Agriculture Adaptation Practices in South Asia

Case of Sri Lanka

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Summary

Coping with climate uncertainty is an eternal challenge faced by farmers all over the world. Farmers have thus far faced the challenge by making regular adjustments to moderate, cope with or take advantage of actual or expected climate variability. This process of adjustments is called adaptation. Sri Lanka is a developing nation with a significant poor population engaged in livelihoods relating to agriculture. Farmers in Sri Lanka have a long history of climate adaptation. This report examines key adaptive practices developed by them in the struggle for coping with climatic shocks. It begins with an overview of climatic conditions in Sri Lanka and their implications on farmers. There are two major climatic zones in Sri Lanka—wet zone and dry zone. The report focuses mainly on adaptation practices of dry zone farmers since dry zone is the major agricultural area in the country and they are more vulnerable to impacts of climate change. Three broad forms of adaptation measures are identified: long-term structural adaptations, medium-term strategic adaptations and short-term tactical adaptations. Out of them, this study examined three selected adaptation practices as case studies. They are: (a) rainwater harvesting in village tanks, (b) tapping shallow groundwater through agro-wells, and (c) adoption of climate resilient traditional varieties and agronomic practices. The study assessed the background and rationale of respective practices and identified their technical, economic and institutional/social potential. It also evaluated the challenges that may emerge under changing climatic patterns and socio-economic conditions. Finally, attention is directed to assess the lessons that can be learnt about the overall strategy, individual and joint actions and the roles of local institutions and indigenous knowledge in adaptation.

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1. Climate Change and Farmers

Climate is intrinsically uncertain and farmers all over the world have witnessed this fact long before present concerns about global climate change came into light. Coping with climatic shocks remains an eternal challenge faced by farmers. Rapid global scale 'changes' of climate due to anthropogenic reasons could only make this struggle more intense. Farmers are inherently adaptive and have made regular adjustments to the uncertainty created by climatic variability. Adjustments made to moderate, cope with or take advantage of actual or expected variability/change of climate are called adaptation (IPCC 2001 and 2007; Risbey et.al. 1999; Smit and Wandel 2006). Adaptation involves individual as well as group decisions and usually has a strong component of social learning (Adger et al. 2009; Pelling and High 2004; Tschakert and Dietrich 2010).

Climate adaptation is an evolutionary process. In this process, farmers have accumulated a wealth of experience and knowledge, which further helps them optimize their choices against climate shocks. Farmers' adaptation efforts have also helped to raise a significant share of livelihood assets of farmers. Such assets may include:

- Biological assets such as species/varieties that tolerate extreme climatic conditions
- Physical assets such as irrigation and rainwater harvesting facilities
- Knowledge assets such as drought/flood management techniques and water conservation methods.

These assets build the 'adaptive capacity' of farmers, enabling them to cope with climatic uncertainty in a more effective manner.

The threat of future uncertainties due to global climate change instigates new challenges to the ongoing struggle of farmers. According to some scholars, 'climate change' could significantly be different from 'climatic variability', known to and experienced by farmers due to potentially irreversible, catastrophic hazards. As a result, unforeseen effects of global climate change enter as an additional element of uncertainty in farmers' decisions on adaptation. Hence, adaptation to climate change is really a matter of how to enhance farmers' adaptive capacity to face the impacts that are beyond the impacts of familiar range of variability and the existing coping capacity.

Despite different levels of uncertainty that may involve in anthropogenic change and natural variability, farmers' decisions to adapt to them may share many common elements. Hence, there are compelling reasons to believe that the most potent source from which farmers can draw on when facing the threat of climate change is their own experience of centuries of adaptation. Firstly, it is logical to expect that learning from past successes/failures would naturally enhance their chances for adaptation to impacts of climate change. Secondly, experience gained from individual and collective decisions on adaptation gives rise to local knowledge systems that fulfil information needs of farmers (Materer et al. 2002; Mbilinyi et al. 2005; Orlove et al. 2009; Roncoli et al. 2002). Thirdly, many rural communities have created local institutions that deal with collective action and common ownership (Ostrom 1990; Agrawal 2001). Such local institutions still continue to play an influential role in governing actions of individuals as well as groups. Therefore, assessing the current and past experience of farmers can be considered as a logical first step towards enhancing their adaptive capacity against future threats of climate uncertainty (Cooper et al. 2008). This requires careful examination of existing practices and knowledge of farmers.

This report examines key adaptive practices developed by Sri Lankan farmers in their long struggle for coping with climatic shocks. Sri Lanka is a developing nation with a significant poor population. It is a tropical island located in South Asia where farmers experience disaster prone weather extremes frequently. A majority of poor living in rural areas is dependent on livelihoods relating to agriculture and fisheries. Being a small island with a significant poor agricultural population located in a disaster prone region, Sri Lanka is highly vulnerable country to impacts of climate change.

Historically, Sri Lanka has been an agricultural civilization that dates back to over two millennia. Due to extensive use of adaptive water resource management practices, it has widely been known as a 'hydraulic civilization'. A significant part of physical and knowledge assets developed over centuries still continues to support farmers' livelihoods, especially in dry zone areas of the country. Historically built irrigation and rain-water harvesting structures as well as recently adopted agro-wells provide examples for farmers' incessant struggle against climatic variability. Management of these facilities has given rise to local institutions that involve collective action and community management of resources. Moreover, generations of experience have helped farmers to accumulate a wealth of local knowledge that guide their decisions on adaptation practices even today. These have contributed to enhance the adaptive capacity of farmers, helping to minimize the risk and uncertainties associated with climate shocks.

1.1 Objectives

The key objectives of the study can be listed as follows.

1. Examine the nature of climate risks and uncertainties faced by Sri Lankan farmers
2. Review and identify key strategies adopted by farmers to face climate uncertainty
3. Make an in-depth assessment of few selected agricultural adaptation practices to understand their implications towards facing the impacts of climate change

4. Identify the prospects for leaning and sharing the experiences of Sri Lankan farmers with other vulnerable communities in South Asia

1.2 Organization of the report

The report is organized in the following order. In the next section, a review of climate in Sri Lanka and nature of climatic issues faced by farmers is presented. This is followed by an overview of adaptation measures practiced by Sri Lankan farmers. The next three sections provide an in-depth examination of three selected adaptation practices. In the final section, lessons that can be learnt from adaptation experience from Sri Lankan farmers and prospects for sharing their experiences with farmers in other South Asian countries are discussed briefly.

2. Climate and Agriculture in Sri Lanka

To make an objective assessment of Sri Lankan farmers' adaptation practices, it is necessary to have an idea about the nature of climatic uncertainties they face. Therefore, in this section, an overview of climatic conditions and its major implications on farmers in different areas of the country is presented. Being a tropical country, Sri Lanka does not have a profile of climate seasons based on distinct temperature regimes. Consequently, there is no significant variation of temperature from season to season in a given location due to the latitude. Only a slight variation of monthly average due to seasonal movement of the sun and due to rainfall can be observed (Abhayasinghe 2007; Chandrapala 2007). However, significant regional variation in temperature could be observed due to the altitude of a location. This has given rise to significant differences in temperature regimes in low country and upcountry areas[1]. Accordingly:

- In low-country areas average annual temperature varies between 26.5 – 28.5^{O} C (average. 27.5^{O} C)
- In up-country, temperature falls quickly as altitude increases (e.g. Nuwara Eliya – average 15.9^{O} C at 1800m MSL)

Variation in temperature regimes due to the altitude determines the type of agricultural activities in low country and upcountry regions to a certain extent. For instance, growing exotic vegetable species is feasible only in cool climatic conditions in the upcountry. It also fulfils the optimum day/night temperature conditions necessary for potato farming. Similarly, elevation regime of tea known as 'up-

[1] Low-country refers to areas below the elevation of 300 m MSL (<300). Usually areas above 300m MSL are known as up-country areas. However, a sub-category known as mid-country is sometimes identified in the range of 300-900m MSL. In that case, areas above 900m MSL(>900m) are considered as up-country.

country tea' also depends on cool climate conditions in central highlands. However, these practices are of relatively recent origin, dating back to late colonial era or post-colonial mid-twentieth century. They involve commercially driven farming activities that depend on high use of chemical inputs and modern farming technology. Hence, they cannot be considered as traditional farming systems in the country.

Generally, type and distribution of farming practices are more dominantly determined by the rainfall distribution pattern than the altitude. The precipitation pattern of the country is governed by monsoonal, convectional and depressional forces (Chandrapala 2007; Abhayasinghe 2007). Accordingly, Sri Lanka has four rainfall seasons:

1. First inter-monsoon season (FIM): March–April (Average annual rainfall - 268 mm; 14 percent)
2. Southwest monsoon season (SWM): May–September (Average annual rainfall - 556 mm; 30 percent)
3. Second inter-monsoon season (SIM): October-November (Average annual rainfall - 558 mm; 30 percent)
4. Northeast monsoon season (NEM): December-February (Average annual rainfall - 479 mm; 26 percent)

First inter-monsoon season (FIM): FIM is caused by convectional rainfall which becomes active when monsoon rainfall is absent. It brings rainfall to south-western quarter and to certain parts of the central highlands during the March-April period. Occasionally it produces mild tornadoes.

Southwest monsoon season (SWM): SWM is resulted by strong westerly or south-westerly wind streams (monsoons) that carry considerable amount of water vapour. It produces significantly high rainfall over south-western parts of the country including hilly areas. Highest rainfall is received in mid-elevation western slopes of central highlands and south-western coastal belt. Usual period of SWM is May-September.

Second inter-monsoon season (SIM): Like FIM, SIM also is based on convectional rainfall. During the SIM, influence of weather systems like depressions and cyclones in the Bay of Bengal becomes prominent. This could lead to the whole country experiencing strong winds and widespread rains, sometimes with floods and landslide hazards. Usual period of rainfall is October-November and it is the season with most evenly balanced rainfall in Sri Lanka. Many areas receive over 400 mm rainfall. SIM is important in the agricultural calendar of the country as it marks the beginning of the major cultivation season known as *Maha*.

Northeast monsoon season (NEM): NEM is caused by air streams originated in north India or northeast Asian landmass (the China-Russia region). Stream from north India is cold and poor in moisture whereas stream from northeast Asian landmass carry large mass of moisture. Hence, the origin of wind streams creates different weather conditions leading to high inter-annual fluctuations. It produces seasonal rainfall in Northern, North central and Eastern parts of the country during the December-February period. Highest rainfall figures are recorded in north-eastern slopes of the hill country and eastern slopes of the Knuckles/Rangala range. NEM is particularly important as it is the major source of water for agriculture in the dry zone which is the major agricultural area of the country.

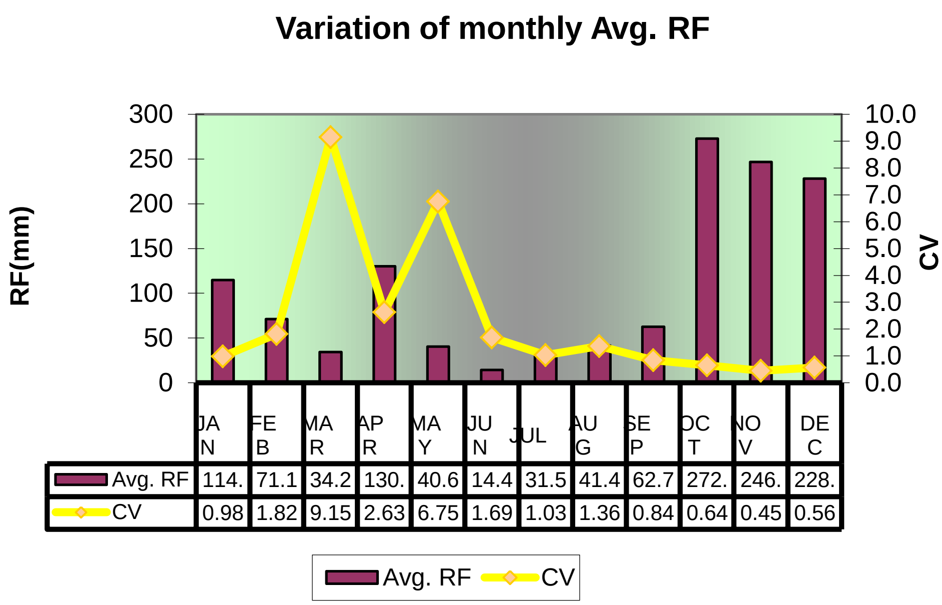
Distribution of agricultural practices in Sri Lanka has mainly been determined by the distribution of rainfall. According to spatial distribution of rainfall, the country can broadly be divided into two areas—wet zone and dry zone. Wet zone receives high average annual rainfall over 2500 mm which is distributed more or less evenly throughout the year. Population of the country is concentrated more in wet zone areas with relative abundance of water, which account only for one third of the total extent of land. With abundant rainfall, farming activities in the wet zone are usually carried out as rain-fed agriculture. Perennial plantation crops—tea, rubber and coconut—are the major forms of agriculture in the wet zone. They are export-oriented cash crops, managed by either large-scale estate companies or small family-run farm units. The land has become the major limiting factor for further expansion of agriculture in the wet zone where a majority of productive agricultural lands has already been occupied by three major plantation crops.

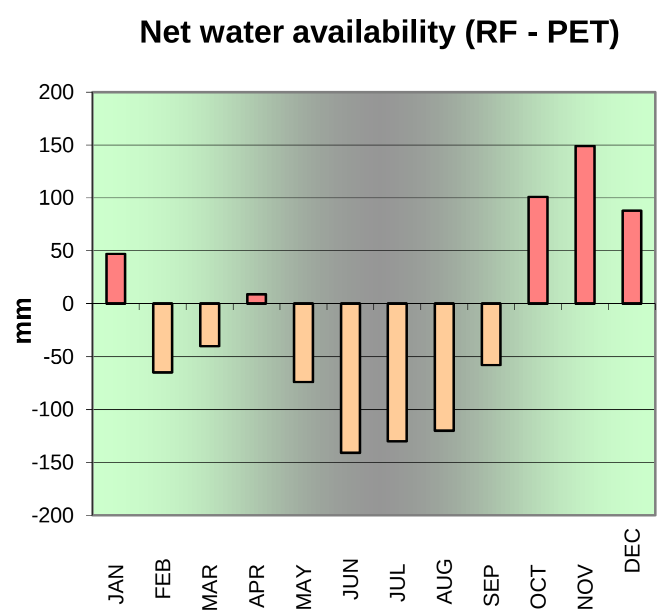
Dry zone is the major agricultural area in Sri Lanka and the majority of agricultural lands are located there. Agriculture in the dry zone is based primarily on small-scale peasant farming enterprises. Naturally, the major challenge faced by farmers in the dry zone is overcoming water scarcity due to limited availability of water from unevenly distributed low rainfall in the area. The key to understanding the climate adaptation strategy of farmers in the area is to examine the pattern of rainfall variability and resultant outcome of water availability in the area.

Figure 2.1 (below) shows the average annual rainfall in Anuradhapura district, a major agricultural area in the dry zone. It indicates that the area has a bi-modal rainfall pattern with a prominent peak during the October-December period and a minor crest in April. On average, 74 percent of annual rainfall is received during the period from October to March. Rainfall during this period is a result of northeast monsoon. The period from April to September has no significant rainfall other than few intermittent rains. Accordingly, two major cropping seasons, '*Maha*' and '*Yala*', have evolved in the farming system of dry zone. *Maha* is the main cultivation season supported by the north-east monsoon, the major source of water for the dry zone. It is extended from October to March. *Yala,* the dry season that extends from mid-March to September, has no major period of rainfall other than few intermittent rains.

Some idea about the annual pattern of rainfall is provided by monthly averages graphed in the top chart of the Figure 2.1. The pattern of monthly average rainfall does not indicate anything about the variability of rainfall. The co-efficient of variation (CV) of monthly averages also is given in the Figure 2.1.

Figure 2.1: Rainfall variability and availability of water in Anuradhapura

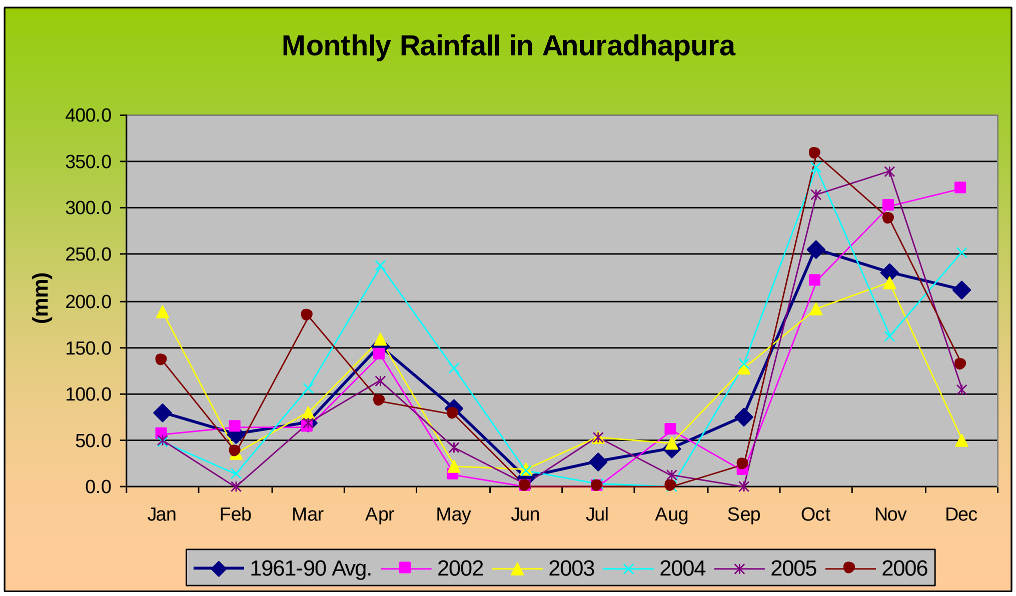




Accordingly, it shows that CV remains low during the eight months from June-January indicating that the variability of rainfall during these months is quite low. In other words, there is a high likelihood for receiving the rainfall indicated by the monthly averages during these months. In contrast, variability of rainfall during four months from Feb-May is relatively high as indicated by the high values of CV during these 4 months. Therefore, the bi-model pattern indicated by monthly averages seems somewhat illusionary due to high probability for inter-annual variation in rainfall in certain months.

The second chart (Figure 2.1) shows the net water availability, the difference between monthly average rainfall and potential evapotranspiration (PET), on monthly basis. It indicates that the area records a water surplus only during the months of October-January and April.

Figure 2.2: Annual fluctuation of rainfall in Anuradhapura



The pattern of rainfall and resultant outcome of water availability defines the overall challenge of climate adaptation faced by dry zone farmers. It helps to identify the specific climate shocks faced by farmers in undertaking their livelihood activities. From the farmers' point of view, not only the average rainfall but the variability also matters. Accordingly, two major forms of climate shocks can be identified:

- Shocks due to major dry spell of 4-5 months period in May-September
- Random shocks due to unexpected changes in average pattern.

The former can easily be recognized in the Figure 2.1 in the May-September period, during which the entire area (with minor local variations) experiences a lengthy dry spell. Second type of shock is random in nature and farmers have little idea about the probability of occurrence. They can be considered as deviations from the average (expected) pattern. Figure 2.2 shows monthly rainfall in the area for the period 2002-2006. Two visible examples in the figure are: relatively high rainfall received in Feb-Mar 2006 during the harvesting period and low intensity of rainfall during Oct-Nov period (peak period of rainy season) in 2003. These are the major climate shocks that determine the situation of water scarcity in the area and farmers have to face them regularly in the course of their farming activities (Tennakoon, 1986).

Given the uneven distribution and high inter-annual variation, prospects for purely rain-fed farming in dry zone are limited. Instead, irrigated farming and semi rain-fed farming under village tank systems[2] are the dominant form of agriculture in the dry zone. Dry zone is scattered with numerous manmade irrigation reservoirs, which are broadly categorized as; (a) major irrigation schemes (irrigation command area > 2000 acres), (b) medium irrigation schemes (irrigation command area > 2000-200 acres) and, (c) minor irrigation schemes (irrigation command area < 200 acres). Massive public investments have been expended on rehabilitation of the ancient network of irrigation tanks as well as construction of new multipurpose trans-basin diversion projects (Aluwihare and Kikuchi 1991; Kikuchi et al. 2002). Existence of numerous reservoirs has led to Sri Lanka being ranked on top among the countries with high density of inland water bodies per unit land area (De Silva 1989).

In major irrigation schemes, farmers grow paddy using water supplied from large irrigation reservoirs as the main farming activity. Large irrigation reservoirs store surplus water accumulated through water harvesting process of cascade network as well as water diverted from other surplus sources—some originating from the wet zone—through extensive canal systems. In contrast, village tank systems are semi-rain-fed systems, which depend heavily on local rainfall. Being dependent on local rainfall, village tank farmers are naturally more vulnerable to climate uncertainty than farmers in irrigated schemes. They are in a continuous struggle for livelihood security under the condition of water stress due to rainfall uncertainty. Village tanks, manmade small reservoirs for capturing and storing rain water from direct fall and runoff flow of local precipitation, play an important role in their adaptation strategies to climate variability. As discussed later, the main strategy of climate adaptation in village tank systems has evolved to face the threat of this climate shock.

The global climate change introduces a new dimension of randomness to the climate process thereby altering the prevailing situation of uncertainty of climatic variability familiar to farmers. In our interactions with the farming community, many farmers' acknowledged the perception of changes in rainfall with reference to the familiar pattern of variability known to them. Country level climate forecasts derived from downscaling global circulation models (GCM) have predicted significant

[2]Sometimes village tanks are also referred to as minor irrigation schemes. This is a misnomer given the tanks are dependent solely on local RAINFALL without no additional supply of water from surplus sources and farming systems practiced under village tanks have predominantly rain-fed characteristics.

fluctuations in precipitation and near surface air temperature in the future (Basnayake 2007). Table 2.1 provides a projection for the district that indicates the severity of general effect created by this major shock in terms of water scarcity (Amarsinghe et al 1999).

Table 2.1: Water scarcity projections for Anuradhapura district

Scarcity indicator		*Yala* (dry season)	*Maha* (rainy season)
UN indicator	1991	Severe	Severe
	2025 – Scenario 01	Severe	Severe
	2025 – Scenario 02	Severe	Severe
IWMI indicator	2025 – Scenario 01	Severe absolute	Severe absolute
	2025 – Scenario 02	Severe absolute	Little

Notes: Scenario 1- Efficiency of the irrigation remains at the current level; Scenario 2 - Irrigation efficiency improves over the project period.

Many problems they face currently are imminent to aggravate in the future with pending uncertainties of the global climate change. Farmers are a significant population of the country, and constitute majority of the rural poor. As agriculture is directly dependent on weather conditions, any adverse change in already volatile weather patterns are likely to create chaotic conditions and affect their livelihoods. Hence, the farmers in the dry zone deserve priority attention of policy makers while developing country wise adaptation strategies to face the threat of climate change.

The threat of future uncertainties due to the global climate change introduces new challenges to the ongoing process of adaptation taking place in the rain-fed dry zone areas. In our interactions with farmer groups, many farmers indicated about certain notable changes in the recognized patterns of climatic variability at least during the last few years. Losses and damages encountered by farmers due to unanticipated changes in the climate during the recent past, to some extent, indicate that long-term and short-term adaptation measures adopted by farmers may not be fully adequate to face this challenge. Therefore, adaptive capacity of farmers has to be enhanced to face this challenge.

3. Overview of Agricultural Adaptations in Sri Lanka

In this section, a broad overview of agricultural adaptation practices adopted by Sri Lankan farmers is presented. Here the focus is mainly directed on adaptation practices of dry zone farmers as it is the major agricultural area in the country with a long history of adaptation. Also, dry zone farmers represent an immediately vulnerable group to the impacts of climate change in Sri Lanka. The review is organized according to the classification of agricultural adaptations proposed by Risbey et al. (1999). Accordingly, three broad forms of adaptation measures adopted by farmers to face climatic uncertainty can be identified:

- Long-term structural adaptations
- Medium-term strategic adaptations
- Short-term tactical adaptations

3.1 Long-term structural adaptations

Structural adaptations refer to broad strategies adopted by farmers that extend over long time horizons of decades or more. Two of the most prominent structural adaptations currently in practice in the dry zone agriculture are:

- extensive practice of rainwater harvesting through community-managed village tanks; and
- widespread adoption of large diameter shallow wells known as 'agro-wells'

Both of the strategies have been developed to face the risk of lengthy dry spell experienced in rainfall pattern of the dry zone. Farmers have historically constructed village tanks to harvest water in small community-managed reservoirs during the rainy season so that it can be used in the dry season. Recently, farmers have further augmented the supply available for dry season by tapping the groundwater storage through agro-wells.

While decisions to make use of water from facilities such as village tanks and agro-wells can be considered as short-term adaptation responses, decisions to invest on such facilities are essentially long-term structural adaptations. Such decisions are usually taken to fill gaps and deficits identified in the existing strategies and harness opportunities detected through long-term practical experience. Construction of village tanks is a historical example for such a long-term structural adaptation strategy. Compared with the historical village tanks, extraction of groundwater for agriculture through agro-wells is a recently adopted private adaptation measure, which became popular during the last 2-3 decades.

3.2 Medium-term strategic adaptations

Medium-term strategic adaptations usually refer to practices that involve usual time horizons of one to few years. Such strategic adaptations may include:

- adjusting the portfolio of crops and farm practices periodically to match the changing conditions; and
- adopting technological innovations such as resilient varieties, improved agronomic practices, resource conservation techniques and protective forms of agriculture.

In addition to suitability for climatic conditions, strategic decisions such as selection of varieties and agronomic methods are also strongly influenced by socio-economic concerns. Until recently, such decisions used to be dominated by green revolution technologies. However, given gradual understanding of the downside of certain strategies, some sections of farmers have begun to explore the potential of traditional varieties and agronomic/conservation practices for overcoming those limitations. One desired feature expected from switching to traditional varieties and adopting agronomic/conservation practices is improving the climate resilience of farming activities—an essential step for enhancing the adaptive capacity of farmers.

3.3 Short-term tactical adaptations

Tactical adaptations are practices concerned with short-term intervals, involving seasonal or annual changes. Observations suggest that in every season farmers adjust their farming activities to some extent, responding to variations observed in weather pattern that can be considered as short-term measures for coping with intra-seasonal variability of climate (Tennakoon 2001 and 2004; Handawala 2004). A common type of tactical adaptation is adjustment of the timing of operational arrangements of farming activities based on the clues provided by local climate indicators. Farming under direct rainfall is the least cost option available for supply of water. This is done by timing of farming activities according to a pattern so that best possible match is found between changing water requirements of crops and farmers' expectations of rainfall of the progressing season. This helps farmers to minimize the uncertainty associated with water directly available from rainfall for farming. However, even well-timed farming activities may have to face random shocks and farmers need to make quick adjustments to fine tune their choices.

Every season farmers adjust their activities, responding to unexpected variation (shocks) of rainfall. Few examples for such short-term adaptation responses gathered in the interactions with farmers are given below:

- Dry sowing of paddy in upland areas (locally known as *Kekulam*) is one of the first rain-fed activities in the *Maha* season in certain areas. Decisions for this activity are highly dependent on the observations on intensity and duration of early rains in the season.

- Varietal selection of number of crops is dependent on the starting dates and intensity of rainfall during the early period of the season. For instance if rains delay, farmers switch from long maturing (4-5 months) to short maturing (3 months) varieties. Similarly, low intensity rains during the early period of the season could lead to selection of drought tolerant varieties.

- If untimely rains occur in the *Yala* season, farmers harvest the chilli crop as fresh chilli. Otherwise fruits are allowed to ripen and dried before marketing, which usually is the more lucrative option.

As a short-term strategy, farmers sometimes resort to gambling with weather, especially in periods with high rainfall variability. For instance, farmers used to sow gingerly (sesame) after harvesting the maize crop around late February-mid March to coincide with relatively uncertain rainfall in the March-April period. This can be done with minimum aftercare operations and can be harvested around May-June if the crop becomes successful with sufficient rainfall. Otherwise, they abandon the crop and leave the fields to fallow until the next rainy season. Farmers used exact words with the meaning of 'gamble' or 'lottery' to describe this activity indicating it as a high-risk activity. However, it was reported capable of bringing substantial cash returns in successful years

3.4 Selected case studies

This study selected three adaptation practices for in-depth examination as case studies:

Case Study 1: Rainwater harvesting in village tanks
Case Study 2: Tapping shallow groundwater through agro-wells
Case Study 3: Adoption of climate resilient traditional varieties and agronomic practices

They represent two long-term structural adaptations (village tanks and agro-wells) and medium term strategic adaptations. In the presentation of case studies, focus is directed on three aspects, namely:

- assess the background and rationale of respective practices;
- identify the technical, economic and institutional/social potential of them; and
- evaluate the challenges they may face under ongoing changes in climatic patterns and socio-economic conditions

They have been selected for considering the potential for learning and sharing the experience with farmers in other regions in South Asia. Three cases were built upon information from primary and secondary sources. Primary information was collected from interactions with farmer groups in Anuradhapura (village tanks, agro-wells and traditional agronomic practices) and Kandy (indigenous paddy varieties) districts. Responses from farmers were supplemented with information from few experts from state agencies and NGOs who had long-standing experience about respective farming systems. In addition, extensive review of literature on selected practices and general aspects of agricultural adaptation was carried out. Sources of literature included journal articles, working papers, official reports and statistical bulletins. Insights from these secondary sources were used to enhance the understanding obtained from primary sources.

Case Study 1: Rainwater Harvesting in Village Tanks: A Historical Long-term Structural Adaptation

Background

Successive governments in Sri Lanka invested massive public funds on irrigation projects to improve the situation of water scarcity faced by dry zone farmers (Aluwihare and Kikuchi 1991; Kikuchi et al. 2002). Despite relative improvements brought about by the irrigation schemes, a significant population of the dry zone still lives under rain-fed areas, which are not supported by any trans-basin irrigation project. A notable feature of many rain-fed areas in the dry zone is they are covered by a network of small village tanks that act as community-managed rainwater harvesting devices. Apparently, small village tanks have been constructed historically to fill the observed gap of temporal scarcity of water during the lengthy annual dry spell. They make a substantial contribution by helping to control and manipulate the limited local supply of water available during the short season of rainfall. With the gradual exhaustion of relatively cost-effective options for transferring water from surplus to deficit areas, village tanks have begun to attract the attention of policy makers.

There are over 18,000 village tanks, scattered throughout the dry zone areas. In Anuradhapura district alone, number exceeds 2500 small village tanks[3] (Panabokke et al. 2001). The highest densities of tanks are reported from Anuradhapura and Kurunegala districts. Some of them date from the earliest era of country's human settlement (Siriweera 1994). Tennakoon (2001) provides a detailed account on evolution of village tank systems under the specific geo-morphological and socio-economic conditions found in the dry zone. Despite their manmade origin, village tanks have become a unique type of wetland eco-system in the dry zone land scape, offering a multitude of ecological services in addition to their contribution to livelihoods of farmers (Panabokke et al. 2001; Tennakoon, 2004). A majority of village tanks are seasonal in nature due to the availability of water only for a limited period of time in a year (Chakrabarty and Samaranayake 1983)

[3]While numbers of large and medium tanks have been enumerated with some accuracy, no one knows the exact number of village tanks which are scattered throughout the dry zone of the country. Ratnatunge (1979) has estimated over 18,000 based on island wide map of 1:63300 scale.

The village tanks represent an immense physical diversity in terms of size, shape, form, geographical location, hydrological endowment, command area as well as number of farmer families being supported. Therefore, there is no prototype for village tanks (Panabokke et al. 2001). Recent studies have identified that many village tanks are interconnected with a cluster of surrounding tanks (about 3-15) through surface and sub-surface channels of water, giving rise to networks of reservoirs known as 'cascade systems'[4](Madduma Bandara 1985; Panabokke et al. 1999; Tennakoon 2001). Cascade systems were identified to generate many hydrological benefits to local micro-catchments as well as higher order units of watersheds (Tennakoon 2001; Shakthivadivel et al. 1996; Navaratne 1998; Dharmasena 2004). The tanks located in uppermost micro-catchments depend entirely on local precipitation whereas tanks located in lower reaches of cascades are fed by surplus water from up-stream tanks too. Organizations of village tanks as cascade systems appear to fulfil a unique role in enhancing adaptive capacity of farmers. Functional aspects of this system can be summarized as follows (Shakthivadivel et al. 1996; Madduma Bandara 1985; Panabokke et al. 2001).

- Individual tanks are strategically positioned in micro-watersheds to harvest rainwater in maximum efficiency.
- A collection of hydrologically interconnected village tanks forms a tank cascade that covers the drainage flow of a meso-catchment—a sub-unit of a hierarchical order of watersheds that forms a river basin. Usually numerous tank cascades are located within a river basin.
- Larger units of watersheds (e.g. river basins) include not only the village tanks but also large and medium tanks that have extended water spread areas and command areas. As a result, surplus of drainage from smaller tanks are finally collected in larger reservoirs.
- The water harvesting process of village tank networks is facilitated by a network of canals and sub-surface water movements.

Overall, village tanks collectively help to form a huge rainwater harvesting system in the water scarce dry zone agro-ecosystem, contributing immensely to enhance the adaptive capacity of farmers. Therefore, from the perspective of climate adaptation, village tanks can be identified as the most important adaptation support facility available to farmers in the dry zone.

Technical, Economic and Social Potential

Village tanks play a prominent role in the climate adaptation efforts of farmers. Unlike in the wet zone with abundant rainfall, rain-fed farming in the dry zone under poorly distributed low rainfall conditions is a challenging task. Village tanks are a facility that helps to alter the time availability of water received from local rainfall by storing the surplus from the short rainy season to be used in the lengthy dry spell that follows. They increase the efficiency of using limited local supply of water

[4] Cascades are locally known as 'ellangawa'

while helping to minimize and even out the risk of seasonal water scarcity through community management of tanks. This has enabled farmers to practice a farming system which is based on lowland paddy farming and cultivation of highland seasonal crops.

Table 3.4.1: Traditional farming system in village tank systems

Farming system activity	Crops	Seasonality		Water supply		Location	Economic status
		Maha	*Yala*	*Maha*	*Yala*		
Lowland farming	Paddy	All plots in the field	Limited area	Rain-fed + tank water	Tank water	Command area of village tanks. Bethma in *Yala*	Mainly subsistence with limited sales if a surplus available
Upland farming	Coarse grains, Grain legumes, Pulses, Vegetables, condiments, Gingery	1-5 ac avg. by all HH	Gingerly	Fully rain-fed	Fully Rain-fed	Shifting agriculture in commonly owned uplands	Mainly subsistence with few cash crops
Permanent crops	Coconut, fruits, multipurpose trees	No seasonality		Rain-fed + retained moisture in soil		Home gardens	Mainly subsistence with few cash crops

Source: Senaratne and Wickramasinghe (2011)

Table 3.4.1 highlights the farming system and water management strategy in the village tank systems. Village tank farmers have a farming system that includes highland farming activities as well as wetland paddy farming (Somasiri 2001; Handawala 2004). Two major components of highland farming were cultivation of seasonal field crops under '*chena*' farming (an evolved form of shifting cultivation) and mixed farming of seasonal and permanent crops in homestead gardens (Abeyratne 1956; Weerakoon et al. 1987). Paddy as well as other highland field crops are cultivated during two cropping seasons '*Yala*' and '*Maha*' which are determined by the rainfall availability from monsoons. *Maha* is the main season supported by the North East Monsoon, which is the major source of water for the dry zone. The highland farming components are purely rain-fed. Traditionally, the mixed-crop *chena* (shifting cultivation) used to be a highly important component of the farming system (Tennakoon 2001). Wetland paddy cultivation in *Maha* season depends partially on rainfall during the early stage of the crop. However, later stages of paddy cultivation are supplemented with water stored in tanks (Handawala 2004). During the *Yala*, there is no sufficient rainfall for rain-fed farming. Farming activities in this period are adjusted in such a way that they are carried out subject to water availability from village tanks. Available water storage is a function of rainfall intensity of the past rainy season and PET of the ongoing dry season. Common ownership of village tanks has enabled unique arrangements of joint adaptation scheme popularly known as *Bethma* (division).

Overall, in the climate adaptation strategy of dry zone farmers, village tanks fulfil two major functions:

- Enable cultivation of the major crop—paddy—in the dry season subject to the level of water available in tanks
- Supplement later water needs of *Maha* season (rainy season) paddy crop established with the support of north-east monsoon rainfall

In addition, being a unique type of wetland eco-system, village tanks offer a multitude of ecological and livelihood services to farming communities in the dry zone (Panabokke et al. 2001; Tennakoon 2004).

Adaptation to climate variability is closely interconnected to institutional arrangements dealing with allocation, distribution and utilization of the limited supply of available water. Village tanks are common property resources (CPR). The use rights for water in commonly owned village tanks are usually held by well-defined agrarian community that owns or cultivates paddy fields in the command areas of tanks. They make decisions on the use of tank water through an institutional mechanism involved with Farmer Organizations (FO). Despite interconnections with surrounding tanks, individual tanks function as independent units supporting well-defined village communities of farmers. Typically, a traditional tank-village consists of few key components: (a) village tank, (b) housing area (*Gangoda*) and homestead gardens, (c) command area of the tank (paddy field consisted of two parts called *Puranawela* and *Akkarawela*), (d) cultivated area of micro-watershed of the tank (Shifting cultivation lands; C*hena*), and (e) uncultivated dry land and wetland components of micro-watershed (Aheeyar 2001; Dharmasena 2004; Somasiri 2001). Housing area was the residential plots surrounded by home gardens. Command area (paddy fields) is usually located in lowlands below the tank. A part of micro-catchment of the tank was utilized for shifting cultivation. Uncultivated dry and wetland components of micro-watershed have been preserved to fulfil specific ecological and socio-economic functions (Ulluwishewa 1997; Dharmasena 2004; Handawala 2004).

The said profile of local resources and traditional farming system has given rise to a unique system of rights and local institutions that include both private and common property rights. Village tanks are common property resources (CPR) and farmers commonly hold the right for water from tanks. This right has to be exercised collectively through Farmer Organizations, which have legally been sanctioned by the state. Currently, village tanks are managed by 'Farmer Organizations', which have been legally sanctioned by the Agrarian Development Act of 2000. Evidence suggests that institutional arrangements in village tanks have evolved in response to changing socio-economic circumstances throughout history (Aheeyar 2001; Panabokke et al. 2002). According to the act, FOs have an extensive mandate that covers activities such as marketing, credit, subsidies, farm input supply, technology transfer and conflict resolution etc. in addition to the management of village tanks. However, all FOs may not be equally capable of delivering such services. On the other hand, farmers hold private property rights to homesteads and surrounding home gardens located in the resident area known as '*gangoda'*. They also have private tenure rights to paddy lands subject to certain conditions. However, tenure of paddy lands is also governed by customary system of rights that align the private and communal interests depending on the conditions of resource scarcity.

Decisions regarding the use of tank water are usually taken in '*Kanna Resweem*' (or Seasonal Meetings), which are participated by members of FO and government officers, particularly from the Agrarian Development Department. In seasonal meetings, farmers collectively decide on: (a) how to use the water available in tank subject to pending uncertainties of rainfall (b) dates of water issue (starting date, periodic issues and last issue), (c) the calendar of cropping activities (time schedule for land preparation, broadcasting, water supply and harvesting), (d) clearing, maintaining and repairing of tank bund, channels etc., and (e) other matters concerning the use of water including fisheries and aquaculture. In addition to irrigation, fulfilment of other rural agrarian needs, which include domestic water uses, bathing and washing and water for animal husbandry etc. are also taken in to consideration by the FOs but are usually governed by social customs rather than formal institutional mechanisms by the same user groups.

Common ownership of village tanks and customary rights for paddy lands have enabled unique arrangements of joint adaptation known as *bethma* (division) under high water scarcity conditions. Accordingly, in the *Maha* season with adequate rainfall, individual farmers are entitled to cultivate their own plots of paddy as private lands under common schedule of water management. However, during the water scarce *Yala* season, the private rights are suppressed in the common interest of food security of the whole community under the institutional arrangement called *bethma* (the division). In such occasions, community members collectively decide the total area of paddy land that can be physically supplied by limited water available in the tank and divide this land among all members disregard of the ownership of respective land plots. In doing so, extent of land allocated for individual farmers are determined in proportion to the individual ownership of land under the tank. In other words, individuals have to make some trade off in privately held rights over land in exchange of commonly held rights to water under conditions of scarcity. This can be considered as a unique social benefit of joint adaptation.

Many village tanks are several centuries old and some date back to around two millennia (Tennakoon 2001; Siriweera 2001). As a result, a significant base of traditional knowledge has developed around village tank systems (Madduma Bandara 2008; Ulluwishewa 1997). According to some researchers, local knowledge on village tanks is a comprehensive body of knowledge that deals not only with technical aspects of construction and maintenance of tanks but also with integrated management of land, water and forest resources associated with these tanks (Ulluwishewa 1997). The fact—despite being ancient structures, a majority of tanks are still in a viable condition fulfilling a central role in dry zone farming system even today— indicates the effectiveness of local knowledge system involved with village tanks. Although not explicitly documented, this body of knowledge carries an understanding on local climatic variability.

Issues and Challenges

Regardless of the support received from village tanks, on the final count, dry zone farmers in rain-fed areas basically depend on local rainfall for their livelihood needs. Many problems faced by them are imminent to aggravate in the future with looming uncertainties of climate change. Compared with their counterparts in major irrigation schemes, village tank farmers are naturally more vulnerable to climate change due to their high dependence on local rainfall for their farming needs. Moreover, three macro-scale processes, namely; growth of population, commercialization of local economies and 'modernization' of agriculture technologies are rapidly transforming the socio-economic conditions in village communities surrounding the tanks (Aheeyar 2001; Panabokke et al. 2001; Senaratne and Wickramasinghe 2011; Ulluwishewa 1997). Broad sweeping changes that introduced such transformations are causing impacts over vital roles played by local institutions and traditional knowledge systems. As a cumulative result of such changing agents, ownership and tenure patterns of village resources associated with the village tank system have undergone significant changes during the recent past (Senaratne and Wickramasinghe 2011). In the traditional system, collective actions involved in many farming system activities and customary systems of rights and practices have governed different aspects of managing local resources (Senaratne and Wickramasinghe 2011; Ulluwishewa 1997). Commercialization of traditional farming system has led to the decline of traditional institutions making them less-effective. As a result, opportunity for utilization of community-based institutional arrangements for climate adaptation seems to be declining.

Therefore, village tank farmers in the dry zone are currently facing a challenge where local institutions and traditional knowledge have come under severe stress while the uncertainty of climate shocks are rising due to global climate change. Given the impact of such parallel transformations, adaptation to climatic variability and change has become a complicated issue with different dimensions. Farmers have to make their choices under dual sources of uncertainty relating to climate as well as socio-economic change. This situation could give rise to vast changes in opportunities and constraints faced by dry zone farmers and alter the choice set available for them to cope with climate uncertainty. Further, new social relationships resulting from changing socio-economic conditions may demand significant modifications in institutional arrangements as well. There is every possibility that this situation could pose a major challenge for farmers in years to come. Hence, farmers in dry zone deserve priority attention of policy makers when they decide on adaptation strategies to face the challenges of global climate change.

Farmers alone may not be able to overcome this challenge through their own efforts. They need the assistance of an 'adaptation policy' which could facilitate voluntary efforts of farmers (individual and joint) through appropriate policy interventions and institutional support. The major role of adaptation policy is to enhance farmers' 'adaptive capacity' to face the changes that are beyond their experienced range of coping capacity. Policy should encourage farmers to search for innovative measures of private as well community adaptation practices. Policy makers have an important role to play here by introducing appropriate policies, institutions and incentive schemes to enhance the adaptive capacity of farmers. Two major gaps to be filled by policy are institutional and information gaps that have been created by changing climatic patterns and socio-economic conditions. This demands innovative institutional arrangements and integration of information from scientific sources into local networks of knowledge.

Case Study 2: Agro-wells: Adjusting to Dual Challenges of Climate and Market

Background

Besides the threat of climate change, the forces of globalization also are transforming the livelihoods of farmers all over the developing world. Being a long-term global process, climate change and economic globalization subject communities around the world to a double exposure with uneven impacts (Coles and Scott 2009; O'Brien and Leichenko 2000). Three major forces of change, namely—rapid growth of population, conversion of traditional farming systems into commercial farming systems and speedy adoption of new technological options—alter the socio-economic scenario faced by Sri Lankan farmers in an unprecedented scale. Such parallel transformations create severe pressure on traditional intuitions and local knowledge systems in dry zone areas, favouring the adoption of more individually–oriented, market driven responses to climate as well as socio-economic change. As a result, private adaptation measures under commercial farming system are becoming more and more popular.

The most prominent private adaptation measure that emerged in the last few decades is utilization of groundwater from shallow regolith aquifer in the area through agro-wells. It came as an adaptive response to both; the long-standing problem of water scarcity in dry zone as well as market signals created by globalization process. It has largely been facilitated by the introduction of small, low-cost pumps operated by diesel or kerosene—a result of modernization of agricultural technologies (Kikuchi et al. 2003). Agro-wells enabled farmers to tap the shallow groundwater storage in addition to surface storage in tanks thereby further reducing the risk of water supply. Compared with the historical village tanks based on the management of water stored in surface water bodies, extraction of ground water for agriculture through agro-wells is relatively a recent development, which has been taking place at a rapid rate for the last 2-3 decades. Although, incentives provided by the state agencies such as the Agriculture Development Authority has played an important role in popularizing agro-wells, many farmers have subsequently constructed them through own private initiative.

Technical, Economic and Social Potential

Technically, agro-wells can be considered as a structural adaptation that came in response to the water scarcity experienced by farmers in the *Yala* (dry) season. They help to alter the space availability of water from shallow regolith aquifer to farm lands thereby enabling farmers to add the shallow groundwater storage also into the available portfolio of water resources. Since the geology of lowland dry zone areas has a relatively uniform crystalline rock foundation, potential for groundwater in the area had initially been considered as insignificant (Fernando 1950). However, subsequent research has confirmed that dry zone areas have two sources of groundwater, namely; weathered overburden named as 'shallow regolith aquifer' and deeper fracture zone aquifer (Herbert et al. 1988; Panabokke 2005 and 2008). While the former has a more extensive spread at depths ranging from 3-12m, the latter shows more sporadic distribution at the deeper zone ranging from 40m and below (Panabokke, 2008).

The shallow regolith aquifer provides the foundation for tapping groundwater for agriculture through agro-wells. Extensive surveys on groundwater resources in 50 village tank cascade areas conducted by Senaratne (1996) and Panabokke (2008) helped to reveal some important information that is relevant for the management of groundwater resources in dry zone areas.

- In the undulating landscape (mantled plain) of the dry zone with highlands and lowland valleys in sequence, shallow groundwater is mainly confined to lowland valley areas. Therefore shallow aquifer occurs as isolated pockets and there is no continuous aquifer that spreads all throughout the plain.
- There is a limited storage capacity within the shallow aquifer, which is annually recharged during the rainy season from October to late December period. In addition, seepage flow from

surrounding irrigation/rainwater harvesting bodies also constitutes one source that replenishes the fluctuating water level.

- Therefore, this limited storage has to sustain through a lengthy period of dry season during which water levels are continuously diminishing. Optimal management of limited groundwater resources in conjunction with the surface water bodies is an essential condition. This implies that proper siting of wells in the landscape, managing sustainable extraction rates (safe yields) and maintaining an optimal density of wells within cascades are critical for sustainable management of water resources.

Thus, agro-wells have effectively contributed to augment the water supply for farming in the dry zone—especially during the dry season—filling an important gap in the farming system. Consequently, choice set available to farmers has enhanced through opening the opportunity for farming cash crops in the dry season. Hence, agro-wells can be considered as a major adjustment in the history of dry zone agriculture. They particularly enhance the water supply for activities undertaken in the *Yala* season. It is an adjustment induced by technological innovations of small, low-cost pumps operated by diesel and kerosene.

Major economic contribution of agro-wells is enabling the cultivation of cash crops during the dry season (Nagarajah and Gamage 1998; Karunaratne and Padmarajah 2002). This has made a significant contribution to increase the income of farmers (Senaratne and Wickramasinghe 2011; Senaratne 2013). The major cropping activities supported by agro-wells are commercial cultivation of chilli, big onion and vegetables. They contain substantial cash earning potential and help raise the economic prosperity in many villages in the dry zone (Senaratne and Wickramsinghe 2011; Senaratne 2013). Spread and development of agro-well based activities have further been complemented by the penetration of large scale buyers of these products (e.g. middlemen, agro-based product manufacturers) with forward contracts and establishment of rural wholesale market centres in certain areas of the dry zone (e.g. Dambulla centre).

However, in spite of high revenue potential, agro-wells are the most expensive option for water supply for farming as compared with the alternatives of farming under village tanks or direct rainfall. Agro-wells require substantial capital and recurrent expenditure for regular operation. This includes high investment costs (cost of construction and pumps) and operational cost of pumping water (fuel) from wells to farm lands. As these costs has to be borne privately by individual farmers, agro-wells is an option available to farmers who can afford it, unlike the relatively uniform, freely available water supply from direct rainfall or commonly managed tanks. Therefore, water extracted from agro-wells is utilized only for high value cash crops (such as chilli and onion) and the level of extraction of water is determined by the price of fuel to a certain extent. Although incentives provided by state agencies such as the Agriculture Development Authority has played an important role in popularizing agro-wells, many farmers subsequently invested in wells without any external support (Karunaratne and Pathmarajh 2002; Panabokke 2005).

Compared with the relatively well established institutional arrangements available for management of surface water resources such as village tanks and large irrigation reservoirs, situation in groundwater utilization through agro-wells is relatively a complex issue. Shallow aquifer is a resource that spreads underneath the dry zone landscape, freely crossing the boundaries of land plots in the surface above it with private tenure rights. Therefore, shallow groundwater pool can be considered as a common pool resource. In spite of that, extraction points (agro-wells) are usually considered as private properties of owners of land plots where they are located. As no rules or regulations are in place to govern the actions of individual agro-well owners, groundwater can be considered as a type of unregulated common property.

Issues and Challenges

An issue raised by number of researchers is the threat of overexploitation of groundwater resources due to unplanned expansion of agro-wells. Groundwater experts seem to be concerned more about the fragile balance maintained between surface and groundwater resources, local eco-systems and inter-connection between shallow and deep aquifers. Senaratne (1996) estimated the optimum number of agro-wells that could safely be accommodated within 50 cascades do not exceed 3600. Disregarding these scientific concerns, a large number of wells have already been constructed and the number is further increasing. Opinion about the impact of agro-wells on surface water bodies and local environment is divided between experts and farmers. Contrary to serious concerns expressed by experts, significant number of farmers and some local officers seem to believe that there is no significant impact on surface water bodies (e.g. village tanks) due to pumping of water through agro-wells. They argue that pumping is usually done in the dry season when tanks provide little support for farming. Therefore, even if some draw down actually takes place, it is more economically advantageous to use water in highland crops with high cash earning potential than more water intensive paddy. They further argue that given that both tanks and wells get filled annually in rainy *Maha* seasons (October-January), there is no long-term issue of sustainability. Experts have suggested that groundwater potential exist only in limited pockets and indiscriminate digging is a wasteful exercise. They point out that large number of abandoned wells is an indicator of this.

Despite the fact that ground water aquifer is a common pool resource, their access rights is determined by the ownership of land plots above the aquifer area. This allows for inequity in allocation of groundwater resources as some farmers can exploit the limited resource at the expense of others. As no rules or regulations are in place to govern the tapping of water by individual agro-well owners, groundwater can be considered as a type of unregulated common property. Moreover, all members of village tank communities cannot afford agro wells. Since there is no control over private tapping and poor farmers cannot afford agro-wells, ensuring sustainability and equity in using limited groundwater resources is an institutional challenge.

Compared with the historical village tanks, extraction of groundwater for agriculture through agro-wells is a recently adopted private adaptation measure. It has become popular during the last 2-3 decades with the introduction of small, low-cost pumps operated by diesel or kerosene. Hence, it can be considered an adaptation practice induced by modernization of agricultural technology. Given the limited time period elapsed since the adoption of agro-wells, there is no traditional knowledge base developed beyond the experience gained in one generation. Therefore, scope for learning from local knowledge is limited in the case of agro-wells.

Case Study 3: Building Resilience to Climate Shocks through Indigenous Varieties and Traditional Practices

Background

Rice is the staple food in Sri Lanka and cultivation of paddy is the major agricultural production activity of the country. Paddy occupies approximately 37 percent (0.77 million ha) of the cultivated land of Sri Lanka, covering both wet zone and dry zone areas. It is cultivated during two major seasons of *Yala* and *Maha*, majority of land being cultivated during the latter. Nearly 1.8 million farm families are dependent on paddy farming throughout the country. The demand for rice in Sri Lanka is projected to increase at a rate of 1.1 percent per year, which requires the production of paddy to also increase at a matching rate of 2.9 percent per year (Department of Census and Statistics 2013).

Green revolution, started in the early 1960s, fast tracked the production of paddy and other seasonal field crops. This has been supported by agricultural policies such as the introduction of new improved varieties (NIVs), promotion of green revolution technologies (i.e. high chemical input use technologies) and fertilizer subsidies. In addition, the national production strategy was complemented by rehabilitation of the ancient irrigation network and construction of new large irrigation schemes. This helped to expand the area available for agriculture production significantly. Subsidized fertilizer, green revolution technologies and expansion of irrigated area has led to an increase in the cultivation area, cropping intensity, productivity per unit land and total output of paddy production.

A cornerstone of this agriculture development strategy was new improved varieties (NIVs). Even though NIVs are known for short maturation and relatively high yield potential, they are highly dependent on use of chemical inputs (e.g. fertilizer, pesticides) and responsible for many negative externalities to the environment (Wiggins and Brooks 2010). Moreover, morphological features of many popular NIVs do not appear to be favourable as far as resilience of crops to climate shocks is concerned. As a result, paddy has been a frequent victim to climate shocks. Time and again, vast extents under paddy have come under heavy damage due to floods and droughts.

Some farmer groups and researchers have pointed out that indigenous paddy varieties coupled with traditional adaptation practices could be expected to generate more successful results in facing the impacts of climate change than NIVs. Around the world, farmers and their families have been consuming traditional rice for many generations (Altieri 2008). Traditional paddy varieties have been naturally selected over many years against climate and environmental changes. As a result they have developed resilient characters to hardy conditions and were adapted to variety of field conditions. Therefore, traditional paddy varieties are capable of maintaining a balanced performance under changing conditions of natural environment and climate (Rathnabharathi 2009). Moreover, application of organic manure and environment friendly agronomic practices increases the population of macro and microorganisms in the field thereby keeping natural food chains in the paddy field intact. Natural food chains would manage the pest problems without disturbing the natural balance of fauna and flora in the surrounding environment (Killebrew and Wolff 2010). Overall, traditional paddy varieties and agronomic practices help to preserve and improve the natural conditions of environment while making crops resilient to climate change impacts.

Taking these advantages into consideration, recently some pioneering efforts have been made by few farmer groups with the support of CBOs and NGOs to restore indigenous varieties and traditional adaptation practices. In addition, signs of a major shift in mainstream agricultural policies that is benign to indigenous knowledge, traditional varieties and environment friendly practices also seem to be emerging gradually. Realizing the importance of traditional practices such as applying organic manure for improving soil conditions and preserving the natural environment, the government of Sri Lanka recently decided to cut down the fertilizer subsidy by 25 percent and encouraged farmers to adopt practices such as organic manure application (Sunday Times 2013).

Technical, Economic and Social Potential

It has been documented that numerous local varieties of paddy were used by farmers in the past (Molagoda 1924). However, only a handful of traditional paddy varieties are cultivated by farmers currently. Among the most cited by farmers are: Suwandel, Rathdel, Kaluheenati, Ma-Wee, Kuruluthuda, Pachchaperumal, Madathawalu, Hetadha Wee, Hondarawalu, Girisa and Heenati. These traditional paddy varieties have some vigour and resilience that help them to survive under climate change impacts such as droughts, heavy rains and floods compared to NIVs used in chemical intensive paddy cultivation. According to farmers, this resilience is based on certain unique characteristics of the traditional paddy varieties. Traditional paddy varieties are capable of being at the nursery stage for a longer period of time compared to NIVs. While new improved varieties only can be raised in a nursery for 3-4 weeks, traditional varieties can hold on up to 2-3 months. Therefore in case of climate shocks such as droughts, floods or heavy rainfall events, the traditional varieties are capable of surviving in the nursery until the field conditions are favourable for planting. Many traditional varieties are tall and have strong stems compared to NIVs. This helps plants to withstand heavy rains, winds, droughts and conditions of heavy evaporation. Furthermore, even when stems have bent due to heavy winds, rains or floods, the plants still have a higher probability of survival. The seeds of traditional varieties also are more resilient. The shell of the seed can tolerate water logging and drought conditions. Overall, according to farmers' experience, traditional varieties are better suited for climate change impacts such as heavy rains, floods, winds and droughts than NIVs.

Climate resilience of traditional varieties cannot be examined in isolation. They have to be taken together with traditional practices of adaptation. There is evidence of many traditional paddy cultivation practices in Sri Lanka, some of which are still widely practiced by farmers. These traditional practices are concentrated around land preparation, water management and organic manure application. Combined with the traditional paddy varieties they could be expected to produce more robust results against climate change impacts. Traditional practice known as the '*Nava Kekulan*' method (dry sawing system) practiced by dry zone farmers even today is a good example. Some special features of the dry sowing method that help to increase the endurance of paddy under adverse climatic conditions are described below.

The dry sowing system was in existence for many generations. It is identified as an environmentally friendly practice. There are some unique features of this cultivation method which makes it resilient to climate shocks. Water management practices in dry sowing method are important for adaptation to climate uncertainty. It has been designed to keep the soil at the level of filled capacity of moisture content and avoid inundation situations. The dry conditions are kept until the stage of panicle initiation starts around two months prior to harvesting. These water management activities will result in extensive root system growth that could hold plants straight while reaching groundwater better. As a result, deep roots help paddy plants to survive under heavy winds, rains and drought conditions (Upawansa 2013).

In addition, other practices associated with the dry sowing method have many agro-ecological benefits. To begin with, the dry sowing method does not need clearing or re-plastering of bunds of paddy plots before the start of cultivation season as in the wetland cultivation of paddy. This initiative will boost the flora and fauna population around the field making the bunds resistance against dry conditions as well as heavy rain conditions. The dry sowing method usually does not apply tillage or if necessary only minimum tillage is applied. This practice will preserve the soil fertility by facilitating the microbes and preserving the soil moisture. Therefore, the paddy fields can preserve its fertility during dry spells. Furthermore, since the biological, physical and chemical properties are preserved, the soil can get back to normal stage once the rainy season starts. Another significant cultivation practice in the dry sowing method is mulching of fields soon after sowing. Mulching acts as a protector against evaporation. Hence, soil moisture is protected during dry spells and crops can tolerate water stress to a higher degree. At the same time, mulching materials will ultimately be incorporated as organic matter to the soil which would increase the water holding capacity. Therefore when the rain comes, the fields are capable of storing much of the water.

The main economic argument usually posed against traditional varieties is that they have low yield potential and are unable to produce economic returns comparable to NIVs. However, farmers have highlighted many potential economic gains from cultivation of traditional varieties. Firstly, they gain from minimized crop damages and yield losses due to robustness of traditional varieties and practices. Another economic benefit is savings due to non-use of chemical inputs. In the market place, traditional paddy varieties usually fetch higher prices. According to farmers, price of traditional varieties could sometimes bring prices three times as higher as the prices of NIVs cultivated under chemical intensive paddy farming. Therefore, farmers have a price advantage for supplying traditional rice to consumers.

In addition, some farmers and experts argue that traditional paddy has a high potential as an export commodity. Consumers in local and global markets have gradually become more conscious about the health, environment and fairness of trade practices. Indigenous rice based on traditional agronomic practices has the potential to fulfil many of these requirements. Such markets still exist as niche markets and exports in bulk is not a viable enterprise since producers also are few and practice in small scale (Samaratunge 2011). Hence, identifying niche markets and targeting them is required to realize the potential. An additional factor that could be promoted with traditional paddy exports is fair trade practices. Organic products are eligible for obtaining fair trade certificates and they are eligible to receive tax concessions from the government. Overall, favourable environment for trading indigenous paddy based on traditional farming practices is emerging and incentives for focusing on export markets appear to be encouraging. Therefore, potentially robust performance under the impacts of climate change together with opportunity for economic gains from trade provide sufficient justification for policy makers and motivation and incentives for farmers to concentrate on promoting and engaging in traditional paddy and agronomic practices.

An additional social benefit associated with indigenous varieties is preservation and protection of traditional knowledge. Traditional farming systems have been practiced for many generations and contains experience and knowledge acquired over centuries. With the spread of chemical intensive 'modern' farming technologies, traditional knowledge associated with agriculture has begun to disappear all over the world. Losing access to this wealth of knowledge while facing one of the greatest threats to human kind—global climate change—certainly is not a desirable situation. Adaptation based on these methods would preserve the knowledge for the next generation while offering many environmental, economic and social benefits. Therefore, traditional paddy farming is capable of preserving a very important traditional knowledge that can enhance the adaptive capacity of not only farmers but human society as a whole.

Issues and Challenges

Even though traditional paddy farming has many potential environmental, economic and social benefits, there are several key challenges in promoting and implementing it in Sri Lanka. To start with, farmers are used to fertilizer subsidies, chemical pesticides and short term production and efficiency oriented paddy cultivation for several decades now. Therefore, reducing the fertilizer subsidy alone will not guarantee that farmers will adopt traditional paddy cultivation. As mentioned earlier, there is a possibility that these farmers would cut down the current extent of cultivation and aim for a guaranteed price rather than adapting traditional agriculture. Hence the challenge is to make sure that given this opportunity, farmers would adapt traditional paddy cultivation.

It is generally accepted that traditional paddy varieties have less yields than chemical intensive NIVs and take more time to harvest. Therefore unless proper markets are established, traditional paddy farming will not generate enough income. Hence the motivation for farmers to adopt these practices could decrease unless supported by proper market development strategies. Finding and ensuring markets is a difficult task since demand for traditional paddy varieties are restricted only to niche markets, both locally and internationally. Therefore, unless sufficient demand is created, farmers will not be effectively persuaded to adopt traditional paddy farming.

Though interactions with farmers have highlighted a handful of traditional varieties in Sri Lanka, historical evidence suggests the existence of a greater number of traditional varieties. However, use of only some limited varieties for several decades has thus resulted in farmers losing access to many of different varieties available. Therefore, while the available traditional varieties are not enough, there is also a danger of losing what exists now. Overcoming this issue is very important, especially if Sri Lanka is to promote traditional paddy as an export commodity. Hence the challenge is to preserve the varieties currently available and then to search for hitherto untapped sources to find more varieties which are especially suitable to withstand the impacts of climate change.

Not only the traditional varieties but also the knowledge of traditional farming methods is on the verge of extinction. The knowledge of traditional varieties and traditional farming systems has been passed down from generation to generation through practice. Discontinuity and replacement of these practices with chemical intensive green revolution technologies has affected this knowledge transmission process adversely. In addition, a growing issue in the agriculture sector is the outmigration of younger generation in search of other livelihood opportunities. This problem is much more prominent in traditional paddy cultivation. Farmers' views suggest that the traditional farming knowledge will disappear within a short period of time unless the young generation is motivated to engage in traditional paddy cultivation. While efforts such as documenting traditional knowledge are quite important, motivating and providing an incentive for youth to take on traditional agriculture is a bigger challenge.

4. Learning from the Experience and Sharing with Others

Farmers in Sri Lanka are inherently adaptive and have a long history of adaptation to climatic variability. The continuous process of adaptation has given rise to a combination of long, medium and short-term strategies that include both individual as well as joint adaptations. The preceding sections provided an outline of key strategies and practices developed by farmers over centuries of adaptation experience. It also suggested that these practices have evolved over time with changes taking place in the physical and socio-economic environment.

Unforeseen effects of global climate change introduce a new element of uncertainty to the farmers' adaptation process. Simultaneously, socio-economic conditions faced by farmers also are undergoing rapid transformation. As a result, farmers have to make their adaptation choices under dual sources of uncertainty relating to climate as well as socio-economic change. This situation has the potential to result in significant changes in opportunities and constraints faced by farmers with a high probability to alter the choices of adaptation options available to them. Due to large uncertainties associated with climate as well as socio-economic change, one cannot prescribe a pre-determined list of adaptation measures/practices suitable for future scenarios of climate uncertainty.

4.1 Key lessons from past and present experience of adaptation

It is over optimistic to expect that the strategies/practices reviewed in this report would equally be effective under emerging scenarios as well unless they are subject to careful modifications. Changing conditions would render some of them obsolete and the others may need subtle adjustments. Hence, what is more important is the critical evaluation of farmers' experience to draw key lessons that can be useful in designing strategies to face future impacts of climate change. Accordingly, attention is directed to assess the essential aspects of the following areas of interest:

- Overall strategy of adaptation
- Individual and joint actions of adaptation
- Adaptation and local institutions
- Adaptation and indigenous knowledge

Lesson 1: Adaptation requires broad strategies, individual practices alone would not be sufficient.

According to the observations on adaptation practices of farmers, it is apparent that adaptation takes place over a course of adjustments of farmers' activities that help to minimize the level of risk and uncertainties they face. Hence, farmers' adaptive actions can best be understood as overall strategies rather than individual practices. Overall strategies of adaptation include long-term structural adaptations, medium-term strategic adaptations and short-term tactical adaptations. Adaptation measures taken at different time horizons are interconnected to each other. Moreover, farmers' adaptation strategies have a combination of individual and joint adaptation measures supported by local institutional arrangements. Village tanks and agro-wells are two long-term structural adaptations by farmers to cope with climate uncertainty under rain-fed conditions. They facilitate short-term tactical adaptations as well as medium-term strategic options available to farmers against climatic shocks. Observations suggest that in every season, farmers adjust their activities to a certain extent, responding to variations expected in rainfall pattern in the short run. Their decisions on such short-term tactical adjustments are facilitated by selection of medium-term strategic adaptations that include different agronomic practices, on-farm water and soil conservation measures, diverse range of crop and varietal selections and so on, all of which make up a part of the overall strategy of climate adaptation of farmers. Together, they enhance the adaptive capacity of farmers.

Lesson 2: Adaptation involves individual and collective actions. Changing socio-economic conditions favour private adaptations

Private actions alone may not be sufficient to face the pending uncertainties of climate change. Farmers need an optimal combination of individual and joint adaptation measures supported by appropriate institutional arrangements. Community management of village tanks provides a fine example for joint community adaptations that have evolved over centuries of experience. However, macro-scale changes that alter the socio-economic context faced by farmers tend to favour individual adaptations based on private assets than joint adaptations based on community assets. Agro-wells are an example of a private adaptation measure induced by new technologies and commercialization of farming systems. Therefore, effective utilization of common property assets for joint adaptation to climate change is largely dependent on conditions created by changing socio-economic context. Farmers' efforts on joint adaptation need to be strengthened and facilitated by appropriate institutional and policy arrangements. It requires significant modifications in current institutional arrangements.

Lesson 3: Local institutions have a key role to play in adaptation, especially in joint adaptations

When communities make joint adaptation decisions, local institutions facilitate interactions among them. In the long process of adaptation, farmers have developed structural facilities such as irrigation systems (reservoirs and canals), rainwater harvesting devices (village tanks) and means for groundwater extraction (agro-wells). Management of these structural facilities has given rise to local institutions, especially in the case of large irrigation reservoirs and village tanks, which involve collective action and common ownership of resources. In addition, many aspects of traditional farming system were governed by customary laws, shaping the behaviour of community members involved in joint adaptation. Hence, local institutions used to play an important role in adaptation strategy of farmers. Changing socio-economic conditions due to increasing population, rapid commercialization and adoption of new technologies have influenced these local institutions, sometimes favouring private adaptation measures. Construction of private wells to tap shallow groundwater resources despite the common pool nature of groundwater resources highlights this trend. Since the surface and groundwater resources in the dry zone are physically and socially interconnected common pool resources, decline of local institutions could lead to problems in sustainable management of water resources. Unless proper institutional solutions are introduced, the situation could lead to conflicts among farmers.

Lesson 4: Indigenous and local knowledge systems are an obligatory component of adaptation strategy

Farmers have developed a system of local knowledge over generations of experience that guide their decisions on adaptation. Examples of such knowledge are indigenous paddy varieties and traditional agronomic practices such as *Kekulan* method. Moreover, farmers appear to possess a reliable knowledge on local patterns of climatic variability. Local knowledge based on repeated observations of events and accumulated experience helps farmers to form expectations about climatic events that guide their adaptation decisions. Timing of farming activities to align them with a recognized seasonal/annual pattern of climatic variability is a fine example for this.

Reviewing the attributes of indigenous varieties and traditional agronomic practices such as dry sowing, it is clear that they can be used to fight climate change impacts effectively. Besides being resilient to climatic shocks, products of local knowledge have many favourable characters in terms of their environment, economic and social performances. Often, different components of local knowledge such as traditional varieties and agronomic practices go hand in hand and also are closely connected to farmers' understanding of local climatic patterns .These have helped to enhance the adaptive capacity of farmers, assisting them to minimize the inherent risk and uncertainties associated with climatic variability. With the aid of structural facilities such as village tanks and agro-wells, farmers could also further cushion the risk of climatic shocks.

In spite of many desirable features, local knowledge systems and their usage by farmers seem to have undergone certain changes. Recent transformation of the system into privately oriented commercial farming system has led to a decline in the usage of certain components of local knowledge by farmers. A good example is the replacement of indigenous varieties with NIVs together with other chemical input intensive green revolution technologies. The decline of local knowledge as a guide to farmers' decisions leaves a wide information gap that needs to be filled.

4.2 Enhancing adaptive capacity of farmers

Emerging evidence suggests that impacts of anthropogenic global climate change could significantly be different from familiar patterns of climatic variability against which farmers have raised their adaptive capacity. Besides unforeseen effects of changing patterns of climate, farmers have to cope with rapid transformation of socio-economic conditions too. Therefore, it is logical to expect that there are gaps to be bridged in farmers existing adaptive capacity if they are to face looming future uncertainties in an effective manner. Farmers alone cannot be expected to overcome this gap through their own effort and they need the support of innovative technical, institutional and policy solutions to strengthen the existing capacity in order to face the emerging uncertainties successfully. This implies that examining farmers' current practices of adaptation alone would not be sufficient to identify appropriate strategies to face the impacts of climate change. It is also necessary to contextualize farmers' current and past experience in the light of possible future scenarios of change.

Building the adaptive capacity of famers is a complex task. It needs the contribution of farmers, policy makers, researchers/academics, private sector and non-state agents (e.g. CBOs and NGOs). Individually and as community groups, farmers have to search for an innovative selection of private and joint adaptation measures. One option open to farmers is fine-tuning the available mix of long, medium and short-term adaptation measures and support facilities to face the emerging changes in an optimal manner. This can be considered as a continuation of the on-going adaptation process, perhaps at an accelerated pace than earlier. While leaving farmers with the choice of finding innovative solutions for adaptation, policy makers also have an important role to play by introducing appropriate policies, institutions and support facilities to enhance and facilitate the adaptation choices of farmers.

In the process, all stakeholders have to also take changing socio-economic conditions into consideration. Unlike in the past, farmers are operating in a market-oriented economic environment which is more open to global competition. In many occasions, the emerging socio-economic context seems to favour commercially driven private initiatives rather than joint community-based initiatives. In this backdrop, farmers' decisions on adaptation involve optimization behaviour subject to the risk and uncertainty, strategic interactions with fellow farmers and level of available information. In a commercially-driven, competitive economic environment like this, market-based strategies of adaptation also have to play an important role. A few initiatives towards this direction have already been launched. Among the market-based instruments for facing the risk of climate shocks are agricultural insurance packages, which are yet to gain a wider acceptance among farmers in Sri Lanka. Recently some agencies have explored the possibility of index-based insurance schemes.

On the other hand, any scheme of activity that aimed at enhancing the adaptive capacity of farmers cannot overlook the impact of local institutions and local knowledge systems on farmers' choices. Adaptive capacity essentially implies the capability of coping with common risks. Hence, cooperation of farmers and learning from past experiences are an indispensable part of enhancing adaptive capacity.

Overall, enhancing adaptive capacity of farmers is a complex task that needs inputs from many stakeholders. The current and traditional experience of adaptation practices is an important source of inspiration and insights to draw on but not the only one. A feasible strategy towards the goal is to develop a set of wide ranging solution strategies that include technical, institutional and policy interventions matching the possible scenarios. Such solution strategies should be developed through a participatory approach. Selected strategies should include flexible institutional mechanisms for further adjustment to specific conditions found in local contexts through community decision-making. The role of policy makers here is to create an enabling environment for the adoption of solution strategies by local user groups through cooperative arrangements.

4.3 Scope for cooperation and sharing experience with farmers in other countries of the region

Many studies suggest that developing countries are likely to face severe consequences of climate change (Bierbaum et al. 2007; IPCC 2007; Stern 2007; UNDP 2007). South Asia is a group of developing nations located in and around the tropics. It houses nearly 25 percent global population in a relatively small stretch of land area making it one of the most densely populated regions in the world. Weather patterns in the region maintain a delicate balance and are frequently subjected to disaster prone weather extremes such as droughts, floods and cyclones under the influence of strong seasonal monsoons and turbulent weather areas such as Bay of Bengal. Predictions by global studies on climate change suggest that such extreme events would increase in intensity and frequency (IPCC 2007; UNDP 2007). A majority of poor in South Asia relies on agricultural livelihoods and any adverse change in already volatile weather patterns is likely to create chaotic conditions. Overall, due to high physical susceptibility to impacts and widespread poverty, farmers in South Asia are among the most vulnerable communities to climate change.

When potential climatic consequences are taken into consideration, despite their close geographical location and commonly shared burden of poverty, countries in South Asia represent a highly diverse scenario. It has large sub-continental mainland nations with lengthy coast lines (India, Pakistan and Bangladesh), island nations (Sri Lanka) and archipelagos (Maldives) as well as land-locked mountainous countries (Nepal and Bhutan). Climatic diversity found in the area ranges from arid tropical deserts to mild temperate mountain climates. As far as impacts of climate change are concerned, predictably, island nations are more susceptible to sea level rise. A significant population of mainland sub-continent is dependent on glacial mountain flows for their main supply of water and therefore is vulnerable to future water shortages as well as to extreme events of floods. Generally, the region is located around tropics which are already a drier area and future increases of atmospheric temperature are likely to generate problems of desertification, adverse impacts on major crops and outbreaks of vector borne diseases.

In this backdrop, the adaptation practices of Sri Lankan farmers reviewed in this report provides strong prospects for cooperation and sharing of experience among farmers in the region. Many adaptation practices examined in the study can be considered as native but non-endemic. It implies that many of them have a local origin but not uniquely Sri Lankan also. For instance, evidence suggest that small manmade rainwater harvesting bodies exist in other areas of the region as well even though network of village tanks have developed locally through centuries of community efforts and consisted of certain features unique to Sri Lankan conditions. Number of studies have shown that irrigation tanks play an important role in agriculture in several Indian states, especially in South India (Balasubramanian and Selvaraj 2003; DHAN Foundation 2002; Palanisami et al. 2001). Similar situation exist regarding other key adaptation practices also—agro-wells, indigenous rice varieties and traditional agronomic practices. Rice is a staple crop in South Asian region and paddy farming is an important part of the livelihoods of farmers in many areas of the region. Likewise, well irrigation is another widely explored practice in South Asia by farmers in several countries.

In this backdrop, regional cooperation and information sharing could be very useful for enhancing the adaptive capacity of South Asian farmers due to several reasons. Some of the more compelling ones can be identified as follows.

- There is accumulated knowledge of adaptation experience in all countries, which could effectively be shared for mutual gain.
- Agro-climatic condition of the region has more or less similar characters. Therefore, high possibility exists for transferring adapting to traditional practices among the countries. For

instance, there could be traditional paddy cultivation methods in India or Bangladesh that could be adapted by farmers in Sri Lanka to address the emerging impacts of climate change.

- There are many traditional varieties that could be shared among farmers in the region. This can be especially useful in the context where only a limited number of traditional varieties are currently being used and farmers are losing traditional varieties as in the case of Sri Lanka.
- There are a number of institutes in South Asia that focus on promoting traditional agriculture. Regardless of whether these organizations are government, private, NGO/INGO there is a greater possibility of collaborative research and information sharing.

Opportunities for cooperation in the case of genetic materials (e.g. indigenous rice varieties) have already been identified and an agreement to establish a South Asian seed bank has been reached. The report discussed some of the key characteristics of village tank systems, agro-wells, indigenous varieties and traditional agronomic practices in Sri Lanka together with challenges to be faced by them during this rising uncertainty due to climate change. Findings of the study help to identify opportunities for sharing experience in both directions—as a provider and a recipient of knowledge. Information sharing is possible in many ways. One avenue is to hold regional workshops and conferences to share and disseminate knowledge on traditional agriculture and publishing the lessons learnt from such exercises.

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