications/ carrier states Monitor pesticides and other harmful chemical contaminants in ware sources. Complement in flood situation/ protracted drought situation related preventive health activities and other programmes.
Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	Frumkin H, McMichael A, and Hess J. *Climate Change and the Health of the Public*. Am J Prev Med. 35 (5): 401-402, 2008. Water Sanitation and Health (WSH) *Water-Related Diseases*. WHO Kumar, A. *Modern Molecular tool and Techniques fo water borne pathogens*.[online]http://www.cpcb.nic.in/modern_molecular.pdf; [Accessed on 15th October 2011.
Implementation assumptions, How the technology will be implemented and diffused across the sector	The health personnel will be provided with a basic skills to use the technology. The laboratories in the hospitals and mobile units will be provided with the required equipment and consumables. The test reports will be provided to the clinicians to give the diagnosed

	cases appropriate and timely treatment. The monitoring and other forms of reports which are already in use will be used to detect unusual numbers of particular diseases. The data collection and analysis at the local level will be improved through available human resources.
Cost	1500$ US per facility

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	As the adverse health effects are minimized, the effects on the income of the people will be marginal. Concurrent public health activities will enhance their knowledge, practices and behaviors which will be conducive to good health. Health in general will be preserved as outbreaks, complications of diseases and injuries are reduced to an acceptable level.
Country economic development priorities	Employment generation-low. Capital requirements will be affordable.
Country environmental development priorities	GHG emissions will be minimal as the energy use will be minimal. Local pollutants, and ecosystem degradation will be averted by adopting to proper clinical waste disposal methods.
Costs	
Capital cost	-
Operational & Maintenance costs	500 $US per facility (maintenance & service/repair/ consumables etc.)
Daily Supply capacity	The supply of services will be 24/7 will depend on the need of the day.
Up-scaling potential	Coverage of 70% priority institutions within three years.

Local context	
Opportunities /barriers	Ample opportunity as there is a need. Barriers will be minimal except that of financial.
Status	This is available in the country in some major institutions in government the private sector as well.
timeframe	Mid 2012-end of 2015

Technology Fact Sheet 03

Technology to detect/prevent and contain vector borne diseases

Sector	Health
Adaptation needs	How to prepare and respond to vector borne diseases, as there is a potential for increase of some and re-emergence or controlled VBD due to effects of climate change
Technology name	Technology to minimize the effects o f VBD (diagnostics/preventive an control aids) for Integrated Vector Control and disease prevention and control
How this technology contributes to adaptation	The diseases include Malaria (which is under control at the moment), Dengue and its complications which is on the rise, Leishmaniasis, Chikungunya, diseases transferred by mechanical means Transfer of knowledge and skills to health personnel to identify, confirm, treat and prevent of further spread of VBD By prevention of large scale outbreaks by early detection and information sharing Implementation of control measures at early stages concurrent ly Logistics management with early warnings Enhancement of the control and related multi-sector activities enabling containment of the disease at an early stage
Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	UNFCC (2006). *Application of environmentally sound technologies for adaptation to climate change.* Technical Paper FCCC/IP/2006 Reducing Vulnerability, Enhancing resilience: The importance of adaptation technologies for the post -2012 climate agreement; A report by CIDSE and Caritas Internationalis. May 2009 Health and Environmental Linkages Initiative (HELI). Vector-borne disease. WHO; UNEP [Online] http://www.who.int/heli/riskss/vectors/vector/index.html. [Accessed on 20/10/22011
Implementation assumptions, How the technology will be	The implementation will be in a phased out basis as well as on a priority basis.

implemented and diffused across the sector	The district Health Authority will be given the to do the planning with the help of central authorities within puts on policy and strategy. The technology will be implemented through the existing health networks both public and the private sector, NGOO with the technical assistance from the UN agencies when and where necessary. Monitoring and evaluation of the progress and the outcomes respectively will be done by further strengthening the existing information system The details will be elaborated in the project proposals.
Cost	3500 $US /district
Impact Statement- How this option impacts the country development priorities	
Country social development priorities	New income generation opportunities will be moderate and will not be permanent. Education among the health personnel will be improved and the general public will enjoy knowledge, practices and behavior change for better health comes.
Country economic development priorities	Jobs will be generated in times of need for temporary involvements. Capital requirements will be moderate in nature.
Country environmental development priorities	GHG emissions will be low. Local pollution and effects on ecosystems will be minimized when using insecticides to vector control by adopting established control measures.
Costs	
Capital cost (per facility)	-
Operational & Maintenance costs	1000 $US (per district)
Daily Supply capacity per facility	The supply of services is continuous and the capacity will depend on the needs.
Up-scaling potential	80% coverage of districts are possible within three years.

Local context	
Opportunities/ Barriers	The opportunities are available in the public and in the private sector as well. In addition there are large number volunteers in the periphery who are willing to participate. Barriers will be mainly monitory in nature.
Country status	This is an ongoing process in the country. However, there are large gaps to be filled as discrepancies among the districts in many aspects related to the technology prevails..
Timeframe	Mid 2012 to end of 2015

Technology Fact Sheet 04

Technology for Early Warning Systems and networking for information exchange on Extreme Weather events and other climate change related events

Sector	*Health*
Adaptation needs	Use of Early Warning System and networking between different agencies for information sharing on Extreme Events and other climate change related events to contain adverse health effects.
Technology name	Generation and sharing of information using Early Warning Systems and networks.
How this technology contributes to adaptation	Risk knowledge gained following risk assessments help to develop preventive mechanisms and further enhance Early Warning Systems and networking among different agencies. Systems with monitoring and predicting capabilities provide timely estimates of the potential risk faced by communities, economies and the environment. Communication networks are needed for delivering warning messages to the potentially affected locations to alert local and regional governmental agencies. The messages need to be reliable, synthetic and simple to be understood by authorities and public. Coordination, good governance and appropriate action plans are a key point in effective early warning. Likewise, public awareness and education are critical aspects of disaster management. The technology through diffusion will contribute to climate change adaptation through providing sufficient time for health personnel to prepare action plans based on contingency plans to minimize, respond to expected effects Provide Health and administrative authorities to make preparations along with the support of NGOO, UN agencies, Private sector and Community organizations The general public at individual, family, community and country level will be informed to participate in adaptation activities.

Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	UNFCC (2006). *Application of environmentally sound technologies for adaptation to climate change.* Technical Paper FCCC/IP/2006 Grasso, VF., Singh, A., Early Warning Systems: State-of –Art analysis and Future Directions; UNEP
Implementation assumptions, How the technology will be implemented and diffused across the sector	The population of Sri Lanka is served by adequate number of personnel such as Doctors, Nurses, and Public Health Midwives and Public Health Inspectors. One of the priority functions of the PHII is to control of Communicable Disease in his respective range. This include identification, confirmation, contact tracing, treatment, health education and many other activities of outbreak control and as in Sri Lanka there is a widespread network of hospital and public health network the outcome of the technology will diffuse from top-to-bottom and other way around efficiently. The information sharing networks should be established between all agencies and Health and the health information shall be provided to the other agencies as well. In addition the alerts can be diffused through the print, electronic mass media and mobile phones. Same can be done by supporting the existing health information at different levels (Country, Provincial, District and Divisional).
Cost	1500 $US per district

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	Income generation due to technology per se is low. The knowledge earned by the health personnel and general public will assist in averting effects of major extreme events (Floods, Landslides, Cyclones, drought, and disease outbreaks etc.).
Country economic development priorities	The number of jobs created will be minimal and most of the time temporary as the event warrants.
Country environmental development priorities	GHG emissions will be low as the energy use is minimal There will be nil or minimal pollution and effect on ecosystems.

Costs	
Capital cost	**-**
Operational & Maintenance costs	**500 $ US**
Daily Supply capacity per facility	Continuous 24/7 at Central and District levels. Other levels on the needs basis.
Up-scaling potential	80% of the country can be covered in three years.
Local context	
Opportunities/ Barriers	The technology is available in the health sector but usually functions only where there is an emergency. The disease EWS as well as other form shall be implemented in the health sector. The opportunity is there as many health workers are provided with awareness. Private sector shall be incorporated. Reluctance to share information. Other Barriers should be studied.
Country status	Technology is available at various levels at different administrative levels. It is not continuous or not a real EWS. Networking shall be made compulsory as a policy measure.
Timeframe	Mid 2012-end of 2015

Technology Fact Sheet-05

Research to identify the magnitude of diseases other aspects affecting human health due to climate change

Sector	*Health*
Adaptation needs	To learn how the climate change affects the human health.
Technology name	Applied research to estimate the impact of known climate change related adverse health outcomes.
How this technology contributes to adaptation	The knowledge of effect of some known adverse health outcomes of climate change will assist the policy makers to take the priority policy and strategy changes. The outcome will enable the researchers to identify the magnitude of the health outcomes and recommend actions as appropriate. It also will provide an opportunity to transfer knowledge and practices and behaviors to the people at risk.
Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	Centres for Disease Control and Prevention. Climate Change & Human Health Kang, E., NIH-led Interagency Group Identifies Research Needs to Study Climate change and Human Health Impacts; National Institute of Health ,UK; April 2010
Implementation assumptions, How the technology will be implemented and diffused across the sector	The research activities shall be directed towards the following, Cardiovascular disease and stroke, Mental health and stress related disorders, Malignancies, neurological disorders and diseases, Asthma respiratory allergies and airway diseases, water borne diseases, food borne diseases and nutrition, extreme event and weather related morbidity and mortality, Heat related morbidity and mortality, Vector borne and zoonotic diseases and effect on human development. In addition adequacy of services and capacity of the health personnel and aspirations and expectations of the general public can be studied. Implementation of studies shall be entrusted to academic institutions and individuals who are involved in academic exercises for their graduate and other forms of studies. As there are many public and private institutions functioning in the island,

	there will be sufficient number of persons interested in this regard. The other avenue is collaborative studies with overseas universities or academic institutions. It is the noble function of the researchers and other institutions to diffuse the information gained through their publications, seminars, mass & print media etc. For the benefit of the community.
Cost	10,000 $US per study

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	Income generation will not be directly benefitted. Education of the general public will help them to adapt to appropriate conditions. Health at different levels will be improved as the consequences are being minimized or averted
Country economic development priorities	Creation of jobs will be limited to few persons involved in research related work. Capital requirements will be minimal.
Country environmental development priorities	GHG emissions will be low. Generation of local pollutants and degradation of ecosystems will be negligible.
Costs	
Capital cost	-
Operational & Maintenance costs	1000 $ per study
Daily Supply capacity per facility	Not applicable.
Up-scaling potential	Based on the success of the initial studies.

Local context	
Opportunities/ Barriers	Opportunities are limited, still there are few who are inspired by the importance as the issues related to climate change has become the number one global problem.
Country status	Some studies are going on. Some have been completed, of which wide circulation is yet to be made available.
Timeframe	2012-2015

Technology Fact Sheet-06

Drinking water quality improvement through continued surveillance during and after extreme weather events

Sector	*Health*
Adaptation needs	How to prevent water borne diseases by continued surveillance of drinking water quality
Technology name	Establishment of monitoring system to detect contaminated water sources and sources of contamination unfit for human consumption
How this technology contributes to adaptation	Identification of water sources contaminated with disease causing pathogens by regular testing Monitoring of purification of drinking water will ensure the quality Contaminated sources can be cleaned and used preventing local shortages The technology can be used to communicate with the local community at different levels, thus improving participation and thus enhancing hygienic practices
Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	Centers for Disease Control and Prevention, Health Water; *Water related emergencies and outbreaks,* Centers for Disease Control and Prevention*; Safe Drinking Water Home,* Water related emergencies and out breaks National Water Supply and Drainage Board. Annual Report, 2009 Ministry of Water Supply and Drainage; *Corporate Plan 2012-2016*; National Water Supply and Drainage Board
Implementation assumptions, How the technology will be implemented and diffused across the sector	The current status of access to safe drinking water is 80% out of which 39% is pipe borne water; The total sanitation coverage is 85.7%. The plan is to increase the pipe borne water coverage to 47.1% by year 2016. The majority of people use well (Dug as well as Tube wells) and surface water from streams and tanks for drinking and other purposes. Therefore it is imperative to establish the surveillance mechanisms in advance. If the climate change affects badly there will be shortage of water not only in rain fed dry and arid zones but in urban and suburban areas

	where the pipe borne water is the main supply route. The surveillance of water quality will be much needed in such instances as well. The surveillance should include physical, chemical, microbiological and other parameters as warranted by the event. The Public Health network can be used to implement the technology. The NGOO and UN agencies and Government agencies involved in WASH activities can also participate in the activities. The initiative shall be monitored at the Divisional level with the assistance of the District level health authorities. Prolonged and regular application of the technology will reduce the impact of water borne diseases and at the same time provide thee health personnel to introduce other health practices to the community.
Cost	1500 $ US/District

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	Income generation during and after an extreme event as well as in protracted droughts is seasonal and temporary Education gained through the technology transfer will help the population to avert water borne diseases
Country economic development priorities	Only a limited number of temporary jobs will be created Capital investment will be bearable
Country environmental development priorities	NO GHG emissions Environmental pollution is minimal and ecosystem degradation is also minimal as chemical use will be restricted.
Costs	
Capital cost	-
Operational & Maintenance costs	500 $US/District
Daily Supply capacity per facility	Functionality will be 24/7.
Up-scaling potential	80 % coverage in the country in three years

Local context	
Opportunities/ Barriers	Ample opportunities are available as many rural areas depend on well or river water. Participation by the public in normal times and less enthusiasm by the health authorities during non emergency periods
Country status	The practice on available and being implemented. Not regularly done in some vulnerable areas.
Timeframe	Mid 2012- end of 2015

Technology Fact Sheet-07

Technology to improve urban health inputs to adapt for climate change and extreme weather events related adverse health impacts

Sector	*Health*
Adaptation needs	How the Urban Health providers will address adoption needs for adverse health impacts due to climate change and extreme weather events
Technology name	Technology to build capacity of the health workers in the urban sector through transfer of knowledge and skills
How this technology contributes to adaptation	Strengthening urban health services will help the urban populations specially, vulnerable groups like slum dwellers, street people, people living in coastal areas to prevent and /or minimize the adverse health effects of climate change The total population of Sri Lanka is 20.45 million (1) and 15.10 %of it is living in urban areas (1). There are 18 Municipalities and 42 Urban councils in the island, where most of the urban population is living. Furthermore, number of people living in the cities and towns will increase over time which demands standard services. The urban populations are provided with primary care health services by the local government bodies. They utilize hospital services which belong to Ministry of Health in their respective areas. In addition waste & rain water drainage, solid waste disposal and maintenance of roads are also the responsibility of the local government. Recent extreme events like floods, earth slips, affected the urban areas badly and regularly. Air pollution,' heat island effect', disease outbreaks and mental stress are other health aspects. Strengthening the health services in urban areas through providing opportunity to develop skills of health care personnel attached to the local bodies will help the urban people to take better alternatives and practices to avoid undue effects of climate change
Background/Notes, of the	(1) Department of Census and Statistics. *Population and*

technology option sourced from ClimateTechwiki, Seminars etc.	*Housing; August ,*2011 (2) Central Bank. *Annual Report*,2010 (3) Climate Change and Human Health. *Urbanization and health*, Global Environmental Change;WHO;2011
Implementation assumptions, How the technology will be implemented and diffused across the sector	The knowledge and skills needed shall be provided to the public health personnel through training programmes. It shall be done on a provincial basis, in a phased out manner. The institutions will be encouraged to prepare plans of action based on contingency plans, along with monitoring plan and financial plans Inter- sectoral collaboration ,involvement of NGOO and CBO shall be encouraged More details will be furnished in respective proposals.
Cost	3500 $ US per province

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	Effects on income generation to be reduced through adaptation Education on possibilities of minimizing effects on health will enhance social development Health effects due to adverse effects of climate change and extreme events will be minimized
Country economic development priorities	There will be no significant employment opportunities generated Capital requirements will be manageable
Country environmental development priorities	GHG emissions will not be increased as energy usage is minimal Local pollutants and ecosystem degradation will be minimal
Costs	
Capital	-
Operational & Maintenance costs	500 $ US per province
Daily Supply capacity per facility	Not applicable
Up-scaling potential	80% shall be covered in three years

Local context	
Opportunities/ Barriers	Opportunities are available as there is a significant number of health

	workers attached to the local government bodies. Attrition of numbers over time may become an obstacle
Country status	The technology is provided in much regular manner to the health personnel attached to the Government health (Central and Provincial). The personnel in the Municipality and Urban authorities do not get many refresher trainings and skill development.
Timeframe	2012-2015

Technology Fact Sheet-08

Technology to enhance adaptability of the people on Psychological effects due to climate change

Sector	*Health*
Adaptation needs	Climate change will have adverse impacts on Mental Health as well, along with other health issues. Incidences of mental illnesses are increasing as a result of climate change. Loss of social cohesion due to extreme weather events related to climate change could be linked to increased incidence of anxiety, depression, Post Traumatic Stress Disorder, bereavement, self harm /suicide and substance abuse. It is estimated one in five people are reported to be mentally affected due to effects of climate change in some countries. Commonly rural areas are more affected. Therefore, it is important to establish networks with skilled personnel to improve adaptability and speedy recovery from such ailments to maintain health of the individuals, families and communities at large to take part in development activities of the country.
Technology name	Technologies to provide knowledge and skills to mental health personnel to identify counsel and refer affected individuals for management.
How this technology contributes to adaptation	The technology will help to identify affected people and to provide assistance for adaptability. The families and communities will be regularly provided the services to minimize the health, social and economic impacts Health seeking behaviour of the community with regard to mental illnesses will be improved
Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	The Climate Institute, A Climate of Suffering: *Mental health and community wellbeing in the wake of extreme weather*, The real cost of living with inaction on climate change (Melbourne and Sydney: The Climate Institute, 2011). WHO. Mental health assistance to population affected by the Tsunami in Asia. [Online].Geneva: WHO, c2008 (www.who.int/menttal_health/resources/tsunami [Accessed on 20th October 2011)
Implementation assumptions, How	The knowledge and skills obtained by the mental health workers will

the technology will be implemented and diffused across the sector	be visiting households, temporary sites (In cases of internal migration/displacement) and provide the necessary counselling services, refer when and where necessary for further management to hospitals and support the families affected. This shall be planned at the centre with the participation of service providers at different levels, NGOO involved in mental health work and UN agencies. Other government and private sector too shall be invited to take part in related activities The trained personnel will be training the field mental health workers and Community Social Workers to assist them. Both the hospital and field health personnel will be provided the opportunities for capacity building. Existing structures will be used for this technology as well Monitoring and evaluation will be done at district levels and information will be shared with all stakeholders
Cost	1500 $ US per district

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	Mental health services will be provided at field level, specially in rural areas The health workers will be provided with skills to identify needy affected and at the same time the community attitude/stigma will be reduced.
Country economic development priorities	The Community Health Workers will be employed to assist the field staff during field activities and this opportunity will be limited and temporary in nature. Capital requirements are negligible.
Country environmental development priorities	No GHG emissions due to high energy use. No effect on ecosystems and no pollution of the environment
Costs	
Capital cost	-

Operational & Maintenance costs	250 $ US per district
Daily Supply capacity per facility	Services will be provided by the facility over the working days of the week. If there is an emergency the services will be provided 24/7
Up-scaling potential	70% coverage can be achieved in three years time

Local context	
Opportunities/ Barriers	Opportunity is there in the public sector. It is important to incorporate NGOO, Community Based organizations and private sector to serve in this technology. Routine transfer of public health personnel , attrition of number of volunteers, mandate of some NGOO can become barriers.
Country status	Ongoing in a very limited way. The services currently provided to the resettled people in the Northern and Eastern provinces
Timeframe	Mid 2012- end of 2015

Technology Fact Sheet- 9

Technology for management of health care waste

Sector	*Health*
Adaptation needs	Improper management of health care waste leads to pollution of soil, water and air leading to health hazards. As the climate change effects and related extreme events are on the increase, haphazard hospital waste management has to be done properly to minimize the adverse health effects
Technology name	Transfer of knowledge and skills on health care waste management to health care personnel
How this technology contributes to adaptation	Reduce the effects on human health and wellbeing Minimize the adverse impacts on environment (air, water, soil, animals, plants and land) Reduce the disturbances to public security and order When HCWM is properly conducted generally poses no greater risks than the ordinary waste
Background/Notes, of the technology option sourced from ClimateTechwiki, Seminars etc.	Health care waste management in Sri Lanka. CORDAID,10085 A; December 2007 The Who manual "Safe management of waste from health care activities"
Implementation assumptions, How the technology will be implemented and diffused across the sector	It is assumed that there is a greater need for proper HCWM to minimize the adverse effects on humans and environment. if not the effects of climate change and extreme events may get aggravated than under normal circumstances. Participation of the public, private sectors which are catering health services can be ensured. Contributions from NGOO, UN agencies and bilateral and multilateral donors also can be expected. The technology shall possess the following components, Assessment of status quo and needs, Development of training module to transfer knowledge and skills, Diffusion of the practices to the lower level through master trainers,

	Development of plans , monitoring mechanism to implement activities, Record keeping, report writing and information sharing Evaluation methodology The technology transfer curriculum shall cover all elements of waste management system (Generation, collection, storage in situ, transport, storage transit, treatment and disposal) Key issues in HCWM (Health & environmental, technical, Institutional, Legal, Financial, and socio-cultural) also shall be addressed. At institutional level all staff members shall be provided training on the importance of HCWM and their responsibilities At target groups technical inputs shall be provided on HCWM
Cost	2000 $US District

Impact Statement- How this option impacts the country development priorities	
Country social development priorities	Income generation will not be affected either way Knowledge and skills on HWCM among the health workers will benefit the society in reducing the undue fears in the community Long term health benefits by containing HCW related physical and psychological ailments
Country economic development priorities	There may be generation of a sufficient number of employment opportunities if the HCWM is out sourced Capital requirement s for the technology transfer will be marginal
Country environmental development priorities	GHG (methane) production will be reduced. Ecological degradation will be minimized Pollution of the environment will be reduced
Costs	
Capital cost	-
Operational & Maintenance costs	750 $US per district per year

Daily Supply capacity per facility	Continuous and available 24/7
Up-scaling potential	70 % coverage can be attained in three years time

Local context	
Opportunities/ Barriers	Availability of trained staff in the public sector. Private sector shall be encouraged to become a stakeholder. Presence of NGOO and UN agencies involved in waste care management. Barriers; negative attitude of the health workers, cultural beliefs of some segments of the community, social stigma,.
Country status	The HCWM system is ongoing in major hospitals. In smaller hospitals and other health care institutions the system is not functioning and many practices are redundant and not suitable.
Timeframe	2012-2015

Technology Fact Sheets (TFS)

Water Sector

Technology Fact sheet 1

Boreholes/Tubewells as a drought intervention for domestic water supply

1. **Sector** – Water
2. **Technology characteristics**

2.1 Introduction

Tube wells and Boreholes can be used as alternative domestic water supplies specially during drought periods. Tube wells consist of a narrow, screened tube (casing) driven into a water bearing zone of the subsurface. Tubewells penetrating bedrock with casing not extending below the interface between unconsolidated soil and bedrock is called a Bore hole. Life time is about 10 years.

2.2 Technology characteristics/Highlights

- Medium-cost
- High technology

2.3 Institutional/ organisational requirements

- Technical advice should be given whenever necessary by skilled persons.
- If used for drinking purposes, arrangements should be provided to test quality of water in a regular basis

3. **Operations and maintenance**

3.1 Endorsement by experts

3.1.1 (i) Operations

- Tube wells can be installed by hand-auguring; Boreholes require a drilling method with an external power source.
- A hand powered or automated pump is used to draw water to the surface.
- Major components of a tube well are:
    - ➢ Plastic or metal casing
    - ➢ In unconsolidated soils, it is necessary to have a screened portion of casing below the water table that is perforated
    - ➢ A sanitary seal consisting of clay to prevent water seeping around the casing
    - ➢ A pump to extract water

  Technology should be implemented based on the following data:
    - ➢ Population distribution
    - ➢ Ground water resources
    - ➢ Water point location
    - ➢ Geological environment
- Water quality should be monitored if use for drinking purposes

3.1.2 Maintenance

- To increase borehole water supply during droughts:
  - Drill new boreholes
  - Repair damaged borehole

3.2 Adequacy for current climate

Negative consequences of the adaption option:

- Ground water shortage

3.3 Size of beneficiaries groups

8% of the total population

4. Costs

4.1 Cost to implement adaptation options

Drilling, casing and completion Rs. 20,000/= to Rs. 80,000/= (depends on the type)

Additional costs to implement adaptation option, compared to "business as usual"

Additional cost is required for monitoring of water quality – Rs. 3000/=

5.0 Development impacts, indirect benefits

5.1 Economic benefits

- **Employment** – medium (drilling)
- **Investment -** Tubewell or Borehole, hand pump/pump

5.2 Social benefits :

- **Income**
  - Decrease the expenditure for purchasing water from other sources
  - Income through employment (horticulture during dry season, agriculture, bottled water industry)
- **Education**
  - Technical advice should be given whenever necessary by experts.
  - Awareness programs, school education and research on this technology - medium
- **Health**
  - Medium impact - Decrease in waterborne diseases, If ground water is polluted – negative impacts

5.3 Environmental benefits

- Impact on ground water quality and quantity – high (this technology can increase the pressure for ground water withdrawal)
- Impact on surface water quality and quantity –No impact
- Impact on flood forming –No impact
- Release of GHG – very little (only during construction)

6. Local context

6.1 (i) Opportunities

- Save time and cost
- Continuous water supply
- Off season vegetable production

(ii) Barriers

- Water can contain iron, fluoride etc.
- Ground water abstraction

6.2 Status

- Tube wells and Boreholes are presently being used in Sri Lanka
- Expanding abstraction of ground water may affect the ground water table

6.3 Acceptability to local stake holders

Because of the low cost, this technology will be acceptable to stakeholders.

7. References

Technologies for climate change adaptation-The water sector; Mark Elliot, Andrew Armstrong, Josep Lobuglio and Jamie Bartram, UNEP, (ISBN 978-87-550-3902-5); 2011.

Technology Fact sheet 2

Desalination of brackish water by reverse osmosis

Technology Name: Desalination of brackish water by reverse osmosis

1. **Sector** – Water

2. **Technology characteristics**

2.1 Introduction

During a water scarcity, desalination can be used to produce fresh water from brackish water or sea water. In this technology, high pressure is applied to brackish water/sea water forcing water molecules to pass through a membrane while retaining salts and other larger molecules. This technology contributes to adaptation in following ways[1].

- Diversification of water supply by providing alternative or supplementary sources of water when current water resources is inadequate in quantity or quality
- Resilience to water quality degradation

2.2 Technology characteristics/Highlights

- High cost
- Advanced technology

2.3 Institutional/ organisational requirements

- It is necessary to determine freshwater resource potential, demand and consumption and then can decide on whether it is required to implement the desalination technology

3 Operations and maintenance

3.1 Endorsement by experts

3.1.1 Operations

- Pressure is used to drive water molecules across a membrane in a direction opposite to that they would naturally move due to osmotic pressure.
- Because osmotic pressure must be overcome, the energy needed to drive water molecules across the membrane is directly related to salt concentration.
- Therefore it is better to use brackish water having lower salt concentration, rather than using sea water.

3.1.2 Maintenance

- Technical capabilities are required
- Membranes have to be replaced

3.2 Adequacy for current climate

Negative consequences of the adaption option:

- Energy requirement is high and therefore GHG emissions will be high.
- Concentrated waste streams can cause negative impacts on ecosystems.

3.3 Size of beneficiaries groups

Areas where other safe water sources are not available

4 Costs

4.1 Cost to implement adaptation options

Combined units for desalination and disinfection are commercially available and it is reported that they can produce water for about $4 per 1m^3 from salt contaminated ground water[(2)].

Additional costs to implement adaptation option, compared to "business as usual"

- Cost for membranes and energy
- Additional cost is required when sea water is used instead brackish water

5 Development impacts , indirect benefits

Economic benefits

- **Employment** – Low
- **Investment -** High

Social benefits:

- **Income –** Low; This is an expensive technology
- **Education –** It is necessary to develop low-cost desalination methods.

Health

- High positive impact; Decrease in waterborne diseases

5.1 Environmental benefits

- High negative impact on surface water or ground water due to effect of concentrated waste streams
- Impact on flood forming – no impact
- Release of GHG – High; Reason - energy consumption for this process is very high

6 Local context

6.1 (i) Opportunities

- When fresh water resources are inadequate to meet the demand
- When abundant sources of brackish water are available
- When consumers do not like to reuse treated waste water

(ii) Barriers

- This is a high cost method.
- It is necessary to replace membranes
- Disposal of concentrated waste cause negative impact on the environment
- Green house gas emissions.

6.2 Status

Cost for providing treated pipe born water and water produce by reverse osmosis of brackish/sea water are Rs. 33/= and Rs.87/= respectively. (Capital cost for a desalination plant is very high and it is is not counted here). Due to high cost, at present the desalination plant in Hambantota is not in use. Certain desalination plants donated to Sri Lanka just after Tsunami are still in use.

6.3 Acceptability to local stake holders

Cost is high and as a result the demand for this technology is low.

7 References

(1) Technologies for climate change adaptation-The water sector; Mark Elliot, Andrew Armstrong, Josep Lobuglio and Jamie Bartram, UNEP, (ISBN 978-87-550-3902-5); 2011

(2) https://energypedia.info/index.php/Decentralized_drinking_water_supply

(3) http://www.alibaba.com/product-gs/493951559/2m3_full_automatic_seawater_desalination_plant.html

Technology Fact Sheet 3

Restoration of minor tank networks

5. **Sector** – Water
6. **Technology characteristics**

6.1 Introduction

Ancient tanks “wewa” are rainwater harvesting systems. These tanks get water from surface water bodies, runoff and from direct rainfall. Area of a minor tank is less than 80 ha. and at present 12,120 are in working order and the total irrigation potential is about 100,00 ha. In addition to that, minor tanks provide water for domestic needs, aquaculture and livestock needs(1). There are dilapidated and / or silted tanks also. Restoration of silted or damaged cascade minor tank systems in vulnerable areas is important.(2). This technology contributes to adaptation for climate change in following ways(3).

- Diversification of water supply
- Storm water control and capture
- Groundwater recharge

6.2 Technology characteristics/Highlights

- High-cost
- High technology

6.3 Institutional/ organisational requirements

- Planning, implementation etc. should be handled by experts.

7. **Operations and maintenance**

7.1 Endorsement by experts

7.1.1 (i) Operations(3)

The adaptation technology on restoration of cascade tank systems involves:

- Identification of location, condition and need for rehabilitation etc. of minor tanks.
- Preparation of planning maps showing water shed boundaries, microcatchment areas, cascade boundaries and predominant land use etc.
- Studies on hydrological potential of the tank, location in the cascade system, cultivation pattern etc.
- Steps for preservation, rehabilitation and modernisation of those tank systems (excavating soil, desiltination the tank bed, construction of new sluice gates, new spills, primary outlets etc.)
- Plant trees to cool waterways in order to minimise evaporation and also to minimise erosion. It would also facilitate the removal of pollutants.
- Water quality monitoring programs

Compacting the bund(5)

Sloping the bund(5)

Turfing against erosion(5)

(ii) Maintenance

Minor tanks are managed by farming community or farmer organisations with the technical support of the line agency as required

7.2 Adequacy for current climate

Negative consequences of the adaption option in the current climate:

Variations in normal rainfall pattern

7.3 Size of beneficiaries groups

About 3000 farmer families[1].

8. Costs

8.1 Cost to implement adaptation options

$ 932,500 for 50 minor tanks[1]

Additional costs to implement adaptation option, compared to "business as usual"

Additional cost is required:

- If the capacity of the tank will be increased
- Water quality testings

9. **Development impacts , indirect benefits**

9.1 Economic benefits

- **Employment** – Medium
- **Investment -** High; restoration of tank networks

9.2 Social benefits :

- **Income**
  - High; through agriculture, aquaculture etc.
- **Education**
  - Medium; Awareness programs should be given by experts.
  - Technical advice should be given whenever necessary by experts.
  - School education and research on this subject - medium
- **Health**
  - Medium effect; Decrease in diseases due to better sanitation because of the availability of water

9.3 Environmental benefits

- Impact on ground water quality and quantity –High; positive
- Impact on surface water quality and quantity – Medium
- Impact on flood control –High impact
- Release of GHG – high, due to the use of machines

10. **Local context**

10.1 (i) Opportunities

- Government has identified the importance of accelerating the development of irrigation and drinking water infrastructure and have taken steps to implement many irrigation development projects. It is planned to restore 100 small tanks per 5 years
- When other water sources are far away from home or when the quality of water is degraded
- Save time and cost

(ii) Barriers

- High cost
- High evaporation loss due to high ration of surface area to volume
- Seepage of tank volume and percolation losses from minor tanks is about 20%[(2)].

10.2 Status

- Tanks in various conditions can be seen in North Central, North, South and North of Sri Lanka.

10.3 Acceptability to local stake holders

- This will be acceptable to majority of local stakeholders as it would provide water during droughts, act as buffer reservoirs during floods and help in agriculture.

11. **References**

(1) Adaptation Fund: Proposal for Sri Lanka, AFB/PPRC. 14/11; Project and programme review committee, Bonn, June 2011

(2) Runoff rainwater harvesting interventions in Sri Lanka, M.A.C.S. Bandara and M.M.M. Aheeyar; (ISBN 978-955-612-116-2; 2010)

(3) Sri Lanka : Water Development Report:2010 ; K.A.U.S. Imbulana, N.T.S. Wijesekera, B.R.Neupane, M.M.M. Abeeyar and V.K. Nanayakkara, (ISBN 978-955-8395-02-8)

(4) Technologies for climate change adaptation-The water sector; Mark Elliot, Andrew Armstrong, Josep Lobuglio and Jamie Bartram, UNEP, (ISBN 978-87-550-3902-5); 2011

(5) 75 Minor tank development, Tec paper 21, 2002, Inventory, planning and mapping programme; Integrated Food Security Programme, Trincomalee

(6) Small village tank systems of Sri Lanka; Their evolution, setting, distribution and essential functions; P.R.Panabooke (2009)

Technology Fact Sheet 4

Rainwater Harvesting from Rooftops for Drinking and Household Uses

12. **Sector** – Water
13. **Technology characteristics**

13.1 Introduction

This technology involves harvesting and storing rain water from roof tops of houses/schools/hospitals/industries/other institutions as an alternative water source. This could provide about 30% of drinking and non-potable water (cooking, washing, agriculture) demand per household and specially addresses the water shortage in the dry zone and the intermediate zone. This technology contributes to adaptation for climate change in following ways[1].

- Reduces water stress during droughts
- Diversification of water supply
- Reduce the dependence on ground water and surface water.
- Recharge ground water aquifers.
- Reduce drinking of ground water containing pollutants
- Storm water control and capture (e.g. collection of rain water from roof tops of flats in Colombo can mitigate flooding)

13.2 Technology characteristics/Highlights

- Low-cost
- Simple technology

13.3 Institutional/ organisational requirements

- Awareness programs and initial training required should be given by experts.
- Construction and repairs should be done/managed by households.
- Technical advice should be given whenever necessary by skilled persons.
- Arrangements should be provided to test quality of stored water in a regular basis

14. **Operations and maintenance**

14.1 Endorsement by experts

3.1.1 Operations

Major components required for this technology are as follows:

- **Catchment area-**

  Catchment area is the roof surface consists of tiles/asbestos/zinc/aluminium/cement. Painted roofs can be used if the paint is non-toxic. Roofs made out of organic materials are not good.
- **Transport system for water** - gutters and pipes (PVC/aluminium)
- **How to prevent reaching contaminants present on the roof into the storage tank:**
  - Close the down pipe with an end cap or valve and discard the first flush.

- Rain water will be passed through a plastic mesh for screening and then pass through a filter unit (e.g. rubbles, charcoal, coarse sand and rubbles arrange from bottom to top in the filter unit) before collecting in the storage tank.
- Chemical disinfections can be added to preserve water

- **Storage tank** - Ferrocement tanks/plastic tanks or cheaper alternatives could be used as ground/underground or surface storage tanks.
- **Method for drawing water from the storage tank** - Depending on the type of tank, tap or pump can be used.

20 m^3 - partial underground tank at Maha Oya school[2]

Household surface tank at Komari[2]

Maintenance[3]

- Storage tank should be closed using a lid and should not allow sun light to enter.
- The whole rainwater collecting system should be cleaned at least 2-3 times per year, especially prior to the monsoon/ after a long period of dry weather/ after strong winds.
- Catchment surface and gutters have to be kept free of bird droppings, leaves and rubbish.
- The filter should be changed once in every three months.
- If RWH for piped systems is to be promoted, certain modifications may be necessary.

14.2 Adequacy for current climate

Negative consequences of the adaption option in the current climate:

- Mosquitoes can breed in lidless tanks
- Algae will grow in sunlit water
- Roofs that are inaccessible for cleaning get dirty

14.3 Size of beneficiaries groups

About 100% of population

15. Costs

15.1 Cost to implement adaptation options

Capital cost : Rs. 42000/= per 5 m^3 tank[(3)] (The cost of storage tank depends on its size, quality etc.)

Maintenance cost : Rs. 5000/=

Additional costs to implement adaptation option, compared to "business as usual"

Additional cost is required to:

- Increase the capacity of the tank – depends on the size

Monitoring of water quality – Rs. 3000/= per year

16. Development impacts , indirect benefits

16.1 Economic benefits

- **Employment** – medium (construction, cleaning)
- **Investment -**
  - Medium
  - If suitable roof is available, gutters, pipes and storage tanks are the capital requirements.
  - Operation life of a rooftop rainwater harvesting is 20 years

16.2 Social benefits :

- **Income**
  - Medium
  - Decrease the expenditure for purchasing water from other sources
  - Income through employment (construction etc)
  - Home gardening
  - Reduce cost & energy
- **Education**
  - Awareness programs to change public and community attitudes
  - Initial training required should be given by experts.
  - Technical advice should be given whenever necessary by skilled persons
  - School education on this subject – High
  - Research requirement - Medium
- **Health**
  - Medium effect; Decrease in waterborne diseases

16.3 Decrease in waterborne diseases

Environmental benefits

- Impact on ground water quality and quantity –medium (this technology can reduce the pressure for ground water withdrawal)
- Impact on surface water quality and quantity – medium
- Impact on flash flood forming – High
- Release of GHG – very little

17. Local context

17.1 (i) Opportunities

- *UDA* (Amendment) *Act*. no. 36 of 2007(5)
- In Sri Lanka, about 60% of the rain water (around 60 billion m^3) tend to run off finally ending in the sea(7).
- Save time for fetching water and cost
- Improved water quality
- High fluoride concentrations in drinking water and resultant diseases (e.g. Dental fluorosis) have become a common geo-environmental problem in the dry zone in Sri Lanka. Rainwater harvested from roof runoff is a good solution for this problem
- When other water sources are far away from home/degraded quality/unreliable/expensive
- Continuous supply of water
- Reduce flash flood due to rain storms

(ii) Barriers

- Severe droughts
- Inadequate or unsuitable roofing
- Lack of space for appropriate storage containers
- Areas having extreme air pollution (e.g. urban areas)

17.2 Status

- In Sri Lanka, at present supply of water through roof top rain water harvesting is less than 2%
- Capacity of the household water tank in wet zone is normally 5000L and in dry zone it is about 8000L(3).
- Millenium Information Technologival Ltd., Malabe, Maharagama Divisional Secretariat are a few examples for large scale applications(3)
- 20000L and 58000L storage tanks are currently being used in Ampara and Galle respectively(3).
- The roof size, roof material and the rain fall determine run-off rain water content

17.3 Acceptability to local stake holders

Because of the following reasons this technology will be acceptable to stakeholders.

- Low-cost and absence of fluoride and other contaminants in harvested water
- Control flash flood due to rain storms

18. References

(1) Technologies for climate change adaptation-The water sector; Mark Elliot, Andrew Armstrong, Josep Lobuglio and Jamie Bartram, UNEP, (ISBN 978-87-550-3902-5); 2011

(2) Lanka Rain Water Harvesting Forum, 2005

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(4) Water for rural life- 21st March 2009 (The Island, 21-03-2009) http://www.island.lk/2009/03/21/features1.html

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(6) Development through rainwater harvesting - Sustainable social and economic development for resettlements in North and East through rainwater harvesting (Daily News, 19-09-2009) http://www.dailynews.lk/2009/09/19/fea01.asp

(7) Sri Lanka Water development report-2010, K.A.U.S. Imbulana, N.T.S. Wijesekera, B.R. Neupane and V.K. Nanayakkara; ISBN 978-955-8395-02-

Technology Fact Sheet 5

Solar Distillation

Sector – Water

- **Technology characteristics**

1. **Introduction**

Intrusion of sea water into fresh water will be a problem due to sea level rise. Under such a situation, this technology can be used to produce fresh water. In this method safe drinking water is produced through distillation of fresh water contaminated with sea water/ brackish water by using solar energy. As the water evaporates, water vapour rises and condenses on a glass surface for collection. Life time of the still is about 20 years(1).This technology would give 44% of drinking water requirement in areas vulnerable to sea level rise. Solar distillation technology can also be used to remove fluoride from fluoride containing water.

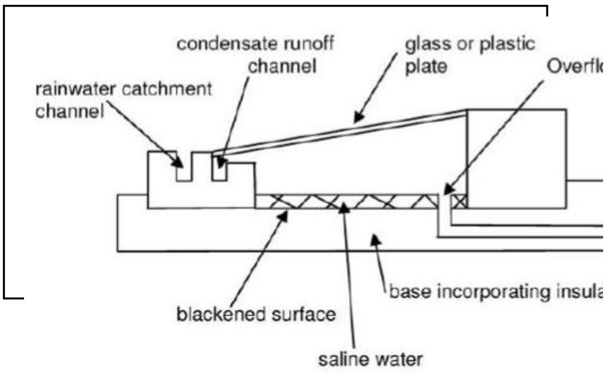
2. **Technology characteristics/Highlights**
   - Low cost
   - Simple
3. **Institutional/ organisational requirements**
   - Awareness programs and initial training required should be given by experts.

- **Operations and maintenance**

4. **Endorsement by experts**

   i. **Operations(2)**

- Solar still is a passive solar distillation process and the only energy source needed is solar energy.
- A flat and level area with direct access to water and sun is necessary.
- A conventional solar distiller is a box with a glass roof (glaze) set at an angle from the horizontal to ensure optimal exposure to sun light. This angle is roughly equal to the latitude of the location.
- Untreated water is routed into a holding basin inside the distiller.
- Radiation from sunlight penetrates the glass and heats the inside of the distiller, causing the water in the basin to evaporate.
- The absorption of higher frequency radiation heats the water. The glaze traps infrared re-radiation cause a greenhouse effect resulting in higher temperatures.
- The evaporation process separates contaminants from the water and results in a thin condensate on the underside of the glass cover.
- The condensed, distilled water then runs off the glass into a trough, and is transferred to a water storage container for domestic use.
- Two diagrams of the system are given below(3).



ii. **Maintenance**

- May need to add required amounts of minerals.
- Contaminants and particulates remain in the basin must be washed away periodically

b. **Adequacy for current climate**

Negative consequences of the adaption option in the current climate:

- Production rate is about 6 L per sunny day per square meter.
- Efficiency of a single basin solar still is 60%(2)(Solar still efficiency is the amount of energy utilized in vaporizing water in the still over the amount of incident solar energy on the still)

c. **Size of beneficiaries groups:**

Coastal population and the population using water containing with fluoride ions)

5. **Costs**

a. **Cost to implement adaptation options**

- SolAqua – Rain maker is commercially available in certain other countries
- The price is $ 489(2) + shipping charges
- Instead of purchasing the SolAqua system, similar solar still systems can be made locally and it will be cheaper

Additional costs to implement adaptation option, compared to "business as usual"

- Additional cost is required for greater water production (e.g. for a community)
- If it is necessary to pump water and operate the above plant; The power necessary to pump water could be obtained by fitting solar panals to the plant.

6. **Development impacts , indirect benefits**

a. **Economic benefits**

- **Employment** – Medium (construction of solar distillation units etc)
- **Investment -** Medium **(**Production of solar distillation units)

b. **Social benefits**:

- **Income –**
  - Medium
  - Additional income from the by-product salt formed during desalination of sea water
  - Decrease expenditure for purchasing water from other sources
- **Education**
  - Awareness programs and initial training required should be given by experts for the target groups.
  - Technical advice should be given whenever necessary by experts.
  - This will be an additional education in solar technology for students, possibly taking the knowledge with them in their daily lives, and to the future
- **Health –**
  - High impact; Decrease in waterborne diseases
  - Long term health benefits due to drinking of good quality water

5.3 Environmental benefits

- Impacts on ground and surface water quality - none
- Release of GHG –No; Energy consumption- solar energy

6. Local context

6.1 (i) Opportunities

- Solar energy is freely available in Sri Lanka
- Due to climate change, if fresh water gets contaminated due to intrusion of salt water, this technology will be useful.

(ii) Barriers

- Release of waste containing salt can affect the environment.
- Production is low; e.g. Production per day by the above plant is about 10L (Tropical country)[1]

6.2 Status

Over the past century, hundreds of solar still plants and thousands of individual stills have been built around the world

6.3 Acceptability to local stake holders

Due to low cost and low technology this will be acceptable to stake holders. This technology will be especially useful for the vulnerable areas to sea level rise and also for the dry zone having high fluoride contents in water.

7 References

(1) www.solucionespracticas.org.pe/fichastecnicas/pdf/solar_distillation.pdf

(2) www.solaqua.com/solstilbas.html

(3) wikipedia:solar distillation

(4) http://issuu.com/hanac66/docs/solar_distillation

Technology Fact Sheet 6

Surface Runoff Rainwater Harvesting

7. **Sector** – Water
8. **Technology characteristics**
   a. **Introduction**

In Sri Lanka about 60% of rain water is running to the sea without direct use(1) . Non-availability of adequate rainfall during “Yala” season is a problem for crop production in the dry zone. In this technology, surface run-off rain water is collected in ponds. This is a micro storage facility and especially suitable for arid and semi-arid regions. It provides supplementary irrigation for about 1-2 ha. of land.

Collection of surface runoff rainwater as pokuna/pathaha is presently practising in certain areas and it has to be expanded. This technology contributes to adaptation for climate change in following ways(2).

- Additional water supply
- Reduce pressure on surface and ground water resources
- Control soil erosion due to rain storm flow
- Reduce flood inflow to rivers and channels
- Stabilise ground water table

b. **Technology characteristics/Highlights**

- Low cost
- Simple technology

c. **Institutional/ organisational requirements**

- Expert assistance should be given by experts to select appropriate sites based on soil permeability, run-off direction etc.
- Information on quantity of water required for irrigation purpose, rainfall pattern of the area and amount of investment that can be made should be made available when constructing a pond.
- Technical advice should be given whenever necessary by skilled persons

9. **Operations and maintenance**
   a. **Endorsement by experts**
      i. **Operations(3)**

Major components of a surface runoff rainwater system are as follows.

- Microscale water harvesting ponds (Unlined: 300–500 m^3 capacity or lined ponds (3-3.6m depth and 3-4m diameter: 120-150m^3capacity) are excavated using soil excavators; These ponds should be built at lower elevation of the farm land via contour drainage using the gravitational flow[(3)].

- Based on the soil type unlined or lined ponds have to be selected, If the soil type is sandy, it is necessary to build lined ponds
- Depth of the pond is important to minimise evaporation (e.g.3-4.5 m diameter; 3-3.6 m depth)
- Lined ponds are completely lined with bricks and cement
- Construct the earth bunds using excavated soil
- Use a soil trap to trap the silt coming with run off
- Mud- filters are used to reduce the flow of waste items into the tank.
- Spill space (outlet) should be constructed in order to facilitate the flow of excess water
- Hand pumps or peddle pumps can be used to lift water from lined ponds.

ii. Maintenance

- Owned and maintained by individual beneficiaries.
- To prevent soil erosion, maintain grass on the bund around the ponds.
- A small thatched hut and fence should be constructed around the tank to reduce the evaporation of water and for the security of children & domestic pets/other animals.
- When the tank is empty, remove all soil deposits and other waste products from the bottom of the tank and clean it well.
- Should not let aquatic plants to grow in the tank as these will increase water loss through evapotranspiration.
  - Still waters are breeding grounds for mosquitoes. Therefore fish which kill mosquito larvae eg. ‘ Korali’- Oreochromis mossambicus should be introduced into the tank.
- When the soil type is sandy, it is necessary to build lined ponds and it is expensive.

b. Adequacy for current climate

Negative consequences of the adaption option:

- Mosquitoes can breed in water in the pond
- During severe droughts pond can get dried due to evaporation
- Technical errors and poor quality construction can cause leakage of stored water within a short period of time
- Low water availability will also be a failure

c. Size of beneficiaries groups

About 30% of the total population (dry zone)

10. **Costs**

   a. **Cost to implement adaptation options**

   Rs. 25000 - 150000/= per tank (cost varies with the size and the type of the tank)

   b. **Additional costs to implement adaptation option, compared to "business as usual"**

   Additional cost is required to increase the capacity of the pond

11. **Development impacts , indirect benefits**

   a. **Economic benefits**

- **Employment** – Medium (construction, agriculture, aquaculture)
- **Investment -** Medium **(**Cost for construction of lined or unlined ponds)

   b. **Social benefits** :

   Income

- Medium
- Additional income through agricultural intensification, enhanced livestock and aquaculture
- ➢ Decrease the expenditure for obtaining piped water for agricultural purposes
- ➢ Income through soil excavation, construction etc

   Education

- Awareness programs and initial training required should be given by skilled persons.
- Technical advice should be given whenever necessary by experts.

   Health

   c. **Environmental benefits**

  - Reduce pressure on surface and ground water resources
  - Effect on ground water recharge– Very high
  - Effect on surface water – Medium
  - Control floods and soil erosion due to rain storms
  - Release of GHG –Medium; Energy consumption- Medium

12. **Local context**

   a. **(i) Opportunities**

  - In Sri Lanka about 60% of rain water is running to the sea without direct use(1).
  - The land area under the dry zone is about 4.5 million ha and it is about 65% of the land in Sri Lanka. The dry zone receives most of the rain from the NE monsoon rains. At present, out of the total land area of the dry zone only about 2 million ha are used for agriculture mainly due to unavailability of adequate water(3).
  - Various NGOs and other organisations have given the necessary support to construct surface run-off rainwater harvesting systems

   (ii) Barriers

  - Longer droughts
  - Unless the most suitable sites are not selected scientifically, it can be a failure
  - Lined ponds are not economically feasible

- Low water availability and the lost of harvested water within a short period in certain ponds

b. Status

- At present, available in districts such as Puttalam, Moneragala, Hambata and Anuradhapura.
- Capacity of most of the unlined and lined ponds are about 300–500 m^3 and ponds: 120-150 m^3respectively).
- Life time of a pond is about 10 years.

c. Acceptability to local stake holders

This technology will be acceptable due to following reasons:

- Simple technique
- Low cost
- Additional water supply for agriculture, aquaculture etc.

13. References

(1) Rain Water harvesting, Practitioners guide for Sri Lanka; Lanka Rain Water Harvesting Forum (ISBN 978-955-1064-06-8);2009

(2) Technologies for climate change adaptation-The water sector; Mark Elliot, Andrew Armstrong, Josep Lobuglio and Jamie Bartram, UNEP, (ISBN 978-87-550-3902-5); 2011

(3)Runnoff rainwater harvesting interventions in Sri Lanka, M.A.C.S. Bandara and M.M.M. Aheeyar; (ISBN 978-955-612-116-2; 2010

Technology Fact Sheet 7

Household Drinking Water Treatment and Safe Storage

19. **Sector** – Water

20. **Technology characteristics**

20.1 Introduction

It is reported that in 2010, up to 88% of waterborne diseases in Sri Lanka were due to consumption of unsafe drinking water(1). Scarcity of water due to climate change can increase this problem. In 2007, 10% of the total population did not have access to safe water(2). In 2010, piped borne water coverage in Sri Lanka was around 39%(2). When safe water is not available, a safe drinking water supply should be provided. Household drinking water treatment is a possible solution for this problem. Incorporation of a chemical coagulation step for particle removal (flocculation) and a chlorination step for disinfection can be used for this purpose. Water purification sachets containing chemicals required for above purpose could be produced /imported and distributed for people who do not have access for safe drinking water. This technology contributes to adaptation for climate change by ensuring a supply of safe drinking water

20.2 Technology characteristics/Highlights

- Low-cost
- Simple technology

20.3 Institutional/ organisational requirements

- Encourage relevant parties to produce water treatment sachets locally.
- Awareness programs and initial training required should be given by experts to households.
- Technical advice should be given whenever necessary by experts.
- Arrangements should be provided to test quality of purified water in a regular basis.

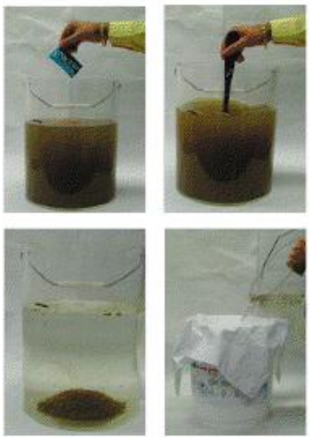
21. **Operations and maintenance**

21.1 Endorsement by experts

21.1.1 Operations

- Water purification sachets contain calcium hypochlorite for disinfection and a flocculant (e.g.ferrous sulphate) to precipitate dirt, parasites etc. and other impurities from water
- Water purification sachets will be provided to homes/schools etc. where safe drinking water supply is not available
- Contents in the sachets are added into 10L of water. Stir well for 5 minutes and then leave it for 5 minutes. If water is not clear, stir again until the flock is separated.
- Using a clean 100% cotton cloth or a suitable filter, filter it. Leave it for 20 minutes and then store in a container.

- If water is coloured should not use that water
- Water treatment sachets called Pu-R developed by Proctor & Gamble (P&G) in collaboration with the US Centers for Disease Control and Prevention (CDC)[(2)] are commercially available in certain countries.
- It is reported that, use of Pu–R have reduced diarrheal disease incidence by 16 % to more than 90 % in five randomized controlled health intervention studies[(2)].



3.1.2 Maintenance

- A clean cotton cloth should be used to separate the flock from water
- A clean container should be used to store purified water
- Quality of treated water should be tested

21.2 Adequacy for current climate

Negative consequences of the adaption option in the current climate:

- Salinity, nitrates, fluorides etc. are not removed by this method

21.3 Size of beneficiaries groups

19% of the total population, who does not have access for safe drinking water.

4.0 Costs

21.4 Cost to implement adaptation options

- The cost of a sachet is about 0.10 US $ + shipping charges
- Water quality testings (Rs. 5000/=)
- Expenditure for research on development of low cost purification sachets (Rs. 50000/=)
- Maintenance cost (Rs.200)

Additional costs to implement adaptation option, compared to “business as usual”

- May be cheaper if produced locally
- Expenses for water quality monitoring is required

22. Development impacts , indirect benefits

5.1 Economic benefits

- **Employment** – medium (Production of water treatment sachets)
- **Investment** - Low, Import/Production of water treatment sachets

5.2 Social benefits :

- **Income**
  - Medium
  - Income through employment (production of water treatment sachets)
  - Less expenditure on medical care
  - Easily transported (due to their small size, long shelf life, and classification as non-hazardous material for air shipment);
- **Education**
  - Awareness programs and initial training required should be given by experts.
  - Technical advice should be given whenever necessary by experts.
  - School education on this subject - medium
  - Research requirement – medium
- **Health**
  - High impact
  - This technology would decrease waterborne diseases due to supply of drinking water without pathogens.
  - Removal or inactivation of viruses, bacteria, parasites, heavy metals, and pesticides

5.3 Environmental benefits

- Impact on ground water quality and quantity –No impact
- Impact on surface water quality and quantity – No impact
- Impact on flood forming – No impact
- Release of GHG – May release GHG during the production of required chemicals

6. Local context

6.1 (i) Opportunities

- When there are severe disasters, this technology can be used to purify water at household level
- In the midst of a waterborne disease outbreak
- Aesthetic improvement

(ii) Barriers

- During non crisis periods demand is low

6.2 Status

- This method was introduced in Ethiopia in 2007
- Certain people in Sri Lanka used this method after Tsunami

6.3 Acceptability to local stake holders

In areas where safe water is not available, this method could be implemented.

7. References

(1) SRI LANKA: Lack of safe drinking water leading to upsurge in health problems, Aug. 2010, http://reliefweb.int/node/365994

(2) Sri Lanka : Water Development Report:2010 ; K.A.U.S. Imbulana, N.T.S. Wijesekera, B.R.Neupane, M.M.M. Abeeyar and V.K. Nanayakkara, (ISBN 978-955-8395-02-8)

(3) Technologies for climate change adaptation-The water sector; Mark Elliot, Andrew Armstrong, Josep Lobuglio and Jamie Bartram, UNEP, (ISBN 978-87-550-3902-5); 2011 www.youthxchange.net/main/purwater.asp

Technology Fact Sheets (TFS)

Coastal Sector

Technology Fact Sheet 1

Restoration of Coral Reefs

23. Sector: Coastal

24. Technology characteristics

24.1 Introduction to establishment of artificial reefs by transplanting corals:

Coral reefs are underwater structures made from calcium carbonate secreted by corals which are biologically classified as Cnidarians (coelenterates). **Corals** are marine organisms in class Anthozoa of phylum Cnidaria typically living in compact colonies of many identical individual "polyps". The group includes the important reef builders that inhabit tropical oceans and secrete calcium carbonate to form a hard skeleton. Coral forming organisms construct the reef by secreting hard skeletons of aragonite (a fibrous, crystalline calicium carbonate). Most coral reefs are built from stony corals, which in turn consist of polyps that cluster in groups. The polyps are like tiny sea anemones, to which they are closely related. But unlike sea anemones, coral polyps secrete hard carbonate exoskeletons which support and protect their bodies. Reefs grow best in warm, shallow, clear, sunny and agitated waters. Garison, 1995; http://en.wikipedia.org/wiki/

Coral reefs often called “rainforests of the sea” and they form some of the most diverse ecosystems on Earth. They occupy less than one tenth of one percent of the world's ocean surface, about half the area of France, yet they provide a home for twenty-five percent of all marine species (Dali et al. as quoted in http://en.wikipedia.org/wiki/Coral_reef) including other marine vertebrates and invertebrates] Paradoxically, coral reefs flourish even though they are surrounded by ocean waters that provide few nutrients. They are most commonly found at shallow depths in tropical waters, but deep water and cold water corals also exist on smaller scales in other areas.

Coral reefs deliver ecosystem services to tourism, fisheries and shoreline protection. The annual global economic value of coral reefs has been estimated at $US375 billion. However, coral reefs are fragile ecosystems, partly because they are very sensitive to water temperature. They are under threat from climate change, ocean acidification, blast fishing, cyanide fishing for aquarium fish, mining for lime industry and overuse of reef resources, and harmful land-use practices, including urban and agricultural runoff and water pollution, which can harm reefs by encouraging excess algae growth. (http://en.wikipedia.org/wiki/Coral_reef; Kumara 2008)

The two main variables determining the geomorphology, or shape, of coral reefs are the nature of the underlying substrate on which they rest, and the history of the change in sea level relative to that substrate.

The approximately 20,000 year old Great Barrier Reef offers an example of how coral reefs formed on continental shelves. Sea level was then 120 metres (390 ft) lower than in the 21st century.(Veron, 2000;

Toller et al., 2001) As sea level rose, the water and the corals encroached on what had been hills of the Australian coastal plain. By 13,000 years ago, sea level had risen to 60 m (200 ft) lower than at present, and many hills of the coastal plains had become continental islands. As the sea level rise continued, water topped most of the continental islands. The corals could then overgrow the hills, forming the present cays and reefs. Sea level on the Great Barrier Reef has not changed significantly in the last 6,000 years (Veron, 2000), and the age of the modern living reef structure is estimated to be between 6,000 and 8,000 years (Barnes & Hughes, 1999). Healthy tropical coral reefs grow horizontally from 1 to 3 cm (0.39 to 1.2 in) per year, and grow vertically anywhere from 1 to 25 cm (0.39 to 9.8 in) per year; however, they grow only at depths shallower than 150 m (490 ft) due to their need for sunlight, and cannot grow above sea level (Hatta, et.al., 1999).

24.2 Technology Characteristics/Highlights

As an adaptation for expected sea level rise as a result of climate change, this natural reef building mechanism continued during the evolutionary process, should be artificially enhanced by providing hard substrata attached with relevant samples of temperature tolerant live corals to produce artificial coral reefs. At University of Ruhuna, transplanting of corals on concrete blocks and tiles have been successfully implemented by a group of marine scientists led by Dr. Terney Pradeep Kumara, under the financial assistance under the SIDA (Sweden) coastal & Marine Science Project of University of Ruhuna and the Tsunami rehabilitation programme funded by CIDA (Canada) (Plates 1 2 & 3).

Plate 1: Tiles used to transplant corals & a tile with corals grown within 1 year

Plate 2: ***Transplanted corals on cement tiles in situ. Initial stages (left) and after the growth of corals (right)*** Photographs by P.B.T.P. Kumara

Plate 3: ***Transplanted corals on wire mesh.*** Photographs by P.B.T.P. Kumara

This includes propagation of corals using small pieces of live coral attached to larger peces of coral rbble (dead coral) which are fixed to different types of artificial material such as concrete tiles, clay tiles or to wire mesh. These methods have been successfully adopted by a group of marine scientists at University of Ruhuna led by Dr. Terney Pradeep Kumara and have been identified as a promising method for restoration of reefs degraded due to natural and anthropogenic disturbances and for development of artificial reefs for ecotourism. This technique could be adopted to reinforce the effect of hard technologies such as sera dikes, sea walls, etc. used (Figure 1) for minimising coastal erosion or to reduce impacts from coastal inundation that may occur as a result of sea level rise due to climate change.

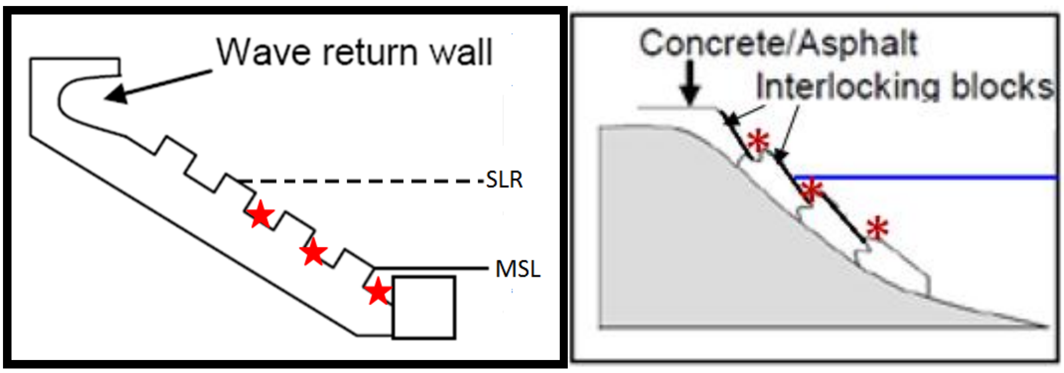


Figure 1: *Modified drawing of a sea wall with a structure that helps the return of the waves could be used as a hard substratum to establish artificial coral beds. Places within an irregular faced sea walls (★) and on the revetments with interlocking blocks (*) sea walls suitable to fix the tiles with transplanted corals or plots with sea grasses considering the water level due to sea level rise. MHWS- MSL- Mean sea level; SLR- Water level at sea level rise. (Source: Adopted from French, 2001)*

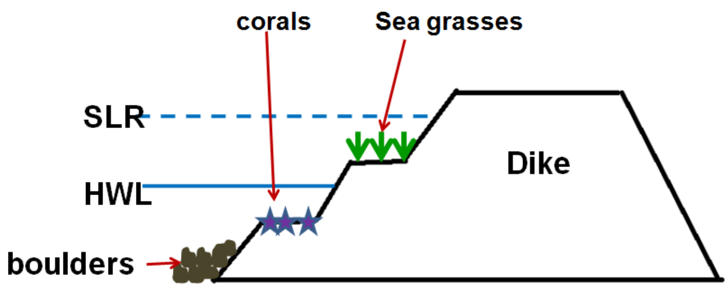


Figure 2: *Proposed design of a dyke with the landward aslope having a terraced structure to enable transplanting corals and establishing seagrass plots during high water levels (HLW) and sea level rise (SLR). This would gradually enhance the settlement of more adaptive temprature tolerant marine benthic organisms*

In areas where there is no impact from river sedimentation corals could be grown on tiles (Plates 1 & 2) and in those affected by sedimentation wire meshes placed above the natural or artificial substratum could be used (Plate 3). Corals can be grown as rock coltures and small pieces of rocks attached with coral plyps could be fixed on to the hard defense structures as shown in Figure 1. As an adaptation for climate change coral species used for transplanting should be the species with high tolerance for upper limits of temperatures prevailing in coastal areas. Transplanting should be done when the sea is calm in order to get the coral polyps established on tiles and a considerable growth is resulted prior to rough conditoions appear during monsoon seasons.

For successful implementation of the above programme carefully monitored research programmes are essential to identify the following

- Temperature tolerant species of corals available in different parts of the coastal belt of Sri Lanka
- Other coastal species found in association of coral forming organisms, that would enhance the growth and existance of natural & transplanted coral forming organsms.

24.3 Institutional/ organisational requirements

Facilities for snorkeling and facilities for construction of cement tiles attached with coral rubble should be provided to academic and research institutions and also to local societies and hoteliers who are involved in coral reef conservation, rehabilitation & management and located in the vicinity of the sites selected within the existing coral reefs that needs restoration and transplanting of corals.

25. Operations and maintenance

25.1 Endorsement by experts

Coral transplanting is a technology accepted worldwide for restoration of coral reefs and to establish artificial reefs

25.2 Adequacy for current climate

Currently coral reefs are existing in Sri Lanka and there are species which can stand higher temperatures than most others and they are found in Sri Labnkan coastal waters. In the Southern coastal belt of Sri Lanka. Coral genera most commonly observed in shallow coastal reefs are *Pocillopora, Acropora* and *Montepora* (Kumara, 2008). Therefore species of these genera which are commonly occurring could be used for transplanting purposes.

25.3 Size of the beneficiary group

Coastal communities depending on reef communities, such as tourist guides, ornamental fish collectors, tourist industry within the coastal belt, etc. could be considered as beneficiaries and to quantify the numbers of beneficiaries detailed surveys should be carried out with respect to the coastal belts associated with different coral reefs. Location of the coral reefs are given in the Map given in figure 2.

Figure 2: **Distribution of coral reefs along the coastal belt of Sri Lanka, Each orange coloued patch indicates one fringing reef (Rajasooriya & White, 1995)**

In addition to the above establishment of artificial reefs will improve the status of the coastal biodiversity and hence the fish populations depending on reefs for food, shelter, etc. This will enhance the coastal fish production.

26. Costs

4.1Cost to implement adaptation options

Costs up to the Phase 4 will be given herein because the area to be included for the Phase 5 will be decided on the success of the project up to phase 4.

Activity	cost	
	Unit cost (US$/m)	Total cost (US $)
Field surveys to decide the suitable sites (duration 6 months)		10,000
Training workshops 10 Nos	3,000	30,000
Material for prepare substrata for transplanting 10 sites of 1 ha (100,000m^2)	40/m^2	4,000,000
Allowances for persons (10) involved in trasplanting and taking care of the transplants for 2 years		40,000
Transport & other miscellaneous costs		8,000
Contigencies		202,000
Total cost up to phase 4	14.3/m^2/yr	4,290,000/10 ha/3yrs

26.1 Additional costs to implement adaptation option, compared to “business as usual”

This technology could be coupled with the construction of hard defenses such as sea walls and dykes as shown in Figure 2 and in such occasions cost for such hard structures also should be taken in to consideration.

To receive maximum benefits from this technology, awareness & sensitivity on the importance of coral reefs should be improved among all stakeholders, who are depending on reefs. Therefore, awareness among coastal communities, school children, hoteliers, industrialists, should be improved. Thus there is a need for conducting awareness programmes whenever necessary.

Development impacts, indirect benefits

26.2 Economic benefits

26.2.1 Employment

This project will provide employment opportunities to person involved in coastal construction sector, coastal zone management sector, tourism industry, etc. Indirectly income of the fishermen will be improved

26.2.2 Investment :

- Improvement of foreign exchange earnings through tourism.
- Income to fisher communities due to improvement of coastal stocks
- Provision of protection to coastal infrastructure
- Opens up recreational sites for holiday makers

26.3 Social benefits :

- **Income**
  - 26.3.1.1.1.1 Improvement of economy as the expenditure on repairing the damages caused to their properties due to coastal erosion.
  - 26.3.1.1.1.2 Socioeconomic status of coastal communities due to reduced risk of coastal inundation and erosion
  - 26.3.1.1.1.3 Increased income to persons involved in tourism (especially in eco-tourism), coastal resource management and hotel sectors.
  - 26.3.1.1.1.4 Increased income to fisher communities
- **Education**
  - Improvement of awareness on the importance of conservation, management and restoration of coral reefs
  - Improvement of scientific knowledge on the sensitivity and complexity of reef building and reef associated biotic communities
  - Adaptation to natural phenomena by scientifically maneuvering the natural coastal ecosystems
  - Knowledge on the establishment of artificial structures within the coastal belt, with least impacts on sensitive ecosystems
  - Transplanted structures could be used for field training
- **Health**
  1. Improved security of coastal dwellings will naturally improve the health & mental conditions of coastal communities
  2. Proper management of coastal ecosystems by controlling harmful anthropogenic activities such as pollution, coral mining, illegal fishing, etc. to protect the reefs will provide the coastal communities a healthy atmosphere and a better income through proper management of coastal fish communities, which will also help them to maintain healthy families.

26.4 Environmental benefits

- Restoration of corals and their transplanting will form a more effective barrier with respect to wave action, inundation, erosion, etc. which will reduce the negative impacts to coral reefs from natural phenomena.
- Provision of shelter for other reef associated organisms will improve the stability of reef ecosystems and also will improve the biodiversity
- Utilisation of CO_2 for internal & external hard skeletons (corals, shellfish such as mollusks, crustaceans, etc will reduce the CO_2 concentration in coastal habitats, reducing its impacts on global warming

27. Local context

27.1 Opportunities & Barriers

27.1.1 Opportunities

- For coastal scientists, coastal engineers and coastal zone managers will get a very good opportunity to use their knowledge and experience to find solutions for global warming and for sustainable management of coastal resources & coastal ecosystems to be adapted for climate change at the local level
- Coastal resource utilisers and those who were involved in destructive activities harmful to coastal ecosystems will get an opportunity to obtain a training to sustainably manage the coastal resources for their own benefit.
- Academics and researchers will get an opportunity to conduct useful scientific research to reduce the impacts of climate change to coastal ecosystems and communities
- Sri Lanka will get an opportunity to make possible contributions to find solutions for local regional and global problems that may faced due to climate change.
- More fish will be available
- Reduce pollution levels

27.1.2 Barriers

- High cost incurred on coastal constructions, coral transplanting, training personnel and to provide security against harmful anthropogenic activities against coral transplants and other associated artificial structures
- Lack of or insufficient political commitment for coastal resource conservation and management.
- Low inputs by the government on coastal & marine science education, due to ignorance of the importance of marine science education and the cost incurred to provide facilities (capacity building) for marine science education.
- Insufficient or lack of motivation and knowledge of the coastal & marine resource utilisers on the importance of sensitive coastal marine ecosystems and their sustainable utilization.
- Reluctance of older generation of the coastal communities to acquire new knowledge and to accept that certain practices adopted by them for fishing and other socio economic activities could cause serious threats to sensitive coastal ecosystems and their biodiversity.

27.2 Status

Technology for coral transplanting has been successfully implemented in the southern coastal belt by a group of scientists led by Dr. P.B.T.P. Kumara (dept. of Oceanography & Marine Geology, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna. Such technologies should be adopted in a larger scale at other reef sites independently and in combination with hard defense technology.

Studies on Coral diversity & distribution has been conducted during the past decade and there is sufficient knowledge with respect to their biology, sensitivity & their resilience.

27.3 Time frame

	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites	X											
Awareness/training		X										
Preparation of transplant material			X									
Transplanting/monitoring				X	X	X	X	X				
Transplant coupled with hard defense structures							X	X	X			
Monitoring								X	X	X	X	
If successful adoption to wider area										X	X	
Evaluation of success						X			X			X

27.4 Acceptability to local stake holders:

- Younger generations with secondary & tertiary education will accept this technology and also during the transplanting programmes carried out by the University of Ruhuna their assistance was obtained and some received an allowance on days of involvement and a few worked voluntarily
- School children showed enthusiasm during workshops conducted on school science day programmes
- Adult male members of the coastal communities involved in fishing and other coastal activities did not show much interest in participating in workshops conducted.
- Hotel owners and diving training institutes of Hikkaduwa offered fullest cooperation.
- CCD & MEPA has continuously provided necessary assistance.

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Technology Fact Sheet 2

Replanting of Sea Grasses

29. Sector: Coastal

30. Technology characteristics

30.1 Introduction to establishment of seagrass beds by replanting seagrasses:

Sea Grasses are flowering plants belong to four families (Posidoniaceae, Zosteraceae, Hydrocharitaceae & Cymodoceaceae) of the order: Alismatales and Class: Monocotyledons, which grow in marine, fully saline environments. These unusual marine flowering plants are called *seagrasses* because the leaves are long and narrow, are very often green and and often grow in large "meadows". They superficially resemble terrestrial grasslands. They are found submerged within the photic zone, in the shallow and sheltered coasts, because they are photosynthetic organisms. They possess a well developed underground plant parts consists of rhizomes and root system which are extensive and close to each other, helps them to be anchored to sand or mud bottoms in many places (Dawes, 1981).

They undergo pollination while submerged and complete their entire life cycle underwater. Seagrasses form extensive beds or meadows, which can be either monospecific (made up of one species) or multispecific (co-existance of many species) and the tropical seagrass beds belongs to the latter.

(http://en.wikipedia.org/wiki/Seagrass)

Plate 1; Seagrasses found in the sea grass bed in Mannar off Pallimunai. *Hallophila ovalis* (left), *Enhalus acoroides,* (middle) & *Cymodocea rotundata* (right) during a study conducted by Cumaranatunga et al.(2010) (Photographed by P.B.T.P. Kumara)

2.7.2 Importance of sea grass beds to other marine organisms

Seagrass beds are productive ecosystems, and they provide permanent or temporary refuge to many other organisms either during the whole life time or during a certain stage of their life cycles. For example juvenile and adult fish, epiphytic and free-living macroalgae and microalgae, mollusks, bristle worms, and nematodes.Scientific investigations have revealed that despite their low nutritional content, seagrass herbivory is a highly important link in the food chain, with hundreds of species feeding on seagrasses worldwide (e.g. green turtles, dugongs, manatees, fish, sea urchins, crabs, etc). (http://en.wikipedia.org/wiki/Seagrass)

2.7.2 Important services provided by the Sea grasses for ecosystem stability

Seagrasses are sometimes referred to as ecosystem engineers, because they partly create their own habitat: the leaves slow down water-currents increasing sedimentation and the seagrass roots and rhizomes stabilize the seabed (http://en.wikipedia.org/wiki/Seagrass.

Their importance for associated species is mainly due to provision of shelter (through their three-dimensional structure in the water column), and for their extraordinarily high rate of primary production. As a result, seagrasses provide coastal zones with a number of ecosystem goods and ecosystem services, for instance fishing grounds, wave protection, oxygen production and protection against coastal erosion. Seagrass meadows account for 15% of the ocean's total carbon storage. They slowdown the water current, maintaining water clarity by trapping sediments to allow light penetration and providing shade and habitats for small marine species. The ocean currently absorbs 25% of global carbon emissions. Due to the above services provided by the sea grass meadows, they are very useful for forming a protective belt as an adaptation for the coastal erosion that may occur due to sea level rise & also for removal of CO_2.

Disturbances and threats to seagrass beds

Natural disturbances such as grazing, storms, ice-scouring, and desiccation are an inherent part of seagrass ecosystem dynamics. Seagrasses display an extraordinarily high degree of phenotypic plasticity, adapting rapidly to changing environmental conditions. Seagrasses are in global decline, with some 30,000 km^2 (12,000 sq mi) lost during recent decades. The main cause is human disturbance, most notably eutrophication, mechanical destruction of habitat (due to using drag nets for fishing and nchorage of boats), and overfishing. Excessive input of nutrients (nitrogen, phosphorus) is directly toxic to seagrasses, but most importantly, it stimulates the growth of epiphytic and free-floating macro- and micro-algae. This weakens the sunlight, reducing the photosynthesis that nourishes the seagrass and the primary production results. **http://en.wikipedia.org/wiki/Seagrass**

31. Technology Characteristics/Highlights

Since Sea grass diversity may change with salinity & temperature, species with wide tolerance range for salinity and temperature variations and those which are having a strong root systems that would help to stand high wave action should be selected for this purpose. This technology could be used as a soft defence technology (Figure 1) and also togethher with hard defence technology as shown in figure 2 & figure 3. Seagrass plots could be propagated in cement tanks with seawater circulation or on the coastal belt where seagrasses are abundant and plots of seagrasses or individual plants could be tranfered to areas where transplanting is needed

32.

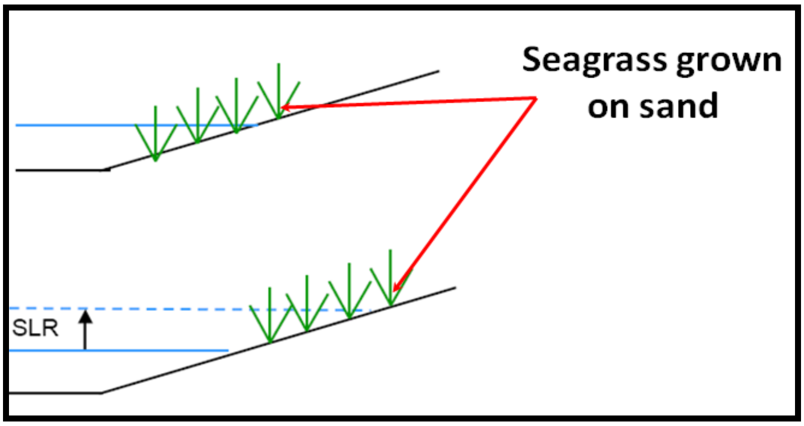

Figure 1: Where hard defences are not present, sor they will migrate upwards and landwards with SLR (modified from Linham & Nicholls, 2010)

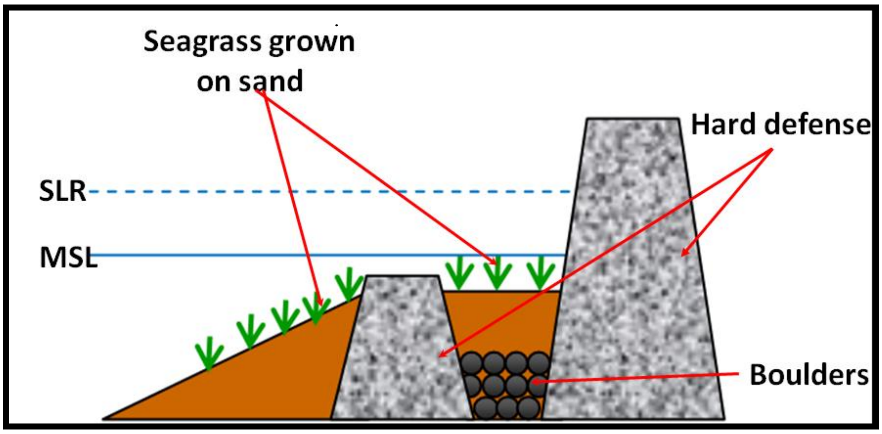

Figure2: establishment of seagrass beds as a soft defense or together with hard defense

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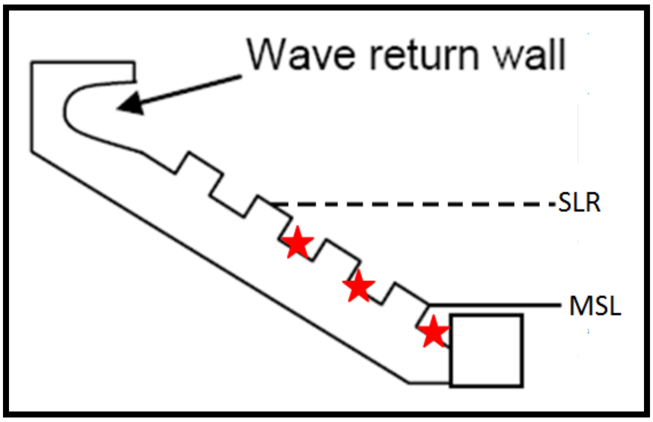

Figure 3: Modified drawing of a sea wall with a structure that helps the return of the waves could be used as a hard substratum to establish seagrass transplants

(Source: Adopted from *French, 2001).* ★ *- Places suitable to establish seagrass plots. MSL- Mean sea level; SLR-Water level at sea level rise*

2.1 Institutional/ organisational requirements

Facilities for snorkeling and facilities for maintain seagrass nurseries in cement tanks should be provided to academic and research institutions and also to local societies and hoteliers who are involved in conservation and management of sea grass beds and with hotels located in the vicinity of the sites selected within the existing seagrass beds that needs restoration and transplanting of corals.

CCD should take necessary action to implement the necessary programme at experimental basis on selected sites

3 Operations and maintenance

3.1 Endorsement by experts

Seagrass replanting is a technology accepted worldwide for prevention of coastal erosion and for ecosystem restoration

3.2 Adequacy for current climate

Seagrass beds are seen on the coastal belt near Mannar and they were abundant within the shallow coastal waters off Manar in the North Western Province and in the southern & South-western province of Sri Lanka (Plate 3

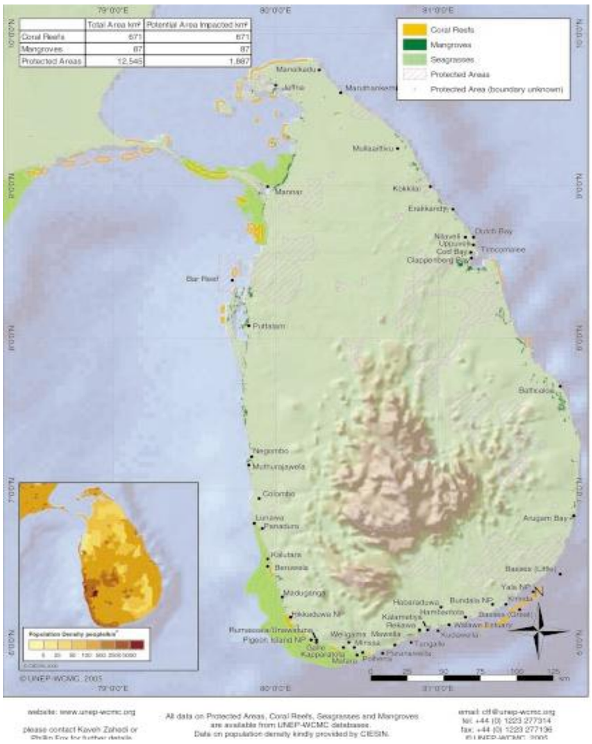

Figure 4: Map of Sri Lanka indicating the locations of Sri Grass beds.

(http://www.unep.org/tsunami/reports/tsunami_srilanka_layout.pdf)

Seagrasses are continuously subjected to the inflowing and outflowing of the tides, and to avoid being washed away the seagrass has a root system and stems. The roots help in stabilising the seabed against powerful water currents. Ability of sea grass beds for survival after a tsunami was evident within the sea grass beds off Weligama, Sri Lanka (Plate 2).

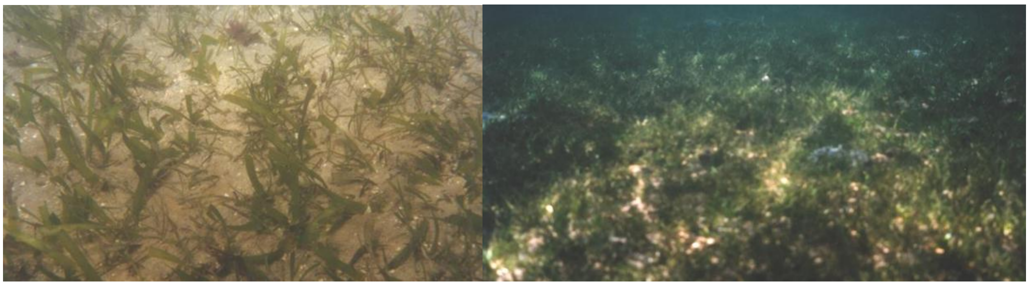

Plate 2: Sea grass bed in Weligama before tsunami in December 2004 (left) and few days after tsunami (right). (Photographed by P.B.T.P. Kumara)

3.3 Size of the beneficiary group

Coastal communities living close to the coastal belt, who are having a risk of losing their properties due to coastal erosion as a result of wave action and storm surge and due to coastal inundation as a result of sea level rise. Fisher communities also could be considered as indirect beneficiaries as the seagrass beds provides breeding sites for marine fish and provide refuge to both larval and adult stages. In order to quantify the numbers of beneficiaries detailed surveys should be carried out with respect to the coastal communities associated with coastal belts rich in seagrass beds. Location of the seagrass beds are given in figure 4.

4 Costs

4.1Cost to implement adaptation options

Costs up to the Phase 4 will be given herein because the area to be included for the Phase 5 will be decided on the success of the project up to phase 4

Activity	cost	
	Unit cost (US $)	Total cost (US $)
Field surveys to decide the suitable sites (duration 6 months)		10,000
Training workshops 10 Nos	3,000	30,000
Material for replanting 10 sites of 1 ha (100,000m^2)	40	4,000,000
Allowances for persons (10) involved in trasplanting and taking care of the transplants for 1.5 year		40,000
Transport & other miscellaneous costs		6,000
Contingencies		4,286,000/10ha/2 yrs
Total cost	21.43/m^2	214,300/ha/yr

4.1 Additional costs to implement adaptation option, compared to "business as usual"

This technology could be coupled with the construction of hard defenses such as sea walls and dykes as shown in Figure 2 and in such occasions cost for hard structures also should be taken in to consideration.

To receive maximum benefits from this technology, sensitivity on the importance of seagrass beds as a ecosystem as a food resource and a shelter for economically important fish resources, etc. should be improved among all stakeholdes living along the coastal belt. Therefore awareness among coastal communities, school children, hoteliers, industrialists, should be improved. Thus there is a need for conducting awareness programmes whenever necessary.

5 Development impacts , indirect benefits

5.1 Economic benefits

- **Employment**

  This project will provide employment opportunities to person involved in coastal construction sector, coastal zone management sector, etc.

  Persons employed in coral transplanting could be used for this matter.

- **Investment :**
  - Income to fisher communities due to improvement of coastal fish stocks
  - Seagrasses could be used as a fodder for fish bred in captivity for food and ornamental purposes

5.2 Social benefits :

- **Income**

  33.1.1.1.1.1 Increase the income of fisher communities due to proper management of seagrass beds which are feeding, breeding and hiding grounds for certain food fish (fin-fish, shellfish, sea cucumber, etc.)

  33.1.1.1.1.2 Improvement of economy as the expenditure on repairing the damages caused to their properties due to coastal erosion is reduced.

  33.1.1.1.1.3 Socioeconomic status of coastal communities due to reduced risk of coastal inundation and erosion

  33.1.1.1.1.4 Increased income to persons involved in coastal resource management.

- **Education**
  - Improvement of awareness on the importance of conservation, management and restoration of seagrass beds
  - Improvement of scientific knowledge on the sensitivity and ecological importance of seagrass beds.
  - Adaptation to natural phenomena by scientifically maneuvering the natural coastal ecosystems

- Knowledge on the establishment of artificial structures within the coastal belt, with least impacts on sensitive ecosystems
- Development of new technologies for restoration of seagrass beds and for utilization of seagrasses for other economic activities
- Engagement in fishery activities without harming seagrass beds

- **Health**
  1. Improved security of coastal dwellings will naturally improve the health condition of coastal communities
  2. Proper management of coastal ecosystems by controlling harmful anthropogenic activities such as pollution, coral mining, illegal fishing, etc., to protect the reefs, will provide the coastal communities a healthy atomosphere
  3. Due to improved income due to proper management of seagrass beds and hence the coastal fish stocks, economy of coastal communities (especially of fisher communities) will improve, resulting them a more prosperous and a healthy life.

5.3 Environmental benefits

- Restoration of seagrass beds through replanting will form a more effective barrier with respect to wave action, inundation, erosion, etc. will stabilize the coastal belt, which will reduce the negative impacts to coast from natural phenomena.
- Provision of shelter for organisms living in association with the sea grass beds will improve the stability ecosystems and also will improve the biodiversity
- Utilisation of CO_2 for photo synthesis by sea grasses will CO_2 concentration in coastal habitats, reducing its impacts on global warming

6 Local context

6.1 Opportunities & Barriers

- **Opportunities**
  - For coastal scientists, coastal engineers and coastal zone managers will get a very good opportunity to use their knowledge and experience to find solutions for global warming and for sustainable management of coastal resources & coastal ecosystems to be adapted for climate change
  - Coastal resource utilisers and those who were involved in destructive activities harmful to coastal ecosystems will get an opportunity to obtain a training to sustainably manage the coastal resources for their own benefit.
  - Academics and researchers will get an opportunity to conduct useful scientific research to reduce the impacts of climate change to coastal ecosystems and communities
  - Sri Lanka will get an opportunity to make possible contributions to find solutions for local regional and global problems that may faced due to climate change.

- **Barriers**
  - Cost incurred on coastal constructions, for planting, training personnel and to provide security to restored seagrass beds and to other associated artificial structures against harmful anthropogenic activities
  - Release of pollutants and nutrients from land based activities and industries.
    Lack of or insufficient political commitment for coastal resource conservation and management.
  - Low inputs by the government on coastal & marine science education, due to ignorance of the importance of marine science education and the cost incurred.
  - Insufficient or lack of motivation and knowledge of the coastal & marine resource utilisers on the importance of sensitive coastal marine ecosystems and their sustainable utilization.
  - Reluctance of older generation of the coastal communities to acquire new knowledge and to accept that certain practices adopted by them for fishing and other socio economic activities could cause serious threats to sensitive coastal ecosystems and their biodiversity.

6.2 Status

Technology for replanting seagrasses have been successfully implemented in other countries and a group of scientists led by Dr. P.B.T.P. Kumara (Dept. of Oceanography & Marine Geology, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna has initiated research related to management of seagrass beds. Such technologies should be adopted in a larger scale at other sites with sea grass beds independently and in combination with hard defense technology

6.3 Time frame

Activity	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites	X							
Awareness/training		X						
Preparation of sea-grasses for replanting			X					
Planting/monitoring			X	X				
Sea-grass plots coupled with hard defense structures				X	X			
Monitoring					X	X		
If successful adoption to a wider area						X	X	
Evaluation of success				X		X		X

6.4 Acceptability to local stake holders:

- Younger generations with secondary & tertiary education have assisted the University staff and undergraduates to conduct research in sea grass beds
- Pilot project should be carried out with thecommunity participation prior to expending the programme to a larger area to find the acceptability.

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Technology Fact Sheet 3

Sand Dune Rehabilitation

34. Sector: Coastal

35. Technology characteristics

35.1 Introduction to restoration of coastal sand dunes:

A sand dune is a mount, hill or ridge of sand that lies behind the part of the beach affected by tides.Soil washes from inland rivers and finds its way to the sea. When this happens, soil layers – for example, humus, clay and sand – separate. Sand deposits on beaches, while clay, which isheavier, reaches open oceans.This deposited layer of sand is shifted constantly by wind and waves. Waves wash sand onto the beach. At low tide, this sand dries and the finest fraction of sand is blown further landward by winds, and can not now be reached by normal waves. The wind keeps pushing this sand landwards in a motion like a sheet moving. The moment the sand reaches the side away from the wind, it settles and forms sand dunes. Some of this sand collects behind rocks or clumps of seaweed. Here, the roots and underground parts of grasses and other vegetation anchored on the dunes trap the sand from being blown away. The leaves of the dune vegetation trap sand promoting dune expansion. Without vegetation, wind and waves regularly change the form and location of dunes. They are formed over many years. The wind then starts eroding sand particles from the windward side and depositing them on the side protected from the wind. Gradually, this action causes the dune to move inland, accumulating more and more sand as it does so. Subsequently, more vegetation grows on these dunes (Hesp, 2000, Mittapala, 2008; www.des.nh.gov/coastal). Sand dunes form in intertidal zones of coastal beaches, where there is enough sand and adequate wind. Sand dunes range in size from ridges less than 1m in height and width, to massive dune fields that extend inland for many kilometres (Hesp, 2000). They are found worldwide but are less developed in tropical and subtropical zones (where wind velocities are lower and the soil is damper) (Packham & Willis, 1997)

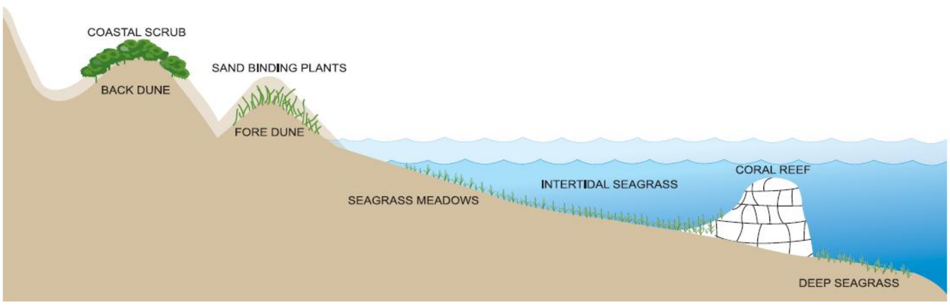

Figure1: typical structure of coastal sand dunes (adapted from Short et al., 2007, quoted by Mittapala, 2008)

Dune vegetation has adaptations to stand the harsh conditions prevail in the coastal environments and the unstable conditions of the substratum on which they are anchored.

Sand dune plants grow in areas where the temperature is high and the winds and waves are strong. This leads to lack of fi rm anchorage, drying up of plant tissue and breakage (Packham & Willis, 1997). These plants have developed specialised adaptations which help them cope with these problems. They are adapted to stand the strong winds and waves in this environment, although the the sand is loose and porous and constantly shifting the substrate. Therefore, plants closest to the sea have roots and shoots that grow sideways and hug the ground. These roots and shoots form a dense mat on the surface as seen in Goat's Foot (*Ipomoea pes-caprae*) and Spinifex (*Spinifex littoreus*). Further inland, where dunes are more stable, plants grow more upright. Dune plants also possess adaptations that prevent desiccation. On clear, sunny days, the temperature in sand dunes can rise to as much as 50°C. There is also a lack of fresh water. Because of this, sand dune plants have evolved xeromorphic characteristics. The outer layer of leaves is very thick and leaves are often reduced to spiny projections (as seen in Spinifex) or rolled up (as seen in Goat's Foot) aiding in preventing water loss (Mittapala,2008). Dune plants such as *Pandanus* sp. Which has … effectively provided protection to certain areas in the Hamantota District where natural dune vegetation was not removed due to human influence (Plate 1)

Plate1: Parts of the coastal belt in Hambantota protected from 2004 tsunami wave due to Pdense dune vegetation dominated by Pandanus sp.

Pandanus sp. propagates readily from seed, but it is also widely propagated from branch cuttings for human activities. It grows fairly quickly, and all parts from the nutritious fruits of certain edible Varieties (in pacific island), to the poles and branches in construction, to the leaves for weaving baskets, etc. *Pandanus* sp. could be planted on the sand dunes by making a terraced structure along the sand dunes. Plantings should be encouraged in protected areas and in well maintained public areas. For example, in Hawai'i plantings of *Pandanus* on hotel grounds were utilized and greatly appreciated by local weavers, due to good access and ease of harvesting. Special attempts should be made to collect and replant endangered varieties with an economic value. The root system of *Pandanus* plants is dominated by thick, slightly spreading prop roots originating from the lower part (1–1.5 m) of the trunk. The prop roots penetrate and are mainly concentrated in the surface soil layers which helps to stay erect and steadily anchored to the unstable soil.

35.2 Technology Characteristics/Highlights

As an adaptation against coastal erosion and inundation, which could be expected to occur due to sea level rise as a result of climate change, these natural sand barriers with their vegetation could be used and wherever they have been removed as a result of human activities these plants should be replanted. Propagation of plants could be done by using seeds.

7.1 Institutional/ organisational requirements

Facilities for collection of seeds of *Pandanus* and to establish nurseries should be provided at academic or research institutes or at centres established with community participation to propagate these plants. In areas where dune sand has been removed for anthropogenic activities, such as construction work, these plantations could be carried after beach nourishment to improve the quality of the substratum to speed up the establishment of dune vegetation. In addition to replanting of *Pandanus* other species of dune plants should be introduced to the same area or they should be allowed to naturally established with time, due to improvement of environmental conditions as a result of replanting *Pandanus* sp. Terraced plantations should be introduced

8 Operations and maintenance

8.1 Endorsement by experts

Pandanus plantations are widely practiced in Pacific islands and kit has been accepted by the local communities due to its economic value. Under the tsunami rehabilitation programme funded by the CIDA (Candada) assisted the coastal communities in reestablishing *Pandanus* sp. Which was not given sufficient attention after the implementation due to the lack of sufficient government patronage to promote such projects. If the funding is made available this project will be a feasible one and would provide opportunities for cottage industries based on *Pandanus* leaves.

8.2 Adequacy for current climate

Plant species that grow on doon sand are abundant in Sri Lanka and scientifically organised terraced plantations would not only provide protection to the coastal sand dunes against coastal erosion, storm surge, tsunami and other harmful coastal activities, but it will provide alternative income sources for coastal communities and also will give a more asttractive appearance to sandy beaches. It will also provide nesting sites to turtles and sea birds, which would attract nature lovers and local and foreign tourists.

Mittapala (2008) has indicated the danger of establishing exotic species such as Whistling Pine (*Casuarina equisetifolia*), which could cause additional problems - such as the prevention of marine turtles from nesting. During a survey conducted by a group of scientists in Matara & hambantota districts revealed that although *Casuarina equisetifolia* would provide some stability to sand dunes when the plants are small and their branches are touching the ground, fully grown plants will not provide any protection to the sand below (Plate 2). This is due to the resistant resulted by the *Casuarina* needles that would not allow an under growth of weeds and shrubs Plate 3. Further Casuarina needles form a mat which takes a long time to degrade and bind with the underlying sandy layers unlike the leaf litter of natural dune vegetation. This mat of undegraded needles will slip over the sandy substratum making it unstable during strong winds and waves, which was evident during the 2004 tsunami (Plate 4)

Plate 2: Protection to sand dunes in Hambantota provided by young Casuarina plants (Lect) and unprotaected dunes with fully grown Casuarinas plants (Right) during the 2004 tsunami. *((phottotographs by P.R.T. Cumaranatunga)*

Plate 3: Left- Casuarina plantations on the sanddunes of Hambantota without an undergrowth. Right- natural dune vegetation with a protective undergrowth *(Photographed by P.R.T. Cumaranatunga)*

Figure 4: Soil profile under natural sand dune vegetation (Left) and the soil profile under Casuarina plantations (Right) (Photographed by P.R.T. Cumaranatunga)

8.3 Size of the beneficiary group

Coastal communities living in the vicinity of sand dunes in the North, Noth-western, South-eastern and Eastern coastal belts will benefit out of this technology. It will provide a protection from coastal erosion and also will act as a wind belt in areas where strong winds persist. In addition to that *Pandanus* plant will provide an alternative income source for coastal communities. With the improvement of soil conditions, as a long term adaptation many other plant communities also will establish in the areas having sand dunes improving its biodiversity.

9 Costs

4.1Cost to implement adaptation options

Activity	Cost	
	Unit cost (US $)	Total cost (US $)
Field surveys to decide the suitable sites (duration 6 months)		10,000
Training workshops 10 Nos	3,000	30,000
Material for replanting *Pandanunus* 2 ha within the each existing sand dune with a maximum of 50 ha at the initial stage	10,000 per ha	500,000
Allowances for persons (100) involved in the replanting programme and maintenance for 2 year		420,000
Transport & other miscellaneous costs		10,000
Unforeseen expenses		95,000
Total cost without beach (sand dune) nourishment	2.13/m^2	1,065,000/50ha

9.1 Additional costs to implement adaptation option, compared to "business as usual"

This technology will provide opportunities to establish cottage industries and therefore funds should be provided for training and establishment of small scale enterprises for women and school leavers in the coastal districts where *Pandanus* plantations are to be introduced . This will help the self sustasinability of the plantation programme and the related industries.

In addition to the above turtle hatcheries (*ex situ* and *in situ*) to conserve turtles and to encourage their nesting in restored sand dune ecosystems. Futher, concurrently with such projects necessary steps should be taken to improve eco tourism.

10 Development impacts , indirect benefits

10.1Economic benefits

- **Employment**

This project will provide employment opportunities to women & school leavers and those who are willing to involve in activities related to eco-tourism.

- **Investment :**
    - Establishment of small & medium scale industries
    - Improvement of tourism
    - If the soil condition improves, dry zone agricultural practices could be established towards the landward area beyond the series of sand dunes

10.2Social benefits :

- **Income**
    - Improvement of economy of coastal communities due to
        a. Establishment of SMEs
        b. Improvement of eco-tourism
        c. Due to provision of protection to the properties of coastal communities from erosion, strong winds and waves.
    - Socioeconomic status of coastal communities will improve as a result of improved income
    - Increased income to persons involved in tourism (especially in eco-tourism), coastal resource management and hotel sectors.
- **Education**
    - Improvement of awareness on the importance of conservation, management and restoration of sand dunes
    - Use of natural vegetation to improve the ecological status of sand dune communities.
    - Improvement of scientific knowledge on the sensitivity and complexity of sand dune ecosystems among coastal communities
    - Adaptation to natural phenomena by scientifically maneuvering the natural coastal ecosystems
    - Knowledge on the artificial propagation of indigenous dune vegetation to establish green belts to reduce the impacts from sea level rise due to climate change
- **Health**
    1. Improved security of coastal dwellings will naturally improve the health conditions of coastal communities
    2. Sustainable management of coastal ecosystems by controlling harmful anthropogenic activities such as destruction of dune vegetation and removal of dune sand would provide coastal communities much stable livelihoods, which would improve their siocioeconomic standards that help them to lead a healthy life.

10.3 Environmental benefits

- Protection to all living terrestrial communities from coastal inundation
- Provision of shelter and breeding sites for turtles, sea birds and other endangered and ecologically important organisms, which would in turn improve the biodiversity in dune habitats
- Utilisation of CO_2 for photosynthesis by the dune vegetation belts will reduce the CO_2 concentration in the atmosphere, reducing its impacts on global warming
- Reduce the impact of sea breeze

11 Local context

11.1 Opportunities & Barriers

- **Opportunities**
  - For coastal scientists and coastal zone managers will get a very good opportunity to use their knowledge and experience to find solutions for global warming and for sustainable management of coastal resources & coastal ecosystems to be adapted for climate change
  - Coastal resource utilisers and those who were involved in destructive activities harmful to dune ecosystems will get an opportunity to obtain a training to sustainably manage the coastal resources for their own benefit.
  - Provide opportunities to unemployed or less income groups to improve their economy through SMEs.
  - Academics and researchers will get an opportunity to conduct useful scientific research to reduce the impacts of climate change to coastal ecosystems and communities
  - Sri Lanka will get an opportunity to make possible contributions to find solutions for local regional and global problems that may faced due to climate change.

- **Barriers**
  - High cost incurred on rehabilitation of dune ecosystems through beach nourishment and replanting of dune vegetation.
  - Unsustainable utilization or destruction of dune vegetation by certain individuals of the community
  - Lack of or insufficient political commitment for coastal resource conservation and management.
  - Insufficient or lack of motivation and knowledge of certain sections of the coastal communities for conservation and/ sustainable management of coastal ecosystems and resources.
  - Reluctance of older generation of the coastal communities to acquire new knowledge and to accept that certain practices adopted by them could cause serious threats to sensitive coastal ecosystems and their biodiversity.

- Hotelliers and beach resort owners prefer an open beach than a sheltered on.

11.2 Status

Knowledge on technology to be adopted for propagation of dune vegetation and beach nourishment is available. Trained and motivated persons for such activities are very few in numbers and therefore prior to implementation of the project thorough training should be provided.

Beach nourishment is presently carried out in Negombo.

11.3 Time frame

	Year 1 divided to 4 quarters				Tear 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites with respect to inundation with SLR	X											
Awareness/training		X										
Establishment of nursaries for dune plants		X	X									
Planting and monitoring and the growth rate & its effect on stability of dunes and maintenance			X	X	X	X	X	X				
Establishment of SMEs for industries related to dune vegetation community participation & government patronage								X	X	X		
If successful adoption to wider area with careful monitoring						X	X	X	X	X	X	
Evaluation of success/self sustainability					X		X		X		X	

11.4 Acceptability to local stake holders:

- Depending on the protection against the coastal erosion and the socioeconomic benefits there is a strong possibility of acceptance by the local stake holders
- Dune vegetation will be a barrier to access to the beach, which will not be acceptable to tourist industry.

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Technology Fact Sheet 4

Beach nourishment

36. Sector: Coastal

37. Technology characteristics

37.1 Introduction to Beach nourishment :

Beach nourishment is an adaptation technology primarily used in response to shoreline erosion, although flood reduction benefits may also occur. It is a soft engineering approach to coastal protection which involves the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit. Nourishment can also be referred to as beach recharge, beach fill, replenishment, re-nourishment and beach feeding.

Addition of beach material rebuilds and maintains the beach at a width which helps provide storm protection. This approach is mainly used on sandy beaches but the term can also refer to nourishment with shingle or even cobbles. The aim, however, should be to ensure that nourishment material is compatible with the existing natural (or native) beach material (Reeve et al., 2004). Nourishment is often used in conjunction with artificial dune creation.

Beach nourishment helps to dissipate wave energy; when waves run up a beach and break, they lose energy and this interaction will be of different extents depending on the beach profile, shapes and gradients. The cross-sectional shape of a beach therefore affects its ability to attenuate wave energy. A 'dissipative' beach – one that dissipates considerable wave energy – is wide and shallow while a 'reflective' beach –one that reflects incoming wave energy seawards – is steep and narrow and achieves little wave energy attenuation. The logic behind beach nourishment is to turn an eroding, reflective beach into a wider, dissipative beach, which increases wave energy attenuation (French, 2001). beach nourishment addresses a sediment deficit: the underlying cause of erosion, while helping to dissipate incoming wave energy. This is achieved by introducing large quantities of beach material to the coastal sediment budget from an external sediment source, also referred to as a borrow site. The term 'sediment budget' is used to describe the careful balance which exists between incoming and outgoing sediment. When more material is added than removed, a build-up occurs and the shore builds seaward; conversely, when more material is removed than deposited, erosion occurs (Morton, 2004).

Nourishment addresses a sediment deficit – the cause of erosion – by introducing large quantities of beach material to the near-shore system. In turn, this can cause the shore to build seaward. It is important to note that beach nourishment does not halt erosion, but simply provides sediment from an external source, upon which erosional forces will continue to act. In this sense, beach nourishment provides a sacrificial, rather than a fixed barrier against coastal erosion. Continuing erosional forces will likely return the beach to a state where re-nourishment is required. When the beach reduces to a critical volume, re-nourishment should be undertaken to avoid damage to coastal infrastructure.

According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990) and areas under each type and the cost for providing necessary protections are also given in Table 1 and out of the total coast 30km^2 have been categorized as beaches and the cost for their nourishment has been estimated as US$ 203

Table 1: Types of Coasts available in Sri Lanka, respective areas &cost for providing necessary protections as estimated in IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990.

Coast type	Length km/Area km^2	Cost US$M
Coast length ("crow")	990 km	
Low Coast Length	4820 km	1,446.0
Total City water front length	124 km	1,860
Beach area	30 km^2	203
Harbour area	1.6 km	37
Total		3,545

37.2 Technology Characteristics/Highlights

Several methods of nourishment can be utilised, including placement by dredge, trucks or conveyor belts. Sand can be placed to create an extension of the beach width or as an underwater deposit which will be gradually moved onshore under the normal action of waves. Supply of nourishment material by offshore dredging is often favoured because it allows for large quantities and this method is practiced ion many countries. It is also possible in Sri Lanka where off shore sand deposits are available, but the high cost incurred for this process is a problem which needs to be solved. Beach nourishment could be enhanced by improvement of dune vegetation which reduces coastal erosion to a considerable extent.

12.1 Institutional/ organisational requirements

This activity should be handled by the Coast conservation department with the assistance of Academic and research institutes, which has the capacity to estimate the annual coastal erosion in selected beaches with a touristic importance and in areas where sand dunes have faced erosion due to anthropogenic activities such as extensive removal sand for construction purposes and due to destruction of sand dune vegetation in order to calculate the volume of sand to be dredged for nourishment of respective beaches. In addition to the above availability of offshore sand deposits and the quantities available for dredging without causing any negative impacts on the coastal belt or the sensitive marine and coastal ecosystems should be estimated. In other words annual sediment budget with respect to beaches having different physical characters should be estimated

13 Operations and maintenance

13.1 Endorsement by experts

Beach nourishment which is a soft defense technology, is known to complement hard protection measures such as seawalls and it is practiced worldwide and which may continue to be used as a last line of defense. The existence of a wide, sandy beach in front of hard defense structures greatly reduce the wave energy reaching them, thus providing additional protection.

13.2 Adequacy for current climate

Beach nourishment alone is not adequate to be practiced alone but it should be implemented as a complementary technology together with other hard defecnse structures such as sea walls, dykes, etc. and soft defense technologies such as restoration of dune vegetation. However it will be an acceptable solution for erosion and inundation due to sea level rise, in beaches which are having an economic importance (beaches facing tourist hotels).

13.3 Size of the beneficiary group

- Persons involved in tourism and hotel industry
- Persons depending on dune vegetation for socioeconomic activities
- Persons using beaches for recreational activities.
- Tourists coming to Sri Lanka (more than 300,000 to 400,000 per year)
- Increase of boat landing sites

In addition to human beings other organisms living in the coastal sands and using them for their biological needs also will benefit out of this technology. Turtles and other organisms using sandy beaches for nesting and organisms living in burrows within sandy beaches also could be considered as beneficiaries. Therefore turtle hatchery owners and the employees of such hatcheries also could be considered as indirect beneficiaries of this project.

14 Costs

According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990) following (a, b &c)are the estimates for types of beach nourishment applied globally

(a) **Beach nourishment of sandy beach without protection works**

Dimenensions:	1 m thick sand layer over morphologic active zone; up to MSL -8 m contour line, approx 1000 m wide
Construction:	Nourishment by "tshd" (trailing suction hopper dredge) from offshore sources or by "csd" (cutter suction dredge) from nearshore/inshore sources

Unit rates:

Project length: 2-6 km, sand from near (<10km) sources - 3.5M$/km

Project length: > 6km, sand from nearby sources- 3.0M$/km

Project length: 2-6 km, coarse sand from remote (>10km) sources- 6.0M$/km

Project length: >6 km, coarse sand or sand from remote sources- 5.5M$/km

Average unit cost- 4.0M$/km

(b) **Beach nourishment of sandy beach with existing protection works (groynes, under water beams, etc.)**

Dimensions: 1 m thick sand layer, over 75% of morphologic active zone, 750m wide
1 m raising of existing construction with 50 ton stone/m construction: nourishment by "tshd" from offshore sources or by "csd" from nearshore/inshore sources stones placed by land dumping or crane placement unit rates: nourishment-
3.00 M$/km [see (a)]stone work:

Over land from local sources	:	0.40 M$/km
Over water from local sources	:	0.80 M$/km
Over water from remote sources	:	1.25 M$/km
Average unit cost	:	4.00 M$/km

(c) **Tourist beaches**

Construction of additional works to preserve specific recreational functions of existing facilities, by various (not specified) measures. Unit cost: estimated additional value of 50% of beach nourishment costs- totally 6.0M$/km

Note1 :It is assumed that tourist beaches cover some 25% of the total beach length to be replenished. Calculations are, therefore, made with a unit rate of 4.5 M$/km beach length, without any further discern of function.

Note 2 :Technical feasibility has been assumed for beach nourishment, including areas where sand sources are expected to be scarce.

4.1 Cost to implement adaptation options

According to the IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise (1990), the average cost for beach nourishment has been estimated as 3.0 to 6.00 MUS$ if the beach is lifted by 1m (see a, b & c), and the beach width and length have been considered as 750m and 1km respectively and the extent of Sri Lankan beaches have been estimated as 30 km and the cost for beach nourishment has been estimated as 203 MUS$ for year 1990. Therefore the cost for nourishment of Sri Lankan Beaches have been calculated as follows.

Cost to nourish 30 km of beach at 1m lifting as estimated by IPCCC (1990)

= 203MUS$

Mean beach width ofv Sri Lanka according to CCD =300m

Cost for beach nourishment per 1m^2 of beach area =203÷(30x1000x300) MUS$

=22.5 x 10^{-6} MUS$=22.5US$

By considering the depreciation of US$ from 1990 to 2011cost for nourishment of 1m^2 of the beach will be taken as 25US$/m^2

Activity	**Unit cost/m2 (US $)**	**Total cost (US $)**
Beach Nourishment for an area withion 3km beach length & 300m mean beach width	25/m^2	22,500,000/3km (or 900,000m^2)
Unforeseen expenses		500,000
Total cost Beach Nourishment for an area within 3km beach length &300m beach width (900000 m^2)	**25.56/m^2**	**23,000,000**

14.1 Additional costs to implement adaptation option, compared to "business as usual"

- Hotels and industries should maintain environmentally friendly methods for disposal of waste water which will not pollute the nourished beaches.
- Coastal waters & sand deposits utilized for nourishment should be tested for possible hazardous material as the sandy beaches will be used for human recreational activities and sunbathing.
- In addition to the beach nourishment beaches used by turtles for nesting should be protected as major alterations may prevent them from visiting their nesting sites.
- In connection with the above, sites used for *ex situ* conservation of turtles also should be taken in to consideration. Beach nourishment should not alter the texture and other physicochemical properties of sand where turtle hatcheries are located.

15 Development impacts , indirect benefits

15.1 Economic benefits

- **Employment**
  - This project will provide employment opportunities for those who involved in the sand mining, dredging and operation of respective machinery during beach nourishment
  - More employment opportunities will be available in the tourism industry and in hotels
  - Coastal communities will make living through activities related to tourist industry
- **Investment :**
  - Improvement of foreign exchange earnings through tourism
  - Coastal SMEs will have economic benefits due to attraction of the attention of foreign and local visitors coming to beach resorts

15.2 Social benefits :

- **Income**
  - Improvement of economy of coastal communities due to
    a. Establishment of SMEs related to tourism
    b. Improvement of eco-tourism
    c. Widening of the beaches increases protection to the properties of coastal communities from erosion, strong winds and waves, which reduces the cost for property owners implementing protective measures.
  - Socioeconomic status of coastal communities will improve as a result of improved income
  - Increased income to persons involved in tourism (especially in eco-tourism), coastal resource management and hotel sectors.
- **Education**
  - Improvement of awareness on the beach sand dynamics and offshore sand dynamics
- **Health**

  There can be both positive and negative impacts

  Positive impacts on health

  1. Improved physical conditions and aesthetic appearance of beaches will help to maintain good health among people living near the coastal beaches and those who visit the beaches for recreational activities
  2. Security of coastal dwellings will naturally improve the health conditions of coastal communities

  Negative impacts on health

  - If off shore sand deposits or any other sands used for beach nourishment contain contaminants they could cause health hazards.

15.3 Environmental benefits

- Widening the beach helps to dissipation wave energy which helps to protect the landward environment ;
- Provision of shelter and additional breeding sites for turtles, sea birds and other endangered and ecologically important organisms and the sand burrowing organisms, which would in turn improve the biodiversity in sandy and dune habitats only if the sand used for nourishment is not containing hazardous material

16 Local context

16.1 Opportunities & Barriers

- **Opportunities**
  - Coastal scientists and sedimentologists will get an opportunity to use their experience and knowledge when extracting offshore sand deposits for beach nourishment.
  - those who were involved in destructive activities within the coastal belt could find an alternative employment related to tourism or beach nourishment

- Provide more opportunities to local & foreign tourists for recreational activities which in turn helps to maintain good health conditions

- **Barriers**
  - Offshore sand deposits should be able to support the annual sand budget requires for nourishment, otherwise erosion will exceed the nourishment rate
  - High cost incurred on nourishment of beaches
  - Illegal sand mining in coastal belts
  - Insufficient or lack of motivation and knowledge of certain sections of the coastal communities for conservation and/ sustainable management and maintenance of beaches to increase its attraction to tourists.
  - Illegal sand mining
  - Release of pollutants and hazardous material from land based industries in to the coastal beaches without proper treatment

16.2Status

- Although knowledge on technology for beach nourishment is locally available its high cost will not allow such activities to be implemented to all beaches.
- Offshore sand deposits which could be used for this purpose has been identified by marine geological surveys and they are utilized for more prioritized construction and beach nourishment activities patronized by the state.

16.3Time frame

	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites for most suitable beaches for nourishment considering its economic importance with respect to expected inundation due to SLR and availability of offshore sand	X	X	X									
Implementation of nourishment to most suitable sites			X	X	X							
Evaluate the cost effectiveness depending on the sediment budget				X	X	X	X					
If economically feasible implementation to more suitable sites							X	X	X	X	X	X

16.4 Acceptability to local stake holders:

- Depends on the economic gains, protection received from wave actions, opportunities for recreational activities acceptability local stakeholders
- There is a strong possibility of acceptance by the local stake holders if the nourished beaches are in the vicinity of touristically attractive sites.

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Technology Fact Sheet 5

Rehabilitation of Mangroves

38. **Sector**: Coastal
39. **Technology characteristics**

39.1 Introduction to rehabilitation of mangroves:

One of the most commonly restored wetland ecosystems for coastal protection are mangroves. Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion management. They induce wave and tidal energy dissipation (Brampton, 1992) and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilise shore sediments, thus reducing erosion (USACE, 1989). Wetland restoration reestablishes these advantageous functions for the benefits of coastal flood and erosion protection. Restoration is required because many of the world's wetlands have become increasingly degraded through both natural and human activities. Techniques have been developed to reintroduce coastal wetlands to areas where they previously existed and to areas where they did not, but conditions will allow.

Mangrove ecosystems played a vital role in buffering the force of the tsunami waves and in protecting the human inhabitations. Even before the Tsunami, Sri Lanka has been experiencing rapid loss of mangrove ecosystems mainly due to anthropogenic factors including unprecedented growth of the tourism sector. In addition to the provision of ecosystem functions, the mangroves are instrumental in supporting the livelihoods of the local coastal communities. These mangrove systems also perform vital hydrological functions and serve as breeding grounds for fish & other marine species. Almost 40% of the world's mangroves are concentrated in Asia, the region also has accounted for the highest loss of mangrove area over the last decade.

The mangrove systems covering an area of 6000-7000 ha are interspersed along the coastline of Sri Lanka. The largest mangrove system is located in Puttalam Lagoon – Dutch Bay – Portugal Bay complex and covers an area of 3385 ha. The other large concentrations are in Batticaloa and Trincomalee districts. The mangrove forests in Bentota are highly threatened as a result of unchecked growth of the tourism sector. In spite of the known ecological and economic value of mangroves there has been indiscriminate exploitation of mangroves for commercial, industrial, housing needs mainly due to the lack of knowledge of the ecological role of the mangroves amongst the decision-makers.

Until recent times, mangrove areas have received very little or no attention in terms of their conservation or sustainable management. As a result, most of the mangrove areas have been lost due to indiscriminate clearing and reclamation for industrial, urban, tourist resorts, roads, aquaculture ponds, and fishing ports development. Although the legal jurisdiction of the mangrove ecosystem falls under the Forest

Department, Department of Wildlife Conservation, and the Coast Conservation Department, there is inadequate legal protection for mangroves in the country.

This unique ecosystem is home to over 20 true mangrove species of Sri Lanka. The major genera that represent these species are *Avicennia, Rhizophora*, *Bruguiera*, and *Sonneratia*. According to mangrove abundance and distribution, they can be categorized as very common, common, and rare; the very common species of Sri Lankan mangroves are *Avicennia marina, Bruguiera gymnorrhiza, Excoecaria aggalocha, Lumnitzera racemosa, Rhizophora mucronata, Rhizophora apiculata, and Sonneratia caseolaris*. The very common species appear to grow under a wide range of soil and hydrological conditions, and are widely distributed in Sri Lanka indicating that they are the most appropriate species for mangrove reforestation. The common category of mangrove species represent *Aegiceras corniculatum, Avicennia officinalis, Bruguiera cylindrica, Bruguiera sexangula, Ceriops tagal, Heretiera littoralis, Pemphis acidula, Sonneratia alba, Nypa fruticans.* Although these species are widely distributed in Sri Lanka, they are low in abundance. There are few species of mangroves categorized as rare species since they are in low abundance and restricted to few locations in Sri Lanka. The rare species of mangrove namely *Lumnitzera littorea, Xylocarpus granatum, and Scyphiphora hydrophyllaceae* in Sri Lanka.

A reduction in installation and maintenance costs of sea defenses may occur when such structures are located behind large areas of mangroves which absorb the energy and slow the water flow of storm surges (Barbier, 2008). Evidence from the 12 Indian Ocean countries affected by the 2004 tsunami disaster suggested that coastal areas with dense and healthy mangrove forests suffered fewer losses and less damage to property than those areas in which mangroves had been degraded or converted to other land use (Kathiresan & Rajendran, 2005). This was observed in the vicinity of Rekawa Lagoon after the 2004 tsunami incident

Plate 1: Mangroves around Rekawa lagoon before andafter tsunami. Disturbances due to the causeway built across the lagoon was the main reason for damages caused.

Observations indicate that a mature mangrove stand will reduce the costs for dike maintenance by 25-30% assuming a stand width at least comparable to the characteristic wavelength of incident waves (Tri et al., 1998). In contrast to hard defenses, wetlands are capable of undergoing 'autonomous' adaptation to

SLR, through increased accumulation of sediments to allow the elevation of the wetland to keep pace with changes in sea level (Nicholls & Klein, 2005) provided wetlands are not subjected to coastal squeeze, and the rate of SLR is not too rapid to keep pace, wetlands are capable of adapting to SLR without further investments.

Coastal wetlands also provide a number of important ecosystem services including water quality and climate regulation, they are valuable accumulation sites for sediment, contaminants, carbon and nutrients and they also provide vital breeding and nursery ground for a variety of birds, fish, shellfish and animals. They are also a sustainable source of timber, fuel and fiber (White et al., 2010). The restoration and recreation of wetlands can also reduce or even reverse wetland loss as a result of coastal development. This is important in terms of maintaining the global area of wetlands and in sustaining wetlands in the face of climate change. Wetland creation may also fulfill legal obligations for the compensation of habitats lost through development.

The disadvantages of wetland restoration are minimal. The restoration of natural ecosystem services, including flood and erosion protection benefits, largely outweighs any disadvantages. One possible disadvantage is the space requirement in locations which are often of high development potential. This must be carefully weighed against the range of benefits accrued. Wetland restoration is also likely to require a degree of expertise, especially in locations where wetland recolonisation has to be encouraged by transplanting wetland plants. Some wetland habitats will no doubt be more difficult to recreate than others and could require greater expertise.

39.2 Technology Characteristics/Highlights

- For Collect plant propagules from a sustainable source
- Preparation of the restoration site for planting and directly plant propagules at regular intervals at an appropriate time of year
- Establish nurseries to stockpile seedlings for future planting
- Mangrove re-establishment can also be achieved by planting dune grasses as these grasses are known to provide a stable, protective substrate for mangroves to establish their root systems and after the establishment of mangroves they over grow the sea grasses allowing mangroves to be dominant . (USACE, 1989).

39.3 Institutional/ organisational requirements

- Local organizations should be given the responsibility of maintaining and sustainable utilization of mangroves, which will reduce the cost for restoration.
- Coast Conservstion Department should collaborate with academic & research institutions and local organisations such as fishermen's societies for the sustainability of the mangrove restoration programmes and to reduce costs for such activities

- Regulations should be strictly enforced with respect toe stablishing prawn farms in mangrove areas, which has been the cause for mass destruction of mangroves in the western and North-western provinces of Sri Lanka
- Commitment of the government is essential for restoration, management and sustainable development of mangrove ecosystems through ensuring cooperation among different agencies and ministries performing various development programmes within coastal districts having sensitive ecosystems.

40. Operations and maintenance

40.1 Endorsement by experts

Replanting mangroves is a widely accept technology for restoration of degraded mangrove ecosystems worldwide.

40.2 Adequacy for current climate

The very common species of Sri Lankan mangroves are *Avicennia marina, Bruguiera gymnorrhiza, Excoecaria aggalocha, Lumnitzera racemosa, Rhizophora mucronata, Rhizophora apiculata, and Sonneratia caseolaris* which grow under a wide range of soil and hydrological conditions, and are widely distributed in Sri Lanka indicating that they are the most appropriate species for mangrove reforestation.

The common category of mangrove species represent *Aegiceras corniculatum, Avicennia officinalis, Bruguiera cylindrica, Bruguiera sexangula, Ceriops tagal, Heretiera littoralis, Pemphis acidula, Sonneratia alba, Nypa fruticans* they are also suitable for replantation purposes due to their wide distyribution although found in few numbers (information brief on mangroves of Sri Lanka, IUCN)

40.3 Size of the beneficiary group

- Coastal communities depending on mangroves for socioeconomic activities reef communities
  - Fisher communities
  - Those use mangroves for their fruits, firewood etc.
  - Tourist industry involved in Ecotourism
  - Research & educational institutes

41. Costs

4.1Cost to implement adaptation options

Activity	cost	
	Unit cost (US $)	Total cost (US $) (per year)
Field surveys to decide the sites need extra attention depending on the inundation level due to SLR		8,000
Training workshops 10 Nos	3,000	30,000
Travelling & transportation costs		8,000
Maintenance of nurseries at lease two in the respective districts up to 20 Nos.	1000/year/nursary	40,000
Replantation of mangoves in 20ha (2 ha each in 10 sites) at $4m^2/m$		200,000
For caretakers for 2 years		25,000
contingencies		18,000
Total cost per year	$1.6/m^2$	319,000/20ha

41.1 Additional costs to implement adaptation option, compared to "business as usual"

To receive maximum benefits from this technology, sensitivity on the importance of mangroves should be improved among all stakeholders who are resource utilisers depending on mangroves and those who visit the area for different economic, research and educational purposes. Awareness among coastal communities, school children, hoteliers, industrialists, should be improved and therefore awareness programmes should be conducted from time to time.

Ecotourism and research centres should be established in mangrove areas with high biodiversity in order to ensure conservation of endangered mangrove species and sustainable utilization of mangrove resources. Which will reduce the cost s for monitoring, security and maintenance cost of replanting sites.

42. Development impacts , indirect benefits

42.1 Economic benefits

42.1.1 Employment

- This project will provide direct employment opportunities to person involved in managing nurseries and ecotourism centers.
- In addition to that persons who are collecting propagules, using fruits for making drinks, tour guides, krall owners and other fishers in the lagoon will earn a living due to mangrove replanting and successful establishment of mangroves.

42.1.2 Investment :

- Improvement foreign exchange earnings through ecotourism.
- Income to fisher communities due to improvement of recruitment of fish stocks in to lagoons and estuaries with thick mangrove vegetations
- If ecotourism & research centers are established they will attract foreign and local tourists and conservationists, which would in turn attract foreign exchange for mangerove rehabilitation programmes
- Reduce costs for construction of hard defense structurs for reducing coastal erosion such as dykes, coastal revertments, etc. as the mangroves and their root systems have a mechanism to stablise the soil in the coastal habitats
- Reduce costs for controlling coastal pollution as mangrove roots act as trap pollutant traps

42.2 Social benefits :

- **Income**
  - Improvement of economy of mangrove depending communities.
  - Socioeconomic status of coastal communities improve due to reduced risk of coastal inundation and erosion
  - Increased income to persons involved in mangrove rehabilitation programmes, tourism (especially in eco-tourism) coastal resource management and hotel sectors.
- **Education**
  - Improvement of awareness on the importance of conservation, management and restoration of mangroves
  - Improvement of scientific knowledge on the sensitivity and complexity of mangrove plant communities and associated biotic communities
  - Gain knowledge on adaptation to natural phenomena by scientifically maneuvering the natural coastal ecosystems
  - Importance of using natural barriers against coastal erosion and inundation
- **Health**
  1. Improved security of coastal dwellings will naturally improve the health conditions of coastal communities living there
  2. Proper management of coastal ecosystems by controlling harmful anthropogenic activities such as destruction of mangroves, establish ment of illegal prawn farms will improve the ecological conditions of mangrove habitats and it will platy an important role in human health
  3. Improvement of area coverrd with mangrove vegetation will also indirectly help in increasing the mangrove forest cover and hence the controlling the release of CO_2 the environment

42.3 Environmental benefits

- It was found that as well as providing protection against coastal erosion, mangrove planting also helped creating large areas of land through accretion, provided large quantities of wood and other forest products and provided employment for local villagers throughout the duration of the scheme.
- Although mangrove plantations could damage during significant storms, full recovery occurs within a short period of time because the system is self repairing.
- In terms of climate change adaptation in the coastal zone, the main benefit of wetland restoration is the reduction of incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone. This is achieved by increasing the roughness of the surface over which incoming waves and tides travel (Nicholls et al., 2007b).
- This reduces the erosive power of waves and helps to reduce coastal flood risk by diminishing the height of storm surges.

43. Local context

43.1 Opportunities & Barriers

43.1.1 Opportunities

- Wetland restoration and its ecosystem functions such as habitat provision, food production and water quality improvement.
- Coastal flood and erosion protection
- Helps reduce wetlands losses as a result of climate change.
- Wetland creation can bring about various economic, social, and environmental benefits to local communities. For example, improve the productivity of coastal waters for fishing
- Increase incomes of local communities and contribute toward local sustainable development.
- Other goods and services provided by wetlands, such as the provision of wood and fibres could also prove highly beneficial to local communities, especially in developing countries.
- Wetland recreation can also create opportunities for eco-tourism and increase recreational opportunities.
- Creation of wetlands, especially in or in close proximity to urban areas can even serve to increase awareness of the important functions performed by these habitats.
- Because wetland restoration meets multiple management objectives – such as habitat protection, public access to environmental and recreational resources and hazard mitigation – and is less expensive and more aesthetically pleasing than some engineering solutions, the approach is likely to find broader public support in the future (Moser, 2000).

- There is also the opportunity to implement wetland restoration or creation together with hard defences such as dikes or seawalls. In such a case, the presence of wetlands on the seaward side of the defence leads to lower maintenance costs over the lifetime of the structure (Tri et al., 1998).
- For coastal scientists, coastal engineers and coastal zone managers will get a very good opportunity to use their knowledge and experience to find solutions for global warming and for sustainable management of coastal resources & coastal ecosystems to be adapted for climate change
- Coastal resource utilisers and those who were involved in destructive activities harmful to coastal ecosystems will get an opportunity to obtain a training to sustainably manage the coastal resources for their own benefit.
- Academics and researchers will get an opportunity to conduct useful scientific research to reduce the impacts related to conservation and propagation of mangroves as an as a climate change adaptation to coastal ecosystems
- Sri Lanka will get an opportunity to make possible contributions to find solutions for local regional and global problems that may faced due to climate change.

43.1.2 Barriers

- Lack of public awareness of the flood and erosion protection benefits offered by these ecosystems.
- Communities press for, hard defence options, for which the protective benefits .
- Incomplete understanding of the ability of a degraded wetland to recover, and of the success rates of wetland creation.
- The establishment of wetlands which provide full coastal flood and erosion protection takes time, and the approach does not offer immediatebenefits.
- A desire to improve wetland habitats also needs to exist before the strategy can go ahead.
- Wetlands only exist under specific conditions and it is not always clear if habitat restoration will be achievable or successful, especially when coastal managers have limited predictive capabilities for shoreline change (NRC, 1994).
- Although studies have shown that it is possible to create wetlands in areas where they did not previously exist (Platong, 1998), sites with the potential for wetland restoration or creation should be identified on a case-by-case basis.
- Identifying individuals and organisations qualified to undertake wetland restoration and recreation work can also prove a barrier to implementation.
- The qualifications and know-how of the implementing organisations directly influence the effective application of scientific knowledge and engineering capabilitiesand ultimately, project performance (NRC, 1994). To address problems associated with limitations in knowledge

43.2 Status

Technology for mangrove restoration has been successfully implemented in many countries including Sri Lanka and in certain parts of Sri Lanka they naturally replenish if kept undisturbed and also due to reduction of human impacts.

43.3 Time frame

Activity	Year 1 divided to 4 quarters				Tear 2 divided to 4 quart ers				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites which needs replanting and restorastion	X	X										
Awareness/training		X										
Collection and preparation of propagulers for replanting		X	X	X								
Planting of propagules			X	X	X	X						
Monitoring				X	X	X	X	X				
Evaluation of success as a barrier for coastal erosion and inundation							X	X	X	X	X	X

43.4 Acceptability to local stake holders:

- Mangrove uses for socioeconomic activities will support the programme
- If it helps to reduce erosion and damage from coastal inundation acceptance of coastal communities could be assured
- Conservationists and Coastal zone managers will have have a positive approach

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Technology Fact Sheet 6

Construction of Sea Dykes

45. Sector: Coastal

46. Technology characteristics

46.1 Introduction to construction of sea dykes

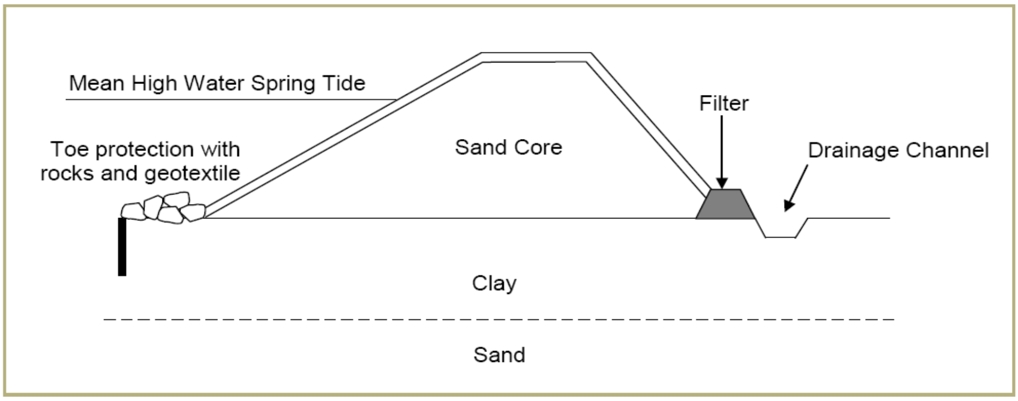
According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990) and areas under each type and the cost for providing necessary protections are also given in Table 1

Table 1: Types of Coasts available in Sri Lanka, respective areas &cost for providing necessary protections as estimated in IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990.

Coast type	Length km/Area km^2	Cost US$M
Coast length ("crow")	990 km	
Low Coast Length	4820 km	1,446.0
Total City water front length	124 km	1,860
Beach length	30 km^2	203
Harbour area	1.6 km	37
Total		3,545

The primary function of sea dikes is to protect low-lying, coastal areas from inundation by the sea under extreme conditions (Pilarczyk, 1998a). Dikes are not intended to preserve beaches which may occur in front of the structure or any adjoining, unprotected beaches. These structures have a high volume which helps to resist water pressure, sloping sides to reduce wave loadings and crest heights sufficient to prevent overtopping by flood waters. They may also be referred to as dykes, embankments, levees, floodbanks and stopbanks., et.al., 1999). Dikes have been extensively utilised as flood defenses in the Netherlands over the past several hundred years. Dikes are widely used to protect low-lying areas against inundation in many countries including Sri Lanka. After the tsunami incident in 2004 such dykes have been constructed along the coastal belt subjected to sever damage. Although it has been successfully protecting the landward properties, it prevents the travelers along the coastal to enjoy the scenic beauty of the sea and the beaches of Hikkaduwa. A number of zones can be distinguished on the seaward slope of a sea dike. The base of the dike, up to MHW will be regularly submerged and will experience constant, low-level loadings. The zone above MHW can be heavily attacked by waves, but the frequency of this occurrence reduces as you move further up the slope. Toward the dike crest, above the design water level, the structure should only be subjected to wave run-up.

Dikes provide a high degree of protection against flooding in low-lying coastal areas. They often form the cheapest hard defense when the value of coastal land is low (Brampton, 2002). The sloped seaward edge of a dike leads to greater wave energy dissipation and reduced wave loadings on the structure compared to vertical structures. This is achieved because the seaward slope forces waves to break as the water becomes shallower. Wave breaking causes energy dissipation and is beneficial because the process causes waves to lose a significant portion of their energy. Because the waves have lost energy, they are less capable of causing negative effects such as erosion of the shoreline. By reducing wave loadings, the probability of catastrophic failure or damage during extreme events is also reduced.



46.2 Technology Characteristics/Highlights

Figure 1 : Cross section of a typical sea dike (Linham et al. 2010)

Figure 1 shows a cross-section of a typical dike, which is predominantly earth structure consisting of a sand core, a watertight outer protection layer, toe protection and a drainage channel. These structures are designed to resist wave action and prevent or minimise overtopping.

Typical dikes employed by the Dutch use following design guidelines will be the most appropriate for eroding coastal belts of Sri Lanka as they are giving a more natural appearance compared to concrete sea walls erected along the coast.

- Sloped seaward face at a gradient of between 1:3 to 1:6 – Reduce wave loadings
- Sloped landward face at a gradient of between 1:2 to 1:3 – Minimises land use and maximises stability

- Impermeable cover layer – this is usually composed of clay but is sometimes supplemented by asphalt. It serves to protect the sand core (Barends, 2003) Toe protection – used as supplemental armour for the beach and prevents waves from scouring and undercutting the structure (Pilarczyk, 1998b)
- Dike core usually composed of sand to ensure that water that does enter can drain away.
- The core provides support for the cover layer and gives the structure sufficient volume and weight to resist high water pressures (Barends, 2003)
- Drainage channel – allows any water which does enter the structure to drain away, therefore ensuring the structure is not weakened by water saturation (Barends, 2003)
- A number of zones can be distinguished on the seaward slope of a sea dike. The base of the dike, up to MHW will be regularly submerged and will experience constant, low-level loadings. The zone above MHW can be heavily attacked by waves, but the frequency of this occurrence reduces as you move further up the slope. Toward the dike crest, above the design water level, the structure should only be subjected to wave run-up.

  If such dikes could be constructed with suitable modifications at the base of the dike towards the seaward slope to attach tiles transplanted with corals and to given an appearance of a terraced structure to enhance growth of sea grasses (figure 2), such dikes could play a more natural role during high water levels due to sea level rise. Sea level rise is a slow phenomenon and if the dykes are designed in a manner , that they will be best adapted to allow benthic marine organisms to settle on it with the gradual sea level rise these dykes will provide a better adapted structure for protection from erosion and inundation.

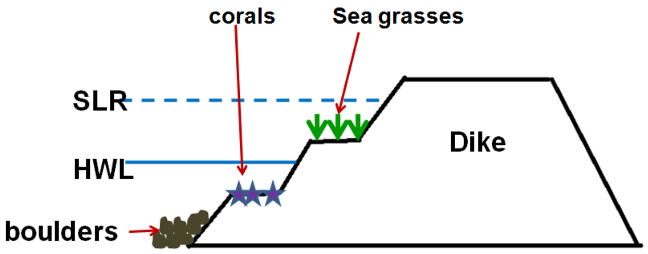


Figure 2: Proposed design of a dyke with the landward aslope having a terraced structure to enable transplanting corals and establishing seagrass plots during high water levels (HLW) and sea level rise (SLR). This would gradually enhance the settlement of more adaptive (temprrature tolerant marine benthic organisms)

46.3 Institutional/ organisational requirements

- Coast conservation department should collaborate with engineers and marine scientists from research & academic institutions when designing most suitable hard defense structures for preventing coastal erosion and coastal inundation.

- Funds should be made available for research on construction of dikes with low cost locally available material and for possible reinforcing their effect by association with soft defense mechanisms (coral transplanting, sea grass replanting, etc.)

47. Operations and maintenance

47.1 Endorsement by experts

- Construction of dikes in low coasts have been already implemented by the CCD.
- Coral transplanting sea grass replanting technologies are adopted independently and their applicability with hard structures should be experimentally tested to obtain the endorsement of experts.

47.2 Adequacy for current climate

- Currently, dikes have been established in eroding low coasts and they have made a very high impact in controlling erosion and inundation in such areas (e.g. Hikkaduwa, Peraliya, etc.) .

47.3 Size of the beneficiary group

- All coastal communities living in the vicinity of eroding coastal belts especially in the western, southern and south-western coasts of Sri Lanka.
- Those who are involved in construction of hard defense structures
- Tourist hotel owners and beach resort owners.
- If coral and sea grass growth could be promoted it will improve the biodiversity and therefore fisher communities and those involved involved in ecotourism will benefit out of this project.

48. Costs

Construction of a 1 m high sea dike with following dimensions have incurred a unit cost of 0.4MUS$/km (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990)

Height	:1 m
Top width	:4 m
Slopes	:1:4
Cross Section	:8m^3/m
Bottom width	:12m
Construction material:	local materials by hydraulic crane and bulldozer; slope protection; asphalt penetrated stone

4.1Cost to implement adaptation options

Dikes to be constructed are expected to have a height of 1m from the Mean High Water level (MHW). According to Linham et al.(2010), construction cost of dikes can range from US$ 1-7.6 million/ km length depending on their global location. According to IPCC Report of the Coastal Zone Management Subgroup (1990), Sri Lanka is having a total Low-Coast Length of 4820km (Low-coast "crow" length = 990km) and for its protection 1,446.0 MUS$ is required and also the total cost for protection of low coasts of the low middle income groups and for Asian Indian Ocean Countries to which Sri Lanka belongs, have been estimated as 33.7 & 23.6 Billion US$ respectively. Considering the above information cost for construction of a dike of 1 km length, 4m crown width, 12m foot width and a height of 1m was taken as 1.6 MUS$ and estimates were carried out.

Total Low-coast length	- 4820km
Total cost for construction of dikes as estimated in 1990(IPCC,1990)	- US$M 1,446.0
Cost/m of coast line as estimated in 1990	- US$ 300
Cost/m as calculated for 2011	- US$ 450
If the base width,crown width & the height of the dike are 8m, 4m and 1m respectively	
Area of land covered by 1m length of dike along the coast	-12m^2
Therefore cost per 1m^2 of the dike constructed along the low coast	**- US $ 37.5**

4.2 Additional costs to implement adaptation option, compared to "business as usual"

- With the increase of sea level dike heightening is needed and costs for such modifications should be included whenever they are necessary.
- If the dikes are modified with applications of coral transplants and establishment of sea grass plots considering the expected sea level rise as shown in Figure 2, respective additional costs should be added.

5 Development impacts , indirect benefits

5.2 Economic benefits

5.2.1 Employment

- This project will provide employment opportunities to person involved in coastal construction sector
- Small & medium scale entrepreneurs will be able to establish new industries within the coastal belt due to the reduced risk to infrastructure from coastal erosion & inundation, which will provide self employment opportunities and employment for others

5.2.2 Investment :

- Investment on new enterprises by coastal communities
- Although there is no direct investment involved, due to protection provided by coastal dikes to coastal structures and properties of coastal communities it is an indirect investment due to reduction of costs for rehabilitation and maintenance of coastal structures and properties.

5.3 Social benefits :

- **Income**
  - Improvement of socioeconomic status of coastal communities due to reduction in loss of land, properties and infrastructure due to coastal erosion and inundation.
  - Increase income of persons involved in construction and maintenance of dikes will improve their socioeconomic status
- **Education**
  - Improvement of knowledge on the effect of hard defense structures against coastal erosion and inundation, when coupled with soft defense structures,

- **Health**
  - Improved security of coastal dwellings will naturally improve the health conditions of coastal communities

5.4 Environmental benefits

- Dikes provide a high degree of protection against flooding in low-lying coastal areas. They often form the cheapest hard defense when the value of coastal land is low (Brampton, 2002).
- The sloped seaward edge of a dike leads to greater wave energy dissipation and reduced wave loadings on the structure compared to vertical structures. This is achieved because the seaward slope forces waves to break as the water becomes shallower.
- Wave breaking causes energy dissipation and is beneficial because the process causes waves to lose a significant portion of their energy. Because the waves have lost energy, they are less capable of causing negative effects such as erosion of the shoreline.
- By reducing wave loadings, the probability of catastrophic failure or damage during extreme events is also reduced.
- With the sea level rise, surface area available for settlement of benthic marine organisms will be increased and it will improve the coastal biodiversity

6 Local context

6.2 Opportunities & Barriers

6.2.1 Opportunities

6.2.1.1 For coastal scientists, coastal engineers , marine biologists, coastal zone managers will get a very good opportunity to cooperate and to use their knowledge and experience to find solutions to possible coastal erosion and inundation due to expected sea-level rise within the coastal belt of Sri Lanka, using locally available material.

6.2.1.2 Academics and researchers will get an opportunity to conduct useful scientific research to develop low cost techniques to construct dikes.

6.2.1.3 Sri Lanka will get an opportunity to make possible contributions to find solutions for local, regional and global problems that may faced due to climate change.

6.2.2 Barriers

- High cost incurred on coastal constructions, coral transplanting, etc.
- Low inputs by the government on coastal & marine science research and education, due to ignorance of the importance of marine science education and the cost incurred for marine science education.

6.3 Status

Technology for dike construction using locally available material, associated with rock revetments and geotextile lining is currently being used in low coasts.

6.4 Time frame

	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Selection of sites and feasibility studies	X	X										
Construction of dykes			X	X	X							
Monitoring						X	X	X	X			
Depending on the success application to more coastal areas									X	X	X	X

6.5 Acceptability to local stake holders:

- If successful following stakeholders will support the programme
  1. Coastal property owners
  2. Tourist hotels
  3. Small & medium scale enterprise owbners

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Technology Fact Sheet 7

Floating Mariculture Systems for Sea Weed Farming

Sector: Coastal

- **Technology characteristics**

1. **Introduction to establishment of floating mariculture systems for sea weed farming**

A reduction in coastal land due to inundation from sea level rise is expected and it will affect the land based agriculture. In addition to the above sea level rise may cause salt water intrusion in to fresh water and reduce the availability of fresh water for aquaculture. As an adaptation to the above, marine and coastal lagoons and bays with the required salinity should be used for aquaculture.

Seaweed farming is a profitable coastal activity which will help to improve the socio-economic standard of coastal communities. It can be introduced as an alternative livelihood activity for coastal communities involve in coral mining & ornamental fish collection, which are currently causing harmful impacts to sensitive coastal ecosystems. This is a farming system which does not need the addition of fertilizers or nutrients as they are freely available in nature. This industry can attract foreign exchange to the country, which will improve the county's economy.

Globally there are over 9,000 species of seaweed divided into three major types;green-6000 species, brown -2000 species and Red 1200. Like land plants, all seaweeds depend on light for growth, so they only occupy the intertidal area or relatively shallow photic (light penetrating) zone. Green seaweeds tend to be found towards the top of the shore, browns from the top to deeper waters, and, since they are adapted to photosynthesise at lower lights levels, red seaweeds tend to dominate the deeper, darker waters and also beneath kelp canopies and in shady rockpools. Seaweed is harvested throughout the world as a food source as well as an export commodity for the production of agar & carageenan products.

Seaweeds have been traditionally cultured for decades and probably for centuries in several Asian nationssuch as China, Korea & Japan. Until 1980s seaweed production in other nations in the Asia has been from wild stocks, although limited culture took place in nations such as Philippines & Indonesia.Species harvested include varieties of *Euchema (Kappaphycus), Gracillaria & Porphyra,* among others. Exports of seaweeds from Philippines increased from - 675 MT in 1967 to 28,000MT MT in 1985. Between 1984 & 1991 production of seaweed increased in Indonesia from 9,100 MT to 19,000MT to which *Eucheuma* contributed 78%. *Eucheuma* was & remains a major component of seaweed export from these countries.

As early as 1970s, it was recognised that demand for seaweed & seaweed products was much higher than the supply & cultivation was viewed as the best means to increase production. Growth in demand encouraged research & development of culture methods & to address problems in the industry such as poor quality & fluctuating prices.

The profitable nature of seaweed farming also became evident & accelerated its expansion.

Sea weeds are important as a source of agar and alginates such as Carrageenan (A chemical categorised as gums)for a range of products including ice cream, yoghurt, pet food, Beauty treatments (as an ingredient in facial & body lotions, in moisturizers, in seaweed baths, as a health supplement, in tooth paste, etc. It is also used in preparation of drugs, in agriculture and horticulture as an organic fertiliser and a soil dressing.

Cutrrently sea weeds are cultured in Sri Lanka as a small scale project and at University the University of Ruhuna Sea weed (*Euchema & Gracilaria*)farming was successfully carried out successfully in floating cages.

2.1.2 Technology Characteristics/Highlights

Light floating cages (2.0x1.0x1.0m^2) should constructed with a PVC tube frames and plastic mesh could be used for sea weed culture (Plate 1). Propagules of sea weed should be tiedto lines fixed to the inside frame of the frame. After that they should be anchored in the shore coastal waters with a water depth of at least 3 meters. Sea weeds would grow to fill the whole cage. Plate 1 Culture should be carried out when the calm conditions prevail in the coastal belt. Coastal bays and the eeastern coast of Sri Lanka are suitable for sea weed farming

Plate 1: Cage used for culturing sea weed Pk\left) with propagules tied to lines in side the cage

Plate 2: Deploying the cages using a canoe (Left) and the floating cage filled with sea weeds grown out of the cage (middle & right)

2.1 Institutional/ organisational requirements

- National Aquaculture Development Authority should take an initiative to introduce sea weed culture to coastal bays and the eastern coast of Sri Lanka.
- Universities and research institutes should carry out research to
  - develop culture methods
  - reduce the cost for production of cages with a material which can stand the energy of sea waves.

3 Operations and maintenance

3.1 Endorsement by experts

Ministry of Fisheries and Aquatic Resurces Development has identified them as priority area

3.2 Adequacy for current climate

- Sea weeds are being farmed
- Tuna & Grouper are available around Sri Lanka

3.3 Size of the beneficiary group

- All person involve in Aquaculture
- Industries using sea-weed products
- All consumers of fish
- Government due to attraction of foreign exchange

4 Costs

4.1Cost to implement adaptation options

Activity	cost	
	Unit cost (US $)	Total cost (US $)
Field surveys to decide the suitable sites (duration 6 months)		8,000
Training workshops 10 Nos		40,000
Material for construction of cages/ha	75/m^2	750,000
Supply of propagules		5,000
Allowances for persons (5) involved in construction of cages,trasplanting, maintenance & harvesting 3 years		60,000
Transport & other miscellaneous costs		25,000
Contingencies		42,000
Total cost for three years considering the life time of cages to be three years		930,000/ha/3years
Total cost for 1 year	31/m^2	310,000/ha

4.1 Additional costs to implement adaptation option, compared to “business as usual”

- Every three years cages will have to be replaced
- During the 2nd and third years propagules could be obtained from the harvest gained every year but it is advisable to obtain new propagules every three years to maintain the quality of sea weeds produced.

5 Development impacts , indirect benefits

5.1 Economic benefits

- **Employment** :
  - Provide self employment opportunities to coastal communities during the periods when calm sea is prevailing
- **Investment :**
  - Since this industry will reduce the cost on the imports of dried sea weeds & Carrageenan to Sri Lanaka and there is a potential to establish an export market, which will contribute to the GDP of the country

5.2 Social benefits :

- **Income :**
  1. It given an additional income to coastal communities three months after the culture cycle is commenced
  2. During the culture trials fisherman in the area reported about the presence of larg aggregates of fish around the tank and they have been harvesting them
  3. Inside the cages certain species of ornamental fish (*Abudufdef* sp) were observed and they were not harmful to the sea weeds but the cages provided them shelter from the predators. This shows that ornamental fish collectors could use this as a device to rear marine ornamental fish which are not feeding on sea weeds and it will provide them with an additional income.
- **Education**
  1. They can obtain a training on how to culture sea weeds, dry them & prepare them for export market
  2. Those who can invest on equipment necessary for extraction of Agar and carrageenan can obtain a training on the extraction techniques and on the industries where these extracted material is used (Confectionary industry, cosmetic industry, etc.)
- **Health:**
  1. Carageenan is used in ice-cream and other products in place of milk and it is good for persons who have problems with cholesterol
  2. Increased income to coastal communities will help to maintain their nutritional standards at a higher level

5.3 Environmental benefits

- Sea weed culture does nor need any inputs such as fertilizer that can pollute the environment

- Sea weeds use the CO_2 in water and will help the reduction of GHG release
- During the experimental trials, fisherman indicated that the fish harvests near the cages increased.
- There were certain species of ornamental fish (*Abudufdef* sp) which were growing inside the mesh cages and they were not harming the sea weeds. Therefore enhancement of biodiversity also was evident

6 Local context

6.1 Opportunities & Barriers

- **Opportunities**
  - Where ever calm sea is prevailing and the water depth is around 3 m this culture method could be adopted
  - This is applicable mainly to eastern coast of Sri Lanka and the bays and sheltered areas in the western & southern coastal belt are also suitable.
  - 2 to 3 month culture cycle is sufficient to get a good harvest.
  - Currently cream biscuit manufacturing companies are importing dry sea weed and carrageenan from far east countries & if local supplies are available money spent on imports could be reduced and if there are excess productions export market also could be developed
  - Carrageenan could be used for cosmetics, confectionaries, tooth paste, etc. and agar could be used in place of gelatine
- **Barriers:**
  - Rough sea prevailing during the monsoon periods are not suitable for this culture programme and therefore inter monsoonal calm sea period could be used for this programme
  - Open farms cannot be used in the vicinity of reefs because certain reef fish such as Parrot fish are feeding voraciously on sea weeds
  - Cages have to be brought to the shore during rough sea conditions to prevent damage to them
  - High initial cost for construction of cages
  - Poaching

6.2 Status:

- Sea weed culture is currently practiced by certain biscuit manufacturing companies (Munchi Biscuit Company) and National Aquatic Resources Development Authority
- Faculty of Fisheries and Marine sciences & Technology of University of Ruhuna also had a trial on cultured *Euchema* & *Gracillaria* in cages at Weligama and it resulted in a high growth within 2 to 3 months.

Time frame

	Year 1 divided to 4 quarters				Tear 2 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites	X							
Awareness/training		X						
Preparation of transplant material			X	X				
Transplanting/monitoring					X	X	X	
Evaluation of success							X	X

6.3 Acceptability to local stake holders:

7 References

- Linham, Mathews M. & Robert J. Nicholls((2010). Technologies for Climate Change Adaptation – Coasta Erosion & Flooding- (Xaanil Zhu ed.). UNEP Riso Centre, University of Southhampton. ISBN978-87550-3855-4
- FAO Mannual for Sea weed farming

Technology Fact Sheet 9

Construction of Groins & Sea Walls

49. **Sector**: Coastal
50. **Technology characteristics**

50.1 Introduction to construction of hard structures such as sea walls (revetments) or storm surge barriers and closure dams:

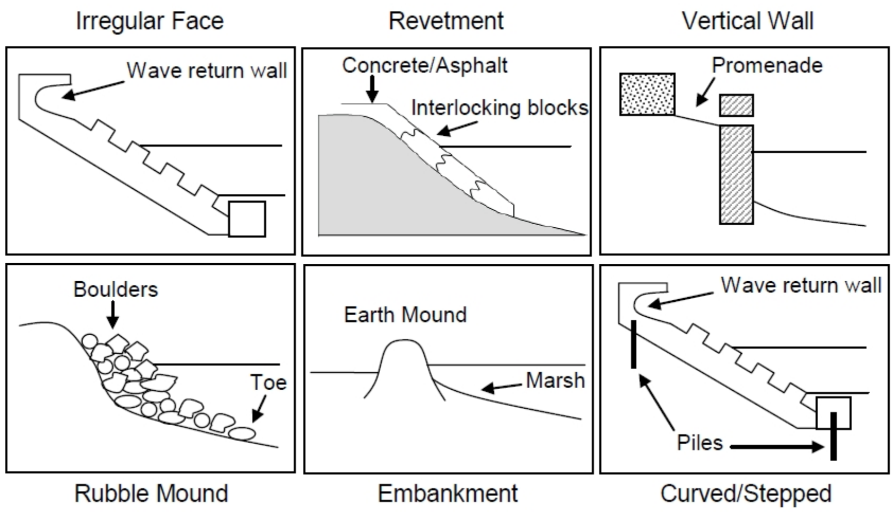
Seawalls are hard defense structures which are built parallel to the shoreline in coastal areas which are subjected to erosion due to sliding of soil as a result of high wave action and coastal flooding. The physical form of these structures is highly variable; seawalls can be vertical or sloping and constructed from a wide variety of materials. They may also be referred to as revetments. The description of this technology originates from Linham and Nicholls (2010). Sea walls are frequently used in locations where further shore erosion will result in excessive damage, e.g. when roads and buildings are about to fall into the sea and they are often built as a last resort, most are continually under severe wave stress. Seawalls usually have a deep foundation for stability. Also, to overcome the earth pressure on the landward side of the structure, 'deadmen' or earth anchors can be buried upland and connected to the wall by rods (Dean & Dalrymple, 2002). However, while they prevent further shoreline erosion, they do not deal with the causes of erosion (French, 2001). Seawalls will provide protection against water levels up to the seawall design height. In the past the design height of many seawalls was based on the highest known flood level (van der Meer, 1998).

Global climate change has already begun to have serious impacts on socio-ecological systems around the world. Increased average temperatures have set in motion a variety of forces that are producing rises in sea levels globally and, in a number of specific locales, they promise to have serious impacts in both proximate (decades) and distant (centuries) futures. Most recent scientific assessments of global climate change indicate that sea level rise will have significant impacts on coastal environments and their biotic communities, including human settlements Oliver-Smith (2009).

According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990), in Sri Lanka, total city water front length and harbour length that needs protection are respectively 4820km and 1.6 km respectively. Cost for protection of above areas from erosion due to high wave action and storm surge is reported as US$M 1,860 and 37 respectively. With the new harbours, which are under construction in Hamabanthota and in the eastern coast of Sri Lanka the cost of construction has exceeded the cost indicated above. Proposed defenses constructed for above purposes (especially for Industrial area and harbours) are raising of low lying outer dike areas by 1 m; strengthening of quay walls by raising or construction of sea dikes. For such constructions unit cost have been estimated as 15 M$/km^2. Current construction costs for hard defense structures were not available to be included in this report, although several attempts were made to obtain them from respective organizations. Therefore the estimates for this report was made using the values given by IPCC (1990) with relevant alterations considering the depreciation of the Sri Lankan rupee against the US$ in 2011.

2.2 Technology Characteristics/Highlights

Seawalls range in type and may include steel sheetpile walls, monolithic concrete barriers, rubble mound structures, brick or block walls or gabions (wire baskets filled with rocks) (Kamphuis, 2000). Some typical seawall designs are shown in Figure 1. Seawalls are typically, heavily engineered, inflexible structures and are generally expensive to construct and require proper design and construction supervision (UNFCCC, 1999).



Hard, concrete structures are typically replaced by revetments and embankment-type structures in more sheltered environments

Figure 1: Variation in design type of seawalls. Source: Adapted by Linham and Nicholls (2010) from French, (2001)

From the above structures recommended by French (2001), rubble mounds constructed using granite boulders is the commonest in Sri Lanka. However during the tsunami they neither protected the coastal infrastructure within the coastal belt of Hikkaduwa, which has been previously altered due to anthropogenic activities such as coral mining for lime industry Plate 1.   Therefore revetments, vertical walls and the sea walls with irregular face with a wave return wall would be the hard defense structures that could be considered as most suitable for coastal belts that needs protection from high wave action and storm surge. Furthermore, as indicated in the Figure 2, if they could be coupled with soft barriers. If such soft barriers could be artificially transplanted within the irregular depressions on the hard defense structures or if they could be designed to give a terraced appearance, such structurs will enhance the effect of hard structures against wave action. Such strctures should be experimentally tested especially in coastal areas such as Hikkaduwa where corals and sea grass beds are naturally occurring.

Plate 1: Disturbed revetments & groins in the Southern Coastal belt of Sri Lanka during tsunami (2004)

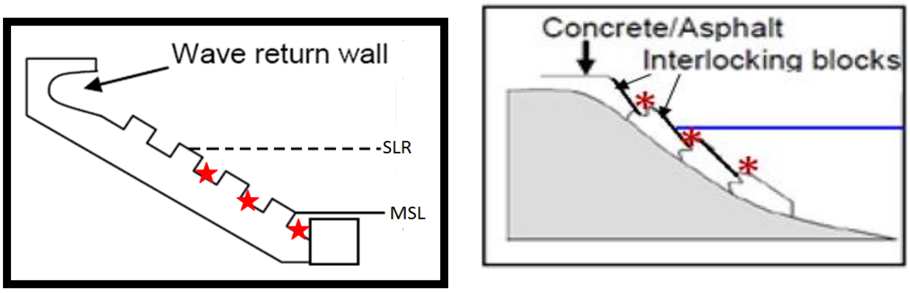


Figure 2: Modified drawing of a sea wall with a structure that helps the return of the waves could be used as a hard substratum to establish artificial coral beds (Source: Adopted from French, 2001). Places within an irregular faced sea walls (★) and on the revetments with interlocking blocks (*) sea walls suitable to fix the tiles with transplanted corals or plots with sea grasses considering the water level due to sea level rise. MHWS- MSL- Mean sea level; SLR- Water level at sea level rise

2.3 Institutional/ organisational requirements

- Coast conservation department should collaborate with engineers and marine scientists from research & academic institutions when designing most suitable hard defense structures for preventing coastal erosion and coastal inundation.
- Funds should be made available for research on construction of sea walls and revetments with suitable designs to accommodate soft barriers and to explore the possibilities of using low cost but strong constructions which could stand the forces of strong waves.

51. Operations and maintenance

51.1 Endorsement by experts

- Construction of groins & revetments have been already implemented by the CCD.

- Coral transplanting and sea grass replanting technologies are adopted independently and their applicability and incorporation in to hard structures should be experimentally tested to obtain the endorsement of experts.

51.2 Adequacy for current climate

- Currently, sea walls groins have been constructed along the coasts close to urban areas, harbours, anchorages etc.
- During monsoonal periods certain areas of the western southern and north western coasts are badly affected due to strong waves and currently CCD is promoting the construction of groins and revetments to prevent coastal erosion and it is given higher priority than to the rehabilitation of soft barriers such as rehabilitation of mangroves for reduce impacts from wave action and coastal inundation in North and western coasts of Sri Lanka (Personnel communication by a CCD official)

51.3 Size of the beneficiary group

- All coastal communities living in the urban areas in the vicinity of eroding coastal belts especially in the western, southern and south-western coasts of Sri Lanka and close to harbours.
- Those who are involved in construction of hard defense structures
- Tourist hotel owners and beach resort owners.
- If coral transplanting (establishment of artificial reefs) and sea grass planting could be incorporated in to the designing of hard defense structures it would improve the biodiversity and therefore fisher communities and those involved in ecotourism will benefit out of such project.

4. Costs

4.1 Cost to implement adaptation options

A study by Linham et al. (2010) indicates that the unit cost of constructing 1 km of vertical seawall is in the range of US$0.4 to 27.5 million, which depend on the height of sea wall required with respect to the wave height. Variation in costs between projects is a result of numerous factors, such as:

- Design height is a major factor affecting costs per unit length of seawall. Height affects the volume of materials required for construction and the build time
- Anticipated wave loadings will affect how resilient the structure needs to be; deeper waters and exposed coasts cause higher wave loadings which will mean the structure needs to be more robust, thus higher costs
- Single or multi stage construction; costs are lower for single stage (Nicholls & Leatherman, 1995)
- Selected seawall design and the standard of protection desired. Certain design features will increase costs and more robust seawalls will be more costly
- Construction materials (e.g. rubble blocks, pre-cast concrete elements, metal, soil, etc.)
- Proximity to and availability of raw construction materials
- Availability and cost of human resources including expertise

Maintenance costs are another significant and ongoing expense when a hard defence is selected. These costs are ongoing for the life of the structure and are therefore likely to result in significant levels of investment through a project's lifetime. Continued investment in maintenance is highly recommended to ensure defences continue to provide design levels of protection (Linham et al., 2010).

According to the estimates done in 1990 by the IPCC Coastal Zone Management Sub Group Sri Lanka's coastal belt could be categorized in to following types (IPCC Report of the Coastal Zone Management Subgroup, Strategies for Adaption to Sea Level Rise, 1990), in Sri Lanka, total city water front length and harbor area that needs protection are respectively 124 km and 1.6 km^2 respectively. Cost for protection of above areas from erosion due to high wave action and storm surge is reported as US$M 1,860 and 37 respectively. With the new harbours which are under construction in Hamabanthota and in the eastern coast of Sri Lanka the cost of construction has exceeded the cost indicated above. Proposed defenses constructed for above purposes (especially for Industrial area and harbours) are raising of low lying outer dike areas by 1 m; strengthening of quay walls and protection of petrochemical areas by raising or construction of sea dikes. For such constructions Unit cost have been estimated as 15 M$/$km^2$. Current construction costs for hard defense structures were not available to be included in this report, although several attemps were made to obtain them from respective organizations. Therefore the estimates for this report was made using the values given by IPCC (1990) with relevant alterations considering the depreciation of the Sri Lankan rupee against the US$ in 2011

Length of the coast line required protection from hard defense structures	-127 km
Total cost estimated in 1990 (IPCC, 1990)	- US$M1897
Total cost calculated to 2011	-US$M2846
Cost per km^2 of sea walls as estimated in 1990	-US$M15
Cost per km^2 calculated for 2011	-US$M22.5
Cost per m^2 in 2011	-US$ 22.5

51.4 Additional costs to implement adaptation option, compared to "business as usual"

- If the sea walls and revetments are modified with applications of coral transplants and establishment of sea grass plots considering the expected sea level rise as shown in Figure 2, respective additional costs should be added.

52. Development impacts , indirect benefits

Seawalls provide a high degree of protection to the coastal belt against coastal flooding and erosion and also they protect the infrastructure within the coastal zone. They will also fix the boundaries between the sea and land, if they are appropriately designed and properly maintained. Seawalls also have a much lower space requirement than other coastal defenses such as dikes, especially if vertical seawall designs are selected. In many areas land in the coastal zone is highly sought-after; by reducing the space requirements for coastal defence the overall costs of construction may fall.

The increased security provided by seawall construction also maintains hinterland values and may promote investment and development of the area (Nicholls et al., 2007b). Moreover, if appropriately designed, seawalls have a high amenity value – in many countries, seawalls incorporate promenades which encourage recreation and tourism.

When considering adaptation to climate change, another advantage of seawalls is that it is possible to progressively upgrade these structures by increasing the structure height in response to SLR. It is important however, that seawall upgrade does not compromise the integrity of the structure. Upgrading defences will leave a 'construction joint' between the new section and the pre-existing seawall. Upgrades need to account for this weakened section and reinforce it appropriately.

52.1 Economic benefits

52.1.1 Employment

- This project will provide employment opportunities to person involved in coastal construction sector
- Small & medium scale entrepreneurs will be able to establish new industries within the coastal belt due to the reduced risk to infrastructure from coastal erosion & inundation, which will provide self employment opportunities and employment for others
- Expansion of tourist hotels will also provide more employment opportunities

52.1.2 Investment :

- Investment on new enterprises by coastal communities
- Although there is no direct investment involved, due to protection provided by coastal dikes to coastal structures and properties of coastal communities and business establishments, it is an indirect investment due to reduction of costs for rehabilitation and maintenance of coastal structures which will be damages due to wave action and coastal inundation in the absence of hard defense structures .

52.2 Social benefits :

- **Income**
  - Improvement of socioeconomic status of coastal communities due to reduction in loss of land, properties and infrastructure and also due to availability of more land for establishment of new business enterprises and tourist hotels.
  - Increase income of persons involved in construction and maintenance of sea walls..
- **Education**
  - Improvement of knowledge on effect of hard defense structures against strong wave action and erosion.
  - Provide opportunities for undergraduate and postgraduate students to carry out research projects to improve the quality of and reduce the cost of hard defense structures and on the possibility of incorporating soft defense mechanisms to enhance the effects of hard constructions

- **Health**
    1. Improved security of coastal dwellings will naturally improve the health conditions of coastal communities

52.3 Environmental benefits

- Sea walls provide a high degree of protection against flooding in low-lying coastal areas. They often form the cheapest hard defense when the value of coastal land is low (Brampton, 2002).
- The sloped seaward edge of a dike leads to greater wave energy dissipation and reduced wave loadings on the structure compared to vertical structures. This is achieved because the seaward slope forces waves to break as the water becomes shallower.
- Wave breaking causes energy dissipation and is beneficial because the process causes waves to lose a significant portion of their energy. Because the waves have lost energy, they are less capable of causing negative effects such as erosion of the shoreline.
- By reducing wave loadings, the probability of catastrophic failure or damage during extreme events is also reduced.
- With the sea level rise, surface area available for settlement of benthic marine organisms will be increased and it will improve the coastal biodiversity.

7.2 **Social benefits** :

- **Income**
    - Improvement of socioeconomic status of coastal communities due to reduction in loss of land, properties and infrastructure due to coastal erosion and inundation.
    - Increase income of persons involved in construction and maintenance of sea walls/revetments will improve their socioeconomic status
- **Education**
    - Provide opportunities for research based studies for persons who are involved in designing sea walls and revetments.
    - Improvement of knowledge on the effect of hard defense structures against coastal erosion and inundation, when coupled with soft defense structures,
- **Health**
    - Improved security of coastal dwellings will naturally improve the health conditions of coastal communities

7.3 Environmental benefits

- Sea walls provide a high degree of protection against rough sea conditions and flooding in coastal cities and harbours.
- Protect coastal agriculture from salt water intrusion and inundation
- Prevent sedimentation in coastal marine sensitive ecostystems

6. Local context

6.1 Opportunities & Barriers

- **Opportunities**
    - For coastal scientists, coastal engineers, marine biologists, coastal zone managers will get a very good opportunity to cooperate and to use their knowledge and experience to construct

sea walls with an ability to stand the wave heights reported from different coastal belts, using, using locally available material.

- Academics and researchers will get an opportunity to conduct useful scientific research to develop low cost techniques to construct sea walls and revetments.
- Sri Lanka will get an opportunity to make possible contributions to find solutions for local, regional and global problems that may faced due to climate change.
- These structures help to increase the land area available for construction of infrastructure for tourism and other coastal industries.

6.2 Barriers

- High cost incurred on coastal constructions, etc.
- Low inputs by the government on coastal & marine science research and education, due to ignorance of the importance of marine science education and the cost incurred for marine science education.
- Sri Lanka is depending on the foreign exchange earnings from tourism and the hard barriers will not allow free access to the beaches and such constructions will affect the natural scenic beauty of the Sri Lankan beaches
- These structures may affect the ecological balance of ecosystems in the intertidal zone as they prevent the free movement of certain organisms. Especially they might affect the migratory circuits of diadromous species.
- If the construction of these walls do not take the extreme conditions of the tidal variations and wave heights, during such events sea water enters the land may not freely return and affect the ground water salinity of adjacent coastal areas, which was observed in the wells of the coastal belt of Sri Lanka after the 2004 tsunami.
- In estuaries, seawalls also cause changes to the area inundated by the tides thus, reducing the available area for occupation by water on a high tide. With the same volume of water flowing into the estuary, the level of the water after seawall construction will be higher. This may mean areas in front of the defence remain submerged longer and by greater depths. In turn, this is likely to affect the distribution of vegetation and could increase tidal range upstream of the defence (French, 2001).
- Seawalls also reduce beach access for handicapped people and for emergency services. This can be problematic if the beach fronting such structures is to be used for recreation. (Linham, 2010)
- Although seawalls prevent erosion of protected shorelines, where the seawall ends, the coast remains free to respond to natural conditions. This means that undefended areas adjacent to the wall could move inland causing a stepped appearance to the coast (French, 2001).

a. Time frame

	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Selection of sites and feasibility studies	X	X										
Construction of dykes			X	X	X							
Monitoring						X	X	X	X			
Depending on the success application to more coastal areas									X	X	X	X

b. **Acceptability to local stake holders:**

- If successful following stakeholders will support the programme
    1. Coastal property owners
    2. Tourist hotels
    3. Small & medium scale enterprise owbners

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Technology Fact Sheets (TFS)

Biodiversity Sector

Technology 1: Restoration of degraded areas inside and outside the protected area network to enhance resilience

1. SECTOR:	Biodiversity
2. TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Restoration of degraded areas inside and outside the protected area network to enhance resilience
2.2 Introduction: *Low/high, Brief introduction to the technology*	Resilience will allow biodiversity to better withstand the impact of climate change. Resilience can be defined as the capacity of a system to absorb disturbance and reorganize, while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks[81]. Some protected areas, although legally declared are degraded due to illegal activities such as encroachments for settlement and clearing, and logging. There will be other areas outside protected areas that many not be legally protected but be important for conservation now, or when species shift their range as a result of climate change. Restoration will require selecting suitable native species and recreating the former conditions of the ecosystem. Some ecosystems that can be restored include forests, wetlands, coastal areas, coral reefs etc. This can be considered to be a low-medium level technology. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action recommends to 'initiate programs to rehabilitate degraded critical habitats', to address impacts on biodiversity[82]. According the National Action Plan for Haritha Lanka Strategy 3.5 to 'Expand programs for afforestation, reforestation and forest rehabilitation, using

[81]Walker BH, Holling CS, Carpenter SR, Kinzig AS. 2004. Resilience, adaptability and trans-formability. *Ecology and Society* 9(2):5

[82]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

	indigenous species as far as possible'; while Strategy 8.3 recommends to 'Initiate programs to identify and rehabilitate degraded critical habitats'[83]. In addition to this Mission 3 of the National Action Plan for Haritha Lanka Strategy is to meet the challenges of climate change. In this section, Strategy 5 broadly refers to 'Promote carbon sequestration. More specifically Strategy 5.1 refers to 'Conserve existing carbon pools such as forests' and 5.2 refers to 'Increase the size of the carbon pool by reforestation and afforestation of degraded forests, marginal croplands and waste lands'[84]. The Climate Change Adaptation Strategy[85] for Sri Lanka and the Sector Vulnerability Profile for Biodiversity and Ecosystem Services[86] has identified to 'Link/restore/conserve, forests and other habitat refugia to increase resilience of ecosystems and species' - (B i).
2.3 Technology characteristics/highlights : *Few bullet points, ie. Low/high cost, advance technology; low technology*	Restoration is not a new technology, in Sri Lanka forest[87], aquatic[88], reef and coastal areas have been restored. Some of these technologies are currently in place, and has been so for several decades. It will require medium to high investment, and will depend on the level of degradation. Restoration in some cases may require manpower and skills as opposed to high infrastructure or hard technologies. However in the case of costal/marine restoration groynesetc can be very expensive. In some cases restoration could even mean minimum intervention of just creating the suitable environment for natural restoration. Some restoration strategies/methods include: • Aided natural restoration • Creation of analogous ecosystem • Expanding market opportunities for products from restoration.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge*	As this is not a 'new technology' the departments currently engaging in this activity will have sufficient capacity to deal with this strategy. Capacity building and knowledge transfer will be required to select suitable restoration methodologies.

[83]National Council for Sustainable Development. 2009. National Action Plan for Haritha Lanka Programme

[84]National Council for Sustainable Development. 2009. Op. Cit.

[85]Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

[86]Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

[87] Ashton, M.S., Gunatilleke, C.V.S., Singhakumara, B.M.P. and Gunatilleke, I.A.U.N. 2001. Restoration pathways for rainforest in south west Sri Lanka: a review of concepts and models, *Forest Ecol. Manage.* 154 (2001), pp. 409–430

[88] MDG SriLanka. 2009. *Ensure environmental sustainability.* Available online from: http://www.mdg.lk/ images/flash/learningzone.swf

transfer is required for the adaptation option to be implemented.	
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. There are several international experts who endorse this strategy as an essential climate change adaptation strategy for biodiversity in papers published in peer-reviewed journals[89,90].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	There is no negative consequence of this option as this is not a new technology. In fact it will also be beneficial for carbon sequestration, which is vital for climate change mitigation. This strategy has been recommended in Sri Lanka as the Biodiversity Conservation - Framework for Action as a current recommendation to address impacts on biodiversity[91].
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	Restoration will ensure that ecosystem services are maintained for the local communities and the larger population. It will also ensure that the ecosystems are healthy, and withstand some of the impacts of climate change. This would mean that ecosystem services will be minimally affected by climate change in the future. It will be beneficial due to various income opportunities such as direct involvement in restoration activities, community conservation, payments for ecosystem services, REDD and ecotourism.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost*	This technology will be medium-high in cost. It could be relatively low if it is an activity such as tree planting, but costly if it requires hard technology in the case

[89]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

[90] Heller, N.E. &Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

[91]Ministry of Environment and Natural Resources. 2007. Op. Cit.

measures	of coastal restoration. It is estimated that this activity will cost Rs. 100 million annually. This is based on the assumption that a budget increase of 5% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out until most prioritized sites are restored, and will have to be an annual budget. Cost will be for site selection (with assistance of models), prioritizing sites, selecting a suitable restoration method (forest restoration, coral planting etc), and monitoring.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There will be costs associated with the restoration process as opposed to do nothing, this additional cost could be fairly significant.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • There will be job creation, as restoration will require manpower. Local communities can easily be involved with some training for this purpose. • Once restored there could be job opportunities associated with ecotourism and sustainable utilization related jobs. **Investment:** • There will be investment required, especially if the restoration requires hard technologies (eg: groynes to restore beach, artificial reefs).
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • There will be social benefits from jobs created due to restoration related work. • There could also be an income from the harvest of non-timber forest products and ecotourism related activities once restoration is completed. **Education:** • An opportunity for students to learn about restoration techniques. • University students can learn and contribute to solutions.

	Health: • Good quality ecosystems will contribute to the quantity of life of communities. This for example could be through the provision of watershed services, providing sufficient water for drinking and sanitation.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	The main benefit of restoration would be from carbon sequestration and thus a mechanism from which climate change can be mitigated. It will also ensure that other ecosystem services are restored.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • There will be no requirement to change policy or legislation. • Restoration for various ecosystems has already been carried out. **Barriers:** • Lack of funds for restoration activities. • There will be a barrier if the degraded lands have an opportunity cost and can be utilized for another purpose.
6.2 Status: *Status of technology in the country*	This is not a new technology. The technology is currently in place and has been so for several decades. For example the Beira lake[92] is an example of an aquatic system that has been restored, degraded parts of the Sinharaja forests have been restored[93], while costal areas, wetlands, reefs etc have also been restored in the country.
6.3 Timeframe: *Specify timeframe for implementation*	Restoration of a particular area will take a few months but will need monitoring and intervention from time to time.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	It will have high acceptability, as it will create environmental benefits and maintain/restore ecosystem services. There could be income related opportunities for local communities and stakeholders.

[92] MDG SriLanka. 2009. Op. Cit.

[93] Ashton et al. 2001. Op. Cit.

Technology 2: Modeling the impact of climate change on biodiversity to predict changes for conservation and management

1. SECTOR: *To be written by sector expert*	Biodiversity
2. TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Modeling the impact of climate change on biodiversity to predict changes for conservation and management
2.2 Introduction: *Low/high, Brief introduction to the technology*	Collaboration across disciplines is necessary to plan conservation responses to climate change adequately. Climate change planning needs to take place on a regional level; driven by both regional climate models and general circulation models. This will ensure that regional climate drivers such as land use change and topography are adequately represented. Sensitivity analysis can be carried out to address the substantial uncertainty inherent in projecting future climates and biodiversity response[94]. This can be considered to be a medium level technology. It does not require sophisticated equipment, but will use software. It will require information on current species location, distributions, climatic ranges plus localized climate predictions. This technology is probably one of the most vital mechanisms as most climate change adaptation strategies will need to be based on prediction, even though they may not be totally accurate. Climate change adaptation strategies in some countries base conservation on modeling predictions. It also allows selecting the minimum areas need to conserve all species and ecosystems. *Reference in existing policies, strategies and action plans:* Mapping climate change vulnerability for biodiversity in Sri Lanka[95] has been carried out as a preliminary exercise. The Sector Vulnerability

[94] Hannah, L., G. F. Midgley, and D. Millar. 2002. Climate change-integrated conservation strategies. Global Ecology and Biogeography 11:485–495.

[95]Ministry of Environment. 2010. Op. Cit.

	Profile states that the mapping exercise itself is preliminary and limited in scope, and should be refined on an on-going basis, based on detailed data, which may become available in the future. The exercise indicates that valuable montane wet zone forests and several lowland forests could be affected. In addition wildlife reserves, including National Parks in the Intermediate Zone, could also be affected.
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	In terms of technology it is not a hard technology but it's a rather new technology. Basic modeling of climate change and biodiversity has been done in Sri Lanka. However for conservation planning more sophisticated modeling will be necessary. Although not totally accurate it is the best possible way of strategically plan for conservation in a changing climate.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	There will be capacity building and knowledge transfer necessary to carry out this activity. However this will not be too expensive as modeling, GIS specialists are available in Sri Lanka who can be trained, along with conservation professionals.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Globally this is an accepted method, with this technology is featured in many peer-reviewed journals[96]. Some express caution and recommend improved modeling capacity as the first step[97].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate*	There will be no perceived negative impacts of this technology in the current climate. The modeling can, and should consider current threats and incorporate these considerations as well, making the models relevant in both the current and future conditions.

[96]Hannah et al. 2001. Op. Cit.

[97] Heller, N.E. & Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

but may have costs and consequences under the current climate.	
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	There will be a large number of beneficiaries who will benefit from climate change adaptation strategies being carried out in a strategic manner using modeling. Although it may not be direct or visible, it will ensure that climate change adaptation strategies can be planned and executed as well as it can be possibly done, ensuring that impacts on biodiversity will be minimal. This will ensure sustainability of biodiversity and associated ecosystem services, and make them more resilient, benefiting many who depend on ecosystem services for well-being and livelihoods.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	This activity will mainly involve modeling using computers, and use of existing species data, which will not be very costly. There will be costs involved with data gathering, training etc and also conservation activities that will need to be carried out to implement it. Modeling will need to be incorporated into all climate-change adaptation strategies to make them effective (which are listed as separate technologies). It is estimated that this activity will cost Rs. 65 million annually. This is based on the assumption that a budget increase of 3.25% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried as periodically and is an annual budget. Cost will be for technology transfer, training, collecting available information, and simulation of models
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There will be some additional costs as modeling for climate change adaptation strategies have not been done at a fine scale in Sri Lanka yet. However this cost will be relatively small, and is essential to plan conservation in a changing climate.
5. DEVELOPMENT IMPACTS,	

INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • This activity will require employment for activities relating to data gathering, modeling etc. • Modeling will lead to climate change adaptation strategies (mentioned separately), which will generate employment. • This technology will lead to suitable conservation activities to conserve biodiversity in a changing climate and many will benefit from it due to community conservation programs and ecotourism. **Capital requirements:** • The capital requirements will be relatively low, as it will not require investments in any hard technology. There will be investment required for computers and other equipment necessary for modeling.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • There will be some income generation from employment. However the bulk of the income will come from the implementation of modeling into conservation activities. • These activities will allow income generation from community conservation, payments for ecosystem services, REDD, ecotourism etc. **Education:** As this is a relatively new and emerging technology, university level student can benefit from exposure to this technology. **Health:** The improvement of biodiversity and ecosystem services through climate change adaptation strategies based on modeling will contribute to health and well being of the population.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	Will contribute to minimizing impact of climate change as it would give a better idea on how adaptation activities should be planned and how biodiversity will be affected. Integration of such a technology in climate change adaptation strategies would allow ecosystems to be more resilient, and damage to ecosystem services be minimized.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and*	**Opportunities:** • Ability to plan ahead for biodiversity conservation (although

issues such as the need to adjust other policies	predictions may not be totally accurate – it could point to possible impacts). • Advanced modeling and planning of strategies climate change adaptation are being carried out in some countries, including the Cape Floristic Region in South Africa[98]. • Adaptation strategies will be more effective if they are based on climate models and existing data. • Ability to gain knowledge and expertise from other countries. **Barriers:** • Lack of data on species locations, ranges etc. • Lack of specialists in modeling biodiversity and climate change.
6.2 Status: *Status of technology in the country*	This technology is very new in the country but with capacity building and technology transfer it should be possible to introduce it relatively easily. This is also because there is considerable data in the Red List, conservation professionals and GIS experts in the country.
6.3 Timeframe: *Specify timeframe for implementation*	Several months to a year or two, for initial modeling and predictions. Will need to be updated periodically.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	It should be attractive to local stakeholders, as predictions will ensure better planning and long-term conservation of biodiversity and ecosystem services. When implemented, there could be opportunities from employment for additional conservation activities, ecotourism, community conservation, payments for ecosystem services, REDD etc.

[98]Hannah, L et al. 2002. Op. Cit.

Technology 3: Increasing connectivity through corridors, landscape/matrix improvement and management

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Increasing connectivity through corridors, landscape/matrix improvement and management
2.2 Introduction: *Low/high, Brief introduction to the technology*	Establishing corridors and improving matrix management is not a new conservation tool. This can be considered to be a medium level technology. Increasing connectivity in the broader landscape is vital for conserving biodiversity during climate change[99]. It is an important mechanism to connect fragmented areas, as many protected areas are isolated from each other. With climate change, corridors become important as they will allow migration of species, whose range will change to the changing climate[100,101]. This strategy involves the protection of areas and regions that would be essential for climate-induced wildlife movements[102]. Technologies that can be used include movement corridors for terrestrial species, while unblocked streams and rivers are important movement corridors for aquatic species[103]. In the case of forests, a system of corridors could be designed utilizing existing patches or augmenting with aided natural restoration or analogue forestry creating an opportunity for short or long term migration. This strategy is consistent with a number of existing management approaches, such as analogue forestry, agroforestry, fish ladders, and improving home gardens. Modeling techniques will be necessary to

[99]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and
Biodiversity conservation. Conservation Biology 23, 1080–1089.
[100]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.
[101] Hannah, L and Hansen, L. 2005. Chapter 20 – Designing Landscapes and Seascapes for Change. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press
[102] Allan, J. D., M. Palmer, and N. L. Poff. 2005. Climate change and fresh- water ecosystems. Pages 274–290 in T. E. Lovejoy and L. Hannah, editors. Climate change and biodiversity. Yale University Press, New Haven, Connecticut.
[103]Mawdsley et al., 2009. Op. Cit.

	assess landscape permeability to species movement and to predict likely paths of dispersal across the landscape matrix under particular climate-change scenarios[104]. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action recommends to 'Study the status/trends in wildlife areas, and identify the need for wildlife corridors and linkages as an option for species conservation'. It also identifies that there is an inadequacy in networking among protected areas. It was recommends programs to rehabilitate degraded critical habitats, and implement strategies for the promotion and strengthening of home gardens[105] – these strategies will allow improvements in the broader landscape to facilitate species movement.[106] According the National Action Plan for Haritha Lanka Strategy 3 in Mission 2: Saving the Fauna, Flora and Ecosystems is to 'Conserve and sustainable use flora and fauna outside the protected area network'[107]. Strategy 2.2 states to 'Study the status/trends in wildlife areas, identify need for wildlife corridors, linkages as an option for species conservation'[108]. The Climate Change Adaptation Strategy[109] for Sri Lanka and the Sector Vulnerability Profile for Biodiversity and Ecosystem Services[110] has identified to 'Link/restore/conserve, forests and other habitat refugia to increase resilience of ecosystems and species' - (B i).
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low*	It is not an advanced technology, and a few forest corridors have already been established[111]. There are also activities that aim to link the broader landscape through land management and working with land users. The cost of this technology will be low-medium.

[104]Mawdsley, et al. 2009. Op. Cit.

[105]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[106]Ministry of Environment and Natural Resources. 2007. Op. Cit.

[107] National Council for Sustainable Development . 2009. National Action Plan for Haritha Lanka Programme

[108] National Council for Sustainable Development . 2009. Op. Cit.

[109]Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

[110]Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

[111]Rainforest Rescue International. 2011. Rainforest Corridor Programme.
http://www.rainforestrescueinternational.org/downloads/rri_rcp_case_study.pdf

technology	There are provisions for such corridors in wildlife legislation and are referred to as 'jungle corridors'[112]. It will require selecting the correct sites that need linking, and also selecting sites that are able to link fragmented areas. Selection of suitable corridors will need to be supported by modeling which will help predict how species will move with changing slime.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	As this is not a 'new technology', support can be obtained from experts involved in this activity currently. Capacity building and knowledge transfer will be required to (1) Select suitable areas based on climate change modeling and predictions, and (2) Select the correct methodology and process to create/enhance the corridor/improve landscape connectivity. Knowledge transfer and capacity building will be required for modeling related activities.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Globally this technology has been recommended as an adaptation strategy for biodiversity for climate change in books and peer reviewed journals[113,114]. According to a study, to improve landscape connectivity, so that species can move, is the most frequent recommendation for climate change adaptation, while the second popular recommendation for improving landscape connectivity is to change how we manage the matrix[115].
3.2 Adequacy for current	There will be no negative impacts under the current climate. In fact it

[112] The Fauna and Flora Protection Ordinance No. 2 of 1937 and Amendment Act No. 49 of 1993.

[113]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

[114] Hannah, L and Hansen, L. 2005. Chapter 20 – Designing Landscapes and Seascapes for Change. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press

[115] Heller, N.E. & Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	will also assist in alleviating existing issues relating to fragmentation of habitats. In the future its usefulness will only increase. Protecting such areas will also allow for ecosystem services, carbon sequestration and a habitat for many critical species that exist outside the current protected area system.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	There will be benefits associated with ecosystem services for the larger population. The enhancement of the landscape will also increase the opportunities jobs and income related to conservation.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	The cost of the technology is variable depending on the condition and connectivity of the matrix. It will require some investment, especially if the area needs to be acquired, restored and managed to facilitate migration. If it mainly works with current land users then the cost be lower. It is estimated that this activity will cost Rs. 90 million annually. This is based on the assumption that a budget increase of 4.5% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. The activity will need to be carried out until prioritized sites are covered, and will have to be an annual budget. Cost will be for site selection (models and available information), prioritization, establishing corridor (legal declaration, land acquisition if necessary), awareness and training for best practices, restoration (if necessary) and monitoring.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	The additional cost will be associated with obtaining the area and it may need to be purchased, people may need to be relocated. There could also be costs in restoring, managing and maintaining it. Funds will be required when educating and working with landowners.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	

5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • There will be some jobs created locally if it requires restoration, monitoring or conservation. • There could be ecotourism, community conservation and sustainable utilization of NTFP **Investment:** • There will not be major capital requirements, however if restoration or any construction (eg: fish ladders) related activities are necessary – it will require some investment. • Investment will need to be made in order to secure land in the case of corridors,. In some cases compensation will need to be paid if there are legitimate owners.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • Income could be generated by jobs associated with corridors and matrix management. • Jobs and income from possible ecotourism related activities. • Possible benefits from community conservation, payments for ecosystems services, REDD, NTFPs etc. **Education:** • Educational benefits will include the ability for students to learn about the technology. • University students can learn and contribute to this technology. **Health:** • It will help sustain biodiversity and ecosystem services, contributing to good environmental quality, which in turn improved well-being and health of people.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	Environmental benefits include maintaining genetic diversity, allowing migration for species with large home ranges, seed dispersal, carbon sequestration and other ecosystem services. It will also allow ecosystems to be resilient to the changing climate as they are better conserved.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers to implementation and issues such as the need to*	**Opportunities:** • The Biodiversity Conservation - Framework for Action recommends this technology[116].

[116]Ministry of Environment and Natural Resources. 2007. Op. Cit.

adjust other policies	• Technology available, and the country has got some experience in this. • Many private owners maybe motivated due to the various benefits and income opportunities. **Barriers:** • It can be difficult to predict future species movements with high degree of confidence (for corridors)[117]. • Availability, acquisition of sites and possible resettlement. • It will be difficult to formalize such a mechanism when working with private landowners. • Landowners may need benefits to motivate their participation. • Participants may be able to pull out anytime and difficult to ensure long-term commitment from participants. • Difficulties in managing and monitoring scattered land areas.
6.2 Status: *Status of technology in the country*	Technology available, as the country has got some experience[118] in this. Some landscape connectivity mechanisms for freshwater systems, wetlands and other ecosystems may be rather new technologies to the country.
6.3 Timeframe: *Specify timeframe for implementation*	It could take a few months to about a year to identify and legalize the corridor, however periodic maintenance and monitoring may be required.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	It is likely that the technology will be acceptable to local stakeholders. The only opposition it could face is from those who may be required to resettle, or if there is demand for other uses. However in most cases this activity will involve working with the current land use. The technology will be attractive as it could draw ecotourism and long-term benefits from conservation-related income.

[117]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.
[118]Rainforest Rescue International. 2011. Rainforest Corridor Programme.

Technology 4: Protecting refugia which are less vulnerable to climatic changes

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Protecting refugia which are less vulnerable to climatic changes
2.2 Introduction: *Low/high, Brief introduction to the technology*	Refugia are areas where climate-change impacts are predicted to be less severe[119]. Plant ecologists and paleoecologistsrecognise that some environments are more buffered against climate change and short-term disturbances than others[120]. Such sites will be vital areas that can be used to conserve biodiversity in a changing climate. There will be refugia already present that may not be conserved or given its due level of legal protection. It is of utmost importance to identify such areas and ensure that these areas are adequately protected. This is considered to be a low-medium level technology. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action, in the section on in-situ conservation, recommends to 'Identify critically important biodiversity hotspots in the country outside forests and bring them under a relevant protected area category'[121]. The Climate Change Adaptation Strategy[122] for Sri Lanka and the Sector Vulnerability Profile for Biodiversity and Ecosystem Services[123] has identified to 'Link/restore/conserve, forests and other habitat refugia to increase resilience of ecosystems and species' - (B i) and to 'Establish and/or effectively manage PAs and other important wildlife refuges in all climatic zones' - (B iv).

[119]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

[120] Millar, C.I., Stephenson, N.L., Stephens, S.L., 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17, 2145–2151.

[121]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[122]Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

[123]Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	This is a low-medium technology as such sites are already present, and the main activity would be to identify suitable areas and protect them. It could involve rating known refugia that have a potential for homeostasis by being situated in favorable areas, followed by legal protection. It may require some management and intervention, but may not require a large investment if the ecosystems are intact. However in some cases restoration maybe requires which could be quite costly. Monitoring and minimizing other threats will also be vital components for its survival. Biological details relating to refugia[124]: Refugial areas are often rich in species, genomes, and alleles. These distinct intraspecific genomes have evolved different genetic adaptation so their potential for future change may vary. Some refugial areas, where genomes survive and diverge over several major oscillations, are likely to allow speciation and accumulation of diversity. These rich areas appear to be those that can sustain populations throughout the climatic fluctuation, rather than just extremes. Mountainous and tropical areas appear to be particularly successful. According to research, divergence and speciation seem to accumulate in refugia.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	There will be some capacity building and knowledge transfer required to identify sites as research will need to be done at a fine scale to identify refugia, which have stable climates. This may require some field study, fine scale climatic data and climate change modeling. Once identified, establishing it will not be considered a new technology, as it will be very similar to creating a new protected area. Monitoring will be necessary.

[124] Hewitt, G.M., and Nichols, R. A. 2005. Chapter 12 – Genetic and Evolutionary Impacts of Climate Change. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press

3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Experts have endorsed the concept of protecting refugia as important areas for conserving biodiversity in a changing climate. These views have been expressed in international peer reviewed journals[125,126].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	Refugia by definition will have stable climates and protecting such an area will not have negative consequences in the current climate. Refugia will have similar benefits to protected areas.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	The main benefits would be from ecosystems services, which for example could be watershed functions, regulating microclimate. It will thus benefit a larger group. There could be some benefits to local communities from community conservation initiatives, REDD, payment for ecosystem services etc.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	There will be low-medium costs associated with this technology as most costs would be to protect and monitor the site, after the initial research and site selection has been carried out. It is estimated that this activity will cost Rs. 85 million annually. This is based on the assumption that a budget increase of 4.25% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out until most prioritized sites are covered, and will have to be an annual budget.

[125]Mawdsley et al, 2009. Op. Cit.

[126]Noss, R. F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology 15:578–590.

	Cost will be for site selection (with use of models and available information), prioritization, establishment (legal declaration, acquisition of land if necessary) and monitoring.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	The additional cost will be rather low as it would mainly be conservation and monitoring related activities. There could be some costs relating to alternative jobs, resettlement if people need to be resettled or in extractive activities need to be stopped.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • There could be some direct benefits from the establishment, conservation and monitoring of the refugia. • Refugia could be highly protected sites and there could be some job opportunities from very low impact ecotourism. **Investment:** • The main investment would be to obtain and legalize the area as a protected site. • There might be investment necessary for monitoring vehicles and equipment.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • Jobs could be created during the establishment for conservation and monitoring related activities. • There could be some income generation from community conservation, ecotourism, REDD and payment for ecosystem services. **Education:** • Student will have an opportunity to study unique refugia and how they can be used to conserve biodiversity in a changing climate. • University students can carry out advanced research, and even contribute to better conservation techniques. **Health:** • Ecosystem services will provide health benefits, especially through water, microclimate regulation, disease control etc. • Good environmental condition will also contribute to general well being.

5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	The main benefits would be the provision of a stable climate and habitat for biodiversity conservation in a changing climate to ensure its viability. There will be a multitude of environmental benefits associated with ecosystem services. These include carbon sequestration, maintaining biodiversity, regulating the microclimate etc. If refugia from all climatic zones can be identified, and protected – persisting populations may be able to recolonize when conditions become more favorable[127].
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers to implementation and issues such as the need to adjust other policies*	**Opportunities:** • There are legal and policy provisions to create such areas as they take the same approach as creating protected areas. **Barriers:** • The challenge would be to identify and select such areas. • Minimizing external threats and extractive use. • May require land acquisition, payment of compensation and resettlement.
6.2 Status: *Status of technology in the country*	This technology will be similar to the creation of protected areas, and is not a new technology. However at the beginning it will require climate change modeling for biodiversity, which can be considered to be a relatively new technology in the country.
6.3 Timeframe: *Specify timeframe for implementation*	It could take a few months, to a year. Continuous monitoring will be necessary.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	It is possible that refugia may be protected under a high protection category and may restrict use. This may not be acceptable to direct beneficiaries although they could benefits form community conservation, REDD, payments for ecosystems services etc.

[127]Noss, R. F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology 15:578–590.

	Identifying a refugia, which is not vulnerable to climatic changes and with an opportunity to contribute to biodiversity adaptation could be considered to be a pride and recognition for local communities and thus be attractive.

Technology 5: Managing and monitoring invasive alien species (IAS)

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Managing and monitoring invasive alien species (IAS)
2.2 Introduction: *Low/high, Brief introduction to the technology*	Invasive Alien Species (IAS) is one of the main threats to biodiversity conservation, and recent research has shown that it is an increasing threat to biodiversity.[128] Climate change is already impacting biodiversity due to increased spread of invasive or non-native species, which include plants, animals, and pathogens.[129] In Sri Lanka IAS is a major issue affecting both agriculture and affecting biodiversity loss. Some of the main IAS include affecting forests include grasses such as *Imperata cylindrical, Lantana camera, Panicum maximum;* and *Myroxylonbalsamum*, a shrub.[130] Climate change will only exacerbate this issue, as conditions could open new opportunities for invasive species[131]. Thus the control of IAS is of utmost importance for conserving biodiversity in a changing climate. Most invasive species are costly, difficult to eradicate and can often have unexpected negative effects on biodiversity and ecosystem services[132]. Monitoring, removal, eradication and preventing IAS is not a new technology, and has been carried out in Sri Lanka. Some mechanisms identified as being important to control IAS include identification,

[128] S. H. M. Butchart et al., Global Biodiversity: Indicators of Recent Declines. *Science* 328, 1164-1168 (2010).
[129]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.
[130]Weerawardane, N.D. R. Status of Forest Invasive Species in Sri Lanka. http://lakdasun.com/forum/doc_base/Status_of%20Forest_Invasive_Species_in_SriLanka.pdf
[131]Lovejoy, T. E. 2005.Chapter 19 - Conservation with a Changing Climate. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press
[132]Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarrés, J.F., Proença, V., Scharlemann, J.P.W., Walpole, M.J. (2010) Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services. Secretariat of the Convention on Biological Diversity, Montreal.

	monitoring or controlling/eradicating for which training on identification, awareness and research facilities and funding are necessary.[133] *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action has recommended that establishing an Invasive Species Specialist Group, prioritizing IAS including GM, terrestrial and aquatic species, preparing a national database on IAS and providing funding for research on methods to control the spread of IAS is necessary to address this issue.[134] According the National Action Plan for Haritha Lanka Strategy 8.2 recommends to 'Ensure management and control of invasive alien species' and Strategy 8.4 to 'Promote research on invasive alien species, with particular focus on documenting their impacts and determining efficient methods for their management'[135]. The Climate Change Adaptation Strategy[136] for Sri Lanka and the Sector Vulnerability Profile for Biodiversity and Ecosystem Services[137] has identified to 'Minimize entry, establishment and spread of IAS' - (F iii).
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	This technology is not new and can be considered to be a low to medium level technology. Legislation and policy is already in place in the country for the prevention and removal of IAS. Eg: Plant Protection Ordinance and Plant Quarantine Ordinance, etc[138] and the Biodiversity Conservation - Framework for Action[139]which have provisions for and endorse the control of IAS. However this issue has not been adequately controlled[140]and will need more resources and enforcement to be successful.
2.4 Institutional and organizational requirements:	There are policies and laws already in place for this technology. However knowledge transfer and some capacity will be necessary on

[133]Weerawardane, N.D. R. Op. Cit.

[134]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[135] National Council for Sustainable Development . 2009. National Action Plan for Haritha Lanka Programme

[136]Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

[137]Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

[138]Weerawardane, N.D. R. Op. Cit.

[139]Ministry of Environment and Natural Resources. 2007. Op. Cit.

[140]Weerawardane, N.D. R. Op. Cit.

How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.	how to effectively minimize IAS with changing climate as conditions are unlikely to be stable.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Control of IAS is one of the biggest threats to biodiversity both in Sri Lanka and globally – thus controlling this issue is considered to be a main conservation method to sustain biodiversity and thus endorsed by experts in the country and globally. Globally many books[141] and peer reviewed journals[142]on biodiversity and climate change issues have included this as an important issue that needs to be addressed.
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	As the control of IAS is vital for conserving biodiversity currently as well, preventing, monitoring and removal of IAS will be very favorable for biodiversity of conservation even under present conditions.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favoured over those that provide larger benefits, but to fewer people.*	There will be many indirect benefits of controlling IAS to a large group of people, although its benefits are unlikely to be visible or felt directly. IAS have the potential to destroy biodiversity, especially native species and can also impact agriculture[143] thus controlling will also be beneficial to the agricultural sector. Additionally if an ecosystem is invaded by invasive species its

[141] 2005. Lovejoy, T. E. Op. Cit.

[142]Mawdsley, et al. 2009. Op. Cit.

[143]Weerawardane, N.D. R. Op. Cit.

	ecosystem services it will face unexpected negative impacts[144]. This will indirectly affect many beneficiaries.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	It is estimated that this activity will cost Rs. 85 million annually. This is based on the assumption that a budget increase of 4.25% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out until IAS are controlled, and will have to be an annual budget. Cost will be for site selection (with use available information, supported by modeling – if necessary), prioritization, and management (eradication, control etc) and monitoring.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There will be costs in terms of prevention, personnel to monitor and enforce, plus investment for IAS control programs. It will require more funds than currently allocated for this activity.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** There will be some job creation for increasing personnel for monitoring, enforcement and removal of IAS. **Investment:** Investment will be required for removal technologies and monitoring.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • There will be some income generation from employment in removal and monitoring of IAS. • Indirect benefits to income from ecosystem services. • Possible income from community conservation, payments for ecosystem services, REDD etc. **Education:**

[144] Leadley, P. et al, 2010. Op. Cit.

	• An opportunity for students to learn about IAS and be involved in monitoring and removal programs through schools. **Health:** • IAS themselves could be pathogens that can cause health issues, and their control is vital. • IAS will degrade the environment and compromise ecosystem services. Thus microclimate, watershed services etc could get affected impacting human health indirectly.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	It will ensure sustainability of biodiversity and minimize degradation from IAS. Ecosystem services such as carbon sequestration, watershed services etc will be restored.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • Controlling IAS has already been identified as a priority in the Sri Lanka Biodiversity Conservation - Framework for Action[145]. • Income from employment and possibility from community conservation, payments for ecosystem services and REDD. **Barriers:** • It will require additional funding[146]. • Difficulties in predicting how climate change will affect IAS.
6.2 Status: *Status of technology in the country*	This is not a new technology and policies and programs are already in place. Sri Lanka also has several laws in place, of which include Plant Protection Ordinance and Plant Quarantine Ordinance, Flora and Fauna Ordinance, Forest Ordinance and others[147]. The Biodiversity Conservation - Framework for Action[148] (addendum) has identified the issues that impact of IAS has not been reviewed. It recommends that IAS are managed and controlled. However the program would need to be expanded plus, climate change models will need to be used for predictions although they may not be

[145]Ministry of Environment and Natural Resources. 2007. Op. Cit.

[146]Weerawardane, N.D. R. Op. Cit.

[147]Weerawardane, N.D. R. Op. Cit.

[148]Ministry of Environment and Natural Resources. 2007. Op. Cit.

	totally accurate.
6.3 Timeframe: *Specify timeframe for implementation*	Removal of invasive species will have to be a continuous program, included in the annual conservation budgets.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	This technology should be acceptable to all local stakeholders as it is a strategy already accepted by government departments as an important conservation issue, and is specifically stated in the Biodiversity Conservation - Framework for Action[149]. It will be favorable as it will prevent ecosystem degradation and associated loss of services and can also affect agriculture and have serious economic implications.

[149]Ministry of Environment and Natural Resources. 2007. Op. Cit.

Technology 6: Reducing other stresses on species and ecosystems

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Reducing other stresses on species and ecosystems
2.2 Introduction: *Low/high, Brief introduction to the technology*	Current stresses on biodiversity include habitat fragmentation and destruction, over-exploitation, poaching, illegal clearing etc. This technology aims to reduce or remove other, non-climate stressors. This will give species the maximum flexibility to evolve responses to climate change[150]. The synergy between "normal stresses" such as habitat fragmentation and altered climate – poses a new challenge to biodiversity[151], with one of the main challenges climate change has on biodiversity is the synergies with other concurrent stresses from human activities[152]. Reduction in the current stresses on species and ecosystems will also allow biodiversity be more resilient and recover from impacts of climate change. This is not a new technology, and reducing such threats are vital for the survival of biodiversity in general. It becomes more important when considering climate change, as it will exacerbate biodiversity loss. As this includes a range of stresses to be managed, the technology can be considered to be low to medium and will not need any new inputs as knowledge and strategies exist. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action has identified many current stresses on biodiversity conservation and has many

[150]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

[151] Hannah, L., Lovejoy, T. and Schneider, H. 2005. Chapter 1 – Biodiversity and Climate Change in Context. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press

[152]Lovejoy, T. E. 2005.Chapter 19 - Conservation with a Changing Climate. In: Lovejoy T, Hannah L, eds. 2005. In Climate Change and Biodiversity. New Haven, CT: Yale Univ. Press

	recommendations. These include managing direct threats to species, rehabilitate critical habitats etc[153]. According the National Action Plan for Haritha Lanka Strategy 9.4 states to 'Monitor protected areas continuously to ensure that uses are sustainable, especially pollution and disturbance caused by vehicles and excessive visitors in fragile ecosystems'[154]. The Climate Change Adaptation Strategy[155] for Sri Lanka has identified to 'Focus on minimizing current stresses on ecosystems' - (G i).
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	This technology is not something new, but concentrates on current conservation methods to tackle existing issues. Improving current management, enforcement, investment and monitoring will be its main characteristics. It would also be useful to conduct research on the response of endemic species to perturbation and stress. This can be considered to be low to medium level of technology.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	This is an existing technology and thus there will not be much additional capacity building or knowledge transfer necessary. However it would be useful for some capacity building and knowledge transfer on innovative and new methods of controlling existing threats to biodiversity, in a changing climate, with minimum use of resources. If management, enforcement, monitoring are to be increased, number of staff in the relevant departments will need to be increased.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. This technology is essential to control biodiversity loss at present, and these stresses are recognized as some of the biggest challenges both globally and in the country.

[153]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[154] National Council for Sustainable Development . 2009. National Action Plan for Haritha Lanka Programme

[155]Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

	Many experts globally have endorsed this mechanism, many appearing in international peer reviewed journals[156].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	As mentioned previously, reducing current stressed on biodiversity will benefit conservation even at present. Thus it will be beneficial and completely suitable in the current climate.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	The beneficiary group will be large, as reducing stresses on biodiversity will ensure that ecosystem services are minimally impacted and will provide food, watershed services, control erosion, regulate disease etc. A well conserved protected area or environment will attract more tourism and visitation, benefiting local livelihoods.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	The costs for this can be considered to be low to medium, and will entail increasing the current conservation budget of the relevant Departments to increase current efforts. It is estimated that this activity will cost Rs. 80 million annually. This is based on the assumption that a budget increase of 4% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out continuously, and will have to be an annual budget. Cost will be for identifying main stresses, prioritizing issues and areas, enforcement, determine necessary conservation activities, implementation and monitoring.

[156]Mawdsley, et al. 2009. Op. Cit.

4.2 Additional costs to implement adaptation option, compared to "business as usual"	Additional conservation of biodiversity would require more investment and thus a higher cost However maximizing and effectively using current resources currently available will help reduce the cost of additional conservation efforts.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • Increasing conservation activities and monitoring will require manpower and will create jobs. • Local communities will also benefit from community conservation and ecosystem related job opportunities. **Investment:** • Investment will be necessary to increase manpower and capital such as monitoring equipment, vehicles etc.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • Increased conservation activities and monitoring would require more personnel and thus there will be creating of job opportunities. • Possible income from community conservation, payment for ecosystem services, REDD etc. • Enhanced conservation could increase ecotourism potential, and jobs associated with it. • Improved ecosystem services could provide income through the sustainable collection of NTFP, microclimate and pest control benefiting agriculture etc. **Education:** • An opportunity for students to learn about current threats to biodiversity in the country. • University students can contribute to research activities that deal with current threats. **Health:** • Good environmental conditions contribute to well-being and health. • Controlling threats such as pollution will have a direct health benefit. • Environmental services will ensure freshwater provision, control of microclimate and disease, which contribute to health.

5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	• This technology will maintain viability and resilience of biodiversity, and better adapted to impacts of climate change. • Enhanced ecosystem services such as carbon sequestration and other environmental services.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • This is not a new technology and will not require many changes to current conservation plans. • No changes institutional or legal changes will be required for this activity. • It will help resolve some of the main issues threatening biodiversity at present as well as in the future. **Barriers:** • There are limited resources available to address the broad range of stressors[157]. • There is potential for a loss of focus and much diffuse action across a broad range of stressors[158]. • Increasing conservation budgets and its funding will be a constraint. • Main threats to controlling biodiversity loss such as habitat conversion, illegal activities will require political support and the involvement of other institutions who may not understand its importance.
6.2 Status: *Status of technology in the country*	Activities necessary to address current pressures on biodiversity has already been identified in the Biodiversity Conservation - Framework for Action, and thus well-recognized and accepted in Sri Lanka.
6.3 Timeframe: *Specify timeframe for implementation*	Minimizing current threats will need to be an on going process and will be in the form of annual Programs which will need to be continued.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	It is likely that most local stakeholders will favorminimizing loss of biodiversity as it would affect local environmental conditions and ecosystem services. It is also attractive as there could be job opportunities and income from various conservation initiatives and ecotourism. Increased conservation would mean the restriction of certain legal and illegal activities, which may be opposed by a small group that benefit from such activities.

[157]Mawdsley, et al. 2009. Op. Cit.

[158]Mawdsley, et al. 2009. Op. Cit.

Technology 7: Adaptive management and monitoring programs of species and ecosystems

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Adaptive management and monitoring programs of species and ecosystems
2.2 Introduction: *Low/high, Brief introduction to the technology*	Adaptive management and monitoring is essential to monitor climate change impacts and associated ecosystem responses and adjust management strategies accordingly. In order to be effective during the uncertainties of climate change – partnership based adaptive management is important as it will allow field managers help to test and refine ideas progressively[159]. Conservationists have suggested dynamic landscape conservation plans, which include information on fixed and dynamic spatial elements. Unlike traditional management plans, these dynamic plans explicitly address the climate adaptation needs of wildlife and biodiversity at a landscape scale[160]. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action recommends to 'establish biodiversity monitoring indicators within a common, flexible and transparent framework, and periodically review indicators'[161]. The Climate Change Adaptation Strategy[162] for Sri Lanka and the Sector Vulnerability Profile for Biodiversity and Ecosystem Services[163] has identified to 'Research and monitoring programs to strengthen knowledge base on CC and terrestrial and aquatic biodiversity' - (F i and Fii).

[159] Hannah, L., G. F. Midgley, and D. Millar. 2002. Climate change-integrated conservation strategies. Global Ecology and Biogeography 11:485–495.

[160] Hannah, L., and Hansen. L. 2005. Designing landscapes and seascapes for change. Pages 329–341 in T. E. Lovejoy and L. Hannah, editors. Climate change and biodiversity. Yale University Press, New Haven, Connecticut.

[161] Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[162] Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

[163] Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	This can be considered to be a low to medium technology – as it is a simple technology which will require some research to identify changes and on the ground monitoring for observation of changes. It will include constant monitoring and responding to changes and conservation needs. It would involve revising of management plans and action plans.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	Extra capacity will be necessary to increase monitoring which is essential for adaptive management, and there will be cost of monitoring resources such as vehicles, equipment and field studies. There will be additional capacity building and knowledge transfer on how to cope with change and manage accordingly.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Adaptive management is recognized both in the country and globally, and favored for biodiversity conservation in general. Peer reviewed journals also recommend it as being important for climate change related impacts. A study, which did a comprehensive review of climate change adaptation strategies has ranked adaptive management as the 7th most cited strategy[164]. The Ad Hoc Technical Expert Group on Biodiversity and Climate Change under the CBD has also identified that adaptive management is important for reducing the impacts of climate change on biodiversity[165].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation*	There will be no negative consequences of this adaptation option as its basis is to respond to change – if and when it occurs so that biodiversity can be conserved accordingly.

[164] Heller, N.E. & Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

[165] Secretariat of the Convention on Biological Diversity. 2009. Connecting Biodiversity And Climate Change Mitigation and Adaptation: Key Messages from the Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change.

option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	Adaptive management is also suitable to address other threats in the current climate, and considered to be an effective mechanism for biodiversity conservation.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	Adaptive management would minimize impacts of climate change and would increase resilience, which will be important for maintaining ecosystem services. This would benefit a large group of people. Additionally there will be increased job opportunities for conservation activities, while local communities could benefit from community conservation, payment for ecosystem services, ecotourism etc.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	There will be some additional cost as it will require additional monitoring which will require both personnel and equipment, while there will be a cost for new conservation initiatives. It is estimated that this activity will cost Rs. 90 million annually. This is based on the assumption that a budget increase of 4.5% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out continuously, and will have to be an annual budget. Cost will be for site selection (with use of models and available information), prioritization, identifying changes through research and observation, revising management activities, identifying appropriate conservation activities, implementation and monitoring.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There would be an increase in monitoring and conservation activities and these will require additional costs compared to business as usual.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: Employment - *Jobs*	**Employment:** • Job opportunities in conservation and ecotourism related activities.

Investment - *Capital requirements*	• Jobs relating to ecosystem services such as the sustainable collection of non-timer forest products. **Investment:** • Investment will be required for more frequent monitoring and field research. • Additional conservation activities may be necessary for management under a changing climate.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • There will be additional job opportunities as there will need to be additional monitoring, field studies and conservation activities. • Possibility of community conservation, payments for ecosystem services, REDD, increased ecotourism opportunities etc. **Education:** • An opportunity for students to observe and learn about how to carry out conservation in a changing climate, and appreciate the importance of biodiversity and ecosystem services. **Health:** • Improved environmental quality will contribute to the well being of local communities through ecosystem services.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	• Increase the resilience and viability of biodiversity as conservation target activities taking to account impacts of climatic changes. • Improvement of ecosystem services such as sequestration, watershed functions etc.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • Constant monitoring and adaptive management will ensure that impacts to climate change can be addressed quickly. • It would also minimize irreversible damage when possible as it will not wait till the impacts become severe. • Such preventative and early action will cost less than intervening when considerable impact has occurred. **Barriers:** • Constant monitoring and field studies will require additional staff, while conservation activities based on results will require additional

	investment. • Some changes to species and ecosystems will be very difficult to detect at early stages.
6.2 Status: *Status of technology in the country*	Adaptive management as a tool is recognized in the country but currently its implementation is limited. It requires frequent monitoring and research, which is not a new technology for the country. However certain climate change related indicators and field studies might be new.
6.3 Timeframe: *Specify timeframe for implementation*	Adaptive management needs to be done continuously, throughout the year.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	• It is likely that adaptive management will gain the support of local stakeholders as it will bring in job and income opportunities. • It will also be favored as an improved ecosystem and a more resilient one will ensure that communities will benefit from ecosystem services. • It may not be acceptable to some stakeholders if adaptive management and subsequent conservation activities prevent certain uses of the ecosystem (eg: no fishing zones, no extraction of forest products etc).

Technology 8: Focusing on conservation of resources and carrying out special management for restricted range, highly threatened species and ecosystems

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Focusing conservation resources and carrying out special management for restricted range, highly threatened species and ecosystems
2.2 Introduction: *Low/high, Brief introduction to the technology*	This technology involves investing resources in the maintenance and continued survival of species that are likely to become extinct as a result of global climate change[166]. Thus it would target species that need special attention, with high vulnerability to climatic changes. Recent studies have shown the ecological changes in the phenology and distribution of plants and animals are already occurring, and have been linked to local and regional climate change. Range-restricted species, particularly polar and mountaintop species, show severe range contractions, and certain such species have gone extinct. Tropical coral reefs and amphibians have been most negatively affected[167]. The Sri Lanka Red List[168] identifies threatened species, and their locations. Thus this can be used to identify and target specific species that may require additional conservation intervention. Globally the IUCN Red List is already being used to identify species at risk with climate change[169]. In some cases, translocation of certain highly vulnerable species may be required. Translocation involves moving animals, plants, and other organisms from sites that are becoming unsuitable due to global climate

[166]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

[167]Parmesan, C. 2006. Ecological and evolutionary responses to recent cli- mate change. Annual Review of Ecology, Evolution and Systematics 37:637–669.

[168] IUCN Sri Lanka and the Ministry of Environment and Natural Resources (2007) The 2007 Red List of Threatened Fauna and Flora of Sri Lanka, Colombo, Sri Lanka. xiii+148pp.

[169] IUCN. 2009. Climate change and species. http://www.iucn.org/about/work/Programs/species/our_work/climate_change_and_species/

	change to other sites where conditions are thought to be more favorable for their continued existence[170]. It must be noted that translocation has not been successful with certain species and caution should be exercised on such an activity and used as a last resort for immobile species. It should not be carried out for species that translocation has been unsuccessful previously. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action, in the section on in-situ conservation recommends to 'prepare and implement recovery plans for threatened species that need special conservation actions (both for in-situ and ex-situ in addition to habitat conservation).[171] According the National Action Plan for Haritha Lanka Strategy 2.3 states to 'Prepare and implement recovery plans for threatened species that need special conservation actions'[172].
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	It could be considered a medium level technology. The cost can vary from medium to high depending on the species and the type of intervention required. This is not an entirely new mechanism, as general conservation tools can be used for this purpose (eg: declaring a core conservation zone where there are threatened species). Additionally there could be species and ecosystems that are currently not threatened, but may have restricted ranges or other threats (eg: edge effects) – and may require targeted protection. It will need to be supported by modeling of biodiversity and climate change, while continuous monitoring will be necessary to identify those vulnerable to climate change. It would be useful to identify researcher focusing on certain taxa, create a database of people and research – and focus on improving research.

[170]Mawdsley et al. 2009. Op. Cit.

[171]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[172] National Council for Sustainable Development . 2009. National Action Plan for Haritha Lanka Programme

	Climate change related impacts will require conservation for plant and animal species in both terrestrial and aquatic areas.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	There will be some additional capacity building necessary to conserve certain species that are currently not targeted specifically for conservation. Information/technology transfer maybe required from other countries on how to identify and conserve species that are vulnerable to climate change, especially from countries that already have specific action plans and conservation strategies for such species.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Focusing conservation efforts on highly threatened and vulnerable species is recommended as a climate change strategy globally, and is suggested in peer-reviewed journals[173,174].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	There will be no perceived negative consequences of this technology in the current climate. The Sri Lanka Red List[175] has already identified threatened species that would need some intervention for their survival. Additional could be identified based on predictions and vulnerability, while in other cases they may need to be identified in the future, depending on how climate affects certain species or ecosystems.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	This mechanism will ensure that biodiversity is conserved in a sustainable manner, preventing any extinction. It will ensure that ecosystem services are maintained – which will benefits a large group of people. There could be direct benefits from conservation related income.

[173]Mawdsley et al. 2009. Op. Cit.

[174] Heller, N.E. & Zavaleta, E.S. (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation*, 142, 14.

[175] IUCN Sri Lanka and the Ministry of Environment and Natural Resources (2007) The 2007 Red List of Threatened Fauna and Flora of Sri Lanka, Colombo, Sri Lanka. xiii+148pp.

4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	The cost could be medium to high, and will depend on the time of intervention and its scale. There will be some cost for monitoring and conservation activities. It is estimated that this activity will cost Rs. 100 million annually. This is based on the assumption that a budget increase of 5% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out continuously and will have to be an annual budget. Cost will be for identification of most threatened species/ecosystems, (with use of models and available information), prioritization, identifying conservation measures, revising management plans/creating species or ecosystem-based management plans, implementing conservation activities and monitoring.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There will be additional cost for this adaptation option, as there will be costs associated with special conservation strategies targeted at threatened species.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • Job opportunities for implementation of the targeted Programs for species. • Ecotourism-related opportunities. **Investment:** • There could be medium to high capital requirements if special facilities or conservation areas need to be established.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with*	**Income:** • Income generation from ecotourism and visitation to conservation facilities/areas where there are targeted programs for threatened species. For ecosystems, this will also have benefits to local communities and other stakeholders who may become involved in ecotourism activities.

different diseases	• There could be benefits from payments for ecosystem services, community conservation and from conservation-related jobs. **Education:** • Students will get an opportunity to study threatened species and understand is importance. • Ability to study how such species can be protected from threats such as climate change. **Health:** • Threatened species will contribute to ecosystem services such provision of water, micro-climate regulation etc that will benefit the well-being and health of communities.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	Such a mechanism will facilitate long-term conservation and viability of species and ecosystems. It will ensure that ecosystem services continue unhindered.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • Biodiversity Conservation - Framework for Action identifies the important of protecting threatened species. • Threatened species have been identified in the Red List, along with some locations, which will ease the difficulty in predicting which species will require special intervention. • There will be opportunities from ecotourism, REDD, payments for ecosystem services, REDD and ecotourism. **Barriers:** • Lack of funding and other resources to target and facilitate specific conservation programs. • Difficulty in predicting how species will be affected by climate change.
6.2 Status: *Status of technology in the country*	Threatened species under current environmental conditions have been identified, and some programs are targeted at these species. The technology will vary from species to species, and will need to consider the changing climate and may need support from other countries.
6.3 Timeframe: *Specify*	The time frame to identify species initially would vary from a few months

timeframe for implementation	to a few years, but the process will be continuous, as identification of vulnerable species may need to be done from time to time. Conservation and monitoring activities will need to be continuous.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Opportunity for local stakeholders to protect high profile and threatened species. There could be income related benefits, which may also increase acceptability.

Technology 9: Improving management of existing protected areas, increasing extent, creating buffer zones and new areas in vulnerable zones

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Improving management of existing protected areas, increasing extent, creating buffer zones and new areas in vulnerable zones
2.2 Introduction: *Low/high, Brief introduction to the technology*	Protected areas are a conservation tool to conserve biodiversity by protecting species and ecosystems. This strategy will focus on effectively managing established protected areas. If possible it will also entail increasing the extent of terrestrial and aquatic habitats, which has been identified as a climate change adaptation strategy[176]. Conservationists often favor protected areas as they aim to provide a safe haven and minimize impacts from humans and other threats. Protected areas have various purposes and levels of protection[177]. In Sri Lanka these vary from Strict Natural Reserves where access is strictly limited to Sanctuaries, which may contain private land[178]. Thus it is vital to ensure that in these areas there is good representation of biodiversity and these also need to be effectively managed for long-term survival. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action for Sri Lanka identified that the current protected area system excludes many biodiversity rich areas, which remain unprotected. It recommends that

[176]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

[177] IUCN. 2011.IUCN Protected Area Management Categories http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/

[178] The Fauna and Flora Protection Ordinance No. 2 of 1937 and Amendment Act No. 49 of 1993.

	critically important biodiversity hotspots in the country to be brought under the relevant protected area category[179]. According the National Action Plan for Haritha Lanka Strategy 2 in Mission 2: Saving the Fauna, Flora and Ecosystems is to 'Establish optimum Protected Area network and ensure recovery of important threatened species'. Section 2.1 specifically refers to 'Identify critically important biodiversity hotspots in the country outside existing protected areas and declare these under a relevant category and develop representative Protected Area Network and Section 2.7 recommends to 'Improve management of Protected Areas by habitat enrichment, boundary demarcation and fire management'[180]. The Climate Change Adaptation Strategy[181] for Sri Lanka and the Sector Vulnerability Profile for Biodiversity and Ecosystem Services[182] has identified to 'Establish and/or effectively manage PAs and other important wildlife refuges in all climatic zones' - (B iv).
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	It is vital to effectively manage existing protected areas as creating new areas is challenging when there is much demand for land in a developing country. However there are numerous areas that are earmarked as proposed reserves, which can be included into the protected area network. Creating new protected areas or expanding existing areas does not require advance technologies. Sri Lanka has been creating such areas from the 1930's. They will require some investment, especially if the area used for other purposes, or if people need to be relocated. Management and conservation activities will also require investment. The technology should ensure biodiversity is well represented in the protected area, include habitats that are threatened and vulnerable to climate change.

[179]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[180]National Council for Sustainable Development . 2009. National Action Plan for Haritha Lanka Programme

[181]Ministry of Environment. 2010. National Climate Change Adaptation Strategy for Sri Lanka 2011 to 2016.

[182]Ministry of Environment. 2010. Sector Vulnerability Profile: Biodiversity and Ecosystem Services.

	New areas can be created through purchase and planting. In order to find suitable areas to be included, climate change and its impacts on biodiversity should be modeled (this is a separate technology).
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	As this is not a 'new technology' the departments currently engaging in this activity will have sufficient capacity to deal with this strategy. Capacity building and knowledge transfer will be required to (1) Effectively manage existing areas, with maximize available resources, (2) Select suitable areas based on climate change modeling and predictions, and (3) To introduce climate change-integrated conservation strategies.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Increasing extent of protected areas has been identified as an important climate change adaptation strategy for biodiversity according to reputed peer reviewed papers in journals[183].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	There is no negative consequence of this option as this is not a new technology. As mentioned above the Biodiversity Conservation - Framework for Action recognizes as this as an important strategy for biodiversity conservation in the current climate[184].
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	The beneficiaries of this technology will include both local and the larger population of the country. Often local communities will benefit from ecotourism related activities and community conservation program, often this is sufficient to offset the benefits of direct use and extraction of the protected area by local people which benefits only a small, select group.

[183]Mawdsley, et al. 2009. Op. Cit.

[184]Ministry of Environment and Natural Resources. 2007. Op. Cit.

	Both local communities and the larger population will benefit immensely from ecosystem services such as micro-climate regulation, watershed services, erosion and flood control, carbon sequestration etc.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	It is estimated that this activity will cost Rs. 90 million annually. This is based on the assumption that a budget increase of 4.5% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. This activity will need to be carried out until most prioritized sites are covered, and will have to be an annual budget. Cost will be for improvement management and conservation activities, enforcement; while for establishing new areas site selection (with use of models and available information), prioritization, establishment (legal declaration, acquisition of land if necessary) and monitoring will be necessary.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	This too will vary. Creating or extending some protected areas will be of low cost if they are unutilized for any other purpose and need to be simply given a legal status – however there will be costs involved in monitoring and conservation. Some protected areas will require more investment as they may require more intervention, restoration and management. It may also include costs of relocating communities and creating park infrastructure, staff and administrative costs. Some of these costs can be offset, especially operation and maintenance by visitation and ecotourism. There could be opportunity costs if the area has other valuable uses.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • There will be an increase in jobs due to work associated with conservation activities and running of the protected area. There will be many opportunities for jobs associated with ecotourism. • There could be future opportunities from community conservation and ecotourism.

	Investment: • Investment will be required to acquire land, purchase, and pay compensation, if necessary.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • There will be income due to tourism, community conservation, REDD and payments for ecosystem services. **Education:** • Educational benefits will include a 'living laboratory' for students to learn about science and nature. **Health:** • Good environmental quality, ecosystem services play a role in creating good health.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	Carbon sequestration, microclimate regulation, flood control conservation of ecosystems and other associated services.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • There will be no legal and policy changes required as these mechanisms are already in place[185,186]. • It will improve ecosystem services and benefits for the larger population. • Possible benefits from community conservation, ecotourism, REDD and payments for ecosystem services. **Barriers:** • Main barrier for implementation will be current activities in the area to be acquired and the ease in which it can occur. • Competition for land due to development and infrastructure projects.
6.2 Status: *Status of technology in the country*	The technology is currently in place and has been so for several decades.
6.3 Timeframe: *Specify timeframe for implementation*	Can vary from a few months to a few years depending on the current use and legal status.
6.4 Acceptability to local stakeholders: *Whether the*	It should have high acceptability as it has been identified as an important recommendation to conserve in-situ biodiversity in Sri

[185]Ministry of Environment and Natural Resources. 2007. Op. Cit.

[186] The Fauna and Flora Protection Ordinance No. 2 of 1937 and Amendment Act No. 49 of 1993.

technology will be attractive to stakeholders	Lanka[187]. Additionally it will create environmental benefits and new opportunities for local communities. There will be some income to local stakeholders as well.

[187]Ministry of Environment and Natural Resources. 2007. Op. Cit.

<u>Technology 10</u>: Reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources and incorporating climate change adaptation considerations (ensuring implementation)

1. SECTOR: *To be written by sector expert*	Biodiversity
2. TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources and incorporating climate change adaptation considerations (ensuring implementation)
2.2 Introduction: *Low/high, Brief introduction to the technology*	This technology focuses on reviewing and modifying existing laws, regulations, and policies relating to biodiversity and natural resources, and involves incorporating such strategies to management plans and action plans. This is necessary to ensure that provisions are consistent with the needs of managers dealing with the effects of climate change[188]. It will entail collecting all existing biodiversity laws, regulations, policies, management plans and action plans and doing a gap analysis to see which sections need modifying to incorporate impacts of climate change on biodiversity. Once this has been identified, amendments will need to be made, and this process will need to be formally integrated to existing laws, policies, plans etc. This is a low level technology, but will require human resources and skill to review existing laws, policies, plans etc. It will need consultation with scientists, decision-makers, policy and lawmakers to ensure that the science can be translated to law, policy and planning. Gap analysis will identify which amendments need to be made, while the next step would be to incorporate such changes and make them formalized so that they can be implemented.

[188]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23, 1080–1089.

	The most vital aspect it not amending these documents, but its eventual implementation. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action[189] does not specifically relate to amending legislation to incorporate climate change considerations – as it was prepared several years prior to climate change becoming as mainstream as it is today. However it recommends various amendments and a similar review and gap analysis can be done for climate change. The Action Plan in the section on Impacts on Biodiversity has identified that impact of climate change and global warming has not been reviewed. According the National Action Plan for Haritha Lanka Strategy 1 in Mission 2: Saving the Fauna, Flora and Ecosystems is to 'Strengthen policy, legal and institutional framework for biodiversity conservation, including information sharing & networking aspects'[190].
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	This is a low level technology, which will require human resources and its success will depend on the skills of the reviewers. Although most reviewing and amendments will be done initially, based on possible predictions – amendments will need to be done periodically.
2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	There will be no special institutional changes to be made, as review of legislation and amendments occur from time to time. Capacity building will be necessary to ensure that the reviewers understand how climate change will impact biodiversity, what changes are required and how legislation, policies and action plans will need to be changed. Implementers will need to be educated about how such changes will affect implementation and conservation activities.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see

[189]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[190]National Council for Sustainable Development, 2009, National Action Plan for Haritha Lanka Programme

	section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Reviewing and modifying legislation, policies, management and action plans occurs from time to time - to incorporate new threats, international conventions and the overall policy of the country. Thus this is not a new process, and planning for climate change is an essential part of this. Experts have identified that reviewing existing legislation and policies as being important for climate change adaptation, by experts in peer-reviewed journals[191].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	There will be no negative consequences of this adaptation policy in the current climate. Such amendments will only be implemented as and when needed, and will not disrupt current activities. Having such amendments in early will ensure that there will be no delay in action.
3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	This process will provide benefits to a large group of people who will benefit from the sustainability, and increase of resilience of biodiversity an ecosystem services.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	It is estimated that this activity will cost Rs. 15 million annually. This is based on the assumption that a budget increase of 0.75% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. Some revision will need to be considered as climate change is a dynamic field and changes will need to be made periodically. Thus this can be considered to be an annual budget.

[191]Mawdsley et al, 2009.

	Cost will be for reviewing of current legislation, policies and plans and analyzing the gaps. The amendments will also not be too costly, however implementation, which will be a different component, will be expensive.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There will be some additional cost as in a business as usual scenario such a comprehensive review may not occur. However, this process will not be expensive.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • There will be a few job opportunity as reviewing will be done by a small group of people. • Implementation will create many job opportunities. **Investment:** • The investment required will be relatively minimal.
5.2 Social benefits: **Income** – *Income generation and distribution* **Education** – *Time available for education* **Health** – *Number of people with different diseases*	**Income:** • The review and amendment process itself will not generate income, but it's implementation could include income generation options such as payments for ecosystem services, community conservation, REDD etc which need to be considered at the review and amendment stage. **Education:** • Lessons and methodology used for this process will be educational for those in the conservation field. **Health:** • There will be no health impacts from this process, but its implementation will ensure better environmental management in a changing climate and thus will contribute to well being and benefits from ecosystem services.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	This review and amendment process will ensure that the regulations and paper work necessary to support beneficial conservation activities are set in place. Thus the implementation will help minimize the impacts of climate change and increase resilience of biodiversity.

6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • It will give an opportunity to be well prepared in advance and have the legal and policy back up for conservation activities in a changing climate - rather than waiting for the changes and then modifying the policies and legislation. • Preparedness and having such legislation and policies will ensure the smooth running of climate change adaptation strategies. It will be attractive to donors. **Barriers:** • Changes that will result from climate change and its predictions may not be accurate and it is difficult to plan under such uncertainty. • Gap analysis and amendments will require skilled human resources – with a good understanding of the possible impacts of climate change on biodiversity.
6.2 Status: *Status of technology in the country*	Review and amendments of laws, polices, management plans and action plans occur from time to time, and thus not a new process.
6.3 Timeframe: *Specify timeframe for implementation*	The exercise can be completed within a year. It will require consultations with various stakeholders in the sector.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	Such a process will be beneficial to stakeholders as it allows better preparation for climate change and will be useful to implement activities when climate change impacts occur. Thus it is unlikely that stakeholders will not support such an endeavor.

Technology 11: Ex-situ conservation for highly threatened species and possible reintroduction

1. SECTOR: *To be written by sector expert*	Biodiversity
TECHNOLOGY CHARACTERISTICS	
2.1 Technology name:	Ex-situ conservation for highly threatened species and possible reintroduction
2.2 Introduction: *Low/high, Brief introduction to the technology*	Ex-situ conservation refers to conservation activities that occur outside the usual habitat of a species. Usually this approach focuses on captive maintenance programs for species that would otherwise become extinct due to climate change. Such an approach would generally be a last resort for species[192]. Zoo's, captive breeding centers, seed banks etc are some example of such conservation activities, and therefore not a new technology. However some advanced facilities may be necessary for certain species. Zoos and breeding centers have long been carrying out captive breeding, especially for keystone mammals. Sperm and egg banks would be rather extreme forms of this strategy, but may be necessary[193]. Often such activities are carried out as insurance against future or unexpected threats that will make in-situ conservation difficult. Ex-situ conservation is usually not favored where in-situ conservation is possible, but its importance as an insurance mechanism is recognized. *Reference in existing policies, strategies and action plans:* The Biodiversity Conservation - Framework for Action has a separate section on ex-situ conservation, recommending activities such as developing ex-situ programs, establishing more botanical gardens and

[192]Mawdsley, J.R., O'Malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversityconservation. Conservation Biology 23, 1080–1089.

[193]Mawdsley et al. 2009. Op. Cit.

	developing the capacity of the National Zoological Gardens, among others[194]. According the National Action Plan for Haritha Lanka Strategy 1.3 states to 'Develop rules and guidelines for starting and operating ex-situ conservation centers including the acquisition of specimens for breeding and the re-introduction of captive-bred specimens'; Strategy 3.1 recommends to 'Identify species requiring ex-situ conservation measures, assess and restore their habitats and provide for their reintroduction'; Strategy 3.2 to 'Establish more botanic gardens and field gene banks and mandate them to undertake ex-situ conservation of biodiversity in all bioclimatic regions of Sri Lanka'; Strategy 3.3 to 'Develop capacity of National Zoological Gardens to engage in ex-situ conservation programs and serve as a regulator for zoological species ex-situ centers in general'[195].
2.3 Technology characteristics/highlights: *Few bullet points, ie. Low/high cost, advance technology; low technology*	This is a medium to high cost technology, as conservation is carried out outside the species habitat, often in an artificial environment. It may require special facilities to be created for some species. It would require the identification of species that could become restricted by climate change. For reintroduction it will be important to identify new habitats. Zoos, botanical gardens and seeds banks are available in Sri Lanka but these may need to be expanded or upgraded. In some situations, ex-situ conservation will need to be carried out until global warming is reversed may be the only chance of survival for some species. Ex-situ collections should have sufficient diversity to allow adaptation[196].

[194]Ministry of Environment and Natural Resources. 2007. Biodiversity Conservation in Sri Lanka: A Framework for Action – Addendum.

[195] National Council for Sustainable Development . 2009. National Action Plan for Haritha Lanka Programme

[196]Noss, R. F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology 15:578–590.

2.4 Institutional and organizational requirements: *How much additional capacity building and knowledge transfer is required for the adaptation option to be implemented.*	There are separate Departments for Botanical Gardens and Zoological Gardens. The Plant Genetic Resources Centre is the main seed bank in the country, and mainly concentrates on crop genetic resources[197]. Captive breeding, mechanisms such as egg and sperm banks, and other new approached may be required and can be obtained through technical assistance. Capacity building may be required to improve existing mechanisms, and for the introduction of new mechanisms.
3. OPERATIONS AND MAINTENANCE	
3.1 Endorsement by experts:	For details of endorsement by local experts and relevant agencies see section on *'Reference in existing policies, strategies and action plans'* in Section 2.1. Some forms of ex-situ conservation have been established for some time in Sri Lanka, including a zoo, botanical gardens and seed banks. Ex-situ conservation has also been identified as an important climate change adaptation strategy by global experts, with views being published in international peer reviewed journals[198].
3.2 Adequacy for current climate: *Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.*	There are currently no negative impacts in the current climate for ex-situ conservation as some activities occur at present. The Biodiversity Conservation - Framework for Action, and international peer reviewed papers also support ex-situ conservation – in many cases as a last resort to save species. However, if large numbers of wild species are removed from the wild, it can threaten wild populations. Ex-situ conservation should also be carried out before it is too late and irreversible.

[197]MuthukudaArachchi, D. H. and Wijerathne, P. M. 2008.Country Report on the State of Plant Genetic Resources for Food and Agriculture – Sri Lanka. FAO. http://www.fao.org/docrep/013/i1500e/SriLanka.pdf

[198]Mawdsley et al. 2009. Op. Cit.

3.3 Size of beneficiaries group: *Technology that provides small benefits to large number of people will be favored over those that provide larger benefits, but to fewer people.*	Ex-situ conservation will ensure survival of certain species that may not survive otherwise. It includes commercially important seeds, which could have direct economic impacts. This activity will need to be carried out continuously and will have to be an annual budget. Improving current ex-situ programs and introduction of new mechanisms, including preparation for future ex-situ conservation activities can generate considerable number of jobs – and especially utilize the expertise of veterinarian, biologists and conservationists.
4. COSTS	
4.1 Cost to implement adaptation options: *Cost measures*	It is estimated that this activity will cost Rs. 100 million annually. This is based on the assumption that a budget increase of 5% of current conservation budgets will be necessary for this activity (based on total Forest Department and Wildlife Department annual budgets). It is estimated that 25% of this will be borne by the public sector. Cost will be for prioritizing species for ex-situ conservation (based on information, level of threats and models), training and capacity building, establishing facilities/upgrading existing facilities, implementing ex-situ conservation.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	There are already certain seeds banks, botanical gardens and zoos in the country – but these would need significant upgrade, and the creation of new facilities if ex-situ conservation is to be carried out.
5. DEVELOPMENT IMPACTS, INDIRECT BENEFITS	
5.1 Economic benefits: **Employment** - *Jobs* **Investment** - *Capital requirements*	**Employment:** • Ex-situ conservation, its the expansion, upgrade and creation of new facilities will provide employment opportunities during the construction and preparation process, and for day to day activities. It will require support staff but also scientists and veterinarians. **Investment:** • There will be medium to high capital requirements to upgrade existing facilities, and create new facilities for ex-situ conservation.
5.2 Social benefits: **Income** – *Income generation and distribution*	**Income:** • Certain ex-situ conservation programs, especially those associated with zoos, botanical gardens and aquaria can generate significant

Education – *Time available for education* **Health** – *Number of people with different diseases*	income from tourists and local visitors. In fact they can draw in larger visitors, as carrying capacity is not an issue, and due to the location and ease of visiting. **Education:** • Zoos, botanical gardens and aquaria are excellent learning platforms for students of all ages and adults. It gives an opportunity to learn about both native and exotic species, and the ability to see a wide variety of species and obtain information, and usually have excellent interpretation centers. • They also provide information on threatened species and importance of conservation, and play an important role in obtaining support of biodiversity conservation in general. **Health:** There are no obvious health benefits from ex-situ conservation, but can contribute to good mental health and relaxation, as it is a recreational activity.
5.3 Environmental benefits: *Reductions in GHG emissions, local pollutants, ecosystem degradation etc.*	The main environmental benefit would be that this mechanism would contribute to the viability of threatened biodiversity, and genetic diversity.
6. LOCAL CONTEXT	
6.1 Opportunities and barriers: *Barriers too implementation and issues such as the need to adjust other policies*	**Opportunities:** • This will be the last resort of saving certain species[199]. • It may allow the re-introduction of species[200]. **Barriers:** • Ex-situ conservation is expensive. The upgrade and creation of new facilities will require considerable funding for both establishing and operation. • It is unlikely to be a viable long-term strategy for any more than a few species[201]. • Under extreme climate change scenarios it may not be feasible to reintroduce captivity-bred species in to the wild[202].

[199]Mawdsley et al. 2009. Op. Cit.
[200]Noss, 2001. Op. Cit.
[201]Mawdsley et al. 2009. Op. Cit.
[202]Mawdsley et al. 2009. Op. Cit.

6.2 Status: *Status of technology in the country*	There are botanical gardens, zoos and seed banks in the country – and the first two attract many local and foreign visitors. However there is opportunity of improving ex-situ conservation in the country, especially in the case of zoos. More advanced ex-situ facilities maybe required for the conservation and captive breeding of certain species, sperm and egg banks, advanced seeds banks may be other necessary mechanisms.
6.3 Timeframe: *Specify timeframe for implementation*	Ex-situ conservation is a mid to long-term strategy and needs to be carried out continuously.
6.4 Acceptability to local stakeholders: *Whether the technology will be attractive to stakeholders*	It is unlikely that local stakeholders will not accept ex-situ conservation as it can bring in conservation benefits and also income and job opportunities.