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Mainstreaming the Adaptations and Reducing the Vulnerability of the Poor due to Climate Change

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Abstract

Many rural poor people in developing countries depend on agriculture and are highly influenced by climatic change. Hence, sustainable livelihood approaches are used at both policy and project level to initiate new poverty reduction activities and modify existing activities to improve livelihood incomes. Practices relevant to climate change adaptation around the world are wide-ranging and include development of technology, management, infrastructure, livestock, groundwater, and knowledge. Both structural interventions (such as building flood embankments, dikes, or seawalls or enhancing the natural setting or landscape) and nonstructural interventions (policies, knowledge development, awareness, methods and operating practices, including participatory mechanisms) have helped to reduce the impact of climate change. Further, market-based instruments such as credits and crop insurance were also developed to help poor households in many developing countries to cope with the uncertainties. The uptake of such adaptation practices is lagging, however, but informal institutions are playing a key role as they rely on enforcement methods and are not supported by the government. Mainstreaming adaptation and enhancing adaptive capacity could be increased by encouraging partnerships between informal processes and formal interventions to facilitate adaptation by the poor. The cost of adaptation is also significantly higher in developing countries. Nonetheless, more attention is needed in addressing future climate scenarios through agricultural research and development, irrigation development, infrastructure, and improved irrigation efficiency.

JEL Classification: N55, O13, Q54

Contents

1. Introduction....................3

2. Climate Change Effects on Agricultural Production....................4

3. Adaptation Experiences in the Context of Sustainable Livelihoods....................6

4. Integration of Structural and Nonstructural Approaches Into National Economies and Poverty Reduction....................10

5. Ameliorating Effects of Structural and Nonstructural Measures: Some Case Studies....................14

6. Role of Formal and Informal Institutions in Implementing Integrated Adaptation Strategies....................17

7. How to Develop National and Regional Measures to Reduce Vulnerability to Income-Generation Opportunities?....................20

8. Key Regional and National Policy Recommendations....................21

References....................22

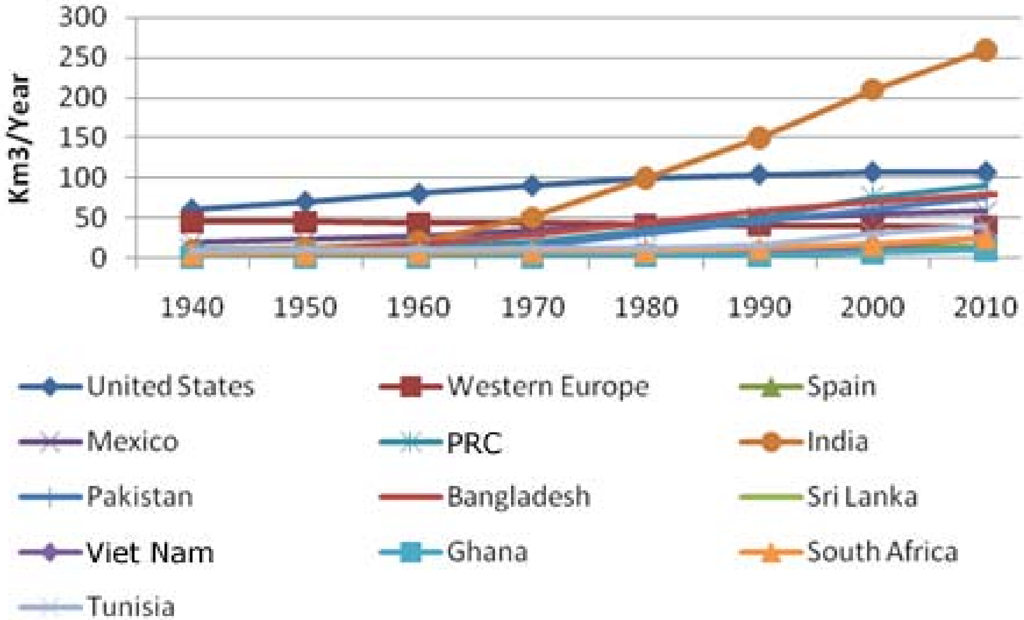
1. INTRODUCTION

Climate change has a vital role in the earth's biosphere, and climate change and variability are concerns of humankind. The consequences of climate change include melting glaciers, more or less precipitation, more (and more extreme) weather events, and shifting seasons. We are going to be affected the most by such climate changes. Climate change started in the last two centuries due to the anthropogenic release of greenhouse gases from the burning of fossil fuels. And the warming will continue during the 21st century due partly to increased aerosol loading and greenhouse gases (Held et al. 2005) ultimately influencing global warming. The main concern already raised by global warming is that climatic variations alter the water cycle. Indeed, in many cases the data show that the hydrological cycle is already being impacted (Dragoni 1998; Buffoni et al. 2002; Labat et al. 2004; Huntington 2006; Intergovernmental Panel on Climate Change [IPCC] 2007). The hydrological cycle of many climatic regions and river basins are mainly disturbed by changes in cropping patterns and land use, and overexploitation of water storages.

The hydrological cycle involves processes of evaporation and precipitation which are predicted to shift with climate change. Decrease in monsoon rainfall will reduce surface flows and net recharge of groundwater. In addition, variability of annual monsoon rainfall also leads to extreme droughts and floods, affecting agricultural production and national economies. Studies on interannual and long-term variability of monsoon rainfall have also indicated that variation in rainfall for the Indian subcontinent is statistically significant (Thapliyal and Kulshrestha 1991; Srivastava et al. 1992). Several authors have also acknowledged that there is an increasing trend in surface temperature, with decreasing trends in rainfall (Hingane, Rupakumar, and Ramana Murthy 1985; Srivastava et al. 1992; Rupakumar, Krishna Kumar, and Pant 1994; Pant, Rupakumar, and Borgaonkar 1999; Singh and Sontakke 2002; Kripalani, Inamdar, and Sontakke 1996). Monsoon rainfall is considered to be the main climatic phenomenon in the Indian subcontinent and the adjoining Asian and African regions. And the use of precipitation primarily depends upon its spatial and temporal distribution. At the same time, a high degree of correlation exists between rainfall and agricultural production (Gadgil 2003).

There are also potentially huge implications for groundwater management as a result of global warming. India has emerged as the global leader in groundwater irrigation, pumping around 220–230 billion cubic meters per year, which is twice the amount of the United States (US) (Figure 1). On the other hand, it is also noted that an average drop in groundwater levels of 1 meter would increase Indian's total carbon emissions by more than 1%, because of the additional fuel needed to extract the same amount of water (Mall et al. 2006). The area covered by groundwater irrigation in 2003 suggests that there could be a 4.8% increase in carbon emissions for each meter drop in groundwater levels. Shukla et al. (2003) also explain that every meter decline in groundwater levels increases greenhouse gas emissions by 5% in India. Nevertheless, Carter (2007) states that natural recharge of groundwater occurs in areas where vegetative cover is high.

Figure 1: Growth in Agricultural Groundwater Use In Selected Countries: 1940–2010



PRC = People's Republic of China

Source: Shah 2009

Using the available literature on climate risk information, a wide range of questions related to adaptation planning can be answered. The adaptation activities that require climate risk information are new infrastructure, resource management, retrofit, behavioral, institutional, sector, communication, and financial (Wilby et al. 2009). In addition, the elements of effectiveness, efficiency, equity, and legitimacy are also important for the success of sustainable development into an uncertain future (Adger, Arnell, and Tompkins 2005). The degree of success depends on the capacity to adapt and the distribution of that capacity.

On the other hand, the forecast studies also point out that the world water situation will undergo significant changes in the coming decades, with large geographical differences in directions and causes (Alcamo, Flörke, and Märker 2007). These authors conclude that water stress will be increasing over most developing regions but decreasing over a significant number of industrialized regions. Nonetheless, adaptation to climate change impacts is increasingly being observed in both physical and ecological systems as well as in human adjustments to resource availability and risk at different spatial and societal scales. Hence, this paper reviews some of the options mentioned for reducing the vulnerability of the poor through integrated climate change adaptation strategies. The paper explains the climate change effects on agricultural production, adoption experiences in the context of sustainable livelihoods, integration of structural and nonstructural measures, amelioration effects and their costs, the role of informal institutions in implementing, and key insights.

2. CLIMATE CHANGE EFFECTS ON AGRICULTURAL PRODUCTION

Since many rural poor people in developing countries depend on agriculture, it is one of the central arenas in which the threat posed by climate change must be confronted by research institutions and implementing agencies or bodies, be it nongovernment or government. The recurrent droughts and floods threaten the livelihood of billions of rural people who depend on agriculture for most of their needs. Agriculture is not only sensitive to climate change but it is also one of the major drivers of climate change. The climate sensitivity of agriculture is uncertain, as there is regional variation in rainfall, temperature, crops and cropping systems, soils, and management practices. Understanding the weather changes over a period of time and adjusting management practices towards achieving better yields is a challenge to the growth of the agriculture sector as a whole. Crop losses may increase if climate change increases climate variability. Different crops respond differently, and so global warming will have a complex impact. The impact of such climate change on agriculture will be one of the major deciding factors influencing future food security.

According to Aggarwal (2008), wheat production decreases over time with changes in climatic conditions. During the last decade, studies have been conducted in southeast South America to assess the impact of climate change and interannual variability on agricultural production and to develop applications for seasonal climate forecasts for the agriculture sector (Baethgen and Margin 1995; Messina, Hansen, and Hall 1999). The studies have considered crops separately and have been oriented towards identifying agronomic management practices to better cope with climate changes and variability.

Finger, Hediger, and Schmid (2010) tested the impact of climate change on Swiss maize production using a biophysical and economic approach. Simple adaptation options such as shifts in sowing dates and adjustments in production intensity with irrigation were considered. The results show that the impact of climate change on yield levels is small but yield variability increases in rain-fed production. Moreover, the authors find that changes in institutional and market conditions will influence the development of Swiss maize production and adoption of irrigation in the future. Another study, by Abraha and Savage (2006), studied the potential impact of climate change on maize yield at Cedara, KwaZulu-Natal, South Africa. The authors used CropSyst, a cropping system simulation model, using actual weather data and weather data modified by future climate change. The planting dates used are normal, 15 days earlier, and 15 dates later. The results indicate that analysis of the implications of variations in the planting date on maize production may be most useful for site-specific analyses of possible mitigation of the impacts of climate change through alteration of crop management practices.

Several approaches have been widely applied to study the impacts of climate change. Three approaches have been widely used in the literature to measure the sensitivity of agricultural production to climate change: cross-sectional models, agronomic–economic models, and agro-ecological zone (AEZ) models. The agronomic and agro-ecological zone models essentially seek to quantify the impact of these anticipated changes on agricultural production systems, mostly by simulating these changes under controlled conditions. Economic components are added subsequently to amplify these effects to larger areas and in terms of economic impact. Cross-sectional models differ in in that they recognize that during the process of climate change the systems subjected to such changes tend to evolve to minimize the risks involved, and stakeholders in these systems tend to adapt through technological and various other options. The cross-sectional studies suggest that adaptation could reduce crop losses in developing countries. The cross-sectional approach examines farm performance across different districts or regions using Ricardian-type models.

The most important advantage of the Ricardian approach is its ability to capture the adaptations that farmers make in response to local environmental conditions. It captures the actual response rather than the controlled ones. In addition, it is capable of capturing the farmers’ choices of crop mix instead of yield. A valid criticism of the Ricardian approach is that it has historically assumed the price to be in a state of equilibrium, and with significant climate change the crop price could change for a prolonged period. Under such circumstances, the Ricardian estimate would be either over- or underestimating the climate change impacts, depending on how the prices change. The bias was calculated to be small in most relevant examples of climate change (Mendelsohn and Nordhaus 1996). Palanisami, Paramasivam et al. (2009) applied the model to the coastal districts of Tamil Nadu state in India and found that annual and long-term climate variables exert significant influences on the dependent variables such as area and yield.

3. ADAPTATION EXPERIENCES IN THE CONTEXT OF SUSTAINABLE LIVELIHOODS

The role of adaptation to climate change and variability is increasingly considered in academic research. The significance of such adaptation is being recognized in national and international policy debates on climate change. The anatomy of adaptation in relation to climate change can be considered by three questions: (i) adapt to what, (ii) who or what adapts, and (iii) how does adaptation occur (Smit et al. 2000). Numerous other definitions for adaptation are available (see, e.g., Burton 1992; Smit 1993; Stakhiv 1993; Smith et al. 1996; Watson, Zinyowera, and Moss 1996). All these definitions have much in common. They all refer to adjustments in a system in response to climatic stimuli. Hence, climate change has a multidimensional effect on humanity in terms of several socioeconomic parameters. Identifying the parameters that have the ability to adjust to, or recover from, the negative impacts and take advantage of positive impacts of current climate variability is essential. Hence, research has taken advantage of climate variability across large geographical areas to study different adaptation strategies.

Scientific studies in the context of such adaptive capacity to vulnerability have also developed (Patt, Klein, and De la Vega-Leinert 2005; IPCC 2007). One of the ways to understand the livelihood systems is to analyze the coping and adaptive strategies pursued by individuals and communities as a response to external shocks and stresses such as drought, civil strife, and policy failures. There is, however, an important distinction between coping and adaptive strategies. Coping strategies are often a short-term response to a specific shock, such as drought. Actions could include switching to cultivation of drought-resistant crops or reliance on external food aid. Adaptive strategies, on the other hand, entail a long-term change in behavior patterns as a result of a shock or stress.

There is no single sustainable livelihood approach and all elements in the approaches are similar. Sustainable livelihood approaches can be used at both policy and project level to initiate new poverty reduction activities and modify existing activities to improve livelihood incomes. Sustainable livelihood thinking considers vulnerabilities of all kinds as being central to the ways in which livelihoods are shaped. Two main aspects of vulnerability are considered within the sustainable livelihood approach: (i) the extent to which different groups are exposed to particular trends, shocks, and seasonality; and (ii) how the livelihoods of the different groups are affected by these influences.

In many countries livestock is considered to be the backbone of agriculture and also an asset which can be used during periods of distress, as animals provide power and manure. There is also increasing demand for livestock products which offers market opportunities and income for smallholder producers and landless people (Kristianson 2009). Livestock production globally faces increasing pressure because of negative environmental implications, particularly greenhouse gas emissions (Steinfeld et al. 2006). In addition to these greenhouse gases, high water requirements in livestock production systems is of major concern. The relationship between livestock and the environment is complex and appears to be viewed very differently in developed countries compared with developing countries. The climate change impacts of livestock production, particularly those associated with rapidly increasing industrial livestock operations in Asia, have been widely highlighted (Steinfeld et al. 2006). Blummel, Wright, and Hedge (2010) also explain the contribution livestock make to climate change and strategies for counteracting the negative environmental effects caused by livestock. The authors have reported on feed mitigation options for reducing carbon emissions.

Till et al. (2010) reviewed 17 studies covering data from more than 16 countries in Africa, America, Europe, and Asia and found 104 different practices relevant to climate change adaptation (Table 1). The number of practices mentioned per study varied from one practice to as many as 29 different options. The practices address a wide range of adjustments in the behavior of individuals, groups, and institutions, and also in the use and development of technologies. The changes in adaptation practices range from construction of reservoirs for irrigation to adjustment to ancient farming practices. As adaptation takes place at multiple levels and involves multiple actors, introducing or adjusting crops by making simple changes to the mix of traditional crops can help smallholder farmers adjust to climate change.

Table 1: Adaptation Practices per Category

Category of Adaptation	No. of Different Practices	No. of Practices Mentioned, Including Multiple Answers
Farm management and technology	51	117
Diversification on and beyond farm	7	33
Farm financial management	5	10
Government interventions in infrastructure, health, and risk reduction	22	29
Knowledge management, networks, and governance	19	31
Total	**104**	**225**

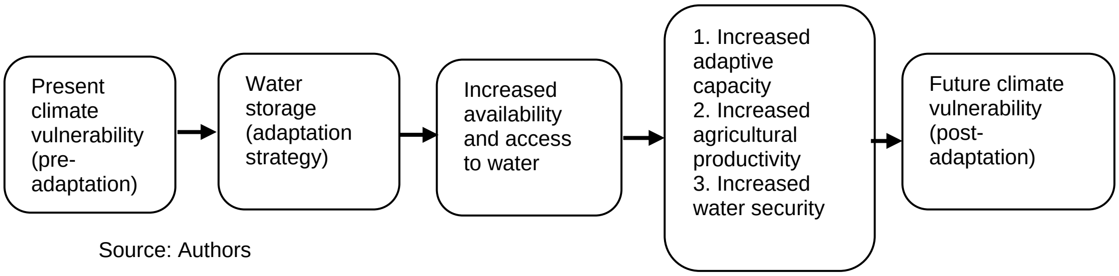
Source: Till et al. 2010.

The farm management category appears to be prominent in the literature. Most of the practices were adjustments in farm management and technology (53%), followed by knowledge management, networks, and governance (15%); diversification (14%); government interventions (13%); and farm financial management (5%) (Till et al. 2010).

The principal medium through which the societal stresses of climate change will be manifested is water (McCartney and Smakthin 2010). Although the exact impacts remain uncertain, in many places, even where total rainfall increases, climate change will most likely increase rainfall variability. Without doubt those who will be most adversely affected are the poor, who already struggle to cope with existing variability. They will find it increasingly difficult to protect their families, livelihoods, and food supply from the negative impacts of seasonal rainfall and droughts and floods, all of which will be exacerbated by climate change.

Hence, water storage plays a major role for both sustainable development and adaptation to climate change. By providing a buffer, water storage reduces risk and offsets some of the potential negative impacts of climate change, thereby reducing the vulnerability of people. Water storage can enhance both water security and agricultural productivity (Figure 2).

Figure 2: Water Storage as an Adaptation Strategy to Reduce Climate Vulnerability



Source: Authors

Storage has its own niche in terms of technical feasibility, socioeconomic sustainability, impact on health, and environment and institutional requirements. Each needs to be considered carefully within the context of its geographic, cultural, and political location. For instance, Palanisami, Meinzen-dick, and Giordano (2010) considered various tank management options in India for sustaining tank irrigation potential and water storage due to climate change. The various management options evaluated by the authors were resource mobilization through multiple uses, conversion of tanks into percolation ponds, canal lining and sluice management, tank desilting, and tank modernization (Table 2).

Table 2: Evaluation of Different Tank Improvement Strategies Under Climate Change

Strategy	**Productivity ratio**	**Equity ratio**	**B/C ratio**	**IRR** (%)
Sluice modification	1.0	-	0.5	0
Sluice management	1.1	2.6	10.0	142.0
Canal lining	1.3	1.6	1.8	24.4
Additional wells	1.3	1.5	1.7	23.5
Rotation management	1.4	1.5	10.8	159.0
Canal lining + additional wells	1.4	1.0	1.5	23.2
Sluice management + additional wells + canal lining	1.5	1.2	1.7	23.7
Rotation management + additional wells + canal lining	1.5	1.2	1.4	32.5

B/C ratio = benefit cost ratio; IRR = internal rate of return

Source: Palanisami, Meinzen-dick, and Giordano 2010

Sluice management increased rice production by 14%. The options of canal lining providing additional wells and sluice rotation increased total rice production by between 30% and 36%. The greatest production increase occurred when management and physical investment strategies were used in combination. The cost–benefit ratio is higher for the rotational water management than for sluice modification, which has the lower cost–benefit ratio and negligible internal rate of return. The internal rate of return is higher for sluice management and rotational management than for other management strategies.

The other options include food storage and management strategies for sustainable livelihood. In Ethiopia farmers are heavily reliant on rain-fed subsistence agriculture. The lack of storage infrastructure means farmers have limited ability to cope with droughts and floods. These limitations are estimated to cost the economy one-third of its growth potential. The Ethiopian case is a good illustration of the urgent need for appropriate investments in water storage to increase agricultural productivity and to ensure that farmers have options for adjusting to the expected climate changes (IWMI 2009).

The adaptation response to climate change was examined in the Cauvery basin in India. It was observed that farmers adopted several strategies in addition to changing the cropping pattern. This included drilling new bore wells, deepening existing wells, introducing water saving irrigation methods, and reducing the number of irrigations (Table 3).

Table 3: Adaptation Response of Marginal, Small, and Large Farmers to Climate Change Impact (Frequency)

	Change in rainfall pattern			Change in temperature			Change in groundwater		
Item	marginal	small	large	marginal	small	large	marginal	small	large
Impact response	14	15	14	10	13	14	7	13	14
Drill new bore wells	3		1	1	0	0	0	0	0
Deepen existing wells	1		1	1	0	0	1	0	1
Adopt drip irrigation methods	0	3	2	0	4	1	0	4	1
Change cropping pattern	5	8	9	4	8	8	1	6	8
Conventional water-saving irrigation methods	3	5	5	2	5	5	4	6	4
Grow rain-fed crops	5	3	5	3	3	8	2	6	3
Change to livestock rearing	8	5	5	6	5	5	6	4	5
Cultivate annual crop to perennial crops	2	11	5	4	11	8	3	8	9
Delay cropping season	9	11	10	10	11	10	7	9	10
Reduce the number of irrigations	8	8	8	7	8	4	8	7	6

Source: Palanisami and Ranganathan 2008.

Marginal, small, and large farmers gave the response that, due to the change in rainfall pattern, temperature, and groundwater levels, most of them are delaying and/or changing the cropping pattern and reducing the number of irrigations. In some cases farmers are changing to livestock rearing as the secondary source of income.

Among the adaptation strategies, the shift in the cropping pattern represents adaptation behavior of farmers. For instance, in Tamil Nadu, in the Cauvery River basin farmers have shifted the cropping pattern to the changing climatic conditions (Table 4). Table 4 gives the information on the cropping pattern followed by the farmers in 2003 and in 2008, and the transitions. A 5-year period is considered reasonable, as farmers' recall bias will be more if we use a longer time period. Also, within the last 5–6 years only, cropping patterns and farming activities have undergone major changes due to variation in water supplies.

Table 4: Cropping Pattern Changes from Selected Samples, 2003 and 2008

(N = 180)

Crop	2003	2008
Paddy	153	133
Maize	0	3
Sorghum	0	3
Groundnut	1	2
Cotton	20	24
Sugarcane	4	13
Coconut	2	2
Total	**180**	**180**

Source: Palanisami and Ranganathan 2008.

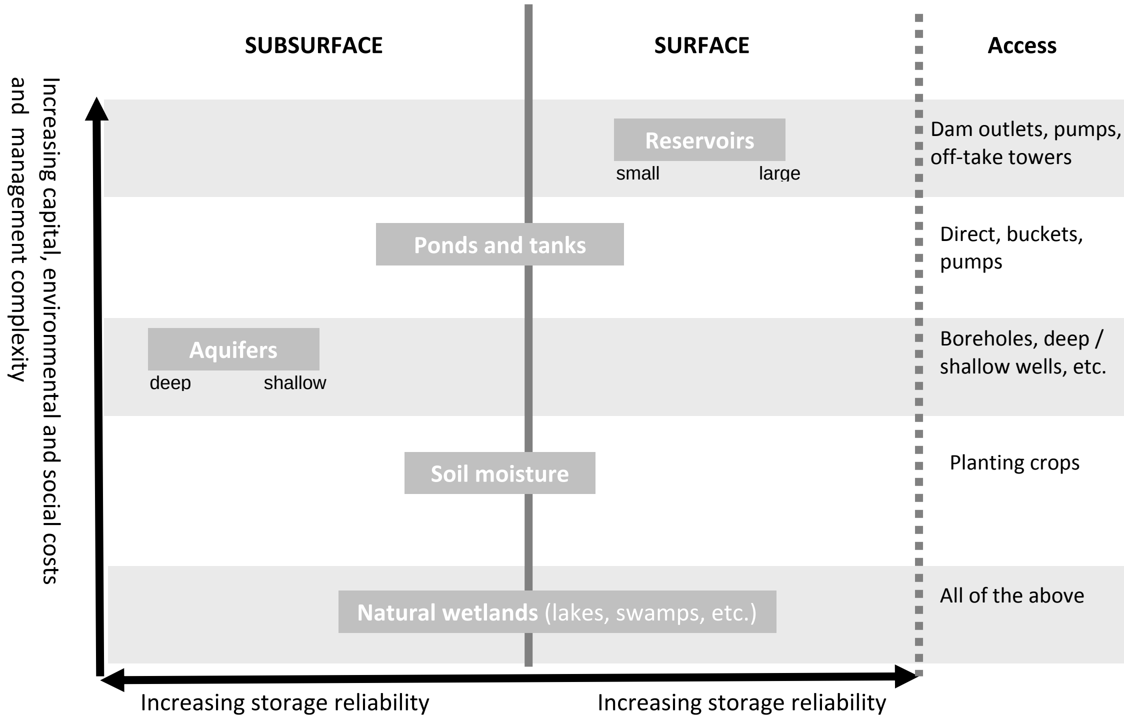
It can be seen that the cultivation of the major stable crop (paddy) has decreased more than commercial crops such as sugarcane and cotton. About 20% of farmers who raised paddy 5 years ago shifted to other commercial crops. The percentage of commercial crop growers increased, from 11% to 14% for cotton, and from 2.22% to 7.22% for sugarcane. Other farmers switched to maize and sorghum crops, which require less water. The percentage of groundnut cultivation increased from 0.56% to 1.11% and coconut cultivation remained the same (1.11%). The shift has implications for food security and overall economy for the farmers and the region.

4. INTEGRATION OF STRUCTURAL AND NONSTRUCTURAL APPROACHES INTO NATIONAL ECONOMIES AND POVERTY REDUCTION

Structural measures or approaches to climate change refers to any physical construction, including engineering measures and construction of hazard-resistant and protective structures and infrastructure, to reduce or avoid negative impacts of hazards (ISDR 2010). Under a disaster risk reduction initiative based upon present and historical experience, there is a greater likelihood that design limits for structural measures, such as flood embankments, will not be adequate in the face of climate change. Similar issues could be faced when considering changes in the frequency and severity of storms, drought, and other climate-related phenomena, including sea-level rise. Initiatives focused on climate change adaptation are more likely to design structural measures with consideration for new predicted impacts (Tearfund 2008). Structural interventions can involve building artificial physical structures in the landscape (e.g., dikes or seawalls), enhancing the natural setting or landscape to provide protection from climate-related coastal hazards, planting mangroves, beach nourishment, constructing reservoirs, etc. For water resources, water storage can be considered a continuum of surface and subsurface options (Figure 3). Each has an important role to play in the right circumstances and can contribute to food security and poverty reduction.

Not all storage and moisture control options fit all purposes. For example, increasing soil moisture can benefit agriculture but will not contribute to hydropower production or industrial and domestic water supply. In any given location the impact of different types of storage on poverty can vary significantly, with some options being much more effective in reducing poverty than others (Hagos et al. 2010). For example, boreholes may have a greater impact than small reservoirs in some circumstances, and the reverse may be true in others. It is not always clear why a particular option is successful sometimes and ineffective other times.

Figure 3: Conceptualization of the Physical Water Storage Continuum



Source: McCartney and Smakhtin 2010

For example, in Ghana, some small reservoirs have led to diversification and more stable and reliable income for farmers while others, constructed nearby under seemingly almost identical conditions, have singularly failed to bring about significant change. Hence, in any given situation, each type of storage has its own niche in terms of technical feasibility, socioeconomic sustainability, and institutional requirements, as well as impact on public health and the environment.

Nonstructural measures refer to policies, knowledge development, awareness, and methods and operating practices, including participatory mechanisms, which can reduce risk and related impacts (ISDR 2010). These nonstructural measures are well placed to serve both disaster risk reduction and climate change adaptation. The dynamism associated with training and awareness-raising means that people and institutions can apply skills and knowledge in different circumstances as they emerge. For example, awareness raising as a component of an early warning system to cope with current flood risks is well placed to form an effective basis for a different future flood scenario. Integrating climate change risks requires approaches that are more flexible, preventive, and forward-looking, and will involve legal, institutional, and policy changes. For example, climate change adaptation could be facilitated through greater use of market-based instruments such as efficient water pricing and water markets, and risk-based insurance for properties, floods, and droughts.

In the absence of market-based instruments such as credits and crop insurance, farm households in many developing countries will not necessarily grow the most profitable crops. Rather, they will choose to devote some (or all) of their land to low-risk, low-yield crops to ensure that they will survive even in worst-case scenarios in which many of the crops fail. There is an ongoing debate about how such market failures affect the extent to which, and how rapidly, farmers in developing countries adapt to climate change, and what the policy implications of this are. Adger (1999, 2003) finds that social and institutional capital is crucial to the capacity of farming communities to adapt. Eakin and Appendini (2008) argue that traditional autonomous adaptation to climate variability is more flexible than planned adaptation activities are likely to be. Shewmake (2008), studying South African farmers, argues that many farmers are already highly vulnerable to climate fluctuations, and hence risk being affected substantially by additional climate change. Eakin (2005) studies climate vulnerability in Mexican farming and finds that market integration per se makes little difference to coping capacity; even farmers who sell most of their produce may remain highly vulnerable to climate fluctuations because they have limited access to, e.g., credit or insurance markets.

Groom et al. (2008) study the role of risk aversion in the farming strategies of ostensibly profit-maximizing commercial farmers in Cyprus, and find that perceived risk matters considerably even for these farmers. Musango and Peter (2007) claim that neither policy makers nor farmers know how sensitive different agricultural activities actually are to climate fluctuations, and study the scope for adaptation strategies given these limitations. Nyong, Adesina, and Osman Elasha (2007) argue that African farmers already have a rich set of coping strategies that policy makers and others can draw upon; Barrios, Ouattara, and Strobl (2008), on the other hand, argue that historical experience demonstrates that African farmers have little capacity to cope with climate fluctuations. Candel (2007), Maddison (2007), and Nhemachena and Hassan (2007) discuss the importance of access to insurance and access to credit for autonomous adaptation. Osgood et al. (2008) study the scope for introducing crop insurance among Malawian farmers as a means of helping them cope with climate change.

The climate change and disaster risk management communities also recognize and accept that poor people are greatly affected by climate hazards. This is because poor people lack access to the means by which they can improve their resilience, whether this is in economic, social, physical, or environmental terms. So, for both adaptation and disaster risk reduction, poverty reduction and sustainable natural resource management are essential components of reducing vulnerability to hazards and climate change. The Government of India has brought about a paradigm shift in the approach to disaster management. The new approach proceeds from the conviction that development cannot be sustainable unless the approach is built into the development process.

Climate change poses a great challenge to the insurance sector but at the same time offers large-scale business opportunities. Significant progress has been made by insurers to develop new products and services to compensate for the negative effects of climate change (Mills 2007). Mills identifies 422 real-world examples from 190 insurers, reinsurers, brokers, and insurance organizations from 26 countries. Many of these products (nearly half of them from the US) have the potential to dramatically reduce greenhouse gas emissions in some of the most energy-intensive parts of the economy.

Farmers in India are also provided with certain support mechanisms in the form of subsidies on inputs, crop insurance, and soft loans to compensate for production losses due to extreme events and climate change. Over the years crop insurance has undergone many changes. At first it was based on an individual approach for assessment of losses and indemnity payment, which incurred very high administrative costs and was limited to very few crops. Later, a homogeneous-area approach was proposed for increasing the viability of crop insurance by lowering the administrative costs and improving the approach to assessing yield loss, as well as expanding the scheme to millets, oilseeds, and certain pulses. Crop insurance was linked to a farm credit where taking insurance was made compulsory for all farmers with loans and was optional for farmers without loans. In recent years, the government has proposed that the village *panchayat* (administrative unit) act as an “insurance unit” where a continuous area of 100 hectares or more is considered as a unit for paying indemnity to farmers. In a case study from

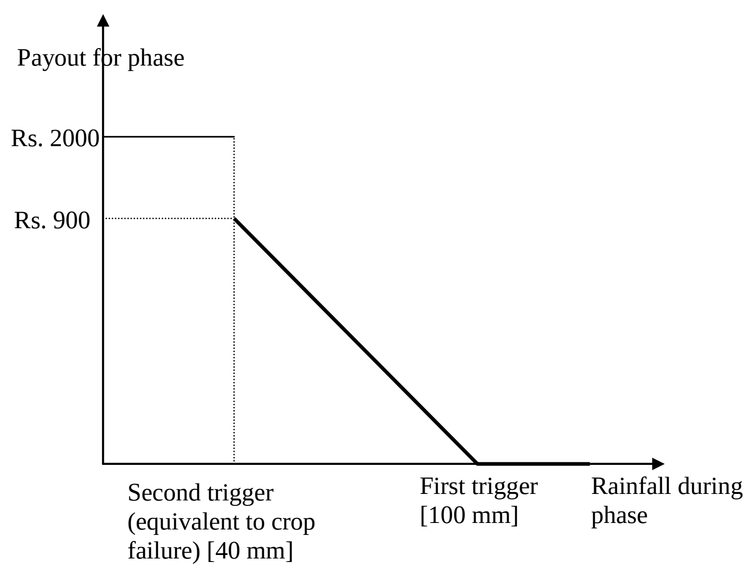
Tamil Nadu, it was found that only 60% of the farmers surveyed were aware of the crop insurance and, in this, only 56% (large farmers) of them were willing to join the plans.

The Food and Agriculture Organization (FAO) considers crop insurance as only one of the limited options for managing farm risks, and suggests that emphasis should be put on other disciplines such as plant and animal breeding, crop and animal husbandry practices, and diversification of farm enterprises.

Rainfall-based crop insurance is useful for compensating farmers for crop failure in most vulnerable agro-climatic zones in India. Palanisami, Paramasivam et al. (2009) developed the composite vulnerability index related to climate change for the different agro-climatic zones of Tamil Nadu, India. The study concluded that the southern and western zones of the state are most vulnerable to climate change. Accordingly, the deficit rainfall distribution index was derived to safeguard farmers from the adverse effect of low rainfall (Xavier, Townsen, and Vickery 2008). The deficit rainfall insurance scheme can be used to provide insurance protection to farmers against reduced rainfall which is deemed to adversely affect the crop during its cultivation period. Deficit rainfall insurance payouts are linked to accumulated low rainfall. The Government of India has introduced weather-based crop insurance in most states to overcome the risks.

The payout structure varies from crop and the phase (Figure 4). The strike or upper threshold corresponds to the 30-year average accumulated rainfall of the respective reference weather station. The exit or lower threshold is intended to equal the water requirement of the respective crop necessary to avoid complete crop failure. From Figure 4 it can be observed that the rainfall insurance policy pays zero if accumulated rainfall during the phase exceeds the first trigger or upper threshold. Otherwise, the policy pays the required amount for each millimeter of rainfall deficiency relative to the first trigger, until the second trigger or lower threshold is reached. If rainfall is below the second trigger value, the policy pays a fixed maximum indemnity.

Figure 4: Structure of Insurance Contract



Source: Xavier et al. 2008

Another explanation for farmers' limited adoption of technical options to adapt to climate change begins with their willingness and ability to accept new practices (Siebert, Toogood, and Knierim 2006). Farmers' willingness depends on their economic interests, social and ecological values and norms, awareness of the problem, and self-perception. Roncoli, Ingram, and Kirshen

(2002), Roncoli, Ingram et al. (2004) and Roncoli, Jost et al. (2005) studied farmers' understanding of seasonal rainfall forecasts in Burkina Faso. They found that farmers think of rainfall as a process rather than in terms of a quantity, as scientists do. The authors argue that farmers will not accept forecasts unless the forecasts are adjusted to their understandings. Patt and Gwata (2002) confirm these findings. A study in Zimbabwe by Grothmann and Patt (2005) revealed that farmers' acceptance of seasonal climate forecasts increased when the forecasts were provided as part of local indigenous climate forecasts. Farmers are more likely to accept external climate forecasts when they can see them in the context of existing practices.

Researchers are also developing climate change forecasts by using innovative approaches to assess the uncertainty of climate impacts (Immerzeel 2008; Mendelsohn et al. 2000). Such climate forecasts tools and scenarios can help to evaluate sector-specific incremental changes in risk over the next few decades (Wilby et al. 2009). Climate scenarios are used mainly for impact assessment since 1990. According to Wilby et al. (2009), climate risk information should be integrated into adaptation planning. It is now a priority for many donor agencies because this planning will help to prepare for climate change impacts across sectors. Table 5 lists adaptation activities that require climate risk information.

Table 5: Examples of Adaptation Activities that Require Climate Risk Information

Adaptation	Examples of Activity Using Climate Information
New infrastructure	Cost–benefit analysis, infrastructure performance and design
Resource management	Assessment of natural resource availability, status, and allocation
Retrofit	Scoping assessments to identify risks and reduce exposure to extreme events
Behavioral	Measures that optimize scheduling or performance of existing infrastructure
Institutional	Regulation, monitoring, and reporting
Sector	Economic planning, sector restructuring, guidance, and standards
Communication	Communicating risks to stakeholders, high-level advocacy, and planning
Financial	Services to transfer risk, incentives, and insurance

Source: Wilby et al. (2009)

Climate scenarios in adaptation planning also depend on the adaptation assessment approach, spatial and temporal scales at which adaptation is taking place, availability of technical and financial capacity to handle scenario information, and the type of adaptation being considered (Dessai, Lu, and Risbey 2005).

5. AMELIORATING EFFECTS OF STRUCTURAL AND NONSTRUCTURAL MEASURES: SOME CASE STUDIES

According to Adger et al. (2003), adaptation is the adjustment of a system to moderate the impacts of climate change to take advantage of new opportunities or to cope with the consequences. Stern (2006) relates adaptation to building resilience, and recognizes that it will be a key response to reduce vulnerability to climate change. Adaptation is not limited to discrete projects (Leary 1999), such as dams and sea walls; it includes a wide range of adjustments by entities such as households, firms, and other institutions in response to the effects of climate change and variability. These include such activities as managing natural resources, input mixes in production, and changes in laws, programs, policies, and investments. In general, adaptation to climate change presents itself as an economic problem because it addresses the bigger problem of allocating scarce resources to attain sustainable development. Ignoring climate change by not building adaptive measures will eventually damage economic growth and other aspects of human and natural well-being, and threatens to reverse the gains made in these areas over the past several decades. The risks posed by climate change to development will be managed more efficiently by putting them in the mainstream of development (GTZ 2007).

Adaptation measures as a response to climate change can be short run or long run (Table 6). Looking at these adaptation categories, the author (Stern 2006) makes it clear that they will not consist exclusively of explicit adaptation decisions. Firms will presumably seek to maximize their profits and households their utility, no matter what the climate situation and no matter what planned adaptation policies are being carried out. The climate and the planned adaptation will affect what choices firms and households can make, and hence also affect their behavior, but they will not affect their overall objectives; they will affect only how successful firms and households are in reaching those objectives. In practice, this means that cost–benefit analysis is likely to be the only framework within which it is meaningful to assess climate change policies (Metroeconomica 2004; Lecocq and Shalizi 2007; Agrawala and Fankhauser 2008).

Table 6: Examples of Adaptation Types

Type of response to adaptation	**Autonomous**	**Planned or policy driven**
Short run	Making short-run adjustments (e.g., changing crop planting dates), spreading the losses (e.g., pooling risk through insurance)	Developing greater understanding of climate risks (e.g., researching risks and carrying out a vulnerability assessment), improving emergency response (e.g., early warning systems)
Long run	Investing in climate resilience if future effects are relatively well understood and benefits easy to capture fully, e.g., localized irrigation on farms	Investing to create or modify major infrastructure (e.g., larger reservoir storage, increased drainage capacity, higher sea walls). Avoiding the impacts (e.g., land use planning to restrict development in floodplains or in areas of increasing aridity)

Source: Stern 2006

In agriculture, the adaptation focus on the implementing measures that help build rural livelihoods is on those most resilient to climate variability and disaster. Even though a large number of studies on central estimates of adaptation costs have not emerged, a relatively narrow range of global estimates has emerged from various studies following a variety of methodologies (Stern 2006; Adger et al. 2007; UNFCCC 2009; Parry et al. 2009; Nelson et al. 2009). Based on the information provided in the national adaptation programs of action of five least-developed countries, immediately necessary adaptation activities will require total funding of US$133 million, which is about US$25 million on average for each of these countries (Stern 2006). Extrapolation of that to all 50 least-developed countries implies there is a need for investments of around US$1.3 billion. According to Stern (2006) the overall multinational commitments needed to assist developing countries to adapt to climate change are estimated at US$234 million–US$634 million.

Nelson et al. (2009) examine welfare in future scenarios with and without climate change, estimate the costs of adapting to climate change, and examine the benefits in terms of reduced vulnerability to climate change. According to the authors, climate change adaptation is increasingly on the agenda of researchers, policy makers, and program developers, who are aware that climate change is real and threatens to undermine social and ecological sustainability. Climate change increases child malnutrition and reduces calorie consumption dramatically. Thus, aggressive agricultural productivity investments are needed to raise calorie consumption, which means it is important to increase investments in adaptation measures (Table 7). In agriculture, this will include investments in agricultural research, rural roads, and irrigation infrastructure that enhance productivity, which in turn will reduce child malnutrition.

Table 7: Developing-Country Agricultural Productivity Investments to Respond to Climate Change

Investment area	**Increase** (%)
Growth in crop yield over baseline	60
Growth in animal numbers	30
Production growth of oils and meals	40
Growth in irrigated area	25
Growth in rain-fed area	(15)
Growth in basin water efficiency by 2050	15

() = negative

Source: Nelson et al. 2009

The additional annual investments needed to return the child malnutrition numbers to the no climate-change results are US$7.1 billion under the wetter National Center for Atmospheric Research (NCAR) model scenario and US$7.3 billion under the drier Commonwealth Scientific and Industrial Research Organisation (CSIRO) model scenario. Sub-Saharan African investment needs dominate, making up about 40% of the total, the vast majority of which is for rural roads. South Asia investments are about $1.5 billion per year, with Latin America and the Caribbean close behind with $1.2 billion per year. East Asia and the Pacific needs are just under $1.0 billion per year. Agricultural research is important in all three of these regions, as are irrigation investments. Unlike Sub-Saharan Africa, road investment needs in these regions are relatively small. With additional investments in developed countries, spillover effects to the developing world slightly reduce the need for adaptation investments. For example, in the NCAR scenario, the annual investment need is $7.1 billion if productivity expenditures are only in the developing world. With developed-country productivity investments, that amount drops to $6.8 billion. The key messages embodied in these results point to the importance of improving the productivity of agriculture as a means of meeting the future challenges of climate change (Nelson et al. 2009).

Kumar and Parikh (2001) and Sanghi and Mendelsohn (2008) have estimated that, under moderate climate change scenarios, there could be about a 9% decline in farm-level net revenues in India. More adverse impacts are expected in high-value agricultural regions such as Punjab, Haryana, Uttar Pradesh, Gujarat, and Rajasthan.

Another study has predicted that the increase in maximum temperature will result in a net revenue loss of 79% in Trichy, 34% in Cuddalore, and 33% in Perambalur districts of Tamil Nadu. The authors have also developed predictions of climate change scenarios for Tamil Nadu by using the HADCM3 scenario (Palanisami, Ranganathan et al. 2009).

Using these values, as well as the results of the marginal effects from cross-sectional data, projected net losses in revenue per acre associated with HADCM3 scenarios for different districts was calculated (Table 8). The results show that the HADCM3 scenario will have maximum effect on Perambalur farmers, with a loss of net revenue of about Rs3,000/acre (Rs7,350 per hectare [ha]), followed by Trichy farmers, whose losses will be around Rs2,740/acre (Rs6,710/ha). But the Nilgiris has an increase in net revenue of Rs11,000/acre

(Rs26,950/ha) with the raise in temperature and loss of about Rs7,800/acre (Rs19,110) due to minimum temperature. This is because Nilgiris is a hill region and any increase in temperature will be helpful to the crops as the region already has a very cold climate and in many years the crops sustain frost damage. The situation is reversed in the case of the Perambalur region, and the rest of the regions have revenue losses due to maximum and minimum temperature variations. Net revenue losses due to rainfall are not at higher rates in all the selected regions as per the HADCM3 scenarios.

Table 8: HADCM3 Projections and Losses in Net Revenue Derived From Models Using Secondary Data

(Rs '000/ acre)

Region	Max Temperature	Rainfall	Min Temperature
Vellore	-1.28	-0.02	-0.94
Dharmapuri	-1.36	-0.02	-1.39
Perambalur	-3.02	-0.01	2.46
Ramnad	-0.30	0.00	0.78
Nilgiris	11.63	0.03	-7.82
Cuddalore	-1.79	0.02	-0.24
Kanyakumari	0.34	-0.02	-0.06
Tanjavur	-1.42	0.01	-0.44
Coimbatore	-1.35	-0.03	-1.57
Trichy	-2.74	-0.01	-0.22
Total (except Nilgiris)	**-1.44**	**-0.01**	**-0.18**

Source: Palanisami, Ranganathan et al. 2009

6. ROLE OF FORMAL AND INFORMAL INSTITUTIONS IN IMPLEMENTING INTEGRATED ADAPTATION STRATEGIES

The global scale of climate change involves large-scale policies. Costs of information and enforcement increase when a top-down policy is applied (Williamson 1985). Often local knowledge and capabilities are disregarded. In this case, a distinction between formal and informal institutions offers insight. Formal institutions are legally introduced and enforced by state institutions, which are embedded in state operations based on laws that are enforced and monitored by the government. Informal institutions rely on enforcement methods not supported by the government. They also have roots in the local communities and are embedded with the existing customs, traditions, rules of conduct, and beliefs. At these lowest levels, informal institutions prevail over the formal ones (Sokile and Van Koppen 2005). In fact, informal institutions are partly extensions and local-level translations of formal institutions, and formal institutions are also derived from and depend on the informal ones for their stability and strength (Saleth and Dinar 2004). Although formal institutions play a bigger role in modern societies, the importance of informal institutions should not be disregarded (Ingram and Neel 1998; World Bank 2002). Both types of institutions have a role to play in adaptation to climate change—formal institutions offer rigid enforcement, while informal institutions use locally rooted compliance based on tradition.

For instance, in India, technology of water use for agriculture has developed over a period of many centuries and its history has run parallel with patterns of human settlement and formation of village societies (Steward 1955). Therefore, water rights are not something which were given to water users but were gained or acquired by them over a long period of time. These are called customary rights and, even though they vary from state to state, they have some common ground such as community rights and informal settings. The impacts of such institutional settings will certainly vary from region to region and even from basin to basin. This poses serious challenges for water resource management in response to a changing climate.

Informal rules reflect the socioeconomic and political structure of society at any given time, and are not static like formal rules but are subject to quite a good deal of change. Historically, informal communities of water users undertook all critical functions of water management, including construction of small diversion weirs and canal networks. The water rights enjoyed by them were due to their hard efforts in construction as well as in maintenance. The community had complete control and access over water resources within their jurisdiction. The system functioned well and there existed well laid-out rules and regulations to govern all critical functions of water management, such as system maintenance, water sharing, conflict resolution, collection of penalty for nonparticipation in maintenance, etc. However, traditional irrigation management had an enforcement mechanism with community rights, which facilitated the smooth functioning of irrigation systems even under changing climatic conditions.

Table 9: Institutional Adaptation Strategies: Case Studies

Author	Region/ Country	Institution	Activity	Adaptation Strategy
Luna 2001	Philippines	Informal	Disaster management	Integrated relief and disaster management
UNFCCC 2002	Northern Tanzania	Formal and informal	Working closely with traditional institutions	Engaging in agroforestry using degraded crop lands and rangeland
Lasco et al. 2006	Philippines	Informal	-	20 different practices such as tree planting, conservation, community-based organizations etc.
Kakumanu 2009	India	Informal	Water resource management	Creating awareness and training on water management activities
Fleming and Smit 2010	Canada subarctic region	Formal	Facilitation and limiting capacity to adapt to changing conditions	Decrease snowfall, pack and changing wildlife abundance and migration patterns

Source: Authors

Case studies from various countries also show the role and success of formal and informal institutions (Table 9). Between 1995 and 2000, more than 75% of disasters and 95% of disaster-related deaths in the Philippines were due to climate hazards, with typhoons, tornadoes, flooding, and landslides being the most prominent hazards. After the Marcos regime, many development nongovernment organizations (NGOs) in the Philippines integrated relief and rehabilitation strategies into their action program. These strategies include socioeconomic projects to reduce local vulnerability, mediation of the flow of government and international assistance, community-based disaster management, small-scale infrastructure development, and training for capacity building. In one interesting case, NGO staff focused on vulnerable communities to identify local leaders, conducted hazard and vulnerability analysis, initiated training related to disaster management, and established village committees to foster effective disaster responses. Other NGOs have provided financial and technical assistance to help in community-based disaster management activities. These examples show the critical role of local informal institutions in any area-based effort to undertake adaptation measures (Luna 2001).

Mainstreaming adaptation and enhancing adaptive capacity could be increased by encouraging partnerships between informal processes and formal interventions to facilitate adaptation. An example of the interaction between formal and informal institutions can be seen in the Shinyanga region in northern Tanzania, which is occupied mainly by the agropastoral Sukuma people. The region used to be extensively forested, but relocation schemes, drought, overgrazing, cash-crop cultivation, destruction of forests to wipe out tsetse fly, and increased demand for firewood have reduced productivity and increased soil erosion. Using indigenous knowledge, the Sukuma people practice a natural resource management system called *ngitili*—a Sukuma word meaning enclosure. Working closely with traditional institutions at the local level, a project under the Ministry of Natural Resources and Tourism has revived the Sukuma people's traditional conservation practices. The Shinyanga landscape is now changing. Working through local institutions, farmers are engaging in agroforestry using degraded croplands and rangelands, employing traditional village guards, and conserving vegetation by closing off ngitilis for regeneration. Through planting activities and community involvement, ngitilis today provides livelihood resources for communities in the region when environmental conditions deteriorate (UNFCCC 2002).

The Lasco et al. (2006) survey of the types of adaptation practices in the Philippines shows more than 20 practices in which local informal institutions play a role. These practices include tree planting and reforestation, selection of conservation, construction of drainage, controlled burning, community-based organizations, a logging ban, coordination among local units, information sharing, development of water resources, research and capacity building, and provision of relief goods. The local institutions themselves are playing a key role in ensuring the success of adaptation measures in different sectors such as water and forests. The most important lessons from the survey concern the need to examine the trade-offs across adaptation options, involve community members to lower the cost of interventions, and effectively present the local needs to policy makers and external actors.

From the point of water resource management, the study by Kakumanu (2009) argues that informal institutions set up with the support of NGOs for creating awareness and training have improved water productivity by 21% in comparison with formal institutions in Andhra Pradesh, India. This improvement as water becomes more scarce with the changing climate would have added advantage.

Nonetheless, little of the existing literature on the subject has attempted to identify the factors relevant to better institutional performance. In attempting to identify the factors that are likely to promote better performance on the part of local institutions, community institutions for resource governance and decentralization of governance can be considered. The relevant factors identified in these institutions are the characteristics of institutions, context of institutions, characteristics of groups served by the institutions, and characteristics of ecological context (Agrawal 2001; Baland and Plateau 1996; Ostrom 1990). Hence, considering the factors relevant to adaptation and policy-relevant framework in the context of rural institutions and livelihoods would enhance adaptation strategies.

7. HOW TO DEVELOP NATIONAL AND REGIONAL MEASURES TO REDUCE VULNERABILITY TO INCOME-GENERATION OPPORTUNITIES?

Adaptation is increasingly seen as an inevitable answer to the challenges posed by climate change. It is an essential ingredient in both the adaptation component and in the development of adaptation policies. In the discussions above, it is clear that an important first step in the economic analysis of adaptation to climate change is assessment of the impacts of various climate change scenarios at disaggregated levels. National- and state-level assessments of each country are needed for designing effective adaptation strategies. Such estimates will be important for climate negotiations as well as for resource allocation. A useful way forward may be constructing cost curves that demonstrate the costs of multiple adaptation strategies. In addition to analysis of the costs and benefits of adaptation strategies, careful economic analysis of the instruments that could facilitate adaptation is thereby essential.

Researchers should also aim to better understand **water resources and storage** under different social and ecological conditions. This will provide insights into potential climate change impacts on water supply and demand, the social and environmental impacts of different storage options, and the implications for scaling-up small-scale interventions. Adaptation to climate change and associated economic analysis are not widely understood, especially in policy and research circles in many developing countries. Hence, there is a need to design short-term training programs for different stakeholders, and for careful long-term learning through collaborative research.

There is a need to think about **new tools such as Ricardian models** for forecasting autonomous adaptation to climate change. Used widely, this model can help inform policy makers about the future needs of agriculture policy. It can help forecast in what ways farmers will wish to adapt. Policy makers can use these forecasts to put policies in place that make the particular adaptation easier.

Crop insurance is a risk management mechanism to cover crop failure. Most farmers are not aware of the **weather-based insurance** premium calculations in many parts of developing countries. Hence, providing capacity building and awareness programs would help teach farmers about the procedure. Research studies should also be developed to establish the farmers' willingness to pay for the weather insurance schemes, and their socioeconomic conditions. This would give policymakers an idea what premium farmers would be willing to pay for risk management due to climate changes. The research studies developed on weather-based insurance is limited to dry or rain-fed climatic conditions only; studies or concepts have to be further extended to irrigated areas and crops.

State or national governments have to carry out studies of the river basins or regions to identify vulnerable areas by calculating the **vulnerability index**. This would help policy makers to concentrate more on the highly vulnerable areas by developing adaptation strategies. Identification and analysis of the existing adaptation mechanisms to climate change in different environments will help to fine-tune the strategies for mainstreaming and up-scaling them with a research and policy focus.

Since climate change is gradual and the impact is marginal over years, it is important to examine appropriate **short- and long-term interventions**. The adaptation practices being utilized in extreme situations should be documented, and the documented interventions should be grouped under short-term and long-term categories and need to be implemented. Short-term interventions normally include the adoption of crop varieties and water management practices to suit the changes of climate. The transaction cost of these interventions should be worked out so that the successful ones can be replicated. Long-term interventions are normally the government programs that help address climate change impacts. Such strategies could also resolve the funding problem. Policy makers should also concentrate on the highly vulnerable areas and accordingly given certain adaptation practices through capacity building programs. This primarily includes the creation of storage facilities both at the community and farm level.

8. KEY REGIONAL AND NATIONAL POLICY RECOMMENDATIONS

In light of the above discussions, the following set of recommendations are made:

- Study and quantify the extent of the climate change impact in different regions and countries using updated information.
- Examine the extent of adaptation mechanisms needed under different country situations and work out the quantum of different investments needed, such as in research, irrigation, infrastructure, technology transfer, etc. In the case of agriculture, research and development aspects that boost crop productivity should be targeted.
- Design and implement appropriate interventions through regional stakeholder participation.
- Make agriculture adaptation a key agenda point within the international climate negotiation process, with food security as the main goal.
- Converge the ongoing and proposed development programs towards climate change adaptation, with active participation of the community and government agencies. Technology transfer and up-scaling should be given priority during implementation.
- Validate the adaptation strategies and cost of adaptation periodically through national and international consultations.

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