Climate change adaptation in water management for food security: Recent developments in Sri Lanka-A review of Existing Knowledge and Information

Prepared by

M.M.M. Aheeyar

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1. Introduction

Sri Lanka situated between 6 and 10 degrees of North of the equator has predominantly monssoonal and tropical climate. The passage of moisture-laden winds from Southwest and Northeast is undoubtedly the determinant of water resources availability. Rainfall supplies nearly all surface and groundwater resources and varies spatially from 800mm to over 5500mm. The island has been divided into three principal agro-climatic zones, viz. wet, intermediate and dry zones, which have been demarcated based on hydrology, meteorology, soils and vegetation (Somasekeram *et al*., 1988). The Wet Zone covers the south-western region including the central hill country and receives relatively high mean annual rainfall over 2,500 mm without pronounced dry periods. The Dry Zone covers predominantly the northern and eastern part of the country, receives a mean annual rainfall of less than 1,750 mm with a distinct dry season from May to September. The Intermediate Zone receives a mean annual rainfall between 1,750 to 2,500 mm with a short and less prominent dry season.

While Sri Lanka is a lower middle-income country and performing well against a number of Millennium Development Goals (MDGs), poverty, food insecurity and under-nutrition are still persistently high in lagging regions. This has been exacerbated by climate change impacts and impacts are expected to get worse. Manifestations of climate change in Sri Lanka, namely, increases in the frequency and intensity of floods and landslides, variability and unpredictability of rainfall, and to a lesser extent and increase in air temperature expected to have the greatest impact on local and national food security.

Ensuring food security is the core principle behind the development of the agriculture, fisheries and irrigation sectors in Sri Lanka's national development agenda. This thrust is further bolstered by the emphasis on nutrition in the health sector. Agriculture accounts for a little over 20 percent of GDP and provides nearly 70 percent of the rural employment. More than half of Sri Lankas food grain production is dependent on irrigated rice. Irrigation is the major user of fresh water consuming over 90 percent of the total annual captured water. The competing demand water from other water-use sectors (domestic, industrial, hydro-power and environmental needs) are also continuously at an increasing trend.

Rice is the staple food of over 20 million Sri Lankans and provides a livelihood for almost two million farmers. More than 30 percent of the total labor force is directly or indirectly involved in the rice sector. Approximately 44 percent of the paddy on which Sri Lankan food security depends is irrigated under major irrigation schemes and 24

percent under minor irrigation schemes, and the bulk of this land is located in the Dry and Intermediate Zones. Sri Lanka produces about 3.1 million tons of paddy annually with a national average yield of 4.0 t/ha. With the current population growth rate of 1.1 percent, Sri Lanka will need about 4.2 million tons of paddy by the year 2020, which is an increase of about 35 percent.

2. Evidence of climate change in Sri Lanka

There is amble evidence to suggest that the climate of South Asian region has already changed (IPCC, 2007; Withanage et al 2009; Eriyagama et al. 2010, Premalal, 2010, Punyawardane, 2011). The number of rainy days has decreased at all the meteorological stations except for the Nuwara Eliya station while shrinking the 2000mm isohyet – demarcating the wet zone of the country (Manawadu and Fernando, 2008). Water volume by watershed shows a clear dichotomous distribution with watersheds in the north having increasing trends, and watersheds in the south having decreasing trends, in water volume. The study finds that although the number of rainy days has decreased, the total annual rainfall has not decreased in the all stations. This could indicate that the intensity of rainfall events may have increased together with increased durations of dry spells. The apparent increased incidence of flooding, landslides and droughts in the recent past could probably be attributed to such changes in the temporal pattern of rainfall distribution (ibid).

Annual rainfall variability has increased almost all over the country, but variability is high in the dry zone than intermediate and wet zone. The coefficient of variation of rainfall distribution between 1931 to 1960 is greater during the Northeast monsoon and Second inter monsoon period (Maha Season) when compared to the period from 1961 – 1990. Southwest monsoon rainfall has not shown any significant change during these two periods (Premalal, 2010). Herath and Ranayake (2004) revealed that the First inter-monsoon period shows the highest decrease in rainfall and in addition to this the numbers of rainy days have reduced giving rise to an increasing rain intensity trend. The total rainfall shows both increasing and decreasing trends within the country and the spatial pattern and magnitude of this change is shown. North-eastern and Western regions experience increasing rainfalls while rest of the country experiences a decreasing trend. This phenomenon is further elaborated by De Silva (2009) using a climate modeling study that, the North-East monsoon rains are predicted to decrease by 34% (A2, the scenario showing the worst impact of climate change-) across the country. These changes in rainfall and temperature, together with other climatic factors, will increase the potential soil moisture deficit significantly.

Rainfall in upper watershed area is reducing by 39.12%. This reducing trend is predicted to continue at 16.6% during next 21 years (Shantha and Jayasundara, 2009). Rainfall has been decreasing in Colombo, Nuwara eliya and Kandy at the rate of 3.15, 4.87 and 2.88 mm/year during last 100 years. There is decreasing rainfall trend in 13

rainfall stations out of 15 during last 50 years (Jayawardene et al, 2005). The variability in seasonal rainfall is illustrated in Table 1.

Table 1: Coefficient of Variation of Seasonal Rainfall in Sri Lanka

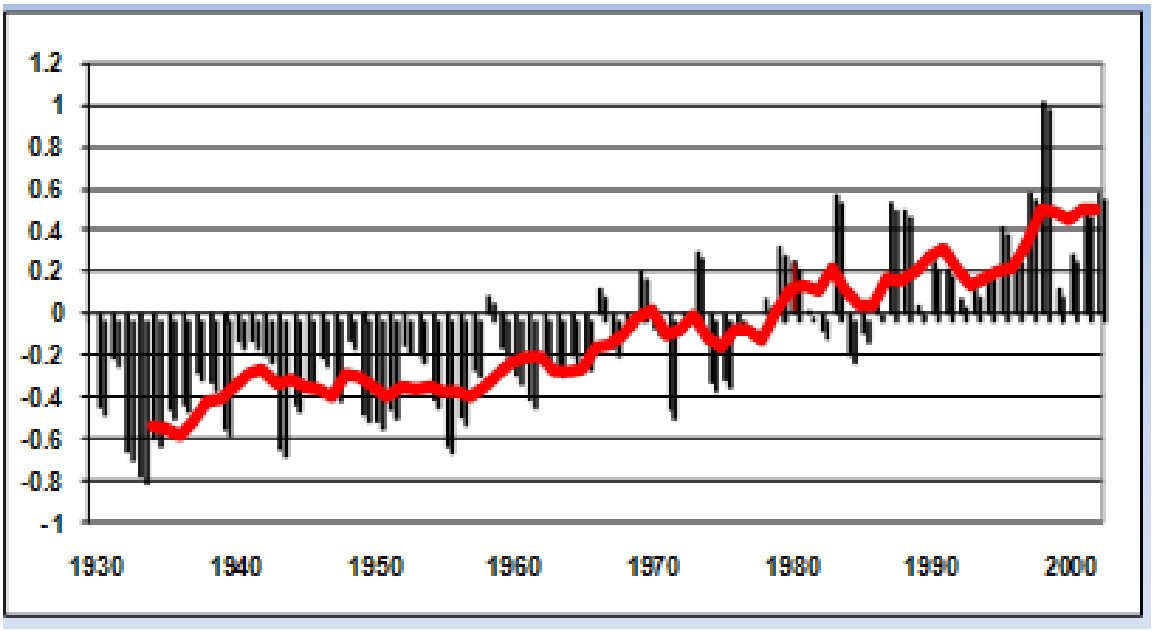
Season	**1931-1960**	**1961-1990**
First Inter Monsoon Season	23%	27%
South West Monsoon Season	21%	16%
Second Inter Monsoon Season	22%	23%
North East Monsoon Season	31%	42%
Annual	11%	14%

Jayatilaka et al, 2005

Annual mean air temperature anomalies have shown significant increasing trends in Sri Lanka. The rate of increase of mean air temperature for the 1961-1990 period is in the order of 0.016^0 C per year. Annual mean maximum air temperatures have shown increasing trends in almost all stations with the maximum rate of increase about 0.021^0 C per year at Puttalam. Night-time annual mean minimum air temperatures have also shown increasing trends with higher gradients. The maximum rate of increase of night-time annual mean minimum air temperature is reported to be about 0.02^0 C per year at Nuwara-Eliya (Premalal, 2009). De Silva, (2009) predicted that, the annual average temperature is to increase further in future.

Time series of annual mean temperature anomalies from 1871-1990 show a significant warming trend at most places in the country during the latter half of this period. The rate of increase in temperature from 1961 to 1990 is about 0.016 °C per year, while the global average for the period 1956-2005 is 0.013 °C per year. According to Chandrapala (2010), since 1960, the temperature rise in Sri Lanka is in the order of 0.16^0 C per decade (Figure 1). Seasonal mean temperatures for the Yala (April–September) and the *Maha* (October–March) agricultural seasons also display similar warming. Mean (annual and seasonal) daytime maximum and mean (annual and seasonal) nighttime minimum air temperatures have both increased during the period 1960-2001 with trends of 0.026 °C and 0.017 °C per year, respectively.

Figure 1: Change in Mean Annual Temperature in Sri Lanka 1930 to 2000



Source: Chandrapala (2009)

There is strong higher variability in monthly precipitation and a declining trend in Sri Lanka's overall mean annual precipitation (MAP) during the last century. The El Niño-Southern Oscillation (ENSO) also influences the country‟s rainfall. Recent studies have estimated a decrease in MAP by 144 mm (7 percent) during the period 1961-1990 compared to that for 1931-1960 (Premalal, 2009). There is also a wide disparity in the magnitude of changes in different rainfall seasons and spatial locations. Although no significant changes in rainfall amount have been observed during the southwest monsoon season (SWM) (mean 546 mm) and the second inter-monsoon season (mean 548 mm), rainfall in the northeast monsoon season (NEM) and the First inter-monsoon season (mean 260 mm) has decreased, with NEM showing increased variability.

The Sri Lanka Country Report on Climate Change (ADB, 1994) has shown that the increase in temperature by 2070 will be in the range of +0.4 °C to +3.0 °C. As per the rainfall predictions, the Wet Zone will record 10% increase per year in both dry and wet seasons. Moreover, the $C0_2$ level in the atmosphere is predicted to be approximately in the range of 600-700 ppm by the year 2100 (Wijeratne, 2009).

The visible effects climate changes on livestock are changing incidences of disease occurrence, changing trends in reproduction and breeding, and varying levels of adaptability of livestock. More than 90% of the livestock sector holdings in Sri Lanka are represented by smallholdings, which consist of systems of operation, which are highly vulnerable to localized trends of climate change compared to intensively managed system. The impacts are complex and indirect. Despite the high variability in localized climatic regimes Sri Lanka possesses, and the importance of smallholder systems to the

livestock sector of the country, the understanding on the interaction of climate change and livestock in the country is not effective enough to face the future development challenges of the sector (Silva, 2009).

3. Policy Development in Relation to CCA in Sri Lanka with Reference to Water Sector

Sri Lanka is a signatory to the United Nations Framework Convention on Climate change (UNFCC) in 1994. Under its obligation to contribute to efforts to mitigate climate change, Sri Lanka has undertaken the first green house gas inventory in 1995 and established a separate Climate Change Division within the Ministry of Environment. A centre for Climate Change Studies (CCCS) was also created at the Department of Meteorology. First National Communication on climate change was made in 2000. Sri Lanka has ratified the Kyoto protocol in 2002. Subsequently two national Clean Development Mechanism (CDM) study centres were established at University of Peradeniya and University of Moratuwa. However these two centers are not functioning fully due to lack of capacity which normally required for the smooth functioning of an institution. Ministry of Environment and National Resources has conducted a thematic assessment of existing capacity to address climate change by preparation of National Capacity Needs Self Assessment Action Plan. Second national communication on climate change was published in 2012.

In most instances it appears that there are no specific policies, legislations, regulations etc. to address climate change impacts and related issues. Hettige, (2008), highlights that, lack of national policies for promoting adaption, low priority for climate change works among development organization, low level of clarity/research in climate change impacts in the country. However the Government has prepared a national policy on climate change. In addition there are several environmental acts in the country that has provisions to deal with climate change effects. The National Environment Act No.47 of 1980 and amended by Act No.56 of 1988 and No.53 of 2000 address climate change. Similarly, the National Environmental policy address conservation of water resources, management of irrigation water, regulation of groundwater, reduction of wastage from irrigation and water supply schemes, reduction of water pollution and restoration of polluted water bodies. Past National Environmental Action Plans (NEAP) address the conservation and management of water and has identified that, absence of policy mechanism to deal with climate change, lack of adaptation strategies, and low level of preparedness among many sectors to deal with climate change are as major gap.

Water as vital resource for all sectors and increasing demand for water within and between different water-use sectors and high priorities for national development, it has

been prioritized and recognized in national policies such in the *Mahinda Chinthana* 2010, *Haritha* Lanka Programme and *Randora* National Infrastructure Development Programme. *Mahinda Chinthana* has recognized the development of agriculture sector to be commercially viable and maximized the water use through modern irrigation techniques as critical aspects of development. "Water for all and always by 2012" and strengthening implementation of integrated water resource management are increased in the mission of the National Action Plan for the Haritha Lanka programme. Change sum of money in earmarked for the development of large national scale water supply and irrigation schemes and also wager supply projects for small towns and arid areas in the Randora National infrastructure development programme.

National Physical Planning Policy and Plan (2006-2030) address 'water resources development' including protection of catchments, water resources and tanks, in order to improve water quality and ensure adequate supply of water for different uses, viz; domestic, agricultural, industrial and power generation activities. The policy specifies the certain principles and strategies to achieve these objectives.

There are over 50 Acts dealing with water supply, quality, drainage, irrigation, including Irrigation ordinance of 1946 and 1951, National Water supply and Drainage Board Act, Water Resource Board Act, Mahaweli Authority of Sri Lanka act, Flood Protection ordinance and National Policies of Rainwater Harvesting, Watershed Management, Wetland, Forestry, Land use and Sand. Successive governments have taken steps to conserve forests and introduce laws and regulations to control deforestation and forest degradation. Over the past few years, the Government has put in place a National Forest Policy and Forest Sector Master Plan as well as a National Watershed Management Policy and various strengthened regulations on land use. Replanting of barren hilltops has been recognized as a matter of national priority and banned human incursion in areas 1,500 meters above mean sea level as per instructions given by H.E President.

However, the absence of a governing policy for the institutions involved in water resources management is a major hindrance in sustainable management of water resource in the country. Further, there are no laws governing excessive water extraction which is considered to be a potential problem for water management in the future (Ministry of Environment, 2010a, Imbulana et.al, 2010). Although many of the laws are strong, their implementation remains inadequate. Water Resources Board is planning to introduce some legal instruments to monitor, control and regulate groundwater extraction in the country. A ten year plan has been prepared to identify the groundwater sources, monitor the quality variation and water table fluctuation.

National climate change policy of Sri Lanka has been developed by the Ministry of Environment to provide guidance and directions for all the stakeholders to address the adverse impacts of climate change efficiently and effectively (Ministry of Environment,

2012). However, adaptation to climate change has not received high priority policy issue in Sri Lanka, as policy makers are pre-occupied with other developmental priorities. Adaptation strategies are largely being dealt in isolation from other developmental issues, though there is a need to link the existing policies on climate risk with development policies, and to mainstream climate change adaptation into development planning (ADBI, 2010). This is further elaborated by Senatne et al (2009), that although farming communities involved in agriculture, forestry and water sectors continuously adapt to variability in climate on voluntary basis, projections on global climate change indicate that future variations of climate parameters could exceed the adaptive capacity of communities unless facilitated by well designed policy supports by the government. Four major gaps act as barriers for formulating viable adaptation policies to face impacts of climate change. They are, namely, information gap, lack (or necessity) of an integrated agenda for action, coordination and resource mobilization gap. Effective adaptation in these sectors would be determined by the success of overcoming these major gaps. Therefore, researchers, academics and policy makers should focus their attention on measures that could help overcome these four gaps.

4. Major Issues in Relation to CCA in Sri Lanka with Reference to Water Sector

4.1 Ability to meet food production demands

Sri Lanka has food crop oriented agricultural economy. Rainfall, temperature, and day lengths are key determinants of the growing seasons, type of agricultural practices and yield levels. Rainfall plays on important role in agriculture as any shortages or excess of rainfall gives way to a reduction in yield. Therefore, climate change undoubtedly would trigger serious impacts on the country's food insecurity and vulnerability patterns. This has been highlighted in the recent study of ESCAP (2010) as Sri Lanka is to be one of the hotspots of food insecurity in the Asia-Pacific region.

Rice- the staple diet is highly susceptible to rainfall variability. Sri Lanka produces about 3.1 million tons of paddy annually with a national average yield of 4.0 t/ha. With the current population growth rate of 1.1 percent, Sri Lanka will need about 4.2 million tons of paddy by the year 2020, which is an increase of about 35 percent. Climatic zone wise rice production figures shows that, the contribution to island-wide rice production from the dry, intermediate and wet zone areas are in the ratio of 3:1:1 (Zubair, 2002). As per available literature, climate change impacts in relation to food crop production are higher for dry zone and possibility to have serious threat on our food security, unless we adopt suitable adaptation strategies. Accordingly to past data, during *El-nino* phase, the *maha* rice production has frequently increased and the *yala* production frequently decreased. Conversely, during La-Nina phase, the *maha* production decreased and *yala* production increased (Zubair, 2002). Most Sri Lankan crops, and particularly rice, are produced at the top end of the optimum temperature range for cultivation, meaning that the anticipated increases in temperature could have a

profound effect on yields. Estimates suggest that rice yield could be reduced upto 6% for 0.1 - 0.5°C temperature rise (Vidanage and Abeygunawardena, 1994; Practical Action, un dated). However, major climate change impacts for rice cultivation are from changes in rainfall amount and distribution. Rice yield in Walawe basin are predicted to increase as a results of enhanced CO_2 levels and higher precipitation (…..).The combined effect of higher temperatures and less rain is projected to lead to a greater than 11 percent loss in revenue from paddy by 2050 (Munasinghe Institute, 2010).

There is already recognition that the country needs to adapt or prepare itself for the implications of future climate change. Current production methods and crop varieties are inadequate for meeting growing demands for food and challenges from climate change. Six research institutes in the country conducting research on Rice, Field crops, Horticultural Crops, Tea, Rubber and Coconut, are in the process of developing pest, drought and salt resistant, short term crop varieties.

Very high genetic variation among indigenous rice varieties is an indicator of excellent potential for varietal improvement for adaptation. The need for development of different age groups of paddy (short term and long term varieties) to suit unpredictable rainfall regimes is also recognized by the Department of Agriculture. Already several New Improved Varieties with varying yield have been developed. Short duration 2.5 to 3 month varieties have been released, but this should be popularized and ensured the supply of necessary seed paddy at needed time.

Although, we have adopted high yielding rice varieties in almost all the areas, they are mostly environmentally unsustainable due to high fertilizer and water requirements. Fertilizer use has raised more than four fold after green revolution, but yield has only doubled. Created water use has increased the problem of soil salinity. Therefore, crop varieties should be developed to withstand higher temperature and precipitation variability while increasing productivity and input use efficiently.

Overall, the extent of paddy lands has increased since the establishment of peace, due to the re-use of a large extent of abandoned paddy lands in the Northern and Eastern Provinces and implementation of fertilizer subsidy.

Weerakoon and De Costa (2009) suggest that, as the direct impact of climate change, especially the negative impacts of the temperature and scarcity of water would be less for wet zone paddies, maximum efforts must be devoted towards achieving the full potential from wet zone rice cultivation. The major expected problems for wet zone paddy cultivation are increased sea level rise and high intense rainfall would increase the submerged paddy area in the wet zone. Therefore, flood and salinity tolerant rice varieties must be developed. It is predicted to shift in biotic pressure on the rice crop by emerging new bio types of both pest and disease and different weed population in

rice field. Therefore, research and development programmes are necessary to utilize positive sides of climate change and minimize the negative impacts of climate to increase rice production and ensure food security.

The combine effects of temperature and relative humidity at the reproductive stage of rice plant plays major role in determining yield level and quality of rice. Therefore breeding programmes to identify cultivars that can withstand higher temperature and relative humidity during spikelet development stage is necessary as an adaptation strategy. Looking into the possibility of adjusting the cropping calendar to avoid unsuitable weather conditions is another option (Rathnayake *et al,* 2009).

There is also possibility of increasing cropping intensities by proper management of irrigation water. Granary Area Programme has ear marked 267,000 ha in selected high potential major irrigation areas for possible increase of cropping intensity from 176% to 186% (M/A&L and M/I&WM, 2003), but this programme is yet to be implemented. Department of Agriculture is promoting cultivation of five other field crops (Cowpea, Blackgram, Greegram, Maize, Soybean) under irrigated conditions with the collaboration of Irrigation Department as a measure to increase cropping intensity, food security and efficient use of available water. It has been found that, climate change has significantly affected the rain-fed paddy farmers in cultural practices, seed paddy broadcasting and harvesting (Ministry of Environment, 2004). However farmers have not shown successful adaptation for this and incurring extra cost per unit of production.

Under the Regional Specialization Drive (RSD), selected Yaya block demonstration project is an institutional programme implemented by the Department of Agriculture in selected tracts of fields in major and minor irrigation and rainfed conditions. The programme ensured the proper cultivation practices and confirms adequate credit and other inputs for selected tracts. It bridges the research extension gap as well as ensured that the optimum inputs were utilized. The programme adopted appropriate location specific varieties, used quality seeds and ensured timely cultivation with the direct participation of farmers and close co-ordination of grass root level officials. The project had a component to improve soil fertility and avoided improper ploughing practices. The other elements are maintenance of optimum plant density, nutrient management, weed and pest control and minimization of post harvest losses. The Yaya cultivation programme should be introduced with the close coordination of officials and farmers to achieve the targets of productivity levels with introducing improved crop management practices.

Being a rain-fed plantation crop, coconut can be adversely affected by prolonged dry spills associated with high temperature (Ranasinghe, 2009). Projections on coconut yield suggest that, production after year 2040 may not be sufficient to cater local consumption (Peiris *et.al*, 2004). Genotype and Environmental interactions based

screening techniques and yield related physiological parameters are proposed to be applied successfully in the screening for drought tolerance in coconut, which is one of the approaches to increase adaptability to inevitable changes of climate (Nainanayake, 2009).

A number of other field crops, including coarse grains, grain legumes, oil seeds and condiments are grown on rain-fed upland areas in the Dry Zone. The production of these crops will also be adversely affected by fluctuations in rainfall.

The effect of enhanced CO_2 levels in the atmosphere may be favourable for many field crops that belong to C_3 group. However, the yield levels of C_4 group plants such as mange, which is in increasing land extent, may be effected due to elevated CO_2 (Malawiarachchi et.al, 2009). De Silva (2009) shows that irrigation requirement for chilli and tomato would increase by 18% and 14% respectively in the dry zone under A_2 scenario of climate change.

Most of the horticultural crops cultivated in the up country wet zone require specific climatic conductions for high quality production and higher productivity. For example, potato, one of the important horticultural crops cultivated in the upcountry area requires a diurnal temperature variation above 80^0C during the cropping period for maximum production. However, the recent past data indicates the tendency for this difference to decrease, which leads to considerable loss in production (Nugaliyadda, 2009). Therefore, new varieties should be developed to overcome this problem. Emergence of new pest and diseases were also reported in potato farming due to changes in temperature and prolonged dry condition *(ibid*).

Most of the fruits, vegetables and other field crops are cultivated in Sri Lanka with the varieties developed in 1960s. There is an obvious gap in this non-paddy crop sector in the research priorities and resources allocations. The gap has to be filled immediately through research and development in order to reduce cost- price squeeze in the sector, improve the product quality and increase the competitiveness. The suitable seed varieties could be imported in short term through proper phyto-sanitary measures to improve the productivity, consumer preference and product quality. Impacts of climate change on certain fruit species are many fold; namely, advances blossoming of fruit trees, extended growing season, and increasing pest population, which ultimately effect in productivity. However, no systematic research has been initiated to identity these issues to increase productivity and profitability and also to develop suitable adaptation strategies (Heenkanda and Pushpakumara, 2009). They have proposed several priority research areas to identify appropriate adaptation strategies for fruit crops such as potential shift of fruit growing areas, changes in flowering and fruiting phonology and stigma receptivity, changes in fruit yield and fruit qualities, and identification of new fruit species and varieties.

However, it takes a considerable period of time to bring about changes to a tree crop system such as fruits and plantation crops. In this strategy, judicious selection of suitable lands for new planting or replanting, use of drought and heat tolerant cultivars, soil and soil moisture conservation, soil improvement, intercropping, crop diversification, and establishment and management of shade trees are the most viable adaptation measures proposed for perennial crops.

Tea is the major plantation crop and one of the export earning industries in the country. The total annual rainfall and its distribution, temperature, and solar radiation are the most influential environmental factors governing tea yield and quality of tea.
Reduction of rainfall by 100 mm per month was found to reduce the productivity of tea by 30 - 80 kg of 'made' tea/ha/month in different regions. Increase in ambient $C0_2$ concentration from the current level (around 370 ppm) to 600 ppm, will increase tea yield by about 33-37%. Increasing temperatures are likely to reduce tea yields in IU, WM and WL regions while increasing the yield in WU region. Tea yields are likely to increase at high elevations due to climate change. In contrast, the productivity of tea plantations at low elevations is likely to be reduced. As low and mid elevations are more vulnerable to the adverse impact of climate change, growers need to pay more attention to implement adaptation measures to minimize such adverse effects (Wijeratne, 2007).

Therefore it is necessary to implement suitable adaptation measures with proven cost-benefits to minimize such adverse effects of global warming and harness maximum benefits of $C0_2$ rise. Rising temperatures above optimum and of dry weather should be aimed at improving crop, soil and aerial environmental conditions. Nevertheless, very low yielding tea lands with poor soil conditions are preferred to be diversified into fuel wood or timber plantations. Marginal tea lands can also be converted to productive lands by planting of rehabilitation grasses and used as a source of green manure for improving soils in the potential tea fields. Shade trees in tea lands can reduce ambient temperature by about 2-3 °C thus attenuating the adverse effects of higher temperatures on growth of tea especially in the low elevations (Sivapalan, 1993).

Use of drought tolerant cultivars and grafted plants with drought tolerant characteristics in drought prone regions and intercropping tea with other tree crops (cash crops) such as rubber and coconut are among the most suitable adaptation measures. High intensity intercropping systems will reduce the ambient temperature around tea bushes and also increases the land utilization efficiency ensuring better returns. Experimental results have shown that the increase in soil organic carbon by 1% could increase annual yield by about 400-500 kg/ha. Irrigation also increases tea yield by about 50-100%. The yield response to fertigation i.e. irrigation with fertilizer, can be as high as 300% during dry weather (TRI, 2001 & 2002).

The critical climatic factors affecting the productivity of sugarcane crop are scarcity of water and prolonged drought periods and shift in mosoonal weather. In addition, winds during North-East monsoon period have been reported as the cause for spread and establishment of the serious sugarcane pest woolly aphid *Ceratovacuna lanigera* in Sri Lanka (Kumarasinghe, 2009). Even though, adaptation measures for such adverse climatic variations is limited in the present context, the change of planting and harvesting schedules and establishment of small ponds within plantation areas to maintain the ground water at a higher level are recognized as possible adaptations to minimize the effects of drought. However, these adaptations impose extra costs to the growers, even though they do not involve new technologies. Consent by farmer communities for allocation of land for establishment of small ponds from their limited land allotments should be addressed at a policy level, which should also include compensation schemes (ibid).

The visible effects climate changes on livestock are changing incidences of disease occurrence, changing trends in reproduction and breeding, and varying levels of adaptability of livestock. More than 90% of the livestock sector holdings in Sri Lanka are represented by smallholdings, which consist of systems of operation, which are highly vulnerable to localized trends of climate change compared to intensively managed systems in the developed countries. The impacts are complex and indirect. However, the current levels of understanding on the interaction of climate change and livestock in the country is not effective enough to face the future development challenges of the sector (Silva, 2009). It is also pointed out that, climate change induced heat stress would negatively effect the reproductive functions of the livestock (Wijayagunawardane, 2009), but current levels of knowledge on the effects of global warming on animal health and reproduction are not updated. Therefore, more in-depth and integrated studies are proposed to fully elucidate the implication of global warming on livestock productivity, socio-economic effects and impacts on the nation and region as a whole (ibid).

A new package for dairy and poultry sector promotion should be introduced to open up opportunities for investors and convert the industry as a vibrant sub-sector to cater to the nutritional needs in the country. In this respect, the following measures are suggested:

- Establish a Livestock Production Cell within the premises of Veterinary Office in each area to provide technological input to boost production particularly in high potential production districts;
- Establish a poultry backyard systems through provision of birds on subsidized prices for rural people

- Encourage with an incentive package to adopt improved and high productive animals in the coconut triangle areas to improve the productivity of milk and increase the farmer income

The potential risks of sea level rise on fisheries include the loss or change of coastal habitats and species distribution. The possible impacts of changes in rainfall regimes and prolonged drought on fisheries can have varied implications affecting mainly inland fisheries, especially in seasonal tanks. On the other hand, flooding will affect inland aquaculture and capture fishery due to pollution, sedimentation and any adverse changes in water quality parameters of surface water bodies. Senartne *et al* (2009) has described that rise in oceanic temperature, changes in precipitation pattern, sea level rise and extreme weather events would lead changes in distribution, growth and reproduction of fish stock, alteration of species composition, damages to fishing infrastructure and disturbance to fishing activities. These would all have serious implications on socio economic conditions of fishing communities, rural nutrition and incomes for dependent communities.

Improve weather forecasting and information dissemination has been identified as one of the adaptation strategies to ensure food security under changing climate scenario (Ministry of Environment, 2010b). Department of Meteorology is currently operating 20 Meteorological stations and 350 rainfall stations throughout the country. Meteorological stations collect three hourly data while rainfall stations records 24 hour rainfall data. The department has digitized daily values of rainfall, maximum and minimum temperature since 1861. However, more important three hourly data is yet to be digitized. In addition 33 Automatic weather systems are linked to the central monitoring station via satellite transmission and 20 automatic rainfall gauging stations are placed in landslide prone areas and linked to Central monitoring system via cellular telecommunication network.

Department of Agriculture operates Agro-Meteorological network to collect weather data twice a day in agro-climatic zones. These data continuously shared with Meteorological Department. Department of Agrarian Development has installed rain gauges in 320 Agrarian development centres and planned to install rest of centres very soon. Rainfall data is recorded by ARPAs for local level planning and decision making. Hydro-meteorological network maintained by Irrigation department consisted of 69 hydrometric stations in 17 river basins, 16 river gauging stations and 11 evaporation pans. The information collected is used by department to issue flood warning. Improvements for Hydro-meteorological network and modeling is planned to forecast flood. Therefore the country have fairly extensive network of metrological information. However, the access to data and dissemination of data is not properly institutionalized.

Department of Agriculture has been working on possible adaptation measures for salinity and drought conditions to enhance capacity to adapt to climate stress within the agricultural sector. There is a need of development of more tolerant varieties for high temperature, droughts, pest and diseases and water saving. The department has already developed 75 day short duration rice variety BG 250, black gram variety '*Anuradha*', maize variety '*Aruna*', Green gram variety *MI-6* which takes short duration and thus capable of escaping prolonged drought condition. Heat tolerant tomato variety called *KC-1* has been developed. These are some of the valuable outcomes of the strategies based on plant breeding. However, these technologies should be transferred to farm level and farmers should be convinced to accept the developed technology. Herath (2012) reveals that, most of the newly developed rice varieties are not popular among farmers and majority of the farmers are using the varieties developed about 15-20 years ago. Currently the highest percentage of rice area is planted with old varieties released before ten years. There are empirical evidences to show inadequate seed stock and lack of access to new improved varieties at rural levels (Aheeyar *et.al* 2012 and 2006).

Current availability of information is considered are not adequate for launching effective programme against threat posed by climate change (Senaratne *et al*, 2009), though few attempts made in the past through various funded project. Effort also made to generate information on local effects of climate change through down scaling global model. Attempts were made to test various strategies at pilot level under different contexts for up scaling. However, the current information gap warrants little room for designing meaningful action against impact of climate change in the country *(ibid*).

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

- 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
- 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
- Promotion of inland aquaculture

It is necessary to establish a specific institution for managing food surpluses, imports, food information and policy analysis relevant to food sector under the Ministry of Agriculture, which is currently been carried out by many institutions and organisations. Further it could monitor food situation regularly and suggest timely policy prescriptions and other options to mitigate any risk involve in the whole process of food production, marketing, storing and distribution.

4.2 Ensuring adequate availability of water for Agriculture

Climate projections indicate that climate change impacts in Sri Lanka are likely to be higher in the Dry Zone, especially in the Northeast and the East, where agriculturally intensive areas are located and are already experiencing water stress. The expected changes may lead to an increase in the Maha (wet) season irrigation water requirement for paddy by 13-23 percent by 2050 compared to 1961- 1990. Reduced rainfall on the other hand can affect seasonal flows of the rivers that originate and flow entirely in the Dry Zone. Observed and projected reduction in rainfall in the Central Highlands is likely to create conflicts between irrigation water supply and hydropower generation from the multipurpose Mahaweli scheme (supplying 23 percent of irrigation water to major irrigation schemes and 29 percent of national power generation). Reduction of river water flows can increase the risk of saltwater intrusion.

High intensity rainfall often leads to significant erosion and runoff reducing retention and re-charge. Unusual flash floods can also damage headworks of irrigation schemes and canal structures which can hinder a reliable water supply. The impacts of temperature increase on water availability include increased rates of evaporation and evapo-transpiration. Thus, during drought periods water availability for irrigation will be affected due to high evaporation rates – this is especially true for the Dry Zone tanks and rivers. Increased evaporation and transpiration can also reduce soil moisture, stream flow and groundwater re-charge, thus reducing water available for food production, and increasing the irrigation requirement.

According to De Silva (2009), irrigation requirement for other field crops too is predicted to increase by 18% and 14% respectively in the A2 scenario for Chilli and Tomato in grown in Anuradhapura. Adaptation measures should focus on increasing irrigation water to ensure food security through dry zone agriculture to overcome the effects of climate change (ibid). Department of agriculture is promoting plastic mulch and green mulch to conserve soil and moisture.

The unpredictability and extreme nature of rainfall have been evident in the recent rainfall events in Sri Lanka. Since end-December 2010, the country has experienced its highest level of rainfall in almost 100 years. There was especially heavy rainfall in the early part of 2011, with consequent flooding in many areas of the country. The impact of

the rain could have been cushioned had the water catchments been adequately covered with trees and small tanks functioned at full capacity.

Research has been done to identify the alternative water management techniques that would reduce the water demand without compromising yield. The findings shows that, the alternative water management techniques that are experienced, namely, saturated rice culture, alternative wet and dry culture and aerobic rice cultural have achieved significant reduction in water use and significant increase in water productivity. However, the existing rice varieties have shown yield reduction under alternative water management conditions compared to cultivation under standing water. Hence research is being conducted to identify genotypes from both local and exotic germplasm, which are able to produce higher yields under alternative water management (Ministry of Environment, 2011).

The adequacy of water supply for food security depends on the supply of water in the source catchments and storage in surface and ground water. This, in turn, depends on an effective tree cover for intercepting rain, sustainable land management to retain soil water, and means to insure adequate water storage. These areas form the pillar of the proposed set of adaptation interventions. In the face of an uncertain climate, Sri Lanka needs to concentrate on "smart investments" and "no regrets" adaptation interventions that simultaneously deliver climate resilience and address current development needs. Both, rainwater harvesting, and restoration of the ancient tank system of the country, are two such adaptation options against future challenges in the water resources and agriculture sectors. Suggestions have been made for provision of rainwater harvesting systems to all households in drought prone areas (De Silva *et al.* 2007), making it a prerequisite to receive drought relief. Development of sustainable groundwater, promotion and adoption of micro-irrigation technologies, wastewater reuse, increasing water use efficiency and change of allocation practices are other adaptation options under consideration in the water resources sector.

Water resource adaptation strategy for climate change in Sri Lanka as observed by Akiko Yamane, 2003 are as follows:

1. Encourage minor storage water reservoirs
2. Investigate feasibility of trans-basin diversion schemes
3. Conserve seasonal water
4. Rehabilitate irrigation water tanks networks
5. Promote micro-watershed management
6. Prepare groundwater extraction regulation policy

7. Introduce permit/monitoring systems for ground water extraction and water quality assessment in vulnerable areas

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)
- Increasing irrigation efficiency
- Water conservation
- Harvesting of surface runoff – unlined ponds and lined ponds
- Tube wells and Boreholes
- Major tanks
- Trans basin diversions
- Wells
- Desalination of brackish water by reverse osmosis

Technology need assessment project currently undertaken by Ministry of Environment in 2012 has prioritized three technologies for adaptation in water sector namely rehabilitation of small tanks, rooftop rainwater harvesting for drinking water needs and boreholes construction.

The government clearly indicates the intention of developing all feasible new irrigation development projects and ways and means of augmenting existing irrigation schemes wherever possible in the ten year development framework (2006-2016) (NPD, 2006). In this line the government has already completed Weli oya and Mau ara projects. Moragahakanda and Kalugnaga reservoirs, Deduru Oya, and Uma Oya, projects have been initiated. The government has planned to implement the Mahen Ela, Menik Ganga, Kumbukkan Oya, Yaan Oya, Wemadulla project to augment Dewahuwa reservoir and Kekir Obada reservoir at Kirama Oya in the forthcoming years. Diversion of Menik Ganga, Deduru Oya and Kumbukkan Oya are to benefit about 18, 000 farmer families to cultivate 54, 000 ac of paddy land in both maha and yala seasons. The diversion is also to provide potable water for tens of thousands of families. The construction of Weharagala reservoir at Lunugamvehera with five small, existing, cascading reservoirs resulted in a 400 percent increase in crop production. In fact, cascading small reservoirs can significantly increase crop water use by capturing drainage, return flow, and surpluses from upstream reservoirs.

Diversion of Mau Ara waters to Malala Oya basin has helped to augment 30 village tanks and their command areas. Studies carried out in the basin show that diversion of water has resulted in sustained groundwater levels during dry periods significantly. Weli Oya

diversion Project has helped to augment 26 village tanks located in the water-short areas of Moneragala District. The primary purpose of the Moragahakanda Project is to provide increased water supplies to about 81,500 ha of drought-prone irrigation areas in the northern and central parts of Sri Lanka. This multi-purpose project is also expected to provide a domestic and industrial water supply to Anuradhapura, Trincomalee, Polonnaruwa and Matale districts and generation of 55 GWh of hydro power annually at Moragahakanda. The project is also expected enhance inland fishing industry and nutritional status of the people in the area. The Uma Oya Multipurpose Project includes the construction of two reservoirs, 90 MW hydropower plant with an annual energy output of 312 GWh and diversion of approximately 150 MCM of water to irrigate about 5000 ha in the Hambantota and Moneragala districts, as well as other downstream benefits. In addition, diversion of perennial water by means of anicuts to farm lands through supply canals for cultivation in the upcountry region is also recognized. It is proposed to develop identified tanks in an integrated manner (Department of National Planning, Ministry of Finance and Planning, Sri Lanka). For example Dry zone Livelihood Support and Partnership Programme funded by IFAD has rehabilitated 750 small tanks and anicuts in four dry zone districts which has helped to increased the cropping intensity, productivity and farmers income, while diversifying farm level activities and increasing household water security (Aheeyar and Bandara, 2012).

The Irrigation Department has prepared several proposals for reservoirs to detain flood waters at strategic locations of selected rivers. Once implemented, some of these reservoirs will serve for hydropower generation and drinking water supply, in addition to flood control. National water supply and drainage board has proposed dedicated drinking water storage tanks for the wet zone – kelani, Attanugalu oya, kalu ganga and Maha oya, which are in progress. A coordinating committee has been appointed with the representatives of Ministry of Irrigation and Ministry of Water Supply and Drainage to negotiate the possibilities of abstracting water for drinking water needs from irrigation tanks without harming farming communities. The committee is holding meeting once in three months.

Rain-fed farmers and the village tank farming community in Sri Lanka are among the most vulnerable communities. These communities thereby deserve the priority attention of policy makers. The seepage and percolation “losses” from small tanks in Sri Lanka account for 20 percent of reservoir volume against 5 percent of reservoir volume in large dams. One of the flagship programmes implemented since 2004 was the Dahasak Maha Wew (Ten thousand tanks) Programme, aimed at effecting necessary repairs to 10,000 small reservoirs and diversion structures. The small reservoirs can act as percolation tanks, recharging aquifers and retarding runoff. Sustainable Water Management Project implemented by the Ministry of Agriculture, Lanka Rainwater

Harvesting Forum, World Vision and Practical Action and many other NGOs have been promoting runoff rainwater harvesting ponds in the rainfed areas in the past to cushion the water scarcity. Development of agro wells was identified as another adaptation strategy to face climate change in the marginal areas. Already large numbers of agro wells have been developed in Northern, North central and North western provinces under government subsidy programmes, NGOs assistance, donor projects and private investments. The government has proposed to rehabilitate around 4000 existing agro wells in Anuradhapura, Polonnaruwa, Kurunegala and Puttalam districts. Over extraction and pollution of groundwater due to intensive cultivation has been reported in many places mainly due to lack of groundwater management policy. The agro-well development has to be undertaken carefully not to exploit the shallow ground water table of the cascade system as it could leads to disastrous economic and environmental consequences. Unlimited pumping of water for industrial purposes by private companies is reported and warrant immediate interventions.

The greatest threat facing existing reservoirs, both large and small, is sedimentation. Therefore, the government has planned to de-silt and rehabilitate 1278 small, medium and large tanks and anicuts starting from 2012 with the estimated budget of Rs 3665 million. Several watershed management project and micro catchment conservation projects were implemented in the past to minimize soil erosion and conserve water. Upper Mahaweli Watershed Management Project, Upper Watershed Management Project, Forestry Land Use Mapping Project and Forestry Master Plan are some of the past projects. Hadabima Authority of Sri Lanka is implementing soil conservation in the up country areas through subsidies and incentives. The authority has implanted soil conservation activities in around 9000 acres during the period of 2009-2012 among 9500 families. The effectiveness of the programme is yet to be known.

Cultivation in hilly areas should be conducted in line with the land use policy of the country since, sloppy land cultivation leads to serious environmental damages. It has been observed that most downstream tanks and reservoirs have already been silted due to man-made soil erosion and it has created problems for irrigated agricultural production and generation of hydropower.

There are land for forest reserves, perennial crops, pastures and annual crops. Steep slope lands are prohibited to cultivate erosive crops. Special attentions have to be paid in cultivation of annual crops in sloppy land, which causes high level of soil erosion, pollution of water resources, sedimentation of reservoirs and eutrophication. Therefore adoption of land use policy is vital for the sustainable development of the country. For a successful adaptation plan, it is necessary to design a comprehensive policy package to enhance the production while maintaining a sustainable land use pattern in the hilly region.

Further, the necessary regulations for aforestation should be enforced for privatised plantation companies, which help reduce the soil erosion and improve the water retaining capacity of the downstream reservoirs. The environmental laws relevant to soil erosion should be strictly enforced by initiating new measures and designing new assistance schemes even for the plantation sector as a measure of polluter gains.

Promotion of advanced irrigation technology is another important adaption strategy to minimize the climate change impacts on water resources. The Government of Sri Lanka and number of NGOs promoted micro irrigation technology through various subsidy programme to increase the water use efficiency at farm level. Numbers of private companies also have been involved in the micro irrigation business in the country. The Ministry of Agriculture has distributed 10,000 solar powered drip irrigation systems for the farmers in the dry and intermediate zones since 2004. However the level of utilization of these systems is very low due to various reasons including poor targeting, lack of after sales services and weaknesses in approach adopted (Aheeyar et al, 2012). There is a vital need to integrate these interventions with climate change adaptations through proper awareness of beneficiary community.

Dam Safety and Water Resources Planning Project (DSWRPP) is currently being implemented which is highly relevant climate change adaptation. The project is aimed improve the safety of dams and their operational efficiency, improvements to the hydro-meteorological information system and multi-sectoral water resources planning to support the government for both develop plans to allocate water resources and guide public investment decisions on new water development projects. The project is in the process of assessing water resources of all river basins which includes current levels of use, balance available and further development possibilities.

Managing the competing demands for water from various sectors will become more crucial in conditions of water scarcity and drought. Different interests of water-use follow their own set of management principles, rules and incentives that are often in conflict with one another. Cross-sectoral, integrated and system-wide approaches to climate change adaptation must be developed, with water management to recognize as central to any development plans. IWRM concept plays key role in sustainable and equitable management of water resources.

It is clear from literature and current levels of available knowledge; the water sector has been the most sensitive to both climatic and non-climatic factors. Water management needs to be realigned to deal with climate variability. Growing population, growing cities, increasing food shortage, etc. can lead to more pressure on water resources. On top of that, climate change will exacerbate these impacts. Whatever actions are taken now to improve water management, will definitely have an important role to play in minimizing the impacts of climate change on water resources.

Adaptation measures for water sector can be categorized into five ways (Eugene Stakhiv and Bruce Stewart, 2009);

i) Planning and applying new investments, and capacity expansion (reservoirs, irrigation systems, levees, water supply, wastewater treatment, ecosystem restoration)
ii) Adjusting operation practices, monitoring and regulation of existing systems to accommodate new uses or conditions
iii) Maintenance and improvement of existing systems (e.g. dams, barrages, irrigation systems, canals, pumps, rivers, wetlands, etc.)
iv) Modifications in processes and demands (rainwater harvesting, water conservation, pricing, regulation, legislation, basin planning, payments for ecosystem services, stakeholder participation, consumer education and awareness) for existing systems and water users
v) Introducing new efficient technologies (desalination, biotechnology, drip irrigation, wastewater reuse, recycling, solar panels)

4.3 Mitigation of Food Security Related Socio Economic Impacts

Climate change will undoubtedly compound existing food insecurity and vulnerability patterns in these countries. ADBI, (2009) mentioned that Asia Pacific region is more vulnerable to climate change due to its exposure to the forces of nature, weak institutions and the poverty of considerable fraction of farming households. In Sri Lanka, agricultural households account for about 40% of the poor. Vulnerability of agricultural community to climate change will be influenced by number of socio economic factors, including status of poverty, insecure land land tenure, amount of resource endowed education levels, institutional supporting framework and government policies. Small-scale farming systems, both rainfed and minor tank irrigated are particularly vulnerable to climate change. As most of the farming community is not in control of sufficient land to produce a marketable surplus, climate effects further reduce agricultural production. According to the IWMI, (2010) the farming districts Nuwara-Eliya, Ratnapura, Anuradhapura, Badulla, Matale and Polonnaruwa are more sensitive to climate change than the rest of the country due to existing soil erosion (up to 60 percent of the land area in Nuwra-Eliya district is affected) and heavy reliance on primary agriculture. Coupled with their low infrastructural and socioeconomic assets and high level of exposure to flooding hazards (some of the highest rainfalls in Sri Lanka have been experienced in the last two decades in these districts), these areas are the most vulnerable to adverse impacts of climate change. As the regular pattern has changed, the climatic changes cannot be predicted. In the past the variation of the dry and wet season could be easily predicted and according to it the agricultural practices were carried out. Due to the unbalanced climatic variations the agriculture pattern and its dependent life has become more difficult.

Communities must prepare themselves for the possibility of food shortages and make appropriate use of resources to protect their livelihoods as well as lives and property. As many people engage in environment related livelihoods are losing the jobs it needs creation of green jobs in the future. Actions are needed for already identified problems and communities must be made aware to prepare themselves for the possibility of food shortages and make appropriate use of resources to protect their lives, livelihoods as well as property.

As Ministry of Environment (2010b) highlighted, there is lack of clear understanding of the scale of socio-economic impacts and the probable scenarios on entire value chains of agricultural products. There are no concrete plans to address the food security related socio economic issue. Climate insurance can provide a temporary buffer for business and households against unexpected climate costs, which can be substantial. Capacity building, provision of new technologies and relief and subsidies plays key role in addressing these issues.

4.4 Increasing Awareness and Mobilizing Communities for Climate Change Adaptation

Recent research findings on climate changes based on beneficiary perceptions show that majority of the farmers and local communities are experiencing increased rainfall, shift in the monsoonal seasons, increase of day and night temperature, decrease of river flow, depletion of groundwater level, increased frequency of floods and increased incidence of landslides (Withanage et al, 2009; Niranjan et- al 2012; Aheeyar et-al, 2012). The above reports clearly indicates that the people who engage in natural resource related employment for a long period of time are very well aware of climate variations. However, the majority of the public are still unaware of the concept of global climate change and its possible causes and impacts. Although some respondents are aware of climate change to a minimum extent, most of them are unaware of the major reasons that lead to climate change. Majority of the people who are aware of climate change have identified deforestation as the major cause for climate variations and development activities. (Withanage et al, 2009).

In most instances it appears that there are no specific policies, legislations, regulations etc. for Education, Training & Public Awareness to create awareness on climate change and related issues. The past efforts have been decidedly patchy and is best described as a start-again, stop-again engagement of the problem. While some excellent work has been done by all sectors in addressing climate change, especially in, overall, practical action has been patchy and initiated without a proper action framework, without sufficient focus on results, very little management of process or process outcomes and very marginal ownership of effort with respect to the citizens of Sri Lanka. As a result,

climate action can be best described as a start-again, stop-again phenomenon where measurable results are few and unsustainable.

While the government sector and other stakeholders have done some excellent work in specific areas over the last few years, overall awareness of the issue, the amount, quality and accessibility to related information, the level to which the problem is being practically addressed and the level of inter-sector corporation in creating a climate aware society and climate neutral processes is relatively weak, especially with respect to how it is factored into development agendas and how mitigation and adaptation mechanisms are implemented to minimize or neutralize climate threat to the most vulnerable groups, their livelihoods, their lifestyles and their life-systems Banda, 2009). The government sector action, most primary stakeholders have conducted ad-hoc combination of training/education/Public Awareness programs as time, resources and funds permitted with mixed results. Building awareness among the civil society is an immediate requirement in Sri Lanka. Meantime those policy planners can learn from the local communities.

The existing extension network in crop, livestock and fishery sector have to play dominant role in creating awareness, transferring new technology and building capacity of the beneficiaries. There should be plan to strengthened the current extension network and building capacity of extension workers, Samurdhi development officers, Grama Niladhari and Agricultural Research and production Assistants (ARPA). It is necessary to overhaul the existing Farm School system by introducing new courses to match the today's needs. The necessary funds and other support should be given to the Department of Agriculture to strengthen the existing agricultural extension delivery systems. The present ARPA cadres should be given training at least in Diploma level to develop their knowledge and skills and also to create a status in the field level.

5. Scientific/Technological Innovations in Relation to Climate Change Adaptation

The level of technology development and utilization in Sri Lankan agriculture is strong in certain fields such as genetic improvement of crop species, particularly in rice and in pest and disease control. Scientific methods of crop protection and integrated pest management technologies have been made popular through the national extension system but levels of adaptation is relatively low.

Also, Sri Lanka is widely known for development and operation of very sophisticated irrigation technology based on water harvesting in reservoirs constructed for it and use of river diversion. However, further development of technologies to achieve improved efficiency in the management of water harvested and stored for food production is an urgent need.

Walawe left bank extension project used several new constructions and management strategies to increase the water distribution efficiency including heightening of the banks of the canals, repairing and replacing of various irrigation structures (gates, valves, and measuring devices) and development of new drainage canals. Numbers of delivery channels were lined by concrete to reduce the conveyance losses. The project rehabilitated 22 existing high tanks and constructed 12 new low tanks and connected to the irrigation network and inter-connected by the Branch Canals of the Walawe Left Bank Main Canal. This system facilitates the re-use of the return flow from one tank to the other using the undulating nature of the land. This is a method of use of irrigation water more efficiently and economically. The project has introduced innovative 'dual canal system' considering the two different soil types in the upland and low land. One canal is designed exclusively for paddy and other one is for other field crops. The technique aimed at promotion of cultivation of other field crops by using water more efficiently. A new method of paddy cultivation called 'parachute' method was introduced, which requires lower amount of water and produce higher yield.

The innovative technologies are proposed to implement in the rehabilitation of irrigation schemes which includes rising of bunds with new innovative sluice designs and spills. Concrete lining of sub canal systems has been included in all new rehabilitation projects to reduce the conveyance losses. Solar powered drip irrigation technology is another innovative and environmental friendly technology introduced to the country, though the level of success is low. Walagambahuwa concept, conservation farming, sandwich crop cultivation, eyebrow bund and pitcher irrigation system are some other remarkable concepts and technologies found under the water retention techniques.

The Department of Agriculture is to promote third crop in a year from next season with the collaboration of Department of Irrigation in the selected schemes through maximum use of rainfall, limiting the land preparation period not to exceed 21 days and shifting of cultivation season. Third season cultivation is already pilot tested successfully in Hambantota district by cultivation of Green gram in mid season.

Several new interventions have been made to upgrade the existing meteorological information network to cater for emerging national requirements. A network of 31 Automatic Weather Stations (AWS) has been established. For further improvement to the observing network, the Department has installed 20 automatic rain gauges at selected remote locations vulnerable to landslides with real time data monitoring facilities at Colombo. Installation of Doppler Radar at Gongala, on the southern range of hill in year 2009/2011 is mainly for the real time monitoring of extreme weather events, such as heavy precipitation and their intensity, location of lightning, tornados etc. For fast dissemination of meteorological data/information, the National Meteorological Centre (NMC) of the Department has been linked to the GTS (Global Telecommunication System) network via internet. AWS have been linked to NMC via

Satellite communication. The network of 20 Automatic rain gauges has been connected to NMC through the network of Dialog GSM.

Department of Meteorology and the universities have formed a joint committee to find out the methodology to provide weather forecast in short term and medium term to be able to make decisions for farmers and other relevant people in their activities appropriately. However, the Centre for climate change studies established in Meteorology Department is not functioning well due lack of physical and human resources. The stakeholder technical coordination committee established in the department also not conducted meeting during last couple of years. There are large volume of data and information available with different departments without proper use for decision support system. For example as pointed out by Zubair (2002), despite advances in the capacity to predict the evolution of the El Niño–southern oscillation (ENSO) phenomenon and advances in understanding the influence of ENSO on rainfall in tropical regions such as Sri Lanka, there has been limited use of climate predictions for agricultural decision-making (Zubair, 2002).

Mobile Technology has been used to disseminate daily market price data collected by Hector Kobbekaduwa Agrarian Research and Training institute through Mobitel for farmers to make quick decisions. The private firm called 'Tradenet' is also providing Daily vegetable wholesale prices at Dambulla market via Dialog GSM.

UNDP, with the support of Climate Change Secretariat has developed a "one-stop-shop" web based data base (Sri Lanka climate change adaptation portal) which include the results of the stocktaking/scoping assessment exercise and include the list of key publications, research papers, case studies, Relevant Projects, Briefs, Policy papers, etc covering different sectors including Water and Agriculture sectors.

Overall, the current general situation of the Networking of climate change related Information in Sri Lanka is at a very nascent stage and even the existing limited networks are not utilized properly for the exchange of climate change related information. It is also observed that Sri Lanka does not have a specific policy for climate change related data management, sharing, access to information and networking. Individual institutions that maintain climate change related data, information and networks; share and access this information informally as there is no policy on information and data exchange. These individual databases are not open to outsiders as they are not networked. Information on climate change issues included in all websites in Sri Lanka is accessible through the internet and websites.

6. Community Empowerment and Awareness Creation on Climate Change Adaptation

Poor people in developing countries are particularly vulnerable, even though their contributions to the causes of climate change are negligible in comparison with the rich people. The poor will suffer the consequences to a much larger degree - partly because they depend more on natural resources for their means of livelihood and so are most affected by a deteriorating environment, because they often live in high-risk areas - for example, on steep slopes or low-lying riverbanks - and because they lack the resources to adapt to the changing conditions. The impact of climate change adds to the existing risks and uncertainties facing vulnerable groups and will interact with, and intensify the impact of other factors and threats such as disease, conflict and social marginalisation already facing them. Climate change has negative effects on peoples' lives through impacts on water resources, agriculture, the environment and human health. The important adaptation strategies for vulnerable communities are building their capacity to make them climate resilient and proving alternative livelihood opportunities. Building capacity of the vulnerable communities is a challenging task in the context of poverty, low level of education and marginalization.

It has been reported that women and female children face additional problems and suffer gender specific vulnerabilities (People Secretariat, on Climate Change, u.d). Women typically tend to undergo depravations and hardships in favor of giving a better quality of life to their children and put themselves at the risk of being afflicted with all kinds of preventable ailments. Their vulnerabilities and hardships increase several fold in times of calamity such as droughts and floods. Almost the entire responsibility of taking care of children and ensuring reasonable nutritional intake falls on the shoulders of women in the immediate aftermath of a disaster. Therefore it is prerequisite to implement programs to encourage women's participation and leadership in efforts to strengthen the social, economic and nutritional situation of those who have become victims of natural disasters. CCA programme should have strategies to enhance women's understanding of food security, food sovereignty and nutrition and thereby enhance their coping capacities while educating them about the possible threat of climate change and on practices and strategies to minimize impact and enhance capacity to respond quickly and effectively.

Community empowerment and awareness creation is a key in making climate sensitive society. While the government sector and other stakeholders have done some excellent work in specific areas over the last few years, overall awareness of the issue, the amount, quality and accessibility to related information, the level to which the problem is being practically addressed and the level of inter-sector corporation in creating a climate aware society and climate neutral processes is relatively weak, especially with respect to how it is factored into development agendas and how mitigation and adaptation mechanisms are implemented to minimize or neutralize climate threat to the most vulnerable groups, their livelihoods, their lifestyles and their life-systems.

Jayatilaka Banda (2009) has emphasized the importance of establishing active, continuous and sustainable participation of the general public in climate action. IPCC notes that, to date, 'social and cultural limits to adaptation are not well researched', acknowledging the scant attention within the climate change literature devoted to addressing social limitations thus far (IPCC, 2007: 737). Social barriers to adaptation are concerned with the social and cultural processes that govern how people react to climate variability and change, be they in the form of prolonged drought, heavier and uncertain rainfall, or rising temperatures. These issues are important to be addressed in order to overcome the various barriers and limits to adaptation, especially social barriers such as cognitive and normative restrictions and institutional inflexibilities. Effective and equitable adaptation only occurs if these restrictions are recognized, influenced and overcome. A concerted effort is needed to increase education and awareness in order to overcome social barriers, address institutional restrictions in behaviour and entitlement, and alter restrictive and maladaptive perceptions, norms and cultural constraints. Initiatives to foster adaptation will ultimately fail if they do not empower and inform individuals who remain confined in their adaptive behaviour and have limited access to key resources. Many of the barriers and restrictions at community level in promoting climate adaptations can be overcome by only through working at the community level and by appreciating, informing and supporting appropriate and logical autonomous actions at this level that restrictive and maladaptive elements within local institutions will, ultimately, be overcome.

The Centre for Climate Change Studies (CCCS) of the Department of Meteorology played a leading role in conducting research and public awareness programs on climate change and related issues. The scientific staff of the Department is capable of conducting climate change related education, training and public awareness programs for educating people at various levels, but the centre is not very active at the moment. There are number of civil society organizations (CSOs) and NGOs in educating and building capacities at grass root levels.

The Green Movement of Sri Lanka Inc. (GMSL), the foremost environment management and sustainable development civil group that comprises of 153 local CSOs and 78 international organizations, formed the "People's Secretariat on Climate Change" (PSCC) in 2008. The PSCC has a steering committee with the heads of other CSOs networks working several other areas and together they represent over 30,000 grass-roots and national level CSOs and is currently the largest and most empowered and institutionally strong network dedicated to addressing climate change. The mandate of the PSCC is to provide education, training & public awareness at all levels, provide technical input into appropriate technology for mitigating and adapting to climate change and engaging the government in policy debate.

Most of the arrangements that exist for public participation are those that are initiated by the civil sector.

While these arrangements are laudable, there is relatively little that such organizations can do to ensure national awareness of the issues at stake and obtain a mass vote for changing lifestyles and mindsets of the whole country (Banda, 2009). In most cases, planning and fund raising/allocation for education, training & public awareness has occurred as a knee-jerk reaction with various interested parties jumping on the "climate change band wagon" with the emphasis on "doing something because there are funds available to do it" rather than on a carefully thought out plan for achieving optimal impact of education, training & public awareness action. The civil society sector has concentrated its activities mostly on grass-roots level training and awareness programs but have additionally sort to incorporated indigenous knowledge into adaptation and mitigation activities through sharing of such knowledge at a relatively micro-level within selected and small communities vetted for climate vulnerability. Again, with CSOs, the problem of sustainability is very significant due to the relatively smaller fund bases and "project life cycle" mentalities.

The government sector have conducted ad-hoc combination of training/education/Public Awareness programs as time, resources and funds permitted with mixed results. Irrigation Department has started to appoint a new cadre called 'Training coordinator' at range level to conduct irrigation related awareness among farmers, school children and youth living under major and minor irrigation schemes managed by the Department of Irrigation.

Most of the funded rehabilitation projects have a component for farmer empowerment and institutional strengthening. For example, PEACE project has provided two day residential training for farmer leaders to develop their capacities in water and infrastructure management, enhance leadership qualities and organizational management. But the elements of climate change impacts are seldom addressed or integrated into these capacity development programmes.

Information generated through research and other activities of the academic sector have limited readership within the academic community and the very nature of such documents makes it resistive reading for other sectors – especially the general public.
Small-scale farming systems, both rain-fed and minor tank irrigated are particularly vulnerable to climate change. Communities must prepare themselves for the possibility of food shortages and make appropriate use of resources to protect their livelihoods as well as lives and property. Therefore, there is an urgent need to target these communities to build their capacities to make them ready to adopt climate change adaptation techniques as there are formidable informational, attitudinal, technological, economical barriers to implementation of adaptation measures.

Overarching all of these is the fact that there has been almost no systematic method of monitoring and evaluating the impact of such exercises with the result that there is no clear idea amongst any of the sector stakeholders as to the real results of their respective efforts. Although some high quality media features have aired in the public domain, overall, media efforts are mostly based on a reactive philosophy of engagement that targets events and emergencies rather than root causes and solutions (Banda, 2009). There is no known mechanism within the private sector of sharing information and knowledge in addressing climate threats with most organizations charting individual courses of action in this regard.

There are enormous traditional knowledge among the communities, which can be easily utilize to mange climate risks, and formulate appropriate community based adaptation strategies. For example, Salt effected soils is one of the problem encountered by coastal farmers in Hambantota District. Regional Rice Research Institute at Ambalantota had developed two salinity resistance rice varieties namely AT- 354 and AT-401 and released to farmers in 1992, but these varieties were poorly accepted by the farmers due to the low quality of rice according to past data. Therefore, Practical Action South Asia pilot tested several traditional varieties among ten selected farmers and find out the most suitable varieties for salinity through participatory process. FOs were provided capacity building training before dissemination of the technology. There is huge demand created in the area for these traditional salt tolerant varieties after the intervention as the introduction of traditional rice has given a new lease of life to abandoned paddy field. The experience indicates that, forgotten types of indigenous rice can offer a home grown solution to the increasing soil salinity and many other environmental problems. There are around 2,000 traditional rice varieties in Sri Lanka. Many are very high in nutritional value and have medicinal properties, and most are resistant to extreme drought conditions, diseases and pests. These varieties were traditionally grown using natural inputs such as organic manure, and no chemical fertilisers or pesticides were used.

Strategies for adaptation need to focus on the needs of the people most affected by climate change impacts and aim to reduce the most significant hazards they face. Identifying communities' own priorities and needs, and valuing their knowledge alongside science-based knowledge is key to development of sound adaptation strategies. Sharing experiences, obstacles and positive initiatives with other communities and development policy-makers must be an integral part of national adaptation strategies. The primary role of governments and international processes is in developing and implementing policy that is enabling for local-level action. To ensure a positive impact on the most vulnerable communities, climate change adaptation should support the development of community based systems of adaptation based on sustainable livelihood options and sound management of ecosystems through

strengthening capacities, skills and institutions to react and adapt to climate generated changes.

Tennakoon (1986) have described number of traditional wisdom and knowledge farmers had in climate forecasting. The main clues to predict a drought in the offing were; blowing of weak wind with constant change in direction, appearance of sky, sunshine and heat, misty and cold weather during the few hours before sunrise and unusual behaviours of animals and plants. early nesting of *weaver birds* (Carpenter birds) in September, High frequency of blck crow nests with multiple eggs in September, the appearance of Swallows (*Vehi Lihiniya*) flying very low in September or early October, excessive flowering and fruiting in Mi (*Marsa perrottetiana)* in August – September are convincing indicator of heavy rain during the *maha* season. Conversely detection of bee hives more frequently sited in old ant hills than in upright hollow trunks, the flowering of *'Tala'* (*Corypha umbraculifera)* , excessive bearing of *wood apple, Katu keliya, Eraminiya, Damba* and *mora* during August- September are uncomfortable signs of nature's hints in advance of a drought in the making. Traditional communities have made several adjustments during the signs of rainfall failure such as mixed planting/sowing in *chena* cultivation, sowing *chena* before irrigated paddy cultivation, short duration paddy cultivation, staggered cultivation and *bethma* cultivation. Therefore, it is vital important to learn from traditional knowledge and practices, which would help to mobilize community for CCA and formulate strategies considering social and cultural barriers.

Therefore, overall, it can be concluded that, the capacity building exercise conducted in the past have had little impact in creating the critical mass required amongst sectors and citizens to change their lifestyles and systems of life to make a real contribution towards climate control. The adaptation must focus on the needs of the people most affected by climate change impacts and aim to secure their livelihoods and reduce the most significant hazards they face. Identifying communities' own priorities and needs, and valuing their knowledge alongside science-based knowledge is key to development of sound adaptation strategies. The primary role of governments is in developing policies that are enabling for local-level action. However, important adaptation activities, such as management of increasingly scarce water resources, will require coordination and investment at the national and intergovernmental levels.

7. Issues of Water Pollution on Climate Change Adaptation

Water pollution problems in Sri Lanka are rapidly increasing with growth of cities & population, industrial expansion, regional development, increased use of pesticides and fertilizer and deforestation. Water pollution is mainly created by nutrients through sewage, pesticides, fertilizers, sediments from cleared lands & toxic metals from industry.

Pollution causes three main problems to water bodies

1. Excess biodegradable matter and nutrient
2. Accumulation of heavy metals in water
3. Build up of pesticides concentrations exceeding safe levels

There are two major causes of water pollution, namely, (i) point sources of pollution and (ii) diffuse sources of pollution. Point sources of pollution include industrial effluents and domestic sewage. The point sources are easily identified and controlled by corrective measures. Especially controlling industrial pollution is easier and cost effective. However, second type of pollution (diffuse sources) is scattered over a wider area of land & controlling is complicated within the existing institutional and legal framework. Water pollution due to agricultural activities is also type of diffuse pollution.

According to the current rate of fertilizer use, Sri Lanka is the highest fertilizer consumer in the SAARC region, but it is considerably lower compared to developed countries. Farmers in Sri Lanka apply two to eight times more fertilizer than other countries in the region (NARESA, 1991). According to Anon (2000), the high figure in Sri Lanka, partly reflects excessive & inefficient fertilizer consumption. A recent study by Dharmakeerthi (2010) conducted in Matale district shows that farmers apply fertilizers more than recommended levels. He further specifies that the level of overuse of Urea is very high compared to TSP and MOP. About 55% of cash crop growers have over used fertilizers and 48.5 percent chance to over use fertilizer when imported hybrids are cultivated.

Intensive agricultural activities in some parts of the country also cause heavy damages to surface and ground water resources. This kind of intensive agriculture is very prominent in Jaffna and Kalpitiya peninsula and the Nuwar-eliya district. Table 3 indicates level of fertilizer use in up country vegetable farming. Although the data source is little older, the findings indicate the attitudes of farmers, even during periods of the absence of fertilizer subsidy.

The frequent application of highly hazardous pesticides in high concentrations was often irrational and posed serious health and financial risks to the farmers and environmental devastation. Sales promotion activities and credit facilities had contributed to this excessive pesticide use. This problem was not counteracted by an agricultural extension service (Van der Hoek W, Konradsen F, Athukorala K, Wanigadewa T., 1998). Another research conducted on the intensive cultivating farmers in the hill country shows that, about 45% of farmers prefer to use more pesticides than the recommended amount and higher frequencies to ensure better results in crop productivity (Watawala *et al*, 2010). The same report further indicates that the farmers have limited knowledge about adverse effects of the pesticides they used. Chandrasekara *et al* (1985) found similar results from Matale, Nuwara-eliya, Badulla

and Kandy Districts. According to the findings for 20 years, 59% of the farmers had used more than recommended amount of pesticides in their vegetable cultivations. According to Jayakkody 2009 (quoted form Lanka Newspapers.com)) the majority of pesticide users (70 percent) had used more than the stipulated dosage and a majority (82 percent) had symptoms of extreme toxicity following spraying.

Run-off of pesticides flowing in to water bodies have the potential to significantly impact aquatic organisms by inhibiting growth and causing weaknesses in reproduction failure. Pesticides can also leach into groundwater causing additional human health concerns in drinking water from contaminated wells.

Water quality analyses conducted in many irrigation reservoirs have shown high nutrient levels including Mahaweli system H and reservoirs in Anuradhapura & Polonnaruwa districts (Piyasiri, 2001). There is a risk that phosphate levels in Nuwara Wewa and to a lesser extent in Thisa Wewa (both in Anuradhapura) are reaching levels which may be high enough to cause severe eutrophication (CEA 1994). Similar studies on for the surface waters in Mahaweli System H have found that the high concentrations of nutrients in the water between Kalawewa and Rajangana indicate high agricultural/agrochemical inputs (Azmy, de Alwis, and Dassanayaka 1993). The heavy metal contents in Parkarama Samudra indicated very high levels of Zn, Cu and Cr compared to temperate lakes of Neusidlersee and Lake Constance which are situated close to industrial centers (Piyasiri, 2002).

The review indicates that of indiscriminate use of fertilizers and agro chemicals by farmers in Sri Lanka is a matter for concern. Soil fertility maps available in the country have been prepared in 1963 and considerable changes in the agricultural sector and field levels had occurred afterwards. Therefore, the government should allocate sufficient resources to undertake a coordinated national programme to prepare soil fertility maps for different cropping systems. Soil test based fertilizer recommendation programme started by the Department of Agriculture in 1993 malfunctioned since 1999 due lack of fund allocation form the Treasury. However TRI has developed soil test based fertilizer recommendation for each series of soils using allocations received from cess fund, where clients have to pay 75% of the soil testing cost.

Some of the issues and problems arising out of indiscriminate use of pesticides are development of resistance in the causative organism of pest and diseases, pest resurgence, health hazards, environmental pollution and lower profits to farmers. Therefore promoting and adopting integrated nutrient management programmes instead of following blanket recommendations of fertilizer, conducting of farmer awareness programmes on proper handling and on hazardous impacts of pesticides, strengthening of the extension system, promoting integrated pest management practices and increase use of organic fertilizers, allocating sufficient resources to

conduct routine field testing of fertilizers to ensure the quality of imported materials, to minimize the negative impacts of overuse of chemical fertilizers and pesticides are recommended.

8. Internalizing Climate Change Adaptation in the Development Agenda of Water Institution

Climate resilient investments are essential to enhance livelihood opportunities and promote sustainable economic growth. At present, major developmental activities are made in climate sensitive regions highly exposed to droughts, floods and cyclones without giving due considerations to climate change. Apart from a few stand alone structural and non-structural practices, current climate risks have not yet been systematically integrated into the design of new projects in agriculture and water sectors. The water sector development agencies have to play a dominant role in formulating polices and making sustainable adaptation strategies which is at early stage or not part of the agenda of most of these organizations.

Climate change is a complex cross cutting issue which has the ability to generate different types and levels of impacts over various sectors. There are common as well as sector specific issues. However all these national, provincial and sectoral issues should be integrated into broad national agenda in a meaningful manner in order to make necessary linkages and coordination in an effective manner.

As Jayathilaka Banda (2009) indicated, mainstreaming climate change issue is further compounded by the fact that there has been almost no inter-sector coordination of activities or much attention given to monitoring and evaluation of individual and collective action to determine their efficacy. Lack of overall policy, lack of proper planning, lack of funds and other resources, and, lack of political will on the part of all stakeholders to work together towards common goals can be cited as reasons for this situation and this state of affairs has resulted in duplication of efforts, gaps in CCA activities, lack of coherence, lack of high impact results and gross inefficiency.

Internalizing adaptation refers to the incorporation of initiatives, measures, strategies to reduce vulnerability to climate change into other existing policies, programs, resource management structures, and other livelihood enhancement activities, so that adaptation to climate change becomes part of these programs. As a policy instrument, mainstreaming can be a more effective and efficient use of institutional and financial resources than designing and managing two separate climate policies. It also reduces the chances of mal-adaptation (ADBI, 2009).

The main barriers in internalizing climate change adaptation in the region are (*ibid);*

1) Limited understanding of the nature and extent of risks and vulnerabilities, or lack of credible climate information
2) Available climate information is often not directly relevant for development related decisions
3) Lack of information on the economics of good adaptation measures, or simply an absence of knowledge on available 'no regret' strategies
4) Trade-off between climate and development objectives exists
5) Lack of available funds or restricted access to finance
6) Segmentation within governments, no strong supportive policies, standards, regulations, etc.
7) Differences in willingness to accept uncertainties
8) Funding modalities are not well established.
9) Difficult for adaptation efforts to attract resources compared to more visible activities such as emergency response, disaster recovery and reconstruction

9. Importance of Capacity Building on Climate Change Adaptation of Water Sector Institutions

The impacts on climate change on water and agriculture sectors will be very high and crucial for the sustainable development. Therefore, water and food sector organizations have to take a leading and active role and be prepared them to address climate change related issues. There should be plan, resources, capacity and agenda to mainstream the climate change adaptation activities in the corporate plans of the water sector organizations. However, the capacity development programmes for these organizations are seemed to be weak and without much focus.

There are training programs conducted regularly by Irrigation Department for In-service officers who are involved in irrigation, water and flood management. Diploma in Irrigation Engineering, Farmer awareness training programs, seasonal training on water management and planning sessions of *Yala* and *Maha* cultivation are some of them. However, capacity building programs specifically designed on climate change are not available at the moment. The existing programs have addressed the influence of climate change in the Irrigation sector.

At the University level almost all Universities have included various aspects of climate change in to the university education. At the undergraduate level climate change has been included as a subject in the field of climatology & forestry and at the postgraduate level environment, forestry, oceanography and climate change have been included as special subjects. In the Faculty of Law, environment related issues (including climate) are addressed under Environmental Law too. Post Graduate Institute of Agriculture is conducting Masters and PhD level courses on IWRM, which is one of the popular courses among water sector professionals.

The Universities of Moratuwa, Sri Jayawardhanapura, Kelaniya and Sabaragamuwa etc. are regularly involved in creating awareness on climate change among University students and the general public in various ways. The Department of Forestry and Environmental Science of the University of Sri Jayawardhanapura is holding "International Forestry and Environment Symposium" annually since 2005 to stage a forum for researches, professionals, policy makers and industry to network and share their research findings and experience. The Sabaragamuwa University of Sri Lanka also conducts similar national symposiums on "Natural Resource Management" annually for various categories of people.

Climate Change Enabling Activity Phase I & II was launched by Ministry of Environment in 1999/2001 and 2002/2004 respectively for enhancing the capacity of stakeholder institutions in assessing vulnerability and developing adaptation & mitigation options. The direct benefits of these projects for water sector institutions are very low.

Senaratne *et.al*, (2009) have identified following information needs/ gaps in food and water sector in introducing adaptation strategies successfully;

- Information on availability and accessibility of water in different agro-ecological zones
- Information on impacts of climate change on availability and accessibility of safe water for human consumption
- Quantitative information on sea level rise and its impact on coastal zone
- Detailed analysis of available hydro-meteorological data
- Information on vulnerability of different crops and livestock varieties
- Information on appropriate agro-technology and management techniques for adaptation
- Land resource availability for agriculture and other allied activities
- Data on stock of fish and sustainable yield
- Information on impacts on fish stocks due to changes in relevant climate parameters.

Therefore, there is a need to address these issues by building capacities of the relevant intuitions enabling them to plant, internalize and implement successful adaptation strategies.

10. Summary of Priority Issues and Challenges for Water and Food Security

I. Changes in spatial and temporal pattern of rainfall, increase of air temperature, enhanced CO_2 levels, soil degradation, soil salinity by salt water intrusion due to sea level rise and over extraction of groundwater in coastal aquifers, emergence of new pests and diseases and pollution of water resources due to intensive agriculture are major factors affecting crop production induced by climate change. It has been recognized that current production methods and crop

varieties are inadequate for meeting growing demands for food and challenges from climate change. Research institutes in the country are conducting research on rice, field crops, horticultural crops, and plantation crops and in the process of developing pest and diseases, drought, flood and salt resistant crop varieties. It was recognized the importance of conducting more research and development programmes to identify the biotic changes and appropriate measures to protect the crops. However there is a gap in the technology developed and the diffusion/adoption of new technologies. Measures are necessary to popularize the new varieties and ensure the supply of necessary seeds at required time and quantity. There is a need to maintain buffer stock of flood, drought and salinity resistant seed paddy varieties and short duration varieties and other suitable seed materials to respond to extreme weather events.

2. Most Sri Lankan crops, and particularly rice, are produced at the top end of the optimum temperature range for cultivation, meaning that the anticipated increases in temperature could have a profound effect on yields. The combine effects of temperature and relative humidity at the reproductive stage of rice plant plays major role in determining yield level and quality of rice. Therefore breeding programmes to identify cultivars that can withstand higher temperature and relative humidity during spikelet development stage is necessary adaptation strategy. Impacts of climate change on certain fruit species and plantation crops are many fold, though there are no systematic research to identify the issues effecting the productivity of perennial crops. judicious selection of suitable lands for new planting or replanting, use of drought and heat tolerant cultivars, soil and soil moisture conservation, soil improvement, intercropping, crop diversification, and establishment of rainwater harvesting ponds and management of shade trees are the most viable adaptation measures proposed for perennial crops. However, some of these adaptations impose extra costs to the growers, even though they do not involve new technologies, thus requiring some interventions from state.

3. It is expected that, the negative impacts of the temperature and scarcity of water would be less for wet zone paddies, other than increased flood levels and soil salinity in some areas. Therefore, there is high potential for developing paddy cultivation in wet zone areas. As already developed some salinity tolerant and flood resistant varieties are not popular among farmers due to inferior quality and low yield, development of appropriate varieties are required, probably breeding with traditional varieties. Development of problem soils such as salt affected soil and water logged soils is another area to be considered in the context of climate change. Introduction of suitable and adequate drainage system is one technique to develop problem soils.

4. Promotion of precision farming and crop diversification are challenging tasks in achieving improve land and water productivities. There are formidable informational, attitudinal, technological, and economical barriers in implementation of adaptation measures related to crop diversification. The government has made several strategies and pilot prtogrammes to increase land and water productivities. Yaya block demonstration programme implemented at pilot scale in major, minor, rain-fed conditions has shown promising results through bridging extension gaps and ensuring optimum input supply. The programme needs to be upscale by allocating sufficient resources. The concept of third crop (Mid season) is successfully practiced in Hambantota district and planned to promote several other irrigated areas. More efforts are needed to change the attitudes of the farmers and address the marketing problem of non paddy crops. Granary Area Programme had planned to increase cropping intensity in selected high potential major irrigation areas, but this programme is yet to be implemented. A programme is planned to diversify the paddy lands by promoting cultivation of five selected other field crops (Cowpea, Blackgram, Greegram, Maize, Soybean) under irrigated conditions as a measure to increase cropping intensity, food security and efficient use of available water. Crop diversification is already practiced in Nagadeepa, Huruluwewa, Dewahuwa, Kirindi-oya and Muruthawela. Diversification to seasonal crops and perennial crops is another approach planned to adopt under irrigated condition to compete with prolonged water shortage

5. Green revolution technologies have enormously increased the both fertilizer consumption and irrigation requirement, but the rate of yield increase is much lower than rate of input requirement causing problems of soil salinity and pollution of water resources. Therefore there is need to promote organic farming, IPM and other appropriate traditional practices. Pollution of water resources is also caused by intensive agriculture, overuse of agro chemicals and fertilizers, and un limited tapping of groundwater. The government has totally banned the importation of agro-chemicals containing heavy metals considering the harmful effect caused by them to the environment. However, there is a possibility of adding heavy metals to the soil through low quality fertilizers. Currently there are no laws in the country to control excessive extraction of groundwater in some areas and under utilizsation of groundwater source in some high potential areas. Water Resources Board is planning to introduce some legal instruments to monitor, control and regulate groundwater extraction in the country, but there is a vital requirement of strengthening of groundwater institutions by providing necessary equipments, human resource and allocating sufficient financial resources.

6. Increasing trend of erosive rain and intensive agriculture, seasonal cultivation in sloppy lands have intensified soil erosion, soil degradation and sedimentation of

reservoirs. Several watershed management projects, reforestation and aforestation were conducted in the past. However, land utilization at farm level in a sustainable way warrants more focused attention to reduce the vulnerability. There are broader crop recommendations based on agro ecological zone which is needed to be fine tune at least GN division level. Current soil conservation Act is not fully implemented at ground level. NRMC is working on the methodology and guideline to implement the Act. The NRMC needed sufficient human and financial resources to intensify the activities. There are several organizations and projects to curtail soil erosion, the works must be implemented in a coordinated manner. Database must be developed using remote sensing GIS techniques for watershed management and identification of degraded lands to introduce protective measures.

7. Rise in oceanic temperature, changes in precipitation pattern (drought and flood), sea level rise and extreme weather events would lead changes in distribution, growth and reproduction of fish stock, alteration of species composition, damages to fishing infrastructure and disturbance to fishing activities. These issues need more research and introduce suitable adaptation strategies.

8. Efficient and improved system of weather forecasting is very important and need special focus. Some efforts have been taken to improve the existing meteorological networks and forecasting technologies. Technologies have been used to modernize the metrological systems and data processing and dissemination. But there is a long way to go in modernizing technology, digitizing data, net working, data sharing and making coordination. The level of use of climate predictions for agricultural decision making is limited.

9. A large number of institutions are mandated with management of water for public use and irrigation. Attempts to formulate a comprehensive water resources management policy have been failed. Climate change is a cross cutting issue for many authorities including environment, agriculture, water and irrigation, fisheries, meteorological, coastal, disaster mitigation and academics. The institutional coordination and policy reforms to incorporate adaptation action into development agenda is an inevitable need. Several sub sectoral policies have been developed, but integrated approach to the water resources management is not in place. Mainstreaming of climate change adaptation into developmental planning is still in early stages or nil. There were institutional arrangements informally such as CCCIM, but not functioning. Mahaweli water panel and coordinating committee of Irrigation Department and National Water Supply and Drainage Board are some other informal arrangements. Reforms are also needed to effectively utilize various water resources such as rainwater, surface water and groundwater conjunctively and to promote community based

watershed protection. Although many of the laws are strong, their implementation remains inadequate. There are no laws governing excessive water extraction by civil society or the private sector.

10. Rain-fed farmers and the village tank farming community in Sri Lanka are among the most vulnerable communities. These communities thereby deserve the priority attention of policy makers. The government has implemented inter basin and intra basin diversions of water to augment minor and major irrigation systems. Programmes are also have been initiated to de-silt and rehabilitate the irrigation schemes. New innovative sluice and spill designs are introduced. Mechanical flap gate has been invented which is non obstructive to water flow and easy to operate. Concrete lining of sub channel systems is recommended and incorporated in most of new rehabilitation projects. The major gap in the renovation and rehabilitation of small irrigation system is in sufficient attention provided in post project sustainable O&M. Rainwater harvesting ponds, development of agro-wells and micro irrigation technology have been promoted among rain-fed farmers to reduce the vulnerability at different levels of success.

11. Over 90% of livestock sector in the country are smallholdings and extensively managed. This type of management system is considered to be highly vulnerable to localized trends of climate change. For example climate change induced heat stress would negatively affect the reproductive functions of the livestock, but current levels of knowledge on the effects of global warming on animal health and reproduction are not updated. Therefore, more in-depth and integrated studies are proposed to fully elucidate the implication of global warming on livestock productivity, socio-economic effects and impacts on the nation and region as a whole. These issues needed to be mainstreamed in the relevant institutions with provision of essential resources.

12. River flows have altered in some of the major rivers due to both unsuitable human activities and climate change related factors. The reduction in available water has created increased competition for water between different water use-sectors. Cross-sectoral, integrated and system-wide approaches to climate change adaptation must be developed, with water management to recognize as central to any development plans. IWRM concept plays key role in sustainable and equitable management of water resources, though it is not well recognized. The government has been implementing and planned to implement number of projects to augment the existing reservoirs and construction new reservoirs to cater the increasing water demands form all water use sectors. Increasing storage capacity has been recognized as one of the important adaptation strategy to minimize the climate change impacts in water food sector.

13. A master plan for water resources is a vital requirement to develop and utilize available water resources in an optimum manner. Dam safety and water

resources planning project has involved in the assessment of water resources in all the river basins in order to assist allocation of water resources and guide public investment decisions on new water development projects. Water Resources board is planning to investigate the ground water resources of the country under a ten year project to identify groundwater potential and fluctuation of quality and quantity over the time. Conjunctive use of water is not properly introduced though agro-well programme was implemented in some areas. There are untapped high potential groundwater sources in the country.

14. Efficient management of available water and water infrastructure in irrigated agriculture, which is the largest water consumer, is a challenging task. Participatory irrigation management policy and irrigation management turnover made attempts in this regard through. Strict adherence to timely holding of seasonal meetings, pre-seasonal meetings and project management committee meeting, strengthening of FOs and other farmer institutions, adoption of system for water issues and allocation schedule, and introduction of a system for effective O&M are some of the management activities currently being implemented. There are some other techniques already adopted in some areas to increase land and water productivities, viz; introduction of short age varieties, use of rainfall at the onset of season for beginning of cultivation, rotational water issues, bethma cultivation, dividing the command are into 2-3 zones and issuing water to most difficult area first, and in the schemes where high and low level of sluices exist, providing the temporal priority of 1-2 weeks always to high level sluice. However, the existing gap in the resource mobilization for sustainable maintenance of irrigation infrastructure should be addressed. Line agencies are implementing training and awareness programmes to strengthen farmer institutions, changing attitudes of farmers and building capacities.

14. Vulnerability of agricultural community to climate change will be influenced by number of socio economic factors, including status of poverty, insecure land tenure, amount of resource endowed, education levels, institutional supporting framework and government policies. There is lack of clear understanding of the scale of socio-economic impacts and the probable scenarios on entire value chains of agricultural products. There are no concrete plans to address the food security related socio economic issue. Actions are needed for already identified problems and communities must be made aware to prepare themselves for the possibility of food shortages and make appropriate use of resources to protect their lives, livelihoods as well as property. Although, public are aware of climate variations, the majority of them are still unaware of the concept of global climate change and its possible causes and impacts. In most instances it appears that there are no specific policies, legislations, regulations etc. for Education, Training & Public Awareness to create awareness on climate change and related issues.

The past efforts have been decidedly patchy and is best described as a start-again, stop-again engagement of the problem.

15. Climate change is a complex cross cutting issue which has the ability to generate different types and levels of impacts over various sectors. There are common as well as sector specific issues. However all these national, provincial and sectoral issues should be integrated into broad national agenda in a meaningful manner in order to make necessary linkages and coordination in an effective manner. Although, various development and research activities under taken in water and food sector in the past are highly linked with CCA, the concept is not mainstreamed in most of the organizations. There should be plan, resources, capacity and agenda to mainstream the climate change adaptation activities in the corporate plans of the water sector organizations. However, the capacity development programmes for these organizations are seemed to be weak and without much focus.

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Annex 1

List of Key Persons Interviewed

Mrs. Abeygunasekara, Irrigation Management Division, Irrigation Department, Colombo 7

Dr. Ajantha De Silva, Regional Research Station, Department of Agriculture, Aralagamwila

Ms. Anoja Herath, Climate Change Secretariat, Ministry of Environment, Ethul Kotte.

Dr. R.M. Herath, Department of Agriculture, Peradeniya

Eng. K.A.U.S. Imbulana, GWP – SA, Colombo

Eng. Janaki Meegastenna, Irrigation Department, Colombo

Mr. K.H.M.S. Premalal, Department of Meteorology. Colombo

Dr. B.V.R. Punyawardane, NRMC, Department of Agriculture

Mr. Ranjith Ratnayake, Sri Lanka Water Partnership, Colombo

Ms. Upul Ratnayake, Rice Research and development Institute, Bathalagoda

Mr. R.M.W. Ratnayake, Ministry of Irrigation and Water Resources Management, Colombo

Mr. M.A. Roonage, NRMC, Department of Agriculture, Peradeniya

Dr. W.M.W. Weerakoon, Field Crop Research Institute, Maha Illuppallama

Dr. Priyanta Weerasinghe, HORDI, Gannoruwa

Dr. M.A. Wijarathne, Tea Research Institute, Ratnapura

Mr. R.H. Wijesekara, Water Resources Board, Colombo 7

Eng. Prabath Witharana, Department of Agrarian Development, Colombo