Action Impact Matrix and Water Resources in view of Climate Change in Sri Lanka.

Ever since the relation between the Green House Gas and Climate Change were established in the 1980s, the Intergovernmental Panel on Climate Change has been assisting the world community to cope with changes through strategies for mitigation and adaptation. While Climate Change scientists were working on this program, water professionals around the world have been developing appropriate management systems to cope with changing weather patterns resulting from both natural weather variability and Climate Change and the consequent water excesses and deficiencies. In certain regions, other natural and man-made phenomena have further complicated the impacts of Climate Change. Global warming will lead to modification in the hydrological cycle through increases in surface temperature and evaporation rate, and in some regions, increases in precipitation. Changes in the total amount of precipitation, its frequency and intensity directly affect the magnitude, timing of run-off and the intensity of floods and droughts. Such changes will have significant impacts on water resources. Another pointing example is the Asian Brown Cloud observed in the Asian regions which have impacts both on rainfall, temperature and solar radiation.

In this alarming context, there was an urgent need to better understand the relationship between Climate Change and sustainable development at the country-specific level. As part of this, a conference of Water Resources expert was organized by the United Nations University in collaboration with the National Water Secretariat of Sri Lanka to examine the impacts of Climate Change on development of water resources, to offer new insights and address perspectives to Climate Change and water, through some series of workshop.

I - Action Impact Matrix and Sustainable Development

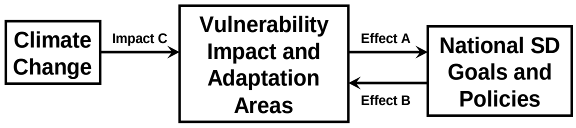
In order to identify the main linkages and prioritize the relations between Climate Change (CC) and national sustainable development (SD) goals and policies, in two areas – vulnerability, impacts and adaptation (VIA), and mitigation, and to explore possible remedial measures, the Action Impact Matrix tools was used through interactive sessions and workshops.

The AIM-based process facilitates early screening and problem identification -- by preparing a preliminary matrix that identifies broad relationships, and providing a qualitative data of the magnitudes of impacts. Thus, the preliminary AIM helps to prioritise key relations between policies and their impacts on sustainability. Yet, Action Impact Matrix (AIM) provides an integrated viewpoint, meshing development decisions with priority economic, environmental and social impacts. The organization of matrix facilitates the tracing of impacts, as well as coherent articulation of links among various development actions – i.e., policies and projects. Thus AIM-building process helps to harmonize views among economists, environmentalists thereby improving prospects for Climate Change successful implementation.

More specifically, AIM may be constructed to identify and analyze economic-environmental-social interactions that play a key role in the implementation of sustainable development goals. It can also be used with great advantage to identify and comprehend linkages between Climate Change and Sustainable Development (SD) at the country-specific level. It helps to determine the priority policies and strategies in economic, environmental and social spheres that will support Climate Change Adaptation and Mitigation efforts.

The Action Impact Matrix can be used to better understand interactions among three key elements, at the country-specific level:
(a) National development policies and goals;
(b) Key SD issues and indicators;
(c) and Climate Change and water resources.

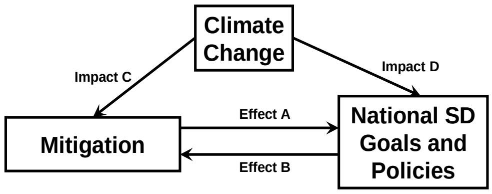
First, the two-way interaction between national development policies and goals with key Sustainable Development issues and indicators are explored. Then, additional impacts of elements on Climate Change and water resources on the above interactions are applied



AED-AIM = Impact C + Effect A
(Adaptation Effects on Development)

DEA-AIM = Impact C + Effect B
(Development Effects on Adaptation)

Action Impact Matrix (AIM) Types for analyzing SD-CC Adaptation Links



MED-AIM = Effect A + Impact D
(Mitigation Effects on Development)

DEM-AIM = Effect B + Impact C
(Development Effects on Mitigation)

Action Impact Matrix (AIM) Types for Analyzing SD-CC Mitigation Links

AED. Vulnerability, Impacts and Adaptation (VIA) – Adaptation effects on Development (AED)
DEA. Vulnerability, Impacts and Adaptation (VIA) – Development effects on Adaptation (DEA)
MED. Mitigation Options - Mitigation effects on Development (MED)
DEM. Mitigation Options - Development effects on Mitigation (DEM)

The first stage of the matrix involves the formulation of four matrices: Adaptation Effects on Development AED, Development Effects on Adaptation DEA, Mitigation Effects on Development MED and Development Effects on Mitigation DEM. Followed by an identification of the main national goals and policies relevant to Climate Change (both Vulnerability Impact and Adaptation, and mitigation options). Deciding on National Goals and Policies relevant to Climate Change are important to the case since each countries policy and goals will differ according the priorities set by the government.

Second, the main areas of vulnerability, impacts and adaptation (VIA) relating to Climate Change were decided – these VIA areas are common to the both AED and DEA matrices. These are specifically sectors in the economy that will be affected by Climate Change, in particular the agriculture, the hydropower, water resources and infrastructure. Similarly, the chief Climate Change mitigation options like the energy conservation and fuel substitution need to be established – they are common to the Mitigation Effects on Development and the Development effects on Mitigation.

II. Climate Change impacts in Sri Lanka

The three areas identified as being the most affected by Climate Change in Sri Lanka are Agriculture, the Ecosystems, Humans and Hydro electricity, and finally on nationality development policy.

A. Climate Change effects on water for agriculture

Hydrological research suggests that Climate Change will strongly influence various forms of water resources such as mean and extreme surface runoff, soil moisture and ground water levels, and changes in sea level and water quality (Dharmasena, 2004). These impacts have serious consequences on water resources planning and management associated with serious environmental and socio-economic consequences.

Increasing concentration of GHG's in the atmosphere cause rise in temperature, which in turn enhances potential and actual evapotranspiration. It is not certain how individual water catchments areas will respond to changing evaporation rates and precipitation. However, it is likely that current dry regions will be more sensitive to changes in climate. Relatively small changes in temperature and precipitation could cause relatively large changes in run-off. Arid and semi-arid regions will therefore be particularly sensitive to reduced rainfall and to increased evaporation.

a. Changes on the Rainfall

An increase in the duration of dry spells will not necessarily lead to an increased likelihood of low river flows and groundwater levels, since increases in precipitation may be experienced during other seasons. More probably, increased rainfall will lead to an increased likelihood of river flooding. Changes in seasonal patterns of rainfall may affect the regional distribution of both ground and surface water supplies. A study by Bandara and Wickramagamage (2004) found that annual rainfall at Nuwara Eliya and the western slopes of the highlands decreased significantly. On the western slopes, the decline was observed mainly during the Southwest monsoon period which accounts for a major portion of the rain in this area. This area receives the highest annual rainfall of the country, often exceeding 5000mm, and also contributes to the largest volume of water for hydro power generation and irrigation. There is also a clear indication of the expansion of the dry zone ad shrinking of the wetzone (Bandara and Wickramagamage, 2004).

Higher rainfall in the dry zone and higher temperatures in the highlands will increase production of rice and highland crops. However, rapid changes in climate are expected to have major implications for agriculture in Sri Lanka and around the World. CC leads to variations in spatial and seasonal distribution of rainfall. Higher intensity of rainfall during short spans of time leads to runoff. Long periods of drought will affect production. ABC reduces both inter-monsoonal rainfall and solar radiation, each of which will reduce crop yields. CC impacts complicates the ABC effect, making management of Yala and Maha seasonal cropping more difficult, and leading to lower production and growth.

b. Warmer Temperature:

Zubair *et al.* (2004) found that in Sri Lanka there is a warming trend of 2.6ºC/100 years for annual maximum temperatures and 1.7ºC/100 years for annual minimum temperatures from 1961-2000. These trends in temperature are found to vary both regionally and seasonally. The South and the East of the Island is found to be warming faster than the North and the West (Zubair et al., 2004). There has been a significant increase in temperature in the highlands, notably Nuwara Eliya, during the last 100 years (Bandara & Wickramagamage, 2004).

Crop growth is often limited by temperature. Moisture and water availability will be affected by a temperature increase, regardless of any change in rainfall. Higher temperatures increase the evaporation rate, thus reducing the level of moisture available for plant growth, although other climatic elements are involved. A very large decrease in moisture availability in the dryer regions would be of great concern to the subsistence farmers that farm these lands. Reduced moisture availability would only exacerbate the existing problems of infertile soils, soil erosion and poor crop yields. In the extreme case, a reduction in moisture could lead to desertification. The southwest monsoon, northeast monsoon and annual rainfall are projected to increase in the future (Basnayake & Vithanage, 2004). Lower rainfall increments on the leeward side of the central hills may lead to water scarcity problems due to population growth and increasing demand for water in the future (Basnayake & Vithanage, 2004).

c. Sea level

Sea levels have been projected to rise by anywhere up to a meter by 2100, although considerable uncertainty is attached to this. The greatest threat to low-lying agricultural regions from sea level rise is that of inundation and flooding. Furthermore, the pollution of surface and groundwater with salty seawater is another potential problem facing farmers situated in low-lying regions. The costs of agricultural production would increase, resulting in higher food prices for the consumer.

d. Asian Brown Cloud

Haze, a brownish layer of pollutants and particulates from increased use of fossil fuels, industrial emissions and biomass burning in South and South East Asia has resulted in the *Asian Brown Cloud (ABC).* The direct adverse effect of the Asian Brown Cloud is a reduction on solar radiation reaching the earth's surface, thus resulting in a decrease in agricultural productivity due to decreased photosynthesis. A study by Swain and Herath (2004) shows a reduction in rice grain yield by 2 to 4% due to a 30% reduction in solar radiation under non-fertilised conditions and a reduction in yield by 12% under fertilized conditions. The impact of solar radiation reduction on rice crops is greater under fertilised conditions than non-fertilised conditions. This increased aerosol radiative causes reductions in rainfall. Percentage reductions are much larger in seasons (such as the intermonsoonal period) and regions (such as the dry zone) with small amounts of rainfall (Herath et al, 2004). Asian Brown Cloud is also likely to decrease temperature particularly the day time temperature (Pathirana and Herath, 2004).

e. Carbon dioxide

Although Climate Changes may have some detrimental impacts on agricultural production, the increase in atmospheric Carbon dioxide concentrations could be beneficial. Plants grow as a result of photosynthesis - the mechanism whereby the plant converts carbon dioxide from the atmosphere into food. With higher levels of carbon dioxide stimulating the rate of photosynthesis, the growth rate and productivity of plants could be expected to increase.

B: Effects of Climate Change on water for Ecosystems

During the 20th century, the global climate has warmed by about 0.6°C, or about 0.06°C per decade. It is currently believed that most ecosystems can withstand at most a 0.1°C global temperature change per decade, before experiencing severe ecological stresses, leading in some cases to species extinction.

The composition and geographical distribution of unmanaged ecosystems will change as individual species respond to new conditions. At the same time, habitats will be degraded and fragmented by the combination of Climate Change, deforestation, desertification and other environmental pressures.

Many biological uncertainties exist in the understanding of ecosystem processes. Laboratory and field studies have demonstrated that climate plays a strong role in limiting species' ranges. Most monitored species that show significant trends have exhibited changes over the past few decades that are consistent with local warming and expected physiological responses. However, potential specific changes in wildlife resulting from Climate Change can be projected only with low confidence for most species because of many possible contributing factors, such as habitat destruction and exotic invasive species. Some species clearly are responding to global change and many more changes probably have gone undetected. Scientists also need to develop a better understanding of how all of the components of ecosystems work together. The role each species plays in ecosystem services, in wild and managed systems, is necessary to understand risks and possible surprises associated with species loss. Without this information, the probability of surprises associated with species loss is high (Gitay et al. 2001).

The most vulnerable ecosystems to global warming include forests, low-lying areas, mountain systems, wetlands, coastal marshes and coral reefs. Changes in other climatic elements in addition to temperature, such as rainfall, sunshine, cloud cover, and the frequency and intensity of extreme weather events, will influence these vulnerable ecosystems.

a. Forests and Woodlands

Changes in climatic conditions affect all productivity indicators of forests and their ability to supply goods and services to human economies. The effects on forested area and forest productivity, however, vary from location to location, with gains in some regions and losses in others. Higher temperatures lead to lowered photosynthetic rates associated with reduced stomatal conductance (Sellers et al., 1997). Drier conditions also result in increased fires, biomass and soil carbon losses (Wirth et al., 1999; Apps et al., 2000). Projected changes in forest area, structure, as a result of Climate Change vary by forest type and biome (Neilson et al., 1998). Climate Change also is likely to include changes in the length of the growing season, nutrient feedbacks (Tian et al., 1998), disturbance regimes (Kurz et al., 1995), and diurnal temperature patterns (Clark and Clark, 1999). Changes in precipitation may not have immediate effects on mature and old-growth forests, which have well-established root systems, but are likely to have pronounced effects on regeneration success for some species following disturbance, such as harvest or fire (Price et al., 1999a, b).

Observed ecological changes in high elevation plateau areas such as Horton Plains are beginning to reflect the effects of Climate Change (Bandara and Wickramagamage, 2004). Climate Change in the highlands will have significant economic as well as ecological implications in the future. The main land use types above 1525m elevation include natural forests, tea, scrublands, forest plantations and grasslands. Of these, natural forests and grasslands remained virtually unchanged, while the area under tea declined rapidly as these crops are significantly affected by dry spells (Bandara & Wickramagamage, 2004).

b. Lakes & Streams and Inland Wetlands

Specific vulnerable elements include increases in extinctions and invasions of exotics, and potential exacerbation of existing pollution problems such as eutrophication. Inland waters are affected hydrologically, physically, chemically, and biologically by Climate Change (Arnell et al., 1996, Cushing, 1997). One reason for their vulnerability is that lakes, rivers, and wetlands integrate and reflect human and natural events in their watersheds and air sheds (Naiman et al., 1995b). Global change impacts on wetlands would cause changes in many of the ecosystem services of wetlands. Especially vulnerable are functions that depend on a high degree of water availability. Services that involve artificial drainage might even benefit from climatic warming and additionally lowered water levels.

c. Coastal and Marine Ecosystems

Global Climate Change will affect the physical, biological, and biogeochemical characteristics of the oceans and coasts, modifying their ecological structure, their functions, and the goods and services they provide. Large-scale impacts of global warming will include increases in sea level and sea-surface temperature, changes in salinity, alkalinity, wave climate, and ocean circulation. Feedbacks to the climate system will occur through changes in ocean mixing, deep water production, and coastal upwelling. Collectively, these changes will have profound impacts on the status, sustainability, productivity, and biodiversity of the coastal zone and marine ecosystems. Scientists recently have recognized the persistence of multi-year climate-ocean regimes and shifts from one regime to another. Fluctuations in fish abundance increasingly are regarded as a biological response to medium-term climate-ocean variations, and not just as a result of over fishing and other anthropogenic factors. Global warming will confound the impact of natural variation and fishing activity and make management more complex. Marine aquaculture production has more than doubled since 1990 and is expected to continue its upward trend. However, aquaculture may be limited if key fish species used in feed production are negatively impacted by Climate Change. Increases in seawater temperature may directly impact aquaculture; such increases already have been associated with increases in diseases and algal blooms.

Coastal zones are among the world's most diverse and productive environments. With global warming and sea-level rise, many coastal systems will experience:

- Increased levels of inundation and storm flooding
- Accelerated coastal erosion
- Seawater intrusion into fresh groundwater
- Encroachment of tidal waters into estuaries and river systems
- Elevated sea-surface and ground temperatures.

The coastlines around Sri Lanka, particularly in areas that are already under stress from human activities, are highly susceptible to global warming impacts. A combination of accelerated sea-level rise and associated more energetic wave conditions will have severe impacts on coastal landforms, settlements, and infrastructure. Coastal areas also include complex ecosystems such as coral reefs, mangrove forests, and salt marshes. Many mangrove forests are under stress from excessive exploitation, and salt marshes are under stress from reclamation. Many coral reefs already are degraded. In such situations, ecosystem resilience will be greatly reduced through human impacts as well as rising sea levels, increasing sea temperatures, and other climate-ocean-related changes, including prevailing wave activity and storm waves and surges.

Ecosystems have evolved to cope with natural Climate Changes, and in some cases, the influences of mankind. It is doubtful, however, given today's globalized and ever increasingly energy and resource-consuming society that ecosystems will be able to respond to unprecedented climatic pressures as they have managed to in the past.

C. Climate Change effects on water for humans

Reduced water supplies would place additional stress on people, agriculture, and the environment. Global warming will exacerbate the stresses caused by pollution and by a growing populations and economy.

Water availability is an essential component of human welfare and productivity. Much of Sri Lanka's agriculture, hydroelectric power production, water needs and water pollution control are dependent upon the hydrological cycle, and the natural recharging of surface and groundwater resources. Changes in the natural water availability as a result of global warming would result in impacts which are generally most detrimental in regions already under existing climatic stresses.

Many areas around Sri Lanka (especially in rural areas) are still without adequate water treatment. In the case of drought, reduced water availability could force people to use polluted water sources in settlements at the same time that reduced flow rates reduce the rate of dilution of water contaminants. In the opposite case, flooding frequently damages water treatment works and floods wells, pit latrines and septic tanks, and agricultural and waste disposal areas and sometimes simply overwhelms treatment systems, contaminating water supplies (Scott and Gupta 2001).

Increases in average atmospheric temperature accelerate the rate of evaporation and demand for cooling water in human settlements, thereby increasing overall water demand, while simultaneously either increasing or decreasing water supplies (depending on whether precipitation increases or decreases and whether additional supply, if any, can be captured or simply runs off and is lost) (Wood et al.,1997).

Extreme rainfall in Sri Lanka caused by weather pattern associated with monsoons, depressions and cyclones has resulted in floods occurring in Sri Lanka. One of the worst flood disasters in recent times occurred in Ratnapura in May 2003, which also extended down to Galle, Matara, and Hambantota districts. The flood of December 1957 in the North Central Province caused extensive damage to irrigation systems and other infrastructure (Fernando and Wickramasuriya, 2004). Flooding causes contamination of all fresh water reserves, leaving the population devoid of access to clean water for drinking and washing resulting in many deaths and the spread of disease. A study by Sanker at al. (2004) found that there is a positive relationship between water related natural disasters and lower macro economic and human development levels (such as level of debt burden, income level, general human development level and female human development level).

D.Climate Change effects on water for hydro electricity

Sri Lanka's agriculture, hydroelectric power production, water needs and water pollution control is dependent upon the hydrological cycle, and the natural recharging of surface and groundwater resources. Changes in the natural water availability as a result of global warming would result in impacts which are generally most detrimental in regions already under existing climatic stresses

E. Effects of Climate Change on development and national goals

In order to maintain agricultural output to meet the demand farmers will have to adjust and adapt as and when necessary to the possible changes imposed by changing climate. Higher temperatures would increase the demand for irrigation of agricultural land. Increased spread of pests and disease may also place additional demands on the need for fertilizers, pesticides and herbicides which are costly. The ability to adapt to the effects of Climate Change will vary greatly between countries and regions. Economic and technological constraints will limit the rate of adaptability. Consequently, without intervention the effects of Climate Change in the 21^{st} century look set to further widen the gulf between developed and developing nations. The three areas of development most affected by Climate Change are: poverty, food security and employment.

a. Poverty Alleviation

In a predominantly small holder system, agriculture is the finest instrument for PA. Disturbance of rainfall patterns adversely affect the rainfed and Chena farmers, the poorest among the farming community. Loss of crops due to floods and droughts saps the farmers of the meager savings and leads them to abject poverty.

b. Food Security

Primary food security comes from locally grown foods such as rice. 70-80% of total rice production comes from major and minor irrigation schemes. Non staples such as yams and legumes are grown in rain fed highlands. Changing patterns of rainfall distribution negatively affects food security. ABC reduces both inter-monsoonal rainfall and solar radiation, each of which will reduce crop yields. CC impacts are compounded by the ABC effect, making management of Yala and Maha seasonal cropping more difficult, and leading to lower production and food security.

c. Employment

Although only approximately 30% of GDP comes from agriculture 75% of the countries employment is dependent on this sector. Agriculture creates purchasing power in the rural sector giving an impetus for employment generating ventures in urban and rural sectors. Droughts and floods leads to loss of employment for seasonal and migrant labour.

d. Growth

Any depletion the quality and quantity of water available to households will affect the productivity of poor. High incidence of disease & malnutrition can be a burden on the budget hence negatively affecting growth.

e. Poverty Alleviation

Water and poverty are closely linked. Excess in the form of floods and shortage in times of drought leads to contamination of water, which might induce sickness and malnutrition.

f. Ecosystems

Freshwater ecosystems, including lakes, streams and non-coastal wetlands will be influenced by changes to the hydrological cycle as a result of global warming. These influences will interact with other man-made changes in land use, waste disposal and water extraction. Water quality may also respond to changes in the amount and timing of precipitation.

Water for animals in wildlife parks helps to maintain a tourist attraction which brings substantial revenue. Scarcities will have a strong impact on growth.

Changes in surface water availability and run-off will influence the recharging of groundwater supplies and, in the longer term, aquifers. Low rainfall due to ABC, reduces recharge of ground aquifers (Pathirana and Herath, 2004). Minor irrigation tanks assume importance since they help to maintain the water table.

Rising seas could invade coastal freshwater supplies. Coastal aquifers may be damaged by saline intrusion as salty groundwater rises. Ecological resources such as wetlands, marshes, & lagoons, which serve as breeding grounds for aquatic fauna are affected both by water scarcity and salinity intrusion. Loss of wetlands will make land available for urban development.

Effects of Water Using Sectors on Development (WED-AIM) in Sri Lanka with CC Impacts

		Vulnerability, Impacts & Adaptation (VIA) in Water Using Sectors				
		(1)	(2)	(3)	(4)	
		Agriculture	Hydro Power	Water for Humans	Water for Bio- & Eco-logical Res.	Row Totals (With CC)
(S0)	**Status (No CC impacts)***	**-1**	**0**	**-1**	**-1**	
(S1)	**Status (+CC Impacts =>)****	**-2**	**-1**	**-3**	**-2**	
=> Dev. Goals/Policies (+CC Impacts)						
(A)	Growth	-3	-1	-2	-2	-8
(B)	Poverty alleviation	-2	-1	-3	-1	-7
(C)	Food Security	-3	-1	0	-1	-5
(D)	Employment	-2	0	-1	-1	-4
(E)	Trade & Globalisation	-1	-1	0	-1	-3
(F)	Budget Deficit Reduction	-1	-1	-1	-1	-4
(G)	Privatisation	0	0	0	-1	-1
Column Totals (With CC)		-12	-5	-5	-7	

Development effects on Water Using Sectors (DEW-AIM) in Sri Lanka with CC Impacts

		Vulnerability, Impacts & Adaptation (VIA) in Water Using Sectors				
		(1)	(2)	(3)	(4)	
		Agriculture	Hydro Power	Water for Humans (Esp. Poor)	Water for Bio- & Eco-logical Res.	Row Totals (With CC)
Dev. Goals/Policies (No CC Impacts) => **						
(A)	Growth	0	1	1	0	**2**
(B)	Poverty alleviation	0	-1	-1	0	**-2**
(C)	Food Security	-1	-1	-1	0	**-3**
(D)	Employment	1	0	0	1	**2**
(E)	Trade & Globalisation	1	1	0	-1	**1**
(F)	Budget Deficit Reduction	-1	-1	-1	-1	**-4**
(G)	Privatisation	-2	1	-2	-2	**-5**
	Column Totals (No CC)	**-2**	**0**	**-4**	**-3**	
(S1)	**Status (+CC Impacts =>)****	**-2**	**-1**	**-3**	**-2**	
	Column Totals (With CC)	**-4**	**-1**	**-7**	**-5**	

II- Development goals and policies recommendation

Development goals and policies to alleviate the effect of Climate Change were identified and discussed, and they mainly focus on the following areas: food security, budget deficit reduction, privatization, agriculture, water for human use, water for Ecological and Biological Resources

a. Food security

Effect of Food Security Policies on Water for Humans and Ecological Resources (Cell C3):

As there is a large amount of untapped water, the effect of increase in food security would not affect human consumption. But there is a risk from increased contamination by nitrates and other pollutants from increased fertilizer use.

- Implement pollution control measures in food production
- Provide food security needs from both local and imported foods, with higher emphasis on local production based on comparative advantage
- Develop appropriate water distribution policies at all levels taking into consideration water for drinking, hydro power, agriculture, water for ecosystems, industry etc.

b. Budget Deficit Reduction

Effect of Budget Deficit Reduction on Water for Humans and Ecological Resources (cells F3&F4)

Reduce funds for budget deficit reduction should be made based on a rational basis and keeping in mind the critical and vulnerability of the areas. Hence prioritization of investment into water is needed to ensure clean and safe water supplies

c. Privatization

Effect of Privatization on Water for Humans (Cell G3)

- Introduce sound regulations that safeguard the rights of the poor at all levels, as the private sector tends to utilize water supplies for higher value added uses in industry and commerce -- at the cost of agriculture and drinking water.
- Concept of Corporate Social Responsibility should be promoted in the private sector.

Effect of Privatisation on Water for Ecological and Biological Resources (Cell G4):

No gains should be envisaged as private firms do not invest in conservation

- Enforce Wetlands Policy in order to prevent damage done to water bodies, wetlands, marshes resulting from development
- Promote the Concept of Corporate Social Responsibility in the private sector

d. Agriculture

Effects of a decrease in Agricultural output on Growth (cell A1): increases in production in dry zone would offset the losses elsewhere.

Irregular weather patterns lead to excess or scarcities of water thus disturbing agricultural production and impeding growth. Hence the following short/ medium term interventions may be considered:

- Put more emphasis on research programmes that develop alternative rice strains and other crop that are resilient, high yielding and short term where appropriate that can cope with drought, water excess, high temperatures, and changes in solar radiation
- Promote technologies and cultivation practices (such as improved cropping systems, improved water conserving management systems, dryland farming, artificial recharge of water, and soil protection technologies etc.)
- Take measures to introduce appropriate watershed management including

  a) increasing ecologically appropriate vegetation
  b) prevention of run off
  c) prevention of soil erosion and siltation
  d) medium and micro level water harvesting systems
- Promote recycling and reuse of water
- Invest on multi purpose reservoirs and maintenance of structures
- Manipulate the subsidy programme to create incentives as well as disincentives (i.e. increase subsidy for mixed cropping reduce subsidy for ground water exploitation

Effects of a decrease in Agricultural output on Poverty alleviation (Cell B1)

- Evolve risk reduction measures for poor groups such as introduction of mixed cropping and agro forestry or crop insurance schemes
- Water allocation policies that improve access of poor groups to water for farming
- Reduce dependence on water/land sector and initiate projects and programs outside the sector preferably in the proximity of their habitats. Programs may include agro based industries as well as cottage industries
- Promote institutional mechanisms such as cooperative farming

Effects of a decrease in Agricultural output on Food Security (Cell C1): food imports can reduce the risks of food scarcity

- Priority for self sufficiency in food
- Improve storage processing and distribution
- In the event of a supply demand gap import the minimum foods required.

Effects of a decrease in Agricultural output on Employment (Cell D1)

- Increase employment employment in agricultural sector by improved farming practices such as transplanting and weeding.
- Promote non-farm employment in the services sector.

Effect of Water for Humans on Growth (A3): Impacts on growth would not be as severe as they are on poverty alleviation.

- Integrated water resources management
- Promote access and raise awareness about unexploited water supply sources such as rainwater harvesting and sustainable extraction of groundwater and watershed management

- Raise public awareness about water conservation, recycling and reuse.
- Promote investments in infrastructure for water development and distribution and maintenance of water resources
- Health sector to commence programmes for sanitation during times of water excess and scarcity, as well as strengthen to primarily health sanitation

e. Water for Human use

Effect of Water for Humans on Poverty Alleviation

- Integrated Water Resources Management
- Promote flood and drought early warning, prediction, forecasting and mitigation systems for urban & rural areas
- At the grass roots level, popularise technologies for water treatment and purification to ensure inexpensive and safe drinking water
- Protect water quality and resources (e.g. wells, streams, lakes etc.)
- Implement existing water quality standards and protect
- Encourage participatory management
- Raise awareness about water quality and conservation

f. Water for Ecological and Biological Resources

Effect of Water for Ecological and Biological Resources on Growth (A4):

The impact of water for ecological resources on growth could include a slight gain to growth as filling of wetlands will make land available for urban development like the case of *Muthurajawela Marsh.*

- Generate policy measures both at the centre and provinces to conserve and manage wetlands, marshes, lagoons and coastal ecosystems through regulation as well as awareness creation
- Implement existing laws and regulations (e.g. minimum stream flows etc.)

Conclusion

The way forward towards sustainable water resources management (SWARM) is by making existing development patterns more sustainable, based on balanced consideration of economic social and environmental elements. Maintaining and accumulating stocks of manufactured natural and social capital is vital for achieving sustainable water resources management.

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