Tracking Adaptation Pathways and Identifying Strategies for Enhancing Grass-root Resilience to Climate Change

Synthesis of Case Studies from Selected Countries of Asia

Bangladesh, China, India, Sri Lanka, Thailand, and Viet Nam

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Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience

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REPORT

Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience (RETA-6439)

Tracking Adaptation Pathways and Identifying Strategies for Enhancing Grass-root Resilience to Climate Change

Synthesis of Case Studies from Selected Countries of Asia

(Bangladesh, China, India, Sri Lanka, Thailand and Viet Nam)

Research Program on Markets, Institutions & Policies

International Crops Research Institute for the Semi-Arid Tropics

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Table of Contents

List of Tables

List of Figures

Boxes

I. Acknowledgements

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II. Executive Summary

The recent 4th Assessment of the International Panel on Climate Change (IPCC) provides the latest revelations on the science, impacts, and potential measures to address climate change. Nevertheless, the state of knowledge that is available at the global level is far from comprehensive. Whereas there has been high focus on continental understanding, the same cannot be said at regional and sub-regional levels (INCAA 2010). The early action plans in response to growing awareness on the challenges of climate change, the governments worldwide, including those from developing countries, have strengthened confidence, capacity, knowledge, and experience to focus on agricultural production systems that are resilient to climate risks.

Motivated by growing interests and building on available knowledge, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) together with six countries in Asia undertook the challenge to "know in order to act" and implemented the project entitled "Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience ".

Funded by the Asian Development Bank (ADB), this study is a comprehensive effort to analyze the vulnerability and adaptation strategies by farmers in the marginal regions of Asia in the context of a changing climate or increasing climate associated variability and risk. We hope the results will provide a basis for further suggestions on strategies and policies to reduce risk and vulnerability, build and strengthen adaptive capacity, to provide options for farmers to be able to cope better with the future climate change.

This study focuses on the most vulnerable farmers in the semi-arid regions of Asia. Six countries participated and their major collaborating Institutes are as follows:

Bangladesh	Center for Policy Dialogue (CPD)
China	Guizhou Academy of Agricultural Sciences (GAAS)
India	Central Research Institute for Dryland Agriculture (CRIDA)
Sri Lanka	Council for Agricultural Research Policy (CARP)
Thailand	Chiangmai Field Crops Research Centre (CFCRC)
Viet Nam	Viet Nam Academy of Agricultural Sciences (VAAS)

This report draws attention on four major components central to the agenda of climate change. The study is designed to realize four key outputs based on key research questions:

1. In the context of climate change, based on a synthesis of knowledge derived from primary data analysis, ascertaining trends and variability that may affect crop productivity and hence livelihood: What is/are consistent across the study/target countries, and what is specific to each country based on a systematic investigation of the degree of climate change vulnerability?

2. The second component entails linking changes in climate and climate variability to crop yields, cropping pattern, income, and employment. Thus, enables the development of a coherent picture on the impact of climate change on livelihood.

3. Third component attempts to verify validity of farmer's experiential knowledge and perception against scientific knowhow based on climate-data analysis. To ascertain whether perception relating to climate change match reality; the perceptions of climate change and rainfall pattern are compared with actual data.

4. The last component focuses on how household indigenous knowledge help communities to adapt and cope. Does perception on climate change translate to behavioral change or adaptive measures at the micro-level across the study countries? It combines and links the traditional, local, and indigenous knowledge on climate change with scientific knowledge on climate change.

5. Based on the above, provide policy options to help government ensure that farmers' are able to cope with the deleterious effects of climate change.

This synthesis report summarizes key findings of the project. It systematically presents answers to the following queries:

- Do we have coherent messages on trends from long-term time-series data on climate parameters, eg. Precipitation and minimum & maximum temperatures?
- Do we see shifts in cropping patterns (annual/perennial, geographical)? If shifts exist, are they driven by: (i) market opportunities, (ii) changing consumer patterns, or (iii) biophysical elements or changes in climate?
- Does crop and system diversification (especially dairy) seem to be a common resilience strategy?
- Is off-farm income increasing in importance?
- On livestock mix (including poultry): Does this reflect the changes in the need for traction power, demand for small/large ruminants, livestock mix (including poultry) increasing demand for chicken meat/eggs, or all of the above?
- What is the importance of community collective action and kinship?
- Is there market access for inputs and outputs?

The grass root level elicitation of farmer's perceptions at the micro level was undertaken in 22 villages/communes from marginal semi-arid environments in the six countries during 2009-2010. The summarized details of the report are presented in broad sections as follows:

Climatic characteristics and Vulnerability to Climate Change

As an initial step to understand climatic trends, long-term data sets were analyzed at various levels (country/regional/district) to ascertain the prevailing trends in these countries. The country-level analysis showed that the annual average temperature is rising significantly in all countries. Even though a majority of countries have not experienced substantial long-term trends (positive or negative) in rainfall, the variability in rainfall and occurrence of extreme events has increased in the recent years. Regional-level analysis also followed a similar trend in temperature and rainfall. However, an exception is seen with a decreasing trend in rainfall and rainy days in the drought and flood-prone areas of Bangladesh, and Guizhou province of China. In India, the annual rainfall increased significantly in Andhra Pradesh and no significant trend was found in Maharashtra. Analysis at an even more disaggregated (district) level demonstrated some differences from aggregated level. In the districts, rising trends in temperature and increasing rainfall variability, i.e., change in onset of monsoon, intra-seasonal droughts, flood occurrence, high rainfall events, and higher probability of drought occurrence etc., are the main features.

In Bangladesh, rainy days showed a decreasing trend in drought-prone regions and an increasing trend in flood-prone regions and in Viet Nam, rainfall increased significantly in Ninh Phuoc district over the years. In general, floods in Bangladesh and Thailand, droughts in India, Sri Lanka, and China and sea water intrusion in Viet Nam are some of the distinct climate-related issues of these countries.

This project seeks to identify regions vulnerable to climate change in these targeted countries of South, Southeast Asia, and China. A comprehensive review of future climatic projections for these countries signaled that impact could be severe in the years to come. In most of these countries, annual rainfall is projected to increase in future; however, its distribution is not clear. Along with rainfall, temperature will rise significantly in the future and successive rise in sea levels threaten countries having long coastlines.

Assessing climate change vulnerability in agriculture is essential in identifying regions most exposed to its impacts and targets such regions for building resilience against impacts of climate change. To characterize regions based on vulnerability to climate change, a detailed vulnerability analysis was carried out in these target countries. A set of agro-socio-economic indicators were used to classify regions based on their extent of vulnerability. Vulnerability analysis showed that the majority of districts in the Indian semi-arid tropical regions, southern districts of Sri Lanka (Seo et al. 2005), major flood- and drought-prone regions of Bangladesh, northeastern region of Thailand, majority of the districts of Viet Nam including the Mekong river delta (a major rice bowl) and arid and semi-arid northwestern region of China fall under the category of 'vulnerable to highly-vulnerable' to climate change. This analysis ascertains that all the semi-arid marginal regions of the South and Southeast Asian countries are highly vulnerable to climate change. There is also local variability within countries; hence there are areas in a country where risks of climate change are high, and low among others.

Divergence in Macro and Micro- Level Information

National climate-related policies and programs are often formulated using the aggregated/macro-level information, projections, modeled scenarios, etc. They seldom consider the micro-level context on response behaviour, existing situation, trends outlook, and coping capacity mainly due to lack of information.

This study demonstrated as to how observed rainfall data varied at different levels (National→ State→District→Mandal/Tehsil→Village) in India and Thailand. A clear divergence of trend was distinctly visible and a huge disconnect between macro- and micro-level information on rainfall pattern was found. In most of the developing countries, absence of infrastructure for gathering information on micro-level context often limit the policy machinery to utilize macro-level information for formulating policies for micro-level impacts and thereby missing the targetted need based approach. This could only be overcome by acquiring micro/village-level information by institutionalizing an efficient mechanism for collecting, collating, and channelizing micro-level information especially related to weather/climate indicators so as policymakers can use them to formulate effective climate-related measures.

Dynamic Changes in Cropping Patterns at Micro-level

Across South and Southeast Asian countries, farmers are trying out new short duration varieties that are less water demanding. Farmers are also replacing water intensive crops with drought-tolerant cash crops to optimize their incomes as well as reduce their water needs. They are changing their crop calendar to adjust to the uncertainties of rainfall. These are the important common adaptations of farmers to address the increased variability and uncertainty in rainfall in the marginal rain-fed environments across the countries.

Among the farmers in South Asian countries, those in rainfed regions of India have shifted from cereal cultivation to short-duration drought-tolerant or less water demanding crops such as soybean during the last four decades. In places where new irrigation potential has been created like canals in Shirapur, Maharashtra, sugarcane has replaced many other prevalent crops which increased incomes. Mixed cropping is being practiced in selected villages like Dokur and Kanzara in Andhra Pradesh as a measure to reduce the risk of income failure. Fodder crops such as maize, grasses, and fodder sorghum have gained importance of late as the dairy industry has started to grow in some villages like Aurepalle in Andhra Pradesh and Shirapur in Maharashtra.

In Sri Lanka, cultivation of finger millets, black gram, and oil seeds have decreased in recent times, while fine cereals and vegetables are increasing. Cotton cultivation is decreasing in most of the villages. Cultivation of annual crops is being reduced in recent decades and farmers are shifting to perennial crops in rainfed villages like Mangalapura in Puttalam district. The shift to perennial crops in Mangalapura is mainly in response to increased uncertainty of rainfall as weatherproofing mechanisms like development of irrigation potential did not take place and farmers not being able to cope with crop losses. Hence, farmers perceived that perennial plants like cashew will fare better over time under these harsh rainfed environments.

In Southeast Asian countries, rice is the main crop. In addition to rice, cassava is also grown as a main crop in Thailand both in upland and lowland villages. However, in recent times, the cultivated area of cassava is increasing at the expense of rice.

Farmers feel that even in the lowland and mid-lowlands villages, cassava provides a more stable yield where standing water does not accumulate. Traditional water-intensive crops like Kenaf/Roselle are slowly disappearing. In Viet Nam, hybrid maize is being replaced by inbred maize due to its low water requirements. In some communes, like Phuoc Nam in Ninh Thuan province, their rice-cultivated area has decreased drastically due to water unavailability. In coastal villages like in Phouc Dinh commune, farmers are switching to aquaculture due to saltwater intrusions. In the coastal areas where farmers perceived saltwater intrusions which altered soil properties, farmers shifted to aquaculture in their traditional rice lands over the last four decades. Boikunthapur district in Bangladesh and Phuoc Dinh commune in Ninh Thuan province in Viet Nam are examples of case areas on saltwater intrusion.

The case of China's southwest region, Guizhou province is different from other countries. The government is focusing on the development of irrigation infrastructure. The idea is to make agriculture climate proof by increasing irrigation potential. Farmers slowly replaced most of traditional crops such as cereals and oilseeds by vegetables and are now cultivating four vegetable crops a year in villages like Lucheba. By increasing crop intensity to 400%, farmers could amply increase profits.

In the study domain, there have been significant changes in cropping pattern, crop and farm management, as well as enterprise diversification which was mostly driven by both price and non-price including changes in climate and dwindling irrigation potential, saltwater intrusion, and floods, among others. Adoption of improved varieties, short-duration cash crops, drought-tolerant crops, monoculture, and shifting method of rice cultivation are some of the major strategies adopted by the smallholder farmers.

Livestock Developments as an Integral Part of Livelihood in the Study Domains

Across the countries, farmers perceived increased mechanization of farm operations with time. This development saw a reduction in the number of bullocks and other farm animals involved in farm operations. One of the downsides is the reduction in the availability of organic manures for soil incorporation. In South Asia, i.e., India livestock is also an option for income diversification through milk production. The same is true for farmers in selected villages in Sri Lanka and India, which have diversified income from livestock rearing with milk production business. These villages have developed milk collection centers, and are on the path of commercializing their dairy outputs. Only one village in Sri Lanka where farmers involved in livestock rearing have decreased as early as from the seventies due to the lack of breeding improvement strategies. The decrease in livestock numbers in villages in recent times is attributed to decreased grazing land and poor maintenance of existing ones.

In Southeast Asia, farmers in Thailand raise livestock for personal consumption and as insurance in the event of distress sale. In Viet Nam, cows and buffaloes are popular in villages; farmers rear them as an income source.

In China's Guizhou province, cows and buffaloes are reared in villages like Lucheba and Dajiang for commercial purposes. Buffaloes are used for farm operations like tillage, etc. Farmers reported perceived that buffalo numbers decreased in recent times mainly due to increased mechanization and introduction of mini-tractors and tillers. Farmers perceived that the number of goats increased in the mountainous areas like Dajiang village, thereby increasing the income of the farmers.

Livestock rearing and earnings from livestock appeared to be an important cushioning occupation to supplement farmers' income apart from crops. However, in Sri Lanka, the importance of livestock has decreased, possibly due to the lack of improved breeds and depleted natural resources, viz., grazing lands and water availability.

Historical Evolution and Current Status of Input and Output Markets

In South Asia during the seventies, input markets were still undeveloped at the village levels; farmers had to travel several kilometers to buy seed, fertilizers, and pesticides. Input markets and access to input markets in most of the villages in India only developed in recent times and most of the inputs are now available in most villages, except in a few, like Dokur and Kinkheda. In Sri Lanka, most of the input markets are still undeveloped in villages even now. Farmers have to travel a minimum of 10 kms to buy inputs. In Thailand, seeds and fertilizers are available in certain villages which experienced some level of development.
Output markets to sell agricultural commodities like food grains, oilseeds, pulses, cotton and other crops, dairy, and livestock are not well-developed in India. Eventhough, there has been some improvement in the last several decades, farmers still have to transport their outputs to nearby markets some 10 to 32 kms away, on their own. These markets act as a cushion at times of stress in terms of access and availability. Similar situations were observed in Sri Lanka, Thailand, and Viet Nam.

Farm Income-Tracking Diversification at Micro-level

Farmers across South and Southeast Asian countries and China are diversifying their incomes within agriculture sector by expanding non-farm enterprise and other income sources. This diversification is mainly dictated by available opportunities, and by infrastructural and governance environments. Among South Asian countries, Indian farmers are keener in diversifying their income sources to reduce risk of income loss due to variability and uncertainty in rainfall and associated increased dry spells. Share of agricultural income to total income ranged from 57% to just 13% across the villages. Income from farm work varies between 3-16%; businesses from 10-19%; livestock from 4-10% of total income. Out-migration and caste occupations are also income sources, albeit insignificant. In Bangladesh, mostly rice and aquaculture predominated in the region but lately with support from government they have started growing high value crops such as betel leaf, mango, litchi, etc. Sri Lankan farmers too have diversified sources of income but their major source of income is still agriculture, dairy and poultry, and non-farm sources. In Thailand, depending on the water availability, farmers are growing water intensive crop i.e. roselle and comparatively less crop demanding crops viz., maize, cassava, sugarcane etc.

In Viet Nam, farmer's income from livestock is highest, between 26-60%, followed by crop production (10-23%) and salaried services and non-farm sectors (17-63%). Farmers in China have also diversified their income to cover the risks in agricultural production; share of income from crop production ranges from 52-54%; income from livestock 17-36% followed by non-farm income (9-31%). There is a marked shift towards non-farm source of income in all the study locations. Though non-farm income provides succor during crop failures, large-scale shift in acreage under staples will have consequential bearing on stabilizing prices of produce and hence on food security.

Farmer's Perception of Climate Variability

Farmer's perception of climate variability echoed many similar observations in all case study countries. Across all selected villages, farmers perceived that there was a decrease in annual rainfall and its distribution was erratic with evidence in decrease in number of rainy days. Farmers, except those from Sri Lanka, perceived a delay in the arrival of monsoon and an increase in the annual temperature. Sri Lankan farmers perceived an early arrival of Southwest and Northeast monsoons and also an increase in dry spells in both Yala and Maha agricultural seasons. In general, farmers' perception about the variability was nearer to actual observations in recent times. They were able to recall their latest observations in the last two decades correctly. Rainfall has been highly variable across the years but district-level rainfall data does not reveal any decreasing trend of annual rainfall. In India, the actual mandal level-data representing the study villages like Dokur showed that there was a delay in the arrival of monsoon in the last two decades by about 10 days. Similarly there was a slight decrease in the number of rainy days. The actual temperature increased over time. These findings mostly concur with farmers' perceptions. In Guizhou province of China, the actual annual rainfall increased by 2% in recent times and farmers also perceived an increase in the rainfall, but due to erraticness of the rainfall, the regions remains largely vulnerable. This study throws light on the fact that there is a need for rainfall data collection and its availability at village-level for micro-level planning. Hence, it was evident that there is congruence in the farmer's perception about climatic indicators and professionals' inferences through in depth analysis. Through these "schools of learning", which are often touted as naïve and traditional, need-based adaptation strategies can be promoted and validated.

Land Management Practices—what farmers are doing at micro-level?

Land management measures using organic matter like green manuring and composting practice of incorporating crop residues into the soil decreased, while field bunding to conserve rainwater and creating drainage channels is followed to varying degrees across villages in India and Sri Lanka. However in Thailand, mulching (not practiced much in India), green manuring, composting, and incorporating crop residues are popular in the upland villages, as seen in Tha Taeng and Nong Muang villages, where over 50% of farmers practice them. These practices are not popular with lowland farmers. The reason for incorporation of organic sources in upland soils in Thailand is due to government interventions in terms of imparting provision of training in organic agriculture to improve soil fertility and water holding capacity in these villages. Adoption of improved land management is a must for long-term sustainability; concerted efforts through different institutional innovations should be pursued in adopting these locally proven practices

Dynamics of Sources and Availability of Water for Irrigation

Water for irrigation is the single most important factor that will neutralize the risk of variability and uncertainty of rainfall. In the seventies, farmers across the villages in semi-arid regions of India were dependent on tanks and open wells for irrigation. During the nineties, selected villages (Kanzara, Shirapur, and Kinked) got infrastructure in terms of canals and surface water for cultivation to insulate crop production from uncertainty of rainfall. Similarly, tube wells were installed in the nineties, and significantly increased in recent decades, thereby exploiting groundwater. Farmers are aware that in these marginal environments, development of irrigation sources is the key driver of change. One adverse result of this development is that most of the open dug wells started drying up due to lowering of the ground water table. Many of the tanks also dried up due to reduced runoff from the catchments. Among the selected Indian villages for the study in the 1900's; water resources development through government interventions in the form of incentives and investments in infrastructure took place. In Sri Lanka, most of the selected villages are rainfed, and very less area is irrigated and a few open wells and tanks are the sources of irrigation. Partial supplementary irrigation is practiced during the post rainy season.

In Southeast Asia, irrigation is mainly through surface water from rivers, canals, and ponds in lowland villages in Thailand. Besides these, groundwater sources like open wells and tube wells cater to irrigation needs to a limited extent. The condition of lowland villages in Thailand is similar to those in India. By contrast, in the upland villages, very little land is irrigated and the few open wells and pond are the only sources of irrigation. But unlike Indian villages, the development of groundwater resources in Thailand through investment by farmers is no longer tenable as groundwater table has gone down significantly. In Viet Nam, canal systems, wells, and tanks are common in the villages and more than 80% of the irrigation needs are met from the canal system and the rest from open wells and tanks. The dependence on the canal system has increased in recent times. In China, one of the villages in southern Guizhou (Dajiang) has met 50% of its irrigation needs from collected water in about 500 small tanks and the rest of the area is irrigated by a pipeline system and a reservoir built in 2009. By contrast, another village, namely Lucheba in central Guizhou irrigates only 5% of its cultivated area through tanks and 33% is irrigated by pumping water from a nearby river. Overall, it can be observed that of late, traditional sources of irrigation have weakened not only due to low water tables but also due to the side effects of other factors viz., market, policy, governance structure, and demographic changes in China. Hence, there is a need to strengthen indigenous knowledge and traditional mechanisms especially for conserving natural resource base.

Predicting Future Crop Needs- Results from Simulation Studies.

Since crop growth is a complex phenomenon involving complex interactions between crops, weather, and soil, it is imperative to understand the effects of these factors and agronomic management on crop growth and productivity. This will aid in the development of promising technologies of crops/cultivar suitable to future conditionalities. An attempt was made in order to understand crop growth and yields under future weather conditions using CMS CERES-Sorghum[1] and CROPGRO[2]-Groundnut simulation models and future weather scenarios predicted by the UKMO-HADCM3 GCM[3] model for the SRES A1B[4] scenario. This was undertaken for the study districts in the semi-arid region of India for the years 2030, 2050, and 2080. The long-term simulations of several scenarios predicted that productivity of both kharif and rabi (post-rainy) sorghum will decrease due to shortened life cycle (crop duration) and decreased crop growth owing to increased water and temperature stress. Progressive increase in climate change will decrease the crop duration of kharif sorghum by 11% in both studied locations (Akola (Maharashtra) and Mahabubnagar (Andhra Pradesh)) of India. Yield of sorghum is expected to decrease by 10-18% in 2080 under a scenario of increased temperature and rainfall, as well as elevated CO2; albeit some beneficial effects of elevated CO2 are also foreseen. Productivity of groundnut is affected in the same way as that of sorghum, except that its crop duration may decrease or increase depending upon current temperatures of sites and future climate change. The traditional growing environments of groundnut in Anantapur district showed a potential yield reduction of 8%, 10%, and 13% in the years 2030, 2050, and 2080 when the combination of temperature and rainfall as well as increased CO2 are considered. For enhancing crop productivity in future climates, we need to develop sorghum and groundnut genotypes with a range in crop duration (short to long duration), and have high-yield potential and tolerance to high temperature and drought stress. As different regions will be affected differently by climate change, the deployment of new genotypes will vary with target region. To cope with future climate changes, farmers must be provided with suitable cultivars developed with specific objectives and targeted towards specific locations. There are knowledge gaps on the physiological responses to extreme climatic parameters like high temperature on crops such as sorghum and maize (Porter and Semenov 2005), which limit the scope of the present

[1] Sorghum growth simulation modeling DSSAT (Decision Support System for Agro technology Transfer)
[2] Groundnut growth simulation model
[3] United Kingdom Meteorological Office – HADley Climate Model 3
[4] Special Report on Emission Scenario by the IPCC

simulation models. It was felt that there is a need to advance scientific understanding and generate long-term datasets in these areas.

Climate Change Impacts on Net Farm Revenue – Indicative Economic Effects

Economic impact analysis using Ricardian approach revealed the sensitive nature of climate on crop productivity. The marginal impact of climate on net income varied with location and crop. However, a rise in atmospheric temperature and reduction in rainfall during crop-growing season significantly affect productivity, thereby casting its shadow on revenue. In Andhra Pradesh, India, increase in temperature by 1°C during the main cropping season (southwest monsoon) is likely to reduce net income from rice crop by $US2.18/ha keeping the same level of technology and other management attributes; this has little effect on gross income after earnings from all crops are taken. These results corroborated other studies in Andhra Pradesh on rice. Over the years, there is a significant downward trend in rice cropped area in rainfed tract of this state; climate, especially date of onset of monsoon rainfall, is one of the major factors although reduction in rice acreage is also attributed to farm gate price instability in the last decade. Similar analysis from Thailand's northeastern region also highlighted the negative impact of temperature rise during cropping season. In northeastern region of Thailand, an increase of 1°C will decrease net revenue by $US0.21-1.58/ha from major crops. Furthermore, it was observed that the 1mm increase in rainfall enhances net revenue of crops, especially from rice and cassava by about $US 0.01- 0.1/ha which is significantly low. Similar exercise could not be undertaken in other countries due to paucity of data sets and inability of the research team to carry out the analysis in spite of the training etc.

Adaptation Measures—How the farmers are practicing at micro-level?

Adaptation to any change in the system is essential to sustain the productivity and profitability of farmers. Across South and Southeast Asian countries, farmers are shifting to short duration cultivars to cope with increased variability in rainfall and to adjust the crop calendars. Another common feature is the adoption of less water demanding cash crops to replace traditional coarse and fine cereals.

Diversification of incomes is another strategy that the farmers are adapting across the countries to reduce their risk from rainfed crop production. There are other adaptation strategies that are specific to each country, and are governed by the contextual situations created by socio-economic environments as well as the government policies.

Groundwater exploitation has rapidly increased in all Indian case villages in recent decades. Farmers perceive that on-demand water availability is the best way of adaptation as the risk associated with uncertainty of rainfall is neutralized by irrigation potential. Many farmers adapted improved seed varieties and shifted from cereal cultivation to less thirsty short-duration crops to short-duration cash crops mainly to reduce risk from uncertain rainfall and stabilize incomes. Mixed cropping is practiced as an effective adaptation measure; this is an indigenous adaptation method most prevalent in rainfed areas with associated dry spells. This was elicited during farm-level investigation, particularly in villages such as Kinkheda and Dokur in India. This practice ensures some returns in the event of failure of monsoon or occurrence of drought.

In Sri Lanka, farmers are shifting from annual crops to perennial drought-tolerant plantations like cashew, etc., particularly in rainfed villages where irrigation potential is not available to avoid the risk of crop failure. Farmers are also increasingly adopting short-duration and drought-tolerant varieties and hybrids, wherever available.

Another important adaptation strategy is diversification of means of livelihood by marginal and small farmers. In Bangladesh, farmers are diversifying their incomes to reduce the risk associated with the vagaries of rainfall on agricultural production. Jute cultivation is being slowly replaced by pulses and vegetables to reduce water demand. Partial shifting from cultivation of cereals and oilseeds to short-duration or perennial cash crops like betel leaf is another adaptation strategy. In the flood-prone areas of Bangladesh, farmers are shifting from traditional rice growing to aquaculture activities to reduce risk and improve incomes. Better access to micro-finance is also seen as an adaptation measure by farmers. Strengthening and maintaining kinship ties for aid in difficult times, is another adaptation strategy that farmers perceive as important.

Among Southeast Asian countries, farmers in Thailand are diversifying their incomes to include sources from non-farm sector. They are shifting to less water demanding crops like cassava or short-duration crops like maize. They are changing crop management practices, like shifting from rice transplanting to broadcasting method, to reduce water demand. In lowland villages, delayed planting of rice to synchronize the delay in monsoon is becoming common. Replacing rice by cassava in marginal lowlands is seen as another adaptation strategy. Obtaining loans for investment to develop irrigation potential is followed by both small and large farmers alike. Soil improvement using organic matter and crop residues, is practiced by farmers in upland villages, which was introduced by the government to enable farmers to improve soil fertility and increase soil moisture retention. Increasing crop intensity to improve farm incomes is another measure practiced by resource-rich farmers. Upland farmers are shifting from growing Kenaf (*Hibiscus cannabinus*) to less water-intensive crops like cassava. Digging and deepening of wells for irrigation is another adaptation measure for conserving water.

In Viet Nam, shift to less water demanding crops and investment in cash crops and increasing irrigation potential by large farmers and working as farm laborers to supplement the farm income (specially marginal and small farmers) are some of the adaptation measures followed by the farmers. Farmers in the coastal regions are shifting from crop cultivation to aquaculture. They are also diversifying into part-time business and salaried services to supplement income and reduce risk in agriculture; they also develop new water sources or improve existing ones for supplementary irrigation.

In China, villagers are practicing unique adaptation measures. In a way, the government is shaping up these measures which include protection and increase in forest cover around the villages, saving power, developing several alternate renewable power sources, and enhancing infrastructure development. Construction of small water tanks and changing cropping system by increasing cropping intensity are some of the adaptation measures that the farmers are also practicing in China.

The key findings on grassroots perspectives emanating from gender-based social analysis revealed that women faced particular constraints in their capacity to adapt to existing and predicted impacts of climate change. Yet many women are already adapting to the changing climate and are clear about their needs and priorities. Focus group meetings and participatory rural appraisals clearly showed that women in rural communities are adapting their practices in order to secure their livelihoods in the face of changes in the frequency, intensity, and duration of droughts and dry spells. The women who took part in the surveys described various adaptation strategies such as changing cultivation to drought-resistant crops, or to crops that can be harvested before drought, i.e., early maturing varieties.

Asian Panorama of Micro-level Constraints to Adaptation

Willingness to act together in the management and access to resources plays a vital role in increasing or decreasing community or individual capabilities; this goes a long way in determining resilience level of a community. A key constraint to adaptation was the lack of institutional arrangements for providing access to input and output markets. It was found that each farmer independently sold their produce at the prevailing market price to the trader. The reasons they cited were: (i) lack of storage facilities in villages and need for finances; as most farmers were smallholders, they had to sell their produce immediately after harvest, mostly distress sale; (ii) absence of own co-operative to help negotiate better prices; farmers lack collective action to create such a cooperative. There are other important constraints to adaptation perceived by farmers in different countries as discussed. In India, major constraints perceived by the farmers are unavailability of drought-tolerant or improved varieties, lack of access to supplementary irrigation, unavailability of potential technologies, lack of capacity for crop diversification by marginal farmers, lack of access to credits against risk, absence of efficient co-operatives/associations tackling risks, lack of efficiency in governance, and lack of incentives to adopt soil and water conservation practices. In Bangladesh, farmers perceived inadequate infrastructure, lack of suitable seeds, inadequate irrigation facilities, lack of credit facility, and universal crop insurance as the major constraints to adaptation.

In Thailand, farmers perceived that small farm sizes, lack of water resource in dry season, little innovation on alternative sources of income and lack of better crop management technologies are some of the major constraints to adaptation. In Viet Nam farmers perceived that some of the technologies available are ineffective, and subsidies are insufficient to make them inaccessible. Farmers felt that financing was available but for want of collateral, they were not able to access it. Low profits, high investment for adaptation, and higher risk of crop failures deter them from adaptation. In China, farmers perceived that lack of investment potential of farmers, lack of technological advancements in terms of varieties and management practices and power sources, infrastructural constraints and some constraints in effective policy are the major barriers to adaptation.

Building Resilience at the Grassroots Level

Overall, country-level studies on adaptation strategies present evidences to show farmers' adaptation strategies which portray spatial and temporal diversity. These strategies are highly dynamic and have potential of including complementarities with agricultural development programs. In this regard, greater attention is needed on the following:

- Understand and promote adaptation strategies at the grassroots level that integrate climate change concerns into development strategies
- Learn and use the rationale (if not the form) of traditional adaptation measures as a part of the strategy
- Reorient approaches of public programs as well as responsible agencies i.e., practitioners and decision makers to implement the above

As reiterated by Campbell et al. (2011), "pursuing early action activities will result in country-specific data and knowledge as well as experience with agricultural practices and policies that could inform long-term national strategies". A strategy that brings together prioritized action, financial incentives, investment policies, institutional arrangements, tenure security, and aggregating mechanisms constitutes an important step in the transition to climate-smart agriculture.

Conclusions

The report is a comprehensive effort to understand and analyze the vulnerability to and impacts of climate change and the adaptation strategies of farmers in the selected regions. It is envisaged that the above issues centric to the agenda of climate change challenges in the marginal regions of Asia will be addressed well by providing suggestions on strategies and policies to reduce the vulnerability, strengthen adaptive capacity and adaptation opportunities, and increase options to farmers to better cope with impending climate change.

To facilitate effective adaptation to climate change, it is important to recognize the uncertainties and information gaps in the micro-level spatial contexts. The study carried out in India and other partner countries had followed a comprehensive analytical framework for identifying the adaptation strategies for enhancing grass root level resilience to climate change. The selection of the targeted location in each country and the partnering institutions has had reflection on the information collected, analysis and its manifestation in addressing the micro level climate change research agenda. Bangladesh, India, Sri Lanka, Thailand and Viet Nam followed the unified framework, work plan and activities. Bangladesh and India has an added distinct advantage of corroborating the farmer's perceptions and impact on livelihoods with the long term panel data sets. Selection of the Guizhou province in China and the partnering institution stems from the idea of following up on the similar RETA of adaptive research undertaken with ADB support by ICRISAT. The advantage and disadvantage in nature of selection of the locations and partners reflected in the results and discussion emanating from the country report and aptly covered in the ensuing sections of synthesis report. There is a crucial need for collection, analysis, and dissemination of reliable information on climate-response related variables (including farmers perceptions) in a diverse micro-level spatial contexts and preparation of area-specific inventories of indicative production and resource use options (possibilities) for dryland agriculture to match with the opportunities and constraints faced by the region.

The search for indicative adaptation options for the above inventory should focus on:

- Prevailing farmers' practices in different areas with varying degree of vulnerability (e.g. water scarcity or aridity) and other environmental constraints;
- Agricultural R&D and location-specific scientific results;
- Formal and informal institutions and support systems including infrastructural changes with specific focus on success stories and visible failures (and their reasons); and
- Strengthening governance system that will ensure the best interest of the farmers and those most affected by climate change.

These factors could help build an inventory of multiple and diverse options farmers could choose from and use depending on the varying climatic conditions in their micro level contexts. There is a further need to focus on the continued improvement of both technical studies and policy development as science-based understanding increases and their interrelationships and complexities become clearer. Study and analysis of social networks is one such methodological tool which will improve our understanding of the impacts of climate change and variability on the livelihoods of the poor.

The insights from the six countries also clearly indicate that more research is needed on the adaptation strategies, particularly for small holders and women in the face of existing climate change impacts on agricultural productivity and food security, including how these are manifested in different contexts, like:

- What are the barriers to women's access to new technologies, extension services, and credit facilities?

- What aspects of their own agricultural knowledge have been overlooked and could contribute to effective adaptation?
- What are women already doing and what do they identify as their needs and priorities and possible solutions?

Future adaptation and/or agriculture policies should explicitly draw on these insights and seek to better support these existing strategies. In order to design gender-sensitive adaptation as well as mitigation strategies, there is a need to know more about gender differences in the impacts of climate change, and locate existing knowledge on climate change, including local practices and indigenous knowledge. Data disaggregated by gender and in-depth qualitative studies on impacts, based on participatory approaches to data collection, are essential to furthering the adaptation agenda and ensuring it is both efficient and equitable.

The overarching recommendation is to diagnose and understand farmer's adaptation strategies to climate variability with a focus on the dynamics of adaptations, implying search for and promoting approaches and options to harness the opportunities in the changing economic, technological and institutional opportunities, which may even exceed what farmers have been practicing in the subsistence-oriented, locally-focused contexts in the past. Dynamism, diversity and flexibility are essential for enhancement and reorientation of the capacities of the farmers and rural communities, as well as the institutional arrangements and innovations supporting them.

List of Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
CCAFS	Climate Change, Agriculture and Food security
CCV	Climate change and Variability
CGIAR	Consultative Group on International Agricultural Research
CHR	Central High Land
CO_2	Carbon dioxide
CRIDA	Central Research Institute for Dryland Agriculture
DFID	Department for International Development
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GHG	Green House Gases
HYV	High Yielding Varieties
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IDS	Institute of Development Studies
IITM	Indian Institute of Tropical Meteorology
IMD	Indian Meteorological Institute
IPCC	Intergovernmental Panel for Climate Change
KVK	Krishi Vigyan Kendra
MAI	Moisture Adequacy Index
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MIDC	Maharashtra Industrial Development Corporation
MRD	Mekong River Delta
NEM	North East Mountainous
NGO	Non-Governmental Organization
NRC	National Research Centre
NREGS	National Rural Employment Guarantee Scheme
NWM	North West Mountainous area
PDS	Public Distribution System
PRECIS	Providing Regional Climates for Impacts Studies
RRD	Red River Delta
SAT	Semi-Arid Tropics
SCR	South Central Region
SER	South East Region
SHG	Self Help Groups
SOC	Soil Organic Carbon
SWM	Soil and Water Management
TERI	The Energy and Resource Institute
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

Glossary

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (**IPCC**).

Adaptive Capacity: The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (**IPCC**).

Biodiversity: The variety of living things on earth and their interactions with the environment. Scientists often categorize biodiversity into three components, i.e., species, genes and ecosystems.

Climate change adaptation strategy: This refers to a general plan of action for addressing the impacts of climate change, including climate variability and extremes. It may include a mix of policies and measures selected to meet the overarching objective of reducing the country's vulnerability (**UNDP**).

Climate: Average weather or pattern of weather in a given period of time.

Climate Change: The change in climate attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural variability observed over comparable time periods (**UNFCCC**).

Drought: It is a normal, recurrent feature of climate that occurs in all climatic regimes and is usually characterized in terms of its spatial extension, intensity and duration. There is no uniform definition. Drought may be regarded as a period of abnormal dry weather sufficiently prolonged leading to lack of water so as to cause hydrological imbalance in the affected areas.

Ecosystem: A dynamic complex of plants, animals and microorganisms and their non-living environment interacting as a unit.

Exposure: The degree of climate stress upon a particular unit analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (**IPCC**).

Extreme weather event: An event that is rare within its statistical reference distribution at a particular place. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10^{th} or 90^{th} percentile. By definition, the characteristics of what is called "extreme weather" may vary from place to place. An "extreme climate event" is an average of a number of weather events over a certain period of time, an average which is itself extreme (eg. rainfall over a season) (**IPCC**).

Flood: A flood is an overflow of an expanse of water that submerges land.

Global warming: Greenhouse gases (GHGs) such as carbon dioxide, carbon monoxide and methane that are emitted into the atmosphere through human activities act such as blanket to heat, which escape from the surface of the earth.

Institutions: Humanly created formal and informal mechanisms that shape social and individual expectations, interactions, and behavior (Ostrom, 1990).

Institutional Access: degree to which households and different social groups in a given location are connected to institutions and have the ability to gain institutional benefits as a result of such connections.

Mitigation: It is the reduction of anthropogenic greenhouse gas emissions or the enhancement of natural sinks through implementation of policies (IPCC 2007).

Moisture Index (Im): This is a derived parameter from water balance analysis, which is defined as difference between annual humidity index (Ih = Water Surplus/Potential evapotranspiration *100) and annual aridity index (Ia = Water deficit /Potential evapotranspiration *100). It is a useful parameter to define the climate of a particular location.

Resilience: Resilience is a tendency to maintain integrity when subject to disturbance (UNDP).

Risk (climate-related): Is the result of interaction of physically defined hazards with the properties of the exposed systems – i.e., their sensitivity or (social) vulnerability. Risk can also be considered as the combination of an event, its likelihood, and its consequences – i.e., risk equals the probability of climate hazard multiplied by a given system's vulnerability (**UNDP**).

Sensitivity: Is the degree to which a system is affected, either adversely or beneficially, by climate related stimuli. The effect may be direct (eg. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (eg., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (**IPCC**).

Socio-economic vulnerability: Is an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbations.

Social resilience: It is composed of components such as economic growth, stability and distribution of income, degree of dependency on natural resources, and diversity in the kind of activities/functions being performed within systems (Adger, 2000).

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (**IPCC**).

Vulnerability assessment: This identifies who and what is exposed and sensitive to change. A vulnerability assessment starts by considering the factors that make people or the environment susceptible to harm, i.e., access to natural and financial resources; ability to self-protect; support networks and so on (**IPCC, 2001**).

Yala and Maha seasons: These are two cropping seasons of Sri Lanka Yala (south west monsoon season) and Maha (north east monsoon).

Introduction

Climate change is emerging as the biggest threat to livelihood sustainability of our times, posing an imminent danger to human security and development of human capabilities. Until recently, the center of attention has been on the actual or potential impact of climatic change and mitigation options. The focus is now shifting to the ways that different socio-economic groups are attempting to cope and adapt to climate variability in particular and climate change in general. International developmental agencies are inclined towards improving their understanding of climate change science, impacts and mitigation of climate change at the global and regional levels (ADB 2009). This focuses on the growing recognition that while climate change is inevitable, its effects can be largely extenuated with better understanding of adaptation and undertaking coping strategies.

> **Box 1: Climate Change Impacts and Adaptation**
>
> "Adaptation is a vital part of a response to the challenge of climate change; it is the only means to reduce the now-unavoidable costs of climate change over the next few decades"
>
> Sir Nicholas Stern, 'The Stern Review' on economics of climate change, October 2006

Global mean temperatures have been rising since the last century mainly due to greenhouse gas accumulation orchestrated mostly by anthropogenic activities. The main causes are the burning of fossil fuels (coal, oil and gas) to meet the increasing energy demand together with intensive agricultural production and deforestation. Along with temperature, the climate itself is perceived to be continuously changing all over the world. Due to its adverse impacts, climate change has always been a matter of great concern to the farming, scientific and developmental communities. Climatic extreme events together with increase in rates of change in climatic parameters could affect various sectors including water, agriculture, health, tourism, transport, energy and the likes. The Human Development Report (2008) states that climate change is one of the greatest challenges humanity faces and/or will be facing, and it is considered the world's most vulnerable population who are immediately at risk. In the future, the climate change associated impacts are imminent with the anticipated vagaries of the weather. According to the latest Assessment Synthesis Report 4, AR4 (IPCC, 2007) the projected changes are summarized as follows:

- The surface air temperature increased worldwide and is greater at higher latitudes. Evidence of changes in natural ecosystems is being affected by regional climate changes, particularly temperature increases. Annual average temperature is projected to rise by 0.6-4.1^{o}C by the end of this century.
- Observed significant increase in precipitation in eastern parts of North and South America, Northern Europe, and Northern and Central Asia, but reduction in Sahel, the Mediterranean, Southern Africa and parts of South Asia.
- Likely increase in extreme weather conditions viz., heat waves, heavy precipitation, cyclone and very likely that precipitation will increase in higher latitudes and decrease in most sub-tropical land regions.

- The water resource sector due to changes in rainfall and increased evapotranspiration will be in crisis in major dry regions in mid-latitude, including the dry tropics. Thereby agriculture will be affected due to limited water availability. Africa and Asia due to a large population and low adaptive capacity are projected to be highly-vulnerable to climate change.

The Intergovernmental Panel on Climate Change (IPCC) and various bodies have therefore defined both vulnerability and adaptation for better understanding of the relationships they share with climate change. The IPCC (2001) defines vulnerability as the degree to which the system is susceptible, or unable to cope with, adverse effects of stresses including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its ability to adaptation or adaptive capacity. The Energy and Resources Institute (TERI) states that vulnerability vary across geographical scales, temporal scales, and must be addressed within complex and uncertain conditions and hence calls for interdisciplinary and multiple expertise (TERI, 2005). Adaptation, on the other hand, is defined by the IPCC (2001) as adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. Hence, adaptation refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change. On the similar lines, Department for International Development (DFID) defines adaptation as reducing the risks posed by climate change to people's lives and livelihoods (IDS, 2006).

Reducing vulnerability by an adaptation and mitigation process requires identification of different potential options that may be selected depending on the local contexts. It has been mentioned that "A wide array of adaptation options are available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. There are barriers, limits and costs, which are not fully understood" in the latest version of the synthesis report (IPCC 2007). Nature, land, water and associated ecosystems are being degraded rapidly undermining food security and rural livelihoods. The expected realm of environmental and socio-economic challenges in the future and the desperate attempt to protect available valuable natural resources are highly sought (Tompkins and Adger, 2004). The United Nations has called for a comprehensive framework for action though the high level task force on global food security and called for addressing the climatic impacts threatening future food and nutritional security (United Nations 2011). The climate change processes and its effects are incremental and cumulative and affect the planets' ability to sustain life. This have been a common problem, known for over half a century to the scientific elites, but not easily understood by common people or the environmental activists or policy makers[5] was not really successful in mobilizing mass support to call for effective controls.

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[5] Highlighting the failure of mobilizing support for the Tokyo Protocol and related international instruments among law makers in developed as well as developing countries and the difficulty of the UN pushing environmental related conventions and follow up action by member governments.

Climate Change and Variability – Asian Perspective

Several coordinated studies including the research conducted by the climate Institute (Washington DC) with the cooperation of Asian countries and support from the Asian Development Bank (ADB), pointed out that the Asian continent is likely to be the hardest hit by the consequence of global warming and climate change (Table 1), leading to serious implication on the livelihood of poor farmers in the most vulnerable countries such as India, China, Sri Lanka, Bangladesh, Pakistan, Indonesia, Malaysia, Viet Nam and the Philippines, among others. Other studies also support similar findings on these countries. A coordinated study conducted by the Challenge Program on Climate Change, Agriculture and Food Security (Ericksen et al. 2011) identified future poverty hotspots as India, Bangladesh and other Southeast Asian countries. The South Asian region has been clearly grouped under chronically food insecure regions along with the African continent. In the future, these regions are expected to experience environmental changes viz., a 5% decline in the length of growing period, high temperature stress (>30^{o}C) and decrease in the crop growing days making farming a risky occupation. These impacts will pose a great challenge to the sustainability of livelihoods among the poor farmers of Asia who greatly depend on agriculture for their sustenance. Hence, the prognosis for Asia particularly for farmers and the poor are especially bleak. If this situation continues unabated, calling for awareness and engagement at all levels of stakeholders (Table 1) is recommended.

Table 1. Summary Comparison of People under Stress Globally and in Asia

Indicators	Global Observed and projected changes	Asia
Atmospheric Temperature	The temperature has risen of about 0.2°C per decade globally. Moderate scenario (B2) project that temperature is likely to increase by 1.4-3.8°C in 2090-2099 from the base years of 1980-1999.	For Asia including South Asia is 3.3°C in 2080-2099.
Flood	Millions of people will face the wrath of flood due to climate change and sea level rise in the densely populated low lying mega deltas of Asia and Africa.	Coastal and mega delta regions in South and Southeast Asian countries are at high risk affecting
Water resource	Population pressure, land use change, together with impacts of climate change is expected to exacerbate the with increased runoff and decreased water availability.	By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease.
Drought	Globally, drought effected area has likely increased since the 1970s. Most of the drought affected areas are projected to face greater stress and distress on livelihood and associated sectors such as agriculture, water energy and health will be adversely affected	Precipitation has been decreasing, especially in south Asia with related impacts of livelihood, health, and natural resources
Crop productivity	Globally, the potential for food production is likely to increase over a range of 1-3^{o}C rise in temperature over the local average, above than a projected decrease.	Asia contributing major share of total worlds tropics and expected

Sources:- IPCC Assessment report 4 (IPCC, 2007); World Resource Institute, 2012; United Nation, 2011b.

Climate Change: Riding through Poverty and Food Security

Among Asian countries, particularly in South and Southeast Asian regions are the poorest, having, only having low to medium ranking in the Human development index (HDI) (Human Development Report 2008). They are only next to sub-Saharan African countries. Climate-related disasters affected about 2 billion people in Asia, representing about 40% of the total population in these countries (FAO 2008). In the 2000's Asian countries including India, Bangladesh (Ahmed 2006), Pakistan and, Viet Nam have significant number of people were affected by various climatological and hydrological disasters such as Tsunami, Cyclones, Typhoons, Flood, Droughts, Landslides and Hurricanes among others.

Agriculture, being the mainstay of the majority of people in Asia, any adverse impact on it will definitely affect their socio economic well-being, increasing poverty and reducing food security. Impacts caused by climate related risks affect directly the farming sector there by threatening the food security. Food security is affected in two areas: - (i) by way of diminished source of food supply and (ii) the reduced primary source of income. This is the case for around 40% of the world's population and an estimated 65% of the Asian population. Hence, adverse impacts on the capacity of farmers to produce food will have profound impacts on rural livelihoods and food insecurity. According to the latest developmental statistics, on an average of 25-30% of the population are already below the poverty line (Table 2).

Table 2:- Developmental status of the study countries

Indicators	India	Sri Lanka	Bangladesh	Thailand	Viet Nam	China
Ranking	134	97	146	103	128	101
Development group	MHD	MHD	LHD	MHD	MHD	MHD
GDP (2011) ('000US$)	1.4	2.8	0.7	4.9	1.4	5.4
Income index (Gross Net income per capita)	0.51	0.559	0.391	0.622	0.478	0.618
%of population below poverty line* (Below US$ 1.25 PPP per day (%)	41.6	7.0	49.6	10.8	13.1	15.9
Number of undernourished population (millions) (2005-2007)	238	3.8	41.7	10.8	9.6	130.4

€ Source: - United Nations Development Programme (2011); FAO (2010); World Bank (2012).
LHD – Low human development group; MHD – Medium human development group; * The values are latest estimates of countries by UNDP.

The rural poor are affected by several extraneous issues over the years which act against the improvement of their socio-economic status. Among these factors, such as climate change or variability and associated changes have a direct impact. They also have indirect effects on rural livelihood and food security (Sanchez 2000). Many scientists argue that, the food insecure countries face insecurity not due to diminishing production but disparity in accessibility to quality food (FAO 2003). Global climate change projections now have a firm scientific basis, and there is a consensus among researchers of growing certainty that frequency of occurrence of extreme events are most likely to rise. This will lead to losses of productive assets, personal possessions, or even loss of life or livelihood. Low food security status of millions of people in disaster-prone areas of Asia will increase. The low income and most vulnerable populations are the ones who are expected to feel the effects of climate change, such as frequent incidence of extreme events and natural disasters. As the result, climate change is most likely to increase the vulnerability of poor farmers who are already struggling with land degradation, price hikes, and other social risks (ADB 2009).

A recent study by the International Labour Organization (ILO, 2011) suggests that there will be significant differences between middle and low-income countries because of the way in which climate change affects agriculture-based livelihoods. Statistically, the phenomena of exodus of population from farm-based employment to non-agriculture are common globally in general and particularly in South and Southeast Asian countries (Table 3). According to several studies, climate change would reduce crop productivity especially in tropics or lower latitude and indirectly affecting the population associated with it directly or indirectly. Reduction in production will negatively impact on the farming sector threatening food security and livelihood. Identifying these perils there have been several scoping studies on impacts and the national and international initiatives against this challenge. Assessment of national action plans on climate change and implementation of this plan plausible way forward on future prospects of adaptation strategies (Adaptation Knowledge Platform, 2010a, 2010b)

Box 2 - Poverty and vulnerability to climate change goes hand in hand

The extreme climatic events & slow continuous change could be a major threat to the rural communities. The consequences could be direct and indirect impacting on agriculture, nutrition, health, socio-economic condition and natural resource base.

(1) Direct impact: Severe and frequent climatic extremes will put more into vulnerable category or push down the order by adopting coping response strategy of selling/divestment of productive assets such as land or livestock.

(2) Indirect: With climatic extremes or shocks makes the price to shoot up for essential commodities and there is also confusion in investment, innovation and development intervention in climate uncertainties.

Table 3. Employment Trend in Agriculture as Share of Total Employment, by Region

Region (%)	**1997**	**2007**	**2009**
World	41.4	35.4	35.0
Southeast Asia and the Pacific	48.8	45.0	44.3
South Asia	59.4	53.5	53.5

Source: -ILO (2011)

FAO (2008) has identified different livelihood groups that needed special attention in the context of climate change, and these include

- Low-income groups in drought and flood-prone areas with poor food distribution and infrastructure and limited access during emergency
- Producers of crops that may not be sustainable under changing temperature and rainfall regimes
  (Box 2. Linkages of vulnerability to climate change and poverty)
- Low to middle-income groups in flood-prone areas who may lose homes, stored food personal possessions and means of obtaining their livelihood, particularly when water rises very quickly and with great force, or as in sea surges or flash floods.

Over the years there has been improvement in the rural economy and also in implementing relief measures against climatic extremes and financing to overcome losses. However, climate change is expected to exacerbate the situation with increased frequency of extreme events in the long term. Hence, a clear strategy should be framed along with fiscal commitment, and should be development oriented to strengthen climate resilience of the rural economy and address root causes of vulnerability. It is important that social scientists and development supporters gear up for the upcoming challenges with the aim of promoting adaptations that are pro-poor and with a long term vision for effective prevention and mitigation (Heltberg et al. 2008; World Bank 2009, 2008).

Several studies have been undertaken to gain insight on micro level opportunities and constraints, along with understanding how the farmer perceives the impact of climate change and variability and elasticity of degree of resilience among the farming strata. Although related studies have been undertaken in West Africa (Mertz et al. 2009), eastern Africa (Hisali, et al. 2011; Below et al. 2012) and southern Africa (Bunce, et al. 2010, Stringer, et al. 2009; Patt and Schroter 2008; Thomas et al. 2007), South America (Simoes et al. 2010) similar studies should be done on Asian countries including sociological perspective of climate change. This is highly recommended to be successful to cope with climate change, particularly targeting the most vulnerable groups (Adger et al. 2005; Adger 2003). This synthesis attempts to capture the way rural folk are affected by climate change and understand their coping strategies and constraints faced. These field level insights and findings could be a stimulus to the policy makers in formulating programs for the target regions and improving and developing strategies against climatic risk.

The global climate change watch mechanisms have been sounding alarm bells since the 1960's warning of rising global temperatures due to greenhouse effects, rising sea levels, and changes in quantum, patterns and intensity in rainfall. There is concern that the most affected will be those most vulnerable i.e., the poor. The Asian region hosts 55% of the world's population which is about 3.8 billion people. In Asia 62% of its people directly depend on agriculture, further 25-30% of the people live below the poverty lines. Increase in air temperature will have a negative effect on crop productivity and, yield as well as farm incomes. In Asia, a large number of people will be directly affected by their way of livelihoods and incomes due to their vulnerability. People with least resilience to withstand the adverse changes and climate shocks are the poor. Rising urban and elderly populations will further strain the countries, resulting in possible conflicts and political instability. On the other hand it is well known that at the village-level there is a vast pool of experimental and traditional knowledge that helps to survive, adapt to changes and continue with their lives.

In this context, the key research problems the studies have addressed are as follows:

1. What are the key climatic changes taking place in the Asian region? To what extent are the trends significant?
2. What are the key changes taking place at the grass root level; as climate being a major driver of change?
3. Do the changes inferred through analysis of climate data match with the experimental learning and shared knowledge of vulnerability with regard to the village communities?
4. How do people respond to these changes with their acquired experiential knowledge and available institutional support?
5. What measures and support will help to improve the resilience and coping mechanisms of vulnerable groups?

Objectives

The project is aimed[6] at providing science-based solutions with a pro-poor approach for adaptation of agricultural systems to climate change, for the rural poor and most vulnerable farmers in semi-arid regions of Asia, especially of India, Sri Lanka, Bangladesh, Thailand, Viet Nam and Peoples' Republic of China (PRC). The overall objective of the project is to identify and prioritize regions most at risk and to develop gender-equitable agricultural adaptation and mitigation strategies as an

[6] As indicated in project proposal - Expected benefits from this project include: (a) Benefits to the poor sector-marginalized, vulnerable and different social groups will be better informed about climate change, adaptation and mitigation strategies, (b) Economic benefits-improved strategies for managing risk and vulnerabilities are expected to diversify sources of livelihood and alternative coping strategies through institutional innovations, (c) Environmental benefits-new policy, institutional and technological options are expected to lead to improved management of scarce water resources and reduced resource degradations through altered cropping patterns, (d) Capacity building- improved databases, information and training lead to enhanced capacity for policy research in the national programs.

integral part of agricultural development in the most vulnerable areas. This research is done with a goal to improve innovations in agricultural institutions, crop and resource management, role of women, social capital and social networks (Adger, 2003) in these study countries. The study takes into consideration the context variability among and within the countries cases and how best to analyze by identifying elements of an ideal governance framework where adaptation can be optimized. The descriptive frame work for addressing the climate change agenda is given below Figure 1.

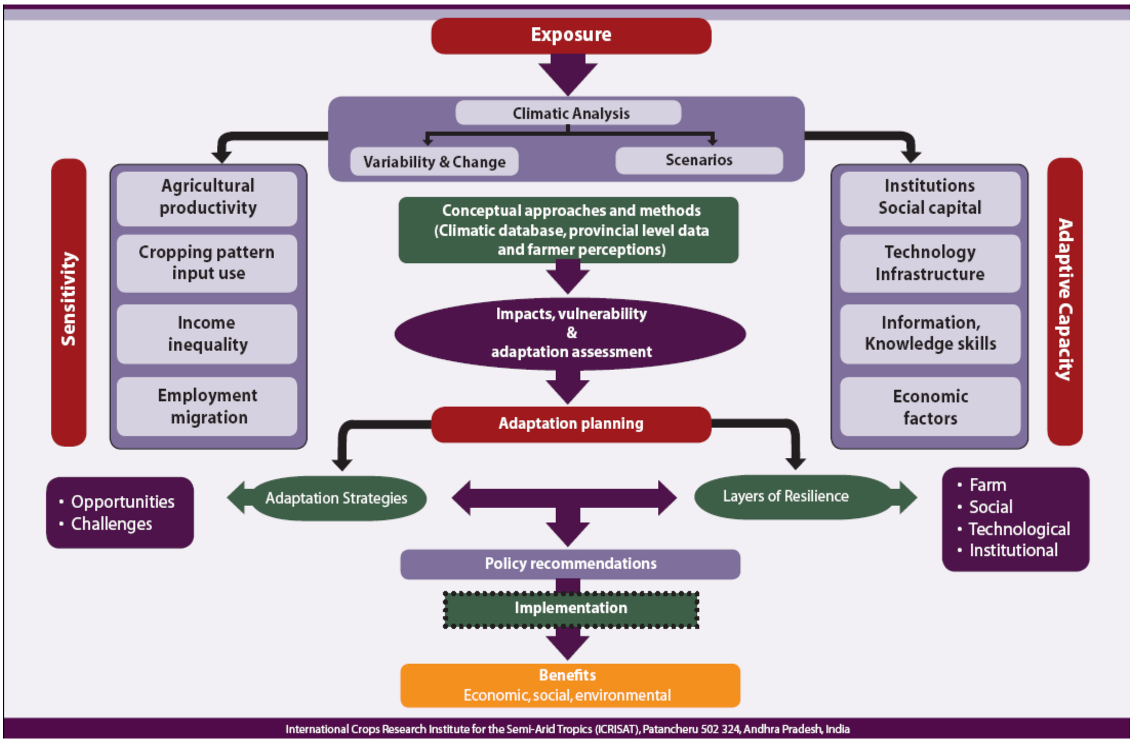


Figure 1. Conceptual framework for addressing climate change agenda.
(Source: - Authors creation for harmonizing objectives and activities of the project)

The project aims to generate valuable outputs that will have policy and livelihood impacts. It is also developing a useful information repository to inform policy decisions on critical issues affecting the future of agriculture and livelihoods in the rainfed SAT. For this to happen, a robust approach with reliable and in depth understanding with a minimum set of key information (Aggarwal, et al. 2010, Vincent, 2007). Hence this project pitches for enhanced information from different components of analysis, argumentation and advocacy (Adger and Vincent 2005; Kelly and Adger 2000).

The key outputs of the project include, (a) an improved understanding of the climate variability (and other related factors) that may be influencing changes in cropping patterns, crop yields, structures of income and employment, and adaptation-coping strategies of the rural poor in SAT villages; (b) best practices and institutional innovations for mitigating the effects of climate change and other related shocks; and (c) strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation.

Formalizing concepts

The framework presented below is developed to analyze the problem and present the research design to assess the situation and identify methods of adaptation (Figure 2). The process will enable us to present policy suggestions to the participating countries to follow-up on.

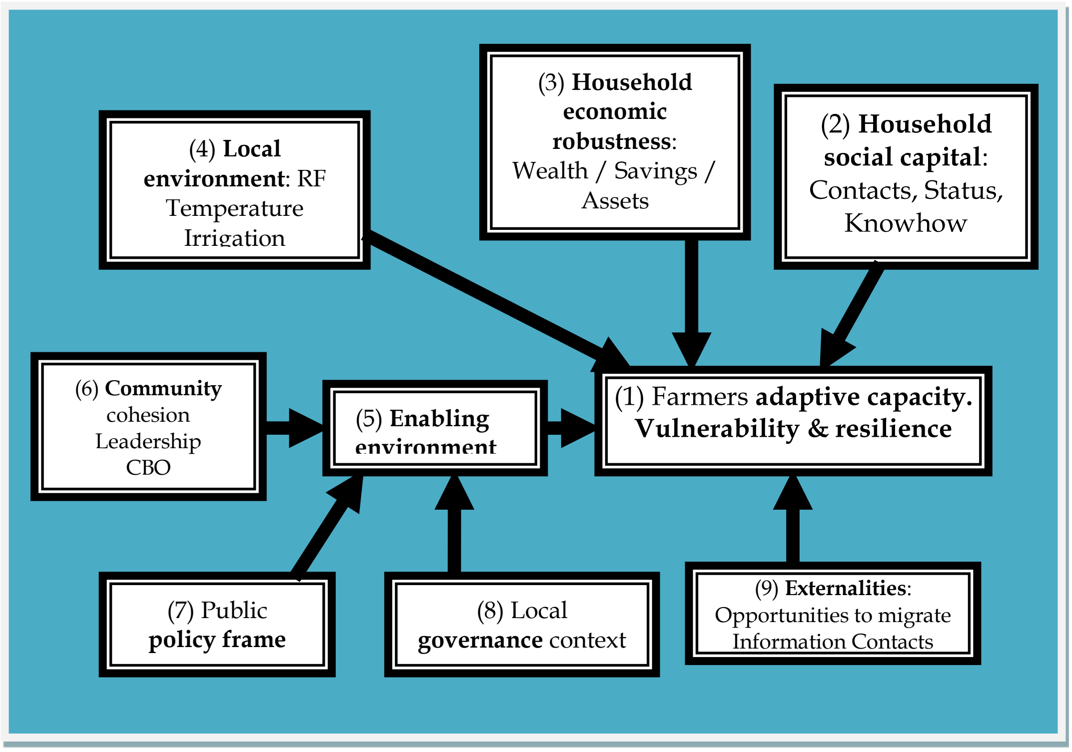
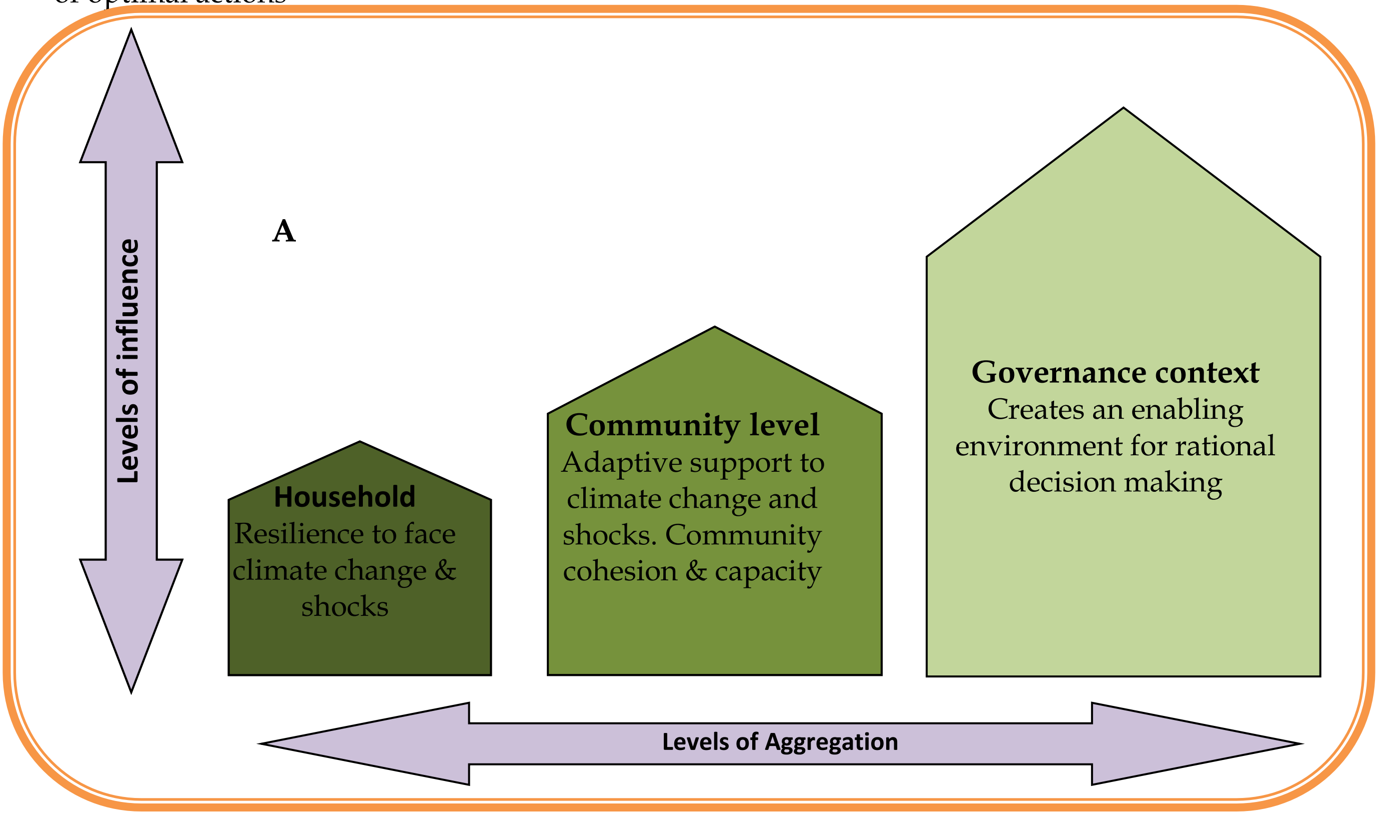


Figure 2. Inter-linkages explaining the influence on adaptive capacity to climate change at micro level (village).

The climatic conditions continue to change. The continued greenhouse gas emissions, deforestation associated with urbanization, energy consumption and over reliance on non-renewable energy put the fragile environment balance at high risk. In the Asian region, large groups of people will be adversely affected if the present trends in climatic change continue. Increases in temperature, rainfall, and unpredictable nature manifested in extreme occurrences that are becoming more frequent, will affect the lives of millions of people. The ability to cope and adapt to these changes will depend on many factors. Most of these factors are beyond the scope of the realm of influence of local farmers in the region. The adaptive capacity if enhanced will enable them to cope with minimal state interventions. There will be considerable variability in the ability of farmers to adapt and adjust. The following figure places in perspective the important factors that have a bearing on the ability of farmers to cope. The conceptual model does not imply causation but visualizes relationships that were examined.

Insights on impacts, section of population affected, extent of effects, changes in bio-physical patterns, changes in socio-economic status etc., are to be gained through these analyses. The impacts could be experienced at different levels of influence i.e., household, community and governance (Fig. 3), and at each level there should be effective mechanism in place to cope with climate change effects at different levels of aggregation. Households will respond differently to these changes. They will depend on the individual household, the community infrastructure, access and existing macro level policies and also on ground programs available. Identifying right indicators is always a challenge and varies with scales of interference and interaction (Vincent, 2007). We hypothesize that all the villages in the SAT are different from one another in bio-physical, socio-economical and available program meant to enhance their coping ability with available support, networks and reliefs (Yohe and Tol, 2002). However, our effort is to pick common threads of opportunities and constraints and to enable them to equip themselves against climate related risks. The response could be of different efficiencies a) at sub-optimal level at household, community or governance structures b) at optimal level, could respond effectively to climate change and related shocks and c) above optimal level. The developmental agencies should push communities to a higher level of capacity to respond optimally and to be resilient enough to cope with the expected climate changes.

Figure 3. Levels of interventions sketched out that have bearings on farmers' potential to cope against the effects of climate changes. a) Levels of influence b) Levels of optimal actions



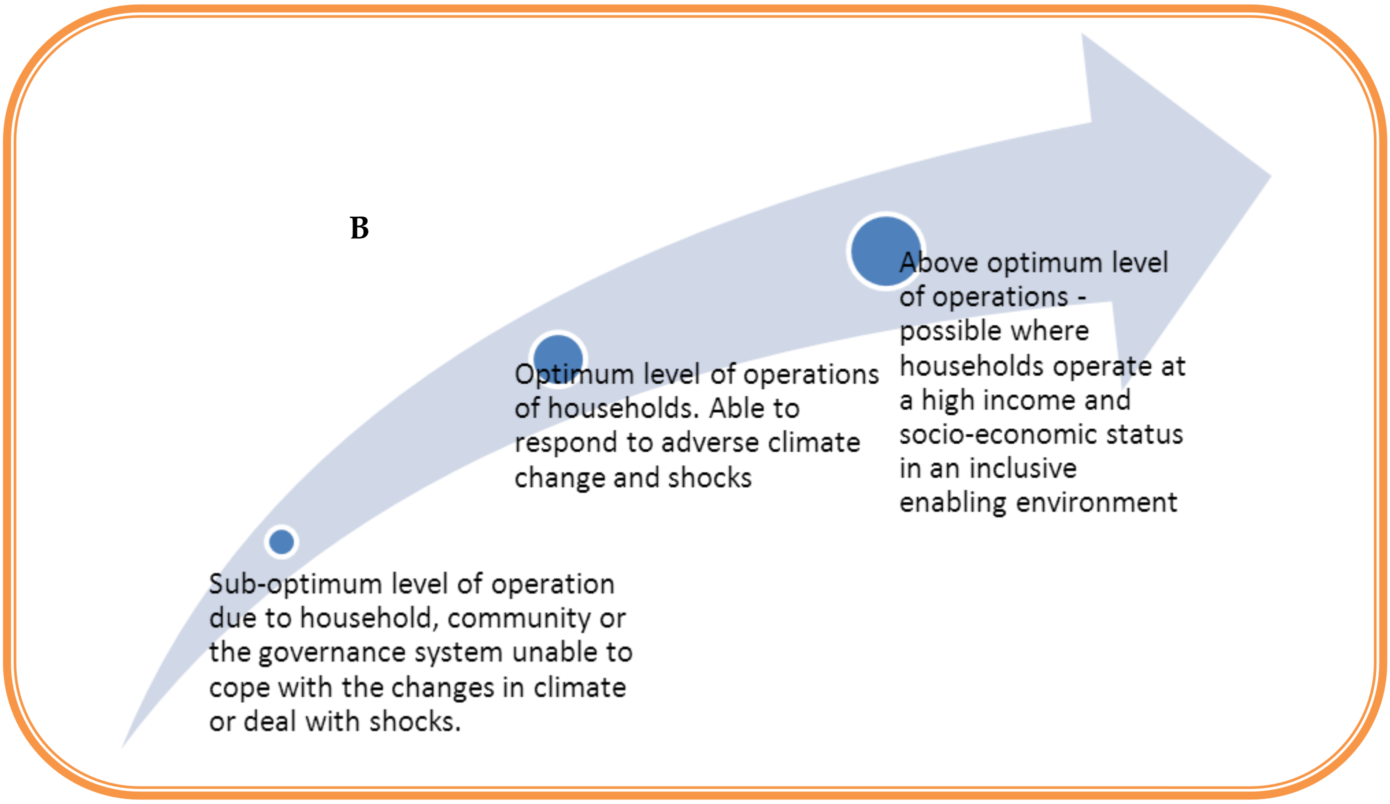


Table 4:- Matrix of climate resilient levels of actions – the ideal, actual and desired actions*

Level of actions	Ideal	Actual	Desired
Household	✓ Adequate wealth and assets to manage needs ✓ Sufficient social capital to mobilize resources, patronage or obtain knowhow ✓ Sufficient savings – income and or food ✓ Knowledgeable, competent to sustain livelihoods and adapt to context change	✓ Inadequate assets and wealth to meet basic needs ✓ Marginalized and disenfranchised ✓ No savings of food or income ✓ Limited world view and unable to adapt to changing situations on location	✓ Capacity to improve asset base to address needs in a sustainable manner ✓ Improve knowhow and competencies to deal with climate change and shocks.
Community	✓ Cohesive & inclusive ✓ Effective leadership to mobilize community ✓ Differentiated to have required competencies to share skills and address common needs ✓ Available and access to markets to trade required goods and services	✓ Fragmented ✓ Leadership self-serving or non-representative ✓ Low competency and skill base ✓ Low access to or prevalence of markets	✓ Collective awareness of the need for community based efforts to mitigate climate change and shocks ✓ Individuals and groups engage in improving their collective capacity
Country governance context	✓ Efficient service delivery system ✓ Responsive to local needs ✓ Inclusive and fair ✓ Ensure access to information and services in an equitable manner ✓ Effective principle of Subsidiarity	✓ Ineffective service delivery system ✓ Non-responsive to local needs ✓ Directed towards selected audience ✓ Community interests and needs decided at the top	✓ Regions adequately linked to the state service delivery system ✓ Strengthen local agency for decision making ✓ Effectiveness and efficiency improved to bridge any gaps in expectations and variability at local level

* Identified and compiled from the study

Farmer's adaptive capacity:

With reference to Figure 2, multitude of agro-socio-economic factors contributes to the power to adapt to the crisis. Adaptation to the slow and extreme changes in the climate is necessary to ward off the negative consequences resulting from it. So, an adaptation is defined as a response to actual or expected climate stimuli or their effects, which moderates harmful effects or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private or public adaptation and autonomous and planned adaptation. The capacity on the other hand is the ability of a system to adjust to change, to moderate potential damage, to take advantage of opportunities or to cope with consequences.

Climate change and its effects are slow in manifestations. The three key indicators that this study used are: (i) rainfall (ii) temperature and (iii) climate shocks. The intensity and the onset of rainfall, and the number of days of rain have a bearing on the lives of farmers both in terms of addressing household and farming requirements. Farmers dependent on water for their cropping and livestock rearing will suffer losses if rainfall is insufficient. On the other hand, an increase in temperatures has been reported worldwide, which only add to discomfort, but also evapotranspiration, thus affects crop productivity and moisture availability.

Farmers may adopt a range of strategies and practices to cope with the changes they experience in their environment. These changes may be a reaction to experiential knowledge and may not necessarily be associated with a rational awareness of the complexities of the environment cycle. Adaptive strategies may be adopted at an individual farm household level or as collective efforts undertaken by villagers.

The adaptive efforts may also be in terms of (i) changes in the technology adopted at the farms (ii) reallocation of resources at the household level i.e., savings, food stores, assets; and (iii) relocation to a new environment or diversifying the life base gain benefit from other opportunities (Table 4).

Farmers Vulnerability / Resilience: A related concept that explains adaptability is farmer vulnerability defined as the degree of susceptibility to adverse changes. Vulnerability is a function of the character, magnitude and rate of change to which a system is exposed, its sensitivity and adaptive capacity. It is also the ability to cope with the external threats. The vulnerability to external negative stimuli such as climate changes and shocks will depend on several intra-household factors such as (i) household economic robustness, and (ii) household social capital.

Household economic robustness: The ability to face any difficult situation in the village is often determined by the economic status of the farmer or the household. In the context of climate change or shocks, it is very plausible that the well-to-do farmers can adapt best and take care of their interests most effectively. Although the economic nexus is a key determinant, it also provides an opportunity to push forward a local agenda that ensures economic development of households in a more equitable manner. Thus with greater food reserves, savings and disposable wealth, more households will be capable of withstanding shocks and disasters associated with climate change. Diversifying income sources, i.e., not solely dependent on farming alone, will reduce risks and vulnerabilities.

Household social capital: It is at the household level that the farmers will most likely adapt to any shocks or trends of climate change. It is here at the family level that the day-to-day livelihood decisions are taken. The level of knowhow will determine how effectively the family will react to any deleterious effects of climate change or associated shocks. The greater the knowledge and competencies, the greater the ease with which they will be able to adapt. The information related to climate change and shocks that are to be experienced, what is suggestive as reaction, what ways are known and are being suggested to the people, what support programs are available etc. will be accessible to people with contacts at relevant personnel and agencies. The social status and competencies of the farmers will also determine the ease at which they obtain the external support available.

Enabling environment

In modern times state formation is a parallel process to development. In all countries the writ of the state is becoming more dominant and pervasive. All countries are espoused to have a strong, accountable and effective state. The ability of farmers, community based organizations and local agencies to act effectively and in the interest of the local residents depends very much on the “space” created for such work. With increasing writ of the state being asserted in the periphery, most services will be delivered by the state minimizing the scope for local engagements. However, the state can also benevolently legislate local involvement of participation.

Given the diversity and complexity of local situations, it is not practical or feasible to obtain total understanding of local situation. State planning cannot be done effectively from the center with minimum engagement of the periphery or the local communities or their representatives. The state should provide effective capacity development, resourcing and instituting a process that enables local participation to improve the validity and relevance of externally facilitated processes. These can include adaptation to climate change, livelihoods and taking preventive measures in preparation for deleterious effects of climate change or climate shocks.

Public policy frame: Consistency, continuity and coherence are ensured by a clear policy frame. In the context of minimizing negative effects on farmers and marginalized communities due to climate change and related shocks, the interest in safeguarding the most vulnerable must be enshrined in clear policy commitments. Failure to do so will divert attention and deflect government and public interest. If not addressed effectively, future impacts will have negative consequences of a larger magnitude. It is therefore necessary to identify a policy frame that enable people’s participation, promote good governance, and investment in strategies and programs to minimize negative impact; such framework must be agreed upon and adopted.

Community cohesion: Farm families live in the context of village communities, which are characterized by a web of social relationships. These relationships are economic, social, and historical. Caste, class, socio-economic status, gender, and age are well-known dimensions along which communities are stratified. In the modern world, occupation, language, political affiliations and patronage, access to information and ICT, overseas capital flow due to migration, social contacts, among others, also add further dimensions to stratification. There are numerous ways in which communities are differentiated too. Differentiation by neighborhoods, institutional affiliations, occupations and membership in social groups such as professional and vocational associations, etc., makes communities complex. This complexity also provides a basis for cohesion and collective ethos. At a symbolic level, communities will have clear demarcation of territorial boundaries, names and other forms in which it develops identity. A cohesive community will be able to identify leaders, identify goals of collective interest, and steer these processes to achieve targets than those that may be fractioned and in conflict.

Communities that have different organizations addressing the needs of its members strengthen the people's sense of community and will be able to address the needs of the members more effectively. This in the context of climate change and the deleterious effects that villagers may have to face, a cohesive community led by well-informed and well-meaning leaders will be able to address their needs more effectively than communities that are not cohesive and do not have effective leadership structure.

Local environment: The need to adapt to climate change is felt due to the realization that the extremes of weather changes experienced at present are a result of long-term climate change. National-level aggregated data analysis show trends and changes. Some changes are significant while others may be more suggestive. There may be patterns emerging in terms of climate-related shocks that have catastrophic effects on people, property, and economies.

However, given the wide variability in agro-ecological situations within each country and also among the countries, the need for location specificity in interventions is imperative. The trends and mean analysis may mask and distort what is experienced at the local level. The local changes must therefore be analyzed and compared with the national aggregates when drawing inferences, conclusions and recommendations.

Another key factor that will have a bearing on the effects of climate change and availability of rainwater is human interventions in transmitting water from areas with an oversupply to areas with an undersupply. The ambitious Indian National River Linking Project (INRLP)[7] started in 2006, where waters from perennial rivers

[7] The ambitious project of linking rivers aimed to reduce the damage of recurrent floods in the north and water shortages in the western and southern part of India. However, they have been oppositions from different group;

are to be diverted to seasonal rivers was one of such initiatives proposed to be a solution to the specific problem in the future. When implemented the water balance situation in large tracts of now arid regions will change, and will have bearing on the utility of land for farming. Hitherto, uncultivable land due to climatic conditions of low rainfall will change drastically. This is an extreme example and there is need to examine more closely the local context when drawing inferences of climate trend and analysis is important.

Local governance: The ability of farmers to cope and adapt to a great extent depends on the governance system that prevails in the localities and the connectivity to the national governance system (Agarwal, 2008). Practice of good governance or best practices by all governance bodies will result in the best alternatives of livelihoods provided to the people. An enabling environment for people to participate freely in governance ensures more positive outcomes such as reduction of poverty, famine, and economic development.

In most Asian countries, there are governance structures permeating to the village level that enables people's participation, such as the Panchayat Committees in India, the Pradeshiya Sabhas in Sri Lanka[8], and other village development societies. These groups ensure that governance systems are close to the people. Engaging in these structures enables people to steer local development planning in key areas such as agriculture, livestock, infrastructure and community development, forestry, green practices, and disaster mitigation and management. The more engaged the agencies are at the local level, the more likely local needs are served.

This is the principle of subsidiary, which is to enable decision making at the level where they have the greatest effect. Hence, an irrigation canal development project for a village is best undertaken at the local level where the beneficiaries are. If the local governance system is functioning well, then the principle of subsidiarity will apply at an optimal level. The climate change effects then can be better addressed with meaningful strategies specific to every locality, rather than blanket policies or programs. The programs and strategies must recognize this variability in terms of quality of governance system and extent of local participation. The conceptual ideal is where the principle of subsidiarity is applied fully under good governance.

Externalities: All villages and households are interconnected in a wide web of socio-economic relationships further enhanced today due to inroads in ICT that connects even the remotest human settlements. Thus with access to information, people can expand their world view and live in different locations to escape risky, violent, and unsustainable environments.

The extent to which the externalities are optimally used will be dependent on the availability and access to information relating to the external contexts and

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currently this project is on hold and concerted studies are undertaken on assessing ecological, social, economic, environmental feasibility.

[8] Lowest local governance structure in Sri Lanka.

opportunities. This may be enhanced due to social contacts already available or through persons already in the new locations or via information trickling from others who are aware of such opportunities (Jackson 2005). Thus the above framework provides the direction and focus for investigation and analysis.

Continuous crop or livestock failures, depletion of savings and assets, non-availability of local support system and state patronage to cushion climate shocks will prompt many to leave their village and migrate[9].

Study approach and methodology

This study involves six countries with varying institutional capacity for climate and socio-economic data collection and analysis.

Table 5. Summary of Methodology

	Research outputs	Methods
1	Trends in:	
	• Rainfall	Longitudinal data analysis of all six countries for last 40 years. Using TRENDZ software of CRIDA, India. In each country the met / climate data were collected from all available government sources from met and agriculture departments.
	• Temperature	Longitudinal data analysis of all six countries for last 40 years.
	• Shifts in onset and conclusion of cropping seasons	Based on Rainfall data analysis
	• Occurrence of extreme events	Assessing linear trends and any deviations in Rainfall and Temperature
2	Vulnerability assessment: Identify regions and population that are at risk due to climate change	Indexing drawing from – IPCC method – i.e., exposure, sensitivity and adaptive capacity. In each country depending on availability of data appropriate measures were used.
3	Estimates of crop yield losses and productivity	Crop modeling was done for selected locations in India and Viet Nam. India – four locations (Mahabubnagar and Anantapur district in Andhra Pradesh; Akola and Solapur district of Maharashtra state; Viet Nam – 8 agro-ecological zones.
4	Economic climate change impact analysis	Using Ricardian approach (Mendelsohn, et al. 1994) in Andhra Pradesh district of India and Northeast region of Thailand.
5	Adaptation strategies	
	• At household level • Collective • Governance context changes	House hold surveys in villages in the climate high risk locations in each country. • Bangladesh (4 villages) • India (6 villages) • China (2 villages) • Sri Lanka (4 villages) • Thailand (4 villages) • Viet Nam (2 villages) Survey of households based on two questionnaires –

[9] Migration can be classified as (i) step-up migration where the migrants will be able to improve their livelihoods (ii) step-down migration where the migrants for various reasons face a more difficult situation of reducing their quality of life due to the conduct of the host location[9] and (iii) where the migrants do not experience a difference.

		quantitative and qualitative Focus Group Discussion in each study village Key informants interviews
		While in all countries the locations were chosen from the semi-arid zones, in Bangladesh 2 villages were from flood prone areas.
6	Understand the social dynamics of adaptation	Drawn from the FGDs, household survey, key informants and published sources
7	Catalogue of adaptation strategies that may be applied in Asian context	
8	Asia region and country specific policy briefs	Policy inferences drawn from studies, reviewed by panels within the country and at a regional plenary session and finalized with in-country stakeholder participation.

A summary of the methodology adopted for each of the key research outputs are presented below and are elaborated (Table 5). A systematic planned methodology was adopted for this study and it was uniformly followed for all the countries. Four rounds of training and coaching support were provided to the lead partner organization on: (i) climate data and socio-economic quantitative data analytical methods; (ii) geo-statistical environmental data analysis; (iii) qualitative data collection and analysis; (iv) crop-environmental modeling; and (v) econometric modeling to assess climatic impact on net revenue. This was undertaken to ensure uniformity in research processes and outputs among the six country cases. However, as datasets were limited in some country cases, findings for these countries are analyzed from a regional perceptive. The research approach encompasses all the three components of climate agenda: namely exposure, sensitivity, and adaptive capacity.

The activities of the project include:

1. Collection and analysis of secondary data on weather parameters, and on cropping patterns, incomes, employment, consumption levels, enterprise economics etc. from representative sample of target countries.
2. Survey and comparison of farmers' perceptions about climate change and variability compared with detailed trend analyses of long-term climate data from nearby stations.
3. Assessment and analysis of past and present adaptation practices, using a social lens, along with biophysical lens to identify what works and what does not.
4. Mapping alternate channels and institutional arrangements for strategies and mechanisms to mitigate the effects of climate change.
5. Documentation of changes, if any, related to climate variability; and report of the cause-and-effect relationships between changes in cropping patterns and productivity levels, changes in weather parameters, length of growing period, policy changes and institutional innovations on the other, employing appropriate statistical tools.
6. Preparing policy briefs and conducting policy workshops to advocate the necessary policy changes to alleviate poverty and reduce the impact of income shocks caused by weather aberrations.

India and Bangladesh had a similar case, which boasts of long term panel data sets that complemented the analysis in capturing various dimensions of village dynamicity. Bangladesh agricultural economy is predominantly rice and aqua based, hence more information and related literature is captured on these facets than the water scarce phenomenon's like drought in semi-arid environment. Sri Lanka, Thailand, Viet Nam undertook cross sectional analysis and were successful in eliciting the most of the information required to accomplish the objective of the study. For China, it was the continuation of the acquired experiences of adaptive research from RETA 5812 on water shed development. It was felt in the beginning that the good rapport of the team developed during implementation of previous RETA 5812[10] will aide in capturing the grass root information more effectively. But, inspite of the various training for capacity building some of the critical dimensions of crop simulation and estimating of economic impacts could not be captured due to:

- Unavailability of minimum input datasets of the study region for carrying out this type of analysis using DSSAT (Decision support system for Agro-technology, a crop simulation model).
- Even though, the country project members were given adequate capacity building through training and workshop by the experts on the respective fields; but they still lacked the required technical understanding and resource personnel to carry out certain analysis.

India analysis was done comprehensively and similar template was followed in all other partner countries. ICRISAT had in-house technical competencies and could hone a great deal from its long term data on various variables and hence the report had enough reflections and information of India than other countries.

Data sources and analysis

Both quantitative and qualitative data and related analytical methods were used to understand biophysical inter-linkages and social relationships with reference to drivers of change, i.e., using data available on socio-economic, institutional and political factors (Bryman, 2006).

A detailed micro level survey was carried out for the identified region highly vulnerable to climate change in these study countries, and a representative sample of farm households in India, Bangladesh, Sri Lanka, China, Thailand and Viet Nam (Table 6) were surveyed for in-depth analysis. The historical weather data was collected from nearby weather stations and from secondary sources. Although the respondents' perceptions on essential weather variables, the main focus was on rainfall related parameters. Respondents were asked as to how they are changing their crops and enterprises in response to the changes perceived about climate. The changes are noted and the climate was compared with the farmers' perceptions. Further, perceptions of temperature, occurrence of extreme events and associated

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[10] The Asian Development Bank supported regional technical assistance project (RETA 5812) to ICRISAT for a project on "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" in 1999. http://www.icrisat.org/what-we-do/agro-ecosystems/ADB/introduction.htm.

changes were recalled for recording. In the next stage of analysis, data on crops and cropping patterns, soil and water management practices and the reasons for changes in cropping patterns, income structures, expenditure patterns, employment structures etc., which were related to the possible changes in weather parameters, characteristics of the natural resource base, institutions, policies etc. in these countries were analyzed. In India, the new information gathered from this study was complemented by available village level longitudinal data as reference. This data set is a unique longitudinal panel data developed and digitized by the ICRISAT and has guided policy analysis on the dynamics of poverty and livelihoods, especially in marginalized and risky environments.

Table 6. Study countries, villages and number of households sampled.

Country	Province/District	Village chosen for study	Number of households sampled for survey*
		South Asia	
India	Andhra Pradesh/	Aurepalle	30
	Mahabubnagar[11]	Dokur	30
	Maharashtra/Akola	Kanzara	30
		Kinkheda	30
	Maharashtra /Solapur	Kalman	30
		Shirapur	30
Sri Lanka	Puttalam	Mangalapura	50
	Anuradhapura	Galahitiyagama	60
	Hambanthota	Bata-Atha	50
		Mahagalwewa	50
Bangladesh	Mymensingh	Nishaiganj	30
	Thakurgaon	Boikunthapur	30
	Madaripur	Paschim Bahadurpur	30
	Chaudanga	Khudaikhali	30
		Southeast Asia	
Thailand	Chok Chai	Don Plai	40
	Nakorn Ratchasima	Kudsawai	40
	Chatturat	Tha Taeng	40
	Chaiyaphum	Nong Muang	40
Viet Nam	Phuoc Nam	Vu Bon	80
	Phuoc Dinh	Nho Lam	80
		China	
China	Guizhou	Lucheba	30
	Guizhou	Dajiang	30

* Surveys done in each village; sample size were fixed based on the resource consideration and 5-10% of the total population (Households).

A review of sociological literature on assessment and analysis of past and present adaptation practices and strategies by the poor and vulnerable was undertaken. Supporting policies and infrastructure required for large-scale adoption by the farmers were also assessed using qualitative assessments and social analysis using tools (eg. Participatory Rural Appraisal's, wealth ranking, social mapping, case histories, venn diagrams, etc.) in order to elicit and document best practices and strategies in adapting to climate change including mapping institutional

[11] In India, climatic analysis at district level were done for four districts, however, further in-depth micro level analysis were done for three districts except Anantapur district of Andhra Pradesh state.

arrangements. It helped in eliciting from the respondents to give their own interpretation of "why" and "how" the phenomenon was happening and 'what' were they doing based on their understanding. This qualitative process hence helped generate explanations regarding the impact and the adaptations, the role of institutions, technology, participation and collective action that were grounded in the context of climate change. Based on the results of the analysis, the role of social institutions in adaptation processes, and mechanisms to mitigate the effects of climate change were identified. The findings helped to identify not only those who are most vulnerable (in terms of extent as well as magnitude) to climate change and its effects but also those who can adapt to climate change and how. This learning helped to identify the characteristics as well as the relationships and institutional access people have to deal with the external shocks.

Capitalizing on existing information base that comprehensively characterizes SAT rural economies (eg. ICRISAT Village-Level Studies (VLS) (Walker and Ryan, 1990) (for India and Bangladesh) have helped in developing and designing long-term investment strategies for poverty reduction. The methodological approaches of the VLS include household and community surveys which was augmented by the use of meso/macro level data sets and micro-macro level modeling (DSSAT, and socio-economic models, (for eg. IMPACT (Rosegrant et al. 2008)) statistical analysis and GIS tools. The methodology is underpinned by a conceptual framework that appeals to a modified livelihoods approach adapted to explain agricultural transformation in SAT Asia.

Quantitative Assessments

The data for the analysis of climatic characteristics was obtained through various governmental agencies and National Research Centers (Table 7). Weather data analyzed are on a daily and monthly basis from 1971-2010. The data period varied among the countries depending upon the data availability. Daily and monthly meso and micro level weather data has been collected for the selected locations from the above mentioned sources. The collected data was examined for quality and averaged (in the case of temperature) or cumulated (in the case of rainfall) to get weekly, monthly, seasonal and annual data. The weathercock, an Agro-climatic analysis software program (CRIDA 2009) program was used to obtain the different formats and analysis - rainy days (days with more than or equal to 2.5 mm rainfall), probability of weekly rainfall for different amounts (Markov Chain probability), meteorological and agricultural drought, extreme weather events (temperature and rainfall), water balance and length of growing period. Non-parametric Mann-Kendall test was performed for identifying the significance in seasonal and annual rainfall and temperature trends over the years using Trends-Toolkit software. Based on the deviation of annual rainfall from its long period average (LPA), meteorological drought has been classified in three categories: 10 to 25% less than LPA – Mild drought; 26 to 50% less than LPA – Moderate drought; >50% less than LPA – Severe drought; accordingly, probabilities of occurrence of different types of drought have been worked out.

Table 7. Data source and reference periods from the study country

	Climatic Data sets*		Vulnerability Indicators	
Country	**Data Source**	**Data period**	**Data source**	**Data period**
India	Agro-met Data-bank (CRIDA), Indian meteorological Department (IMD)' Indian Institute of Tropical Meteorology (IITM, Pune)	1971-2010; Daily rainfall and atmospheric temperature data; district (4 nos.) and sub-divisional (mandal/tehsil) level of the districts	Meso level data base, ICRISAT. India	1971-2008
Sri Lanka	Sri Lanka Meteorological Department	1976-2008; daily, monthly and annual climatic data for 120 stations	Department of Census and Statistics, Department of Meteorology, Hector Kobbekaduwa Agrarian Research and Training Institute, Report of Labour Force Survey, Coastal Zone Management Plan, Coast Conservation Department, Sri Lanka Statistical Abstract,	1977-2007
Bangladesh	Bangladesh Meteorological Department	1971-2008; daily and monthly rainfall data was collected for 27 stations and temperature for 19 locations.	Statistical Yearbook of Bangladesh, Labour force Survey Reports, Agricultural Sample Survey of Bangladesh, and Bangladesh Meteorological Department.	1974-2006
Thailand	Thai Meteorological Department	1970-2008; for 120 stations across the country	Land development department, Meteorological department, Royal forest department, Office of agricultural economics, Royal irrigation department, , Ministry of interior , National statistics office, National economic and social development board	2006
Viet Nam	Phan Rang Meteorological station	For Ninh Thuan province (Rainfall 1979-2008) Temperature 1993 -2008)	General statistical office, Viet Nam	2008
China	Guizhou Weather Bureau and local weather station	1958-2008; Data on temperature and rainfall	-	-

* Climatic data sets period varied among countries depends on its availability

Agricultural drought is defined as a period of four consecutive weeks with rainfall less than 50% of its normal during the weeks with normal rainfall of 5 mm or more from mid-May to mid-October (Government of India, 1976). Based on this, the probabilities of occurrence of agricultural droughts were worked out for the selected stations. The trends in length of growing season were analyzed based on Moisture Adequacy Index (MAI). The weekly climatic water balance analysis for the selected stations/locations, were worked out using Moisture Index as per the Thronthwaite and Mather (1955) method to identify the climatic shift.

Prioritizing the target regions

All study countries are grouped based on extent of vulnerability, from which regions will be prioritized and focused for an in-depth analysis. How far regions in this countries/region differ in terms of vulnerability to climatic-related hazards or change? A vulnerability analysis was undertaken for each of the countries to identify those regions that may be most adversely affected.

Vulnerability – The conditions determined by physical, social, economic and environmental factors or process, which gives the degree of susceptibility of a community/region to the impact of climatic threats. Vulnerability is the key component in climate change research. This vulnerability assessment is helpful for developing and prioritizing regions of concerns and requires efficient channeling of major inputs and development-oriented research and to identify innovative models/strategies meant to reduce vulnerability and to pull regions/districts/countries away from risks.
The majority views vulnerability as a residual of climate change impacts minus adaptations. This paper defines vulnerability as the range of changes in degrees and magnitude at which the system is prone to impact of climatic factors and extreme events. It is also the degree to which the exposure is susceptible to harm due to exposure to a perturbation or stress, and the ability (or lack thereof) of the exposure unit to cope, recover, or fundamentally adapt (become a new system or become extinct) (Kasperson et al. 2003, O'brien et al. 2004, Malone and Engle 2011) It can also be considered as the underlying exposure to damaging shocks, perturbation or stress, rather than the probability or projected incidence of those shocks themselves. The main purpose of analysis is to compute vulnerability to climate change of target countries in South and Southeast Asian countries. This exercise helped to identify, classify, and map the vulnerability in regions/provinces based on a set of multivariate longitudinal data sets.
Vulnerability is a function of the character, magnitude and rate of climate variation. Vulnerability has three components: exposure, sensitivity and adaptive capacity. These three components are described as follows:

i) **Exposure** can be interpreted as the direct danger (i.e., the stressor) and the nature and extent of changes to a region's climate variables (eg. temperature, precipitation, extreme weather events). A rise in extreme events such as high temperature and, low precipitation will have effects on health and lives as well as associated environmental and economic impacts.

ii) **Sensitivity** describes the human-environmental conditions that can worsen or ameliorate the hazard, or trigger an impact.

iii) **Adaptive capacity** represents the potential to implement adaptation measures that help avert potential impacts. There are many opportunities to adaptive capacity such as better water management in times of drought, early warning systems for extreme events, improved risk management and various insurance.

The first two components together represent the potential impact; adaptive capacity; this means the extent to which these impacts can be averted. Thus, vulnerability is potential impact (I) minus adaptive capacity (AC). Vulnerability (V) is mathematically represented as:

$$\mathbf{V = \int (I\text{-}AC)}$$

Throughout the world, each country is facing new climatic challenges. Climate changes include higher global temperature, flood, drought, storm and sea level rise. This reviews the climate impacts, vulnerability, and adaptation capacity in South and Southeast Asia.

Vulnerability Analysis

The impact of climate change will not be similar in all parts of the region. There will be regional variations where some will be more vulnerable than others. This variability must be captured in order to target interventions in a rational manner. Therefore, vulnerability analysis is undertaken to identify high risk areas for prioritizing attention by policy makers and program intervention designers.

A composite index was developed to assess vulnerability and used to rank economic performance of geographic regions. lyengar and Sudarshan's (1982) method or IPCC method was adopted to develop a composite index from multivariate data, and it was used to rank the regions/countries/districts in terms of their economic performance. This methodology is statistically sound and well suited for the development of composite index of vulnerability to climate change. A brief discussion of the methodology is given below.

It is assumed that there are M regions /districts, K indicators of vulnerability and X_{ij} =1,2,..M_{ij} = 1,2,...K are the normalized scores. The level or stage of development of i^{th} zone, y_i is assumed to be a linear sum of X_{ij} as

$$\overline{y_i} = \sum_{j=1}^{K} w_j x_{ij}$$

$(0 < w < 1 \, and \sum_{j=1}^{K} w_j = 1)$ are the weights.

In Iyengar and Sudarshan's method the weights are assumed to vary inversely as the variance over the regions in the respective indicators of vulnerability. That is, the weight w_j is determined by

$$wj = \frac{c}{(var)x_{ij}}$$

Where c is a normalizing constant such that

$$c = \Sigma_{j=1}^{j=k} \frac{1}{var\ \ x_{ij}}^{-1}$$

The choice of the weights in this manner would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter regional comparisons. The vulnerability index so computed lies between 0 and 1, with 1 indicating maximum vulnerability and 0 indicating no vulnerability at all.

For classificatory purposes, a simple ranking of the regions based on the indices viz., y_i would be enough. However for a meaningful characterization of the different stages of vulnerability, suitable fractile classification from an assumed probability distribution is needed. A probability distribution which that is suitable for this purpose is the beta distribution, which is generally skewed and takes values in the interval (0, 1). This distribution has the probability density given by

$$(z) = \frac{z^{a-1}(1-z)^{b-1}}{\beta(a,b)}, 0, z, 1 \text{ and } a, b > 0.$$

where β (a, b) is the beta function defined by

$$\beta\ \ a, b\ \ = \int_0^1 x^{a-1}(1-x)^{b-1}dx$$

The two parameters 'a' and 'b' of the distribution can be estimated and the beta distribution is skewed. Let $(0,z_1)$,(z_1,z_2),$(z_2,,z_3)$,(z_3,z_4) and (z_4,z_1) be the linear intervals such that each interval has the same probability weight of 20%, These fractile intervals can be used to characterize the various stages of vulnerability.

1. Less vulnerable if $0 < \bar{y}_i < z_1$
2. Moderately vulnerable if $z_1 < \bar{y}_i < z_2$
3. Vulnerable if $z_2 < \bar{y}_i < z_3$
4. Highly vulnerable if $z_3 < \bar{y}_i < z_4$

Indicators and periodic data are specific for the analysis based on availability and completeness. The region considered for computing vulnerability varied with agro-ecological/state/district classification of study country (Table 8). For India, a set of 16 indicators were used and 15, 13, 15, 15 for Thailand, Viet Nam, Sri Lanka and Bangladesh respectively.

Qualitative Assessments

To capture farmer's perception on periodical changes in various bio-physical and socio-economy of the rural population and trends in natural resource base, institutions, policies etc., surveys were conducted using detailed and diligently prepared structured questionnaire. The questionnaire had collected information on all key points linked with climate change, agriculture, socio-economic status and trend, collective actions, trends in natural resource base, perceptions, and anticipations. In addition, key informant interviews and focus group discussion (FGD) were conducted to corroborate the information from individual households. Interviews and FGD help attain comprehensive understanding of rural setup and current state of affairs, which supplement household survey information. For India and Bangladesh, long-term panel data was used which was obtained from a long-term project "Village Level Studies" (VLS). This is a classical study of ICRISAT, initiated in the mid-1970s. Longitudinal household level bio-physical and socio-economic data from 1975 onward are available for two different phases i.e., Generation I (1975-1985) and Generation II (2001-present) (ICRISAT, 2008).

A combination of information gathering tools were used at village level to improve the validity of the FGDs. They included the following: (i) undertaking transect walks (ii) drawing time lines of key events and village level changes(iii)undertaking visualized wealth ranking of villagers (vi) visualizing institutional / actor mapping (v) resource mapping and (vi) constructing seasonal calendars. These tools were used by the participating villagers: A manual containing the knowhow developed by ICRISAT was used to train the facilitators who used these tools to elicit information from the villagers in all the participating countries.

Social analysis were undertaken to explore, understand and identify various social facets of climate change and variability at the micro level. The analysis tried to answer critical questions of how farmers are responding to climate change or variability, and also how the individuals or groups who are most vulnerable adapt to effects of climate change. They also helped identify the adaptive capacities. This analysis is expected to provide information on behavioral changes among the households/groups that belong to different socio-economic based strata of rural households in South Asia, Southeast Asia and China.

Purposive sampling was used to select farmers to elicit information to understand and identify perceptions of climate change and subsequent adaptation practices. The sample was separated into large, medium, and small farmers, landless labourers and women. The objective of the field visits was to understand the perceptions of the farmers in terms of the vulnerability to climate change and their adaptation strategies. Specific focus was also placed on the role of formal and informal institutions in facilitating adaptation practices. The methodology used for data collection was based on focus group discussions and a semi–structured questionnaire which was used as an interview guide to probe incidence of climate change and variability, vulnerability across groups, effects and impacts on agriculture and livelihoods as well as adaptation mechanisms. The respondents were mainly farmers and other key informants including local elders, teachers and elected officials. representative groups of women and men participated in the FGDs.

Since adaptation is local, it is vital to understand the role of local institutions in facilitating improvements in adaptive capacities of the rural poor. Through focus group discussions, youth and women were interviewed to get an insight into the relevance of institutions in the villages providing adaptive capacities and resilience against vulnerability in general and climate change in particular. To understand how the community had been coping with climatic shocks in the past and what it could do as a future course of action, a mixed group of middle-aged and elderly farmers were interviewed who gave an account of the incidences of a particular climatic shock in a particular year, the effect it had on the village and how the village reacted to cope with the same. The heart of all the focus groups was however to understand the perceptions that the community has towards the entire phenomenon of climate change.

Table 8. Indicators used to compute vulnerability to climate change*

	India [Andhra Pradesh and Maharashtra state]	FR	Thailand [Over all country plus the provinces in the North East]	FR	Viet Nam [Country level]	FR	Sri Lanka [25 districts of the country covering all 9 provinces]	FR	Bangladesh [Six Ecological zones]	FR
Exposure	Change in Rainfall (%)	↑	Change in Rainfall (%)	↑	Change in rainfall (%)	↑	Flood and drought (Nos.)	↑	Density of population (sq. km)	↑
	Change in maximum Temperature (°C)	↑	Change in Maximum temperature (°C)	↑	Change in maximum temperature (°C)	↑	Maximum Temperature (°C)	↑	Literacy rate (%)	↓
	Change in minimum Temperature (°C)	↑	Change in minimum temperature (°C)	↑	Change in minimum temperature (°C)	↑	Minimum Temperature (°C)	↑		
					Change in average temperature (°C)	↑	Rain fall (mm)	↑	Annual rainfall (mm)	↑
Sensitivity	Percentage of cultivable waste	↓	Percentage of irrigated land to agriculture area	↓	Population density(pop/km^2)	↑	Vegetation degradation (%)	↓	Maximum temperature (°C)	↑
	Percentage of gross area irrigated to gross area sown	↓	Total population per unit area (pop/km^2)	↑	Overall poverty (% population)	↑	Total rural population per Km^2	↑	Minimum temperature (°C)	↑
	Fertilizer use (t/ha)	↓	Percentage of forest area to land area	↓	Food poverty (% population)	↑	No. of Small holdings	↑		
	Population density (Persons/sq.km.)	↑	Percentage of paddy land to agricultural land	↓	Km coastal lines/AEZ	↑	Area under major crops (hectares)	↓		
	Percentage of small farmers	↑	Consumption of fertilizer for rice per unit area (kg/ha)	↓			Irrigation intensity of paddy (%)	↓		
	Percentage of Forest area	↓							Area under food crops (Hectares)	↓
Adaptation Capacity	Livestock (no.per ha)	↓	Literacy rate (Nos.)	↓	Rice Yield (t/ha)	↓	Literacy rate (%)	↓	Cropping intensity (%)	↓
	Percentage of rural agricultural laborers	↓	Average farm size (ha)	↓	Food production (million ton/EAZ)	↓	Unemployment rate (%)	↓	Forest Area (acres)	↓
	Percentage of cultivators	↓	Percentage of people below poverty line	↑	Animal farm (N. Farm/AEZ)	↓	Amount of paddy per hectare	↓	Irrigation intensity (%)	↓
	Percentage of rural literates	↓	Amount of income generated in particular province per capita (Baht)	↓	Percentage forest cover / AEZ area	↓	Number of farms engaged in agriculture	↑		
	Percentage of fodder area	↓	Amount of rice produced per hectare (Kg/ha)	↓	No. of enterprise (Nos.)	↓	Cropping intensity of paddy (%)	↓	Total employed (Nos.)	↓
	Cereals production (tons/ha)	↓	Amount of cassava produced per hectare (kg/ha)	↓			Number of cows used for milk production	↓	Total labor force (Nos.)	↓
	Pulses production (tons/ha)	↓	Gross area comes under cultivation with reference to net area under cultivation (%)	↓					Total self -employed (Nos.)	↓
									Total day laborer (Nos.)	↓
									Exposed area (sq. km)	↑
									Geographic area (sq.km)	↑

* Indicators were selected based on data availability; FR – Functional Relationship; The functional relationship input for different indicators is based on expert judgment from the respective country.

Analysing economic impacts

The Ricardian approach is a cross-sectional model applied to agricultural production. It takes into account how variations in the climate change affects the net revenue or land value. Following Mendelsohn et al. (1994), the approach involves specifying a net productivity function of the form

$$R = \sum p_i q_i (x, f, z, g) - \sum p_x x \qquad (1)$$

where R is the net revenue per hectare in the constant rupees, p_i is the market price of crop i, q_i is output of the crop i, x is a vector of purchased inputs (other than land), f is a vector of climate variables, z is a set of abiotic variables, g is a set of economic variables such as market access, literacy, population density etc, and p_x is a vector of input prices. The farmer is assumed to choose x to maximize the net revenues given the characteristics of the farm and market prices. Assuming a quadratic function for crop output, the standard Ricardian model is specified by the quadratic function

$$R = \beta_0 + \beta_1 f + \beta_2 f^2 + \beta_5 z + \beta_6 g + u \qquad (2)$$

where u is an error term and f and f^2 are levels and quadratic terms for temperature and precipitation. The inclusion of quadratic terms for temperature and precipitation ensures non-linear shape of the response function between the net revenues and climate. Normally we expect that farm revenues will have a concave relationship with temperature. When the quadratic term has a positive sign , the net revenue function is U-shaped, but when the quadratic term is negative, the function is hill-shaped. As each crop has an optimal temperature at which it has a maximum growth, the function is expected to have a hill-shape. From the fitted equation, we can find the marginal impact of a climate variable on farm revenue. The marginal impacts are usually found at the mean level of the climate variable. Thus from equation (2) we have

$$\frac{\partial R}{\partial f} = \beta_1 + 2\beta_2 \bar{f} \qquad (3)$$

Where $\bar{f}$ is the mean of the climate variable. This shows that the marginal effect of a particular climate variable is equal to the sum of i) coefficient of the linear term and ii)twice the product of the coefficient of the quadratic term multiplied by the mean level of the climate variable. The climate variables included in the model are season temperatures and their squares and season precipitations and their squares. MATLAB software package was used to fit the model.

Future impact of climate change on crop yield (India and Viet Nam)

In India, We used the CMS CERES-Sorghum and CROPGRO-Groundnut models, which are a part of the DSSAT v4.5 (Jones et al., 2003) to study the impact of climate change factors and CO_2 on the productivity of sorghum and groundnut, respectively. The major components of these models are vegetative and reproductive development, carbon balance, water balance and nitrogen balance. The model needs input of daily weather data (maximum and minimum temperatures, rainfall and solar radiation), crop and cultivar-specific parameters and soil profile data on physical and chemical properties to simulate the growth and development of crops. Growth and development is simulated using daily time step from sowing to maturity and ultimately it predict yield. The physiological processes that are simulated describe crop response to major weather factors and soil characteristics determining crop growth. The models also incorporate effects of increase in CO_2 concentration in the atmosphere on growth and yield of these crops by increasing photosynthesis or light use efficiency and reducing water loss via reduced leaf conductance. Therefore, the effects of changes in temperature, rainfall and CO_2 associated with climate change can be simulated. As the crop models do not incorporate simulation of biotic stresses (pests and diseases) and their affect on crop growth, the model simulated yields were free from such yield limiting factors. The only factors that the models considered were weather, soil and agronomic management of crops and their interaction on crop growth and yield.

In Viet Nam, three categories of models were used to assess climate change impacts on crop production. This includes crop simulation models, hydrologic models, and river basin models. For river deltas, hydrodynamic models are applied to evaluate sea level rise effects on inundation and salinity intrusion, which affect the availability of cropland, especially rice land. Crop models simulate crop yields based on growing period weather condition, soil properties, crop genetic characteristics, and management. A process-based crop simulation model, WOFOST, and a semi-empirical crop model are conjunctively used. WOFOST (Boogaard et al. 1998) is used to simulate potential yields under baseline and climate change scenarios. Relative potential yield changes due to increases of temperature and atmospheric CO_2 concentration are determined with simulated yields under baseline and climate change scenarios. These relative yield changes are taken by a semi-empirical hydro-crop model that simulates crop yield responses to water deficit, under rainfed and irrigated conditions. For irrigated condition, the hydro-crop model (Thurlow et al. 2009) takes applied irrigation water from the river basin models. For rainfed condition, rainfall and soil moisture are the water input for crop evapotranspiration.

Project findings: Salient features

Synthesis of climatic trends

In climate change studies, it is important to understand the long-term trends and changes in climatic variables. This could be an input in quantifying the impacts at various levels of analysis. Analyzing current climatic trends will improve our understanding of future climate change and variability affecting specific sectors/ regions. This information will help in prioritizing research needs to increase capacity of rural farming communities to cope with the risk associated with climate change impacts (Howden et al. 2007; Morton 2007). It is an understood and accepted fact that climate is changing; but the extent it is changing in the study areas needs to be clarified. Analyzing country level climatic information will provide insights on trends of a country as a whole, but general characterization fail to represent diverse regional or local climatic conditions. The annual rainfall varied from 600mm in India to 5000mm in Bangladesh (Table 9). No significant trend was observed in annual rainfall in all these countries in the last 40-50 years. However, an increasing or decreasing trend at more aggregated (regional) level has been observed. Significant changes in the occurrence of extreme events viz., rainfall and high temperature events were observed. Analysis also indicated increase occurrence of droughts and floods during the recent years in all the target countries (Agrawala et al. 2003).

India

Average annual rainfall in the semi-arid regions of India varies from 600 to 1000 mm. Most of the total annual rainfall (60-70%) is received during the southwest monsoon season (June-Sep). Annual average rainy days are ranged from 30-50 days in the major part of semi-arid regions of India. All India monsoon rainfall analysis showed no significant trend. However, in the West coast region, north Andhra Pradesh and northwestern India showed increasing trends while a decreasing trend observed over east Madhya Pradesh, northeast India and parts of Gujarat, and Kerala. Significant positive trends were observed in heavy rainfall events in the west coast and northwestern parts Peninsula (Maharashtra) (Goswami et al. 2006). Significant increasing trend is observed in annual and seasonal mean temperature, except during the southwest monsoon over India. Annual, post-monsoon, summer and winter season mean temperatures increased by 0.4, 0.9, 0.4 and 0.5°C respectively. No long-term trend was observed in the frequencies of occurrence of extreme events viz., droughts/floods.

Average annual rainfall over Andhra Pradesh is 941 mm and varies from 500 mm in Anantapur district to 1200 mm in North coastal Andhra and northern Telangana regions. In Maharashtra, average rainfall is 1240 mm and it ranges from 600 mm in Ahmednagar district to 3300 mm in Ratnagiri district. Andhra Pradesh receives 68% of the total annual rainfall during southwest monsoon period and 89% in Maharashtra state. No significant trend in annual and seasonal rainfall in both the states except increasing trend was noticed in annual rainfall of Andhra Pradesh at 5% significant level (96 mm during the 1971-2007 periods). Drought analysis of 140 years rainfall data showed that the probability of occurrence of moderate drought is low in the state of Andhra Pradesh (4%) and high in Maharashtra (8%). Negligible probability is observed in Andhra Pradesh (1%) and no such cases were noted in Maharashtra in the case of severe drought. Length of growing season is lowest, (70 days) in Anantapur region of Andhra Pradesh and 90 days in the southern part of Maharashtra. As it moves away from SAT region, the LGP (length of growing period) increases to a maximum of 180 days (Table 9a).

Anantapur and Mahabubnagar district of Andhra Pradesh, Akola and Solapur in Maharashtra state are the selected target regions for in-depth analysis in SAT. Average annual rainfall is 573 mm (1973-2010) at Anantapur and the remaining three districts receive between 720 and 790 mm. Variability in annual rainfall is highest in Anantapur (35%) followed by Solapur (31%) and lowest in Mahabubnagar (25%). 73 – 86% of annual rainfall is received from southwest monsoon season which is the main cropping season in three locations; except in Anantapur where about 60% of the annual rainfall is received from the southwest monsoon and 27% from the northeast monsoon period. No significant trend in annual and seasonal rainfall is observed in all the four locations except in Solapur where in summer rainfall showed an increasing trend at 10 % significant level. Lowest annual rainy days were noticed in Anantapur (34 days) followed by Akola (42 days), Solapur (44 days). The highest is in Mahabubnagar (52 days).

In all the locations, annual mean maximum and minimum temperatures showed an increasing trend except in Akola where a declining trend in maximum temperature was observed (0.01°C / year). Highest rise in maximum annual temperature is seen in Anantapur (0.04°C/year), while Solapur (0.02°C/year) has the minimum temperature. Meteorological drought analysis indicated that the probability of occurrence of mild drought is more at Akola and Solapur (21%) followed by Mahabubnagar (16%) and least in Anantapur (13%). In the case of moderate drought, the highest probability is noticed in Solapur (23%) followed by Mahabubnagar (16%) and lowest is in Anantapur (13%), and Akola (13%).

However, the occurrence of severe drought is approximately once in a 10 year period in Anantapur and with minimum probability in Akola and Solapur (3%). No severe drought was observed in Mahabubnagar. No trend in heavy rainfall events (>50mm /day) in all the locations. Extreme temperature events rose significantly with maximum temperature >40°C at Anantapur in the month of March and > 43°C at Solapur in May.

No significant trend was observed in Mahabubnagar in extreme events both in maximum and minimum temperature. However, decreasing trend in number of days with >42°C in the recent years was noticed in Akola. Length of growing period analysis revealed that the shortest growing season is observed in Anantapur (91 days) < Solapur (148 days) < Mahabubnagar (154 days) < Akola (182). In the case of rainfall, no significant change, but variability is seen in all four locations. From the above analyses it can be concluded that the rainfall in relatively low in these region with high variability in quantum, distribution and onset. Rising temperature is evident with higher probability of meteorological and agricultural drought occurrence. In the recent years, increased variability in distribution and onset of monsoon is observed in targeted regions of SAT-India. Among the districts analyzed, Anantapur is the most vulnerable district with highly variable rainfall , temperature and probability of drought and length of growing season and poor water balance. A comprehensive synthesis of climatic trends at regional level is in Annexure 1.

Table 9. Trends in general climatic characteristics of selected countries in Asia (Country level)

		South Asia			Southeast Asia	
Climatic parameters	**India (SAT)**	**Sri Lanka**	**Bangladesh**	**Thailand**	**Viet Nam**	**China**
Annual rainfall	Rainfall varies from 600-1000 mm.	Average rainfall is 1861mm. and majority area receives 1000 - 2000 mm and western part gets > 3000 mm.	North and south eastern parts receives high rainfall (3000-5000 mm) and western parts receives low rainfall (<2000 mm).	Country average rainfall is 1,555 mm. Most areas receive 1200-1400 mm but eastern and southern parts received >4000 mm	Annual rainfall in Viet Nam varied from 700-2400mm The rainfall has decreased about 2% over the past 50 years (1958-2007)	-
Annual rainfall trend	No significant trend in annual and monsoon rainfall. However trends in regional pattern in monsoon rainfall in West coast, North Andhra Pradesh and northwest India and declining trend in east Madhya Pradesh, northeast India, parts of Gujarat and Kerala was noticed	No significant decrease in annual rainfall but showing decreasing trend of minimum of 2 mm per year in Jaffna (Dry Zone) and maximum 17 mm per year in Kegalle (Wet Zone). However, recent analysis of annual average of rainfall over Sri Lanka decreased by about 7%, during the 1961-1990 period compared to 1931-1960 period.	Annual rainfall showed an increasing trend .	No significant trend in annual rainfall during the past 40 years. There was significant increasing trend in annual and summer (Feb-Apr) rainfall (p<0.1) but no significant trend in winter, early and late rainy season.	Annual rainfall showed declining trend in dry season (Nov.- Apr.) and increasing in wet season (Jul.-Aug.)	No significant trend observed in the past 100 years.
Heavy rainfall frequency	Significant rising trend in heavy rainfall events is observed in West coast and northwestern peninsula (Maharashtra).	Heavy rainfall and high intense rainfall, recent analysis for the period 1961-2008, shows that one day heavy rainfall increased in the western slope	-	-	Frequent occurrence of heavy rainfall events.	Frequency of heavy rainfall is increasing in the Chang Jiang basin and resulting in flooding.

	South Asia			Southeast Asia		
Climatic parameters	**India (SAT)**	**Sri Lanka**	**Bangladesh**	**Thailand**	**Viet Nam**	**China**
% contribution of seasonal rainfall to annual rainfall	70-80% of annual rainfall received during southwest monsoon season (June-Sep) except in Tamil Nadu and South coastal AP (51%).	60% of the annual rainfall is received from the southwest monsoon & 2nd Inter monsoon periods.	80% of the annual rainfall is received during summer (SWM-June to early Oct). Remaining 20% from other seasons.	42% of annual rainfall is received from late rainy (Aug-Oct) & 36% from early rainy season (May-Jul).	-	-
Annual Rainy days and its trend	Annual rainy days varies from 30-50 days in major part of SAT region.	Annual average number of rainy days in the Dry Zone is generally less than 100days. Some parts of Hambantota and Puttalam Districts in the Dry Zone number of rainy days even go below 60. Number of rainy days in the Intermediate Zone ranges from 100 to 180 days, while it is around 180days or above in the Wet Zone districts of Sri Lanka	Increased in recent years (2001-02) when compared to long term average (1971-2000).	Average annual rainy days is 128. Rainy days are more (51days) during late rainy season (Aug-Oct) & followed by 49 days in early rainy (May-Jul).	Number of days with rain significantly increased in the North and reduced in South central coastal and Mekong River Delta	-
Annual temperature trend	Annual mean temperature shows an increasing (0.4°C) trend (1901-2003).	Annual mean temperature increased by 0.2°C during 1951-2006 Both Tmax and Tmin shows an increasing trend. Highest rise in Tmin and Tmax is in high ranges and coastal areas respectively.	Increasing trends in both Tmax and Tmin.	Annual mean minimum temperature showed slight increasing trend from decade 1970s to decade 2000s. Significant rise in both annual min. and max. temp. ($p=0.01$)	Annual mean temperature is increasing at an average of 0.15^0C/decade	Annual mean temperature rose by about 1.1°C in the past 50 years

	South Asia			Southeast Asia		
Climatic parameters	**India (SAT)**	**Sri Lanka**	**Bangladesh**	**Thailand**	**Viet Nam**	**China**
Seasonal temperature trend	No significant trend in mean temperature during monsoon season. Northeast monsoon showed highest increase (0.9°C) followed by winter (0.5°C) and summer (0.4°C) during the period 1901-2003.	-.	-	Significant rising trend in winter and late rain min. temp. (p=0.01) but all the 4 seasons had significant increasing trend in max. temp. (p=0.01)	In some months of summer, temperature increased by 0.1-0.3^{0}C	All seasons showed upward trend during 1951—2001 period. Warming is significant in spring and autumn, but it is very weak in summer.
High temp frequency	-	Both minimum and maximum ambient temperature has increased. The general warming trend is expected to increase the frequency of extremely hot days.	-	-	-	Days with Tmin < 0°C is decreasing significantly since 1950s. No significant increase trend in days with Tmax above 35°C. But, some places of North China showed rising trend.
Drought	No long-term trends in the frequencies of extreme droughts or floods during monsoon season. However, frequency of its occurrence has increased.	The increased frequency of dry periods and droughts are expected. Consecutive dry days are increasing in dry and intermediate zones in Sri Lanka.	-	Only mild drought experienced during the last 40 years (12.5%) with no moderate and severe drought probability	-	Serious drought has been experienced in North China Plain and Northeast China frequently in the past 50 years.
Length of growing period (LGP)	Ranges from 70-120 days in SAT region.	The Yala season is from March to August including First Inter-monsoon and southwest Monsoon, and Maha season is defined from October to February which includes second inter monsoon and northeast monsoon. With respect to rainfall pattern, year around cultivation is practiced.	-	From 150-180 days	From 110 to 60 days for spring rice, 105 to140 for summer rice	

Table 9a. Climatic trends in the study districts of India

Parameters	Andhra Pradesh		Maharashtra	
	Anantapur District	**Mahabubnagar District**	**Akola District**	**Solapur District**
Annual rainfall	573 mm (1973-2010)	784 mm (1971-2010)	791 mm (1971-2010)	720 mm (1971-2010)
Annual rainfall trend	NS	NS	NS	NS
% contribution to annual rainfall	SWM – 61%; NEM – 27% Summer – 12%	SWM – 76%, NEM – 15% Winter – 1%, Summer – 8%	SWM – 86%; NEM – 10%	SWM – 73%; NEM – 17% Winter – 1%; Summer – 9%
Seasonal rainfall trend	NS	NS	NS	NS only Summer RF – Increasing (10%level)*
Annual rainy days	34 days	52 days	42 days	44 days
Seasonal rainy days	SWM -16, NEM-8 days; Winter – 2; Summer - 6	SWM – 40 days; NEM – 7 days; Winter – 0; Summer -5	SWM – 34 days; NEM – 4 days Winter – 1; Summer - 3	SWM – 25 days; NEM – 7 days; Summer – 8 days; Winter -3
Annual mean temperature	Tmax : 34 ºC; Tmin : 21.7 ºC	Tmax : 33.3ºC; Tmin : 21.8ºC	Tmax : 34.2 ºC; Tmin : 19.4 ºC	Tmax : 34.0ºC; Tmin : 20.0ºC
Annual mean temperature trend	Tmax : Increasing (1% level)* (0.038ºC/year); Tmin : Increasing (NS); (0.001 ºC/year)	Tmax : Increasing (5% level)*; (0.01ºC / year); Tmin : Increasing (1% level)*; (0.014 ºC / year)	Tmax : Decreasing (5% level)*; (0.01ºC / year); Tmin : Increasing (5% level)*; (0.017 ºC / year)	Tmax : Increasing (1% level)* (0.016ºC / year); Tmin : Increasing (5% level)*; (0.01ºC / year)
Seasonal mean max temperature and trend	SWM –33.6ºC(5% level) Increasing (0.032ºC/year); NEM – 30.6ºC (1% level)*; Increasing (0.056ºC/year); Winter – 32.3ºC (1% level)*; Increasing (0.058ºC/year); Summer – 38.6ºC ; (10% level)*; Increasing (0.005 ºC)	SWM – 32.2ºC (NS) Decreasing (0.014ºC/year); NEM – 30.7ºC (1% level)*; Increasing (0.047ºC/year); Winter – 31.8ºC (1% level)* Increasing (0.025ºC/year); Summer – 38.5ºC (NS) Increasing (0.005ºC)	SWM – 33.1ºC (NS); NEM – 31.6ºC (NS); Winter – 31.1ºC (NS); Summer – 40.2ºC (10% level)*; Decreasing (0.005ºC/year)	SWM – 32.9ºC (NS); NEM – 31.4 ºC (10% level)*; Increasing (0.031ºC/year); Winter – 32.3ºC (1% level)*; Increasing (0.025 ºC); Summer – 39.2ºC (5% level)* Increasing (0.005 ºC/year)
Seasonal mean min temperature and trend	SWM – 23.6ºC (NS) Decreasing (-0.011 ºC/year); NEM – 19.2 ºC (NS); Winter – 17.5ºC (NS); Summer – 24.3ºC (10% level)*Increasing	SWM – 23.4ºC (1% level)* Increasing (0.012ºC/year); NEM – 19.1ºC (NS); Winter – 18ºC (NS); Summer – 24.9ºC (1% level)* Increasing (0.02ºC/year)	SWM – 23.6ºC (1% level)*; Increasing (0.023ºC/year); NEM – 14.7ºC (NS); Winter – 12.6ºC (NS); Summer – 23ºC; Decreasing (0.02ºC/year)	SWM – 22.5 ºC (1% level)*; Increasing (0.019ºC/year); NEM – 16.8ºC (10% level)*; Increasing (0.001ºC/year); Winter – 15.4ºC (NS) ; Summer – 23ºC (1% level)*; Increasing

	(0.02°C/year)			(0.02°C/year)
Meteorological drought probability	Mild – 30%; Moderate – 15%; Severe – 11%	Mild – 16%; Moderate – 16%; Severe - Nil	Mild – 44%; Moderate – 13%; Severe – 3%	Mild – 21%; Moderate – 23%; Severe – 3%
Extreme rainfall events	> 25 mm / day - Increasing	> 25 mm / day - Increasing	> 25 mm / day – Increasing. Especially during SWM period	> 25 mm / day - Increasing
Extreme temperature events	Tmax >40°C Increasing (5% level)*	No significant trend on high temperature events	Decreasing trend (significant at 1%)* was observed in frequency of occurrence of high temperature > 42°C.	Increasing trend (significant at 5%) was observed in frequency of occurrence of high temperature >43°C. Decreasing trend (significant at 5%)* was observed in frequency of occurrence of low temperature 7 - 10°C.
Length of growing period	Start – 35 week; End – 47 week; Period – 13 weeks	Start – 28 week; End – 49 week; Period – 22 weeks	Start – 26 week; End – 51 week; Period – 26 weeks	Start – 29 week; End – 48 week; Period – 20 weeks
Climate type	Arid (No change)	Semi-arid (No change)	Semi-arid (No change)	Semi-arid (No change)

*Significant; SWM – Southwest monsoon; NEM – North east monsoon; NS – Non significant; Tmax – Maximum temperature; Tmin – Minimum temperature

Sri Lanka

The country's annual average rainfall is 1861 mm. Most areas of the country receives 1000 – 2000 mm and the western part gets >3000 mm of rainfall. Sri Lanka is divided into three regions based on rainfall viz., wet zone (total rainfall >2500 mm), intermediate zone (Total rainfall between 1750 - 2500 mm), and dry zone (Total rainfall < 2500 mm). Among the zones, dry zone is the most water stress vulnerable region in terms of water scarcity and drought. In Sri Lanka, 60% of the annual rainfall is received from the southwest monsoon (May-Sep) and the second inter monsoon (Oct-Nov) seasons. Temperature shows an increasing trend. Annual mean temperature has increased by 0.2°C during 1951-2006 and the increase has accelerated in recent years. Highest increase in minimum temperature is observed in high elevations and maximum temperature in the coastal areas.

Angunakolapellessa in Hambantota district and Eluwankulama in Puttalam district from dry zone were selected for in-depth analysis (Table 9b). The annual average rainfall is 1136 mm (1977-2008) in Angunakolapellessa and little higher rainfall (1193 mm) is received in Eluwankulama (1976-2008). Though not much difference exists in annual rainfall between the two locations, a difference exists in the seasonal rainfall. Angunakolapellessa received 65% of the annual rainfall from the southwest (May-Sep) monsoon and second inter (Oct-Nov) monsoon seasons, and the remaining 35% from the northeast and first inter monsoon periods. But, in Eluwankulama, 45% of the annual rainfall is received from the second inter monsoon and 23% from the northeast monsoon. Both annual mean maximum and minimum temperatures show an increasing trend in Eluwankulama. However, in Angunakolapellessa, a declining trend was prominent in mean maximum temperature up to 1997 and an increase from 1998 – 2008 and minimum temperature decreased till 1994 and has been rising from 1995 – 2008. Analysis of onset and withdrawal of rainy season indicated that there is no significant difference between these two locations. Probability of occurrence of mild drought is higher in Eluwankulam (24%) than Angunakolapellessa (22%) and moderate drought probability is almost the same in both locations (12-13%). In both the locations no severe drought is noticed. In the agricultural drought probability, in Yala season (Mar-Aug) 58-59% probability is seen during 36-42 meteorological weeks in both locations. But in Maha season (Sep-Feb), the highest probability (6%) is observed during 46-51th meteorological weeks in Angunakolapellessa and it is 3% in Eluwankulama. The duration of crop growing season is around 48-50 weeks during the season in both the locations, indicating that year round cultivation is possible in the region. Water balance studies for the period 1976-2008 revealed that both the locations come under dry sub-humid climate and there was declining tendency in moisture index values within the "dry sub-humid climate" type.

Table 9b. Climatic trends in the targeted province of Sri Lanka

Parameters	Angunakolapellessa met. Station (Hambantota district)	Eluwankulama met. Station (Puttalam district)
Annual rainfall	1136 mm (1977-2008)	1193 mm (1976-2008)
Seasonal rainfall	First Inter monsoon (Mar-Apr) – 175 mm; SWM (May-Sep) – 359 mm; Second Inter monsoon (Oct-Nov) – 373 mm; NEM (Dec-Feb) - 229 mm	First Inter monsoon (Mar-Apr) – 211 mm; SWM (May-Sep) – 180 mm; Second Inter monsoon (Oct-Nov) – 537 mm; NEM (Dec-Feb) - 265 mm
% contribution to annual rainfall	First Inter monsoon (Mar-Apr) – 15 %; SWM (May-Sep) – 32%; Second Inter monsoon (Oct-Nov) – 33%; NEM (Dec-Feb) - 20%	First Inter monsoon (Mar-Apr) – 17%; SWM (May-Sep) – 15%; Second Inter monsoon (Oct-Nov) – 45%; NEM (Dec-Feb) - 23%
Annual mean temperature trend	Tmax – Decreasing up to 97, then rising from 1998-'08; Tmin - Decreasing up to 94, then rising from 1995-'08	Tmax – Increasing ; Tmin - Increasing
Onset and withdrawal of rainy season (week number)	Yala – Onset – 13; Maha – Onset – 42; Yala – Withdrawal - 23 Maha – Withdrawal - 5	Yala – Onset – 13; Maha – Onset – 41; Yala – Withdrawal – 23; Maha – Withdrawal - 4
Meteorological Drought Probability	Mild – 22%; Moderate – 13% and Severe - Nil	Mild – 24%;; Moderate – 12% and Severe - Nil
Agricultural Drought probability	Yala –59% (36 – 42 week); Maha – 6% (46 – 51 week)	Yala – 58% (36 – 42 week); Maha – 3% (46 – 51 week)
Length of growing season (no. of weeks per year)	48-50	
Climate type (Im – Index of moisture adequacy)	Im = - 28.4% (Dry sub humid); Im is declining within Dry sub humid type (1977-2008)	Im = - 23.3% (Dry sub humid); Im is declining within Dry sub humid type (1976-2008)

SWM-South monsoon; NEM- Northwest monsoon; Tmax – Maximum temperature; Tmin – Minimum temperature; Yala and Maha are cropping seasons of Sri Lanka.

Bangladesh

Annual average rainfall in Bangladesh is 2428 mm received on an average of 106 days. The highest rainfall (3000-5000 mm/year) is received in the North and south-eastern parts of the country, followed by the West central part, which receives the lowest rainfall (<2000 mm/year). The entire western part of the country gets the least amount of rainfall (around 1564 – 1739 mm), and that includes the drought prone areas. Around 70% of the annual rainfall is received from the southwest monsoon (Jun to early Oct), 20% during pre-monsoon season (Mar-May), and the remaining 10% in the post monsoon (Oct-Nov) and winter seasons (Dec-Feb). An increasing trend was noticed in annual rainfall and in the rainy days in recent years (2001-2002) when compared to the long term average (1971-2000). April is the warmest month (33.2°C) and January is the coolest (12.5°C). A warming trend is observed in both annual mean maximum and minimum temperature since 1971. Two zones viz., flood and drought prone zones were selected for the study.

Nishaiganj (Mymensingh district) and Paschim Bahadurpur (Madaripur district) villages from flood prone areas and Boikunthpur (Thakurgaon district) and Khudaikhali (Rajshahi district) villages were chosen for the study (Table 9c). Analysis of annual rainfall and rainy days showed a declining trend in both zones. Declining trend in annual rainfall was observed in three villages and cyclic pattern was noticed in Khudaikhali village since the 1980's. However, the number of rainy days has increased by 2-3% in these villages of the flood prone zone during 2001-02 compared to 1971-2000. However, declining trends were observed in Boikunthpur village (27%) and Khudaikhali village (3%). Rainy days during the main rainy season (southwest monsoon) also showed a similar pattern. In the case of annual mean maximum temperature, a declining trend (0.2 – 0.5°C between 2001-08 and 1971-2000) was seen in the three villages except Nishaiganj, where an increasing trend (0.2°C between 2001-08 and 1971-2000) was observed. Annual mean minimum temperature showed an increasing tendency in all four villages. However, the rate of increase in temperature was higher (1.6°C) in villages of drought prone areas, while in flood prone villages it varied from 0.4 to 1.4°C.

Table 9c. Climatic trends in the targeted flood and drought prone regions of Bangladesh

Parameters	Flood prone		Drought prone	
	Nishaiganj (Mymensingh District)	**Paschim Bahadurpur (Madaripur District)**	**Boikunthapur (Thakurgaon District)**	**Kudhaikhali (Rajshahi District)***
Annual rainfall trend	Cyclic pattern since 1971 and declining in the late 1990's	Below normal since 2000	Decreasing since mid-1980's	Cyclic pattern since 1980's
Annual rainy days Rainy days trend	106 Increasing (2%); (Comparing 1971-2000 and 2001-02)	103 Increasing (3%)	89 Decreasing (27% between 1971-2000 and 2001-02)	86 Decreasing (3%)
Seasonal rainy days trend	SWM: Increasing (9%); PM: Increasing (13%); Winter: Increasing (17%); Pre monsoon: Increasing (14%)	SWM: Increasing (9%); PM: No change; Winter: Increasing (14%); Pre monsoon: Decline (13%)	SWM: Decreasing (11%); PM: Decreasing (45%); Winter: Increasing (17%); Pre monsoon: Decline (43%)	SWM: Decreasing (6%); PM: No change; Winter: Decline (150%); Pre monsoon: Increasing (9%)
Annual mean temperature	Tmax:30.0°C; Tmin: 20.7°C	Tmax: 30.9 °C; Tmin: 21.2 °C	Tmax: 30.0°C; Tmin: 19.7°C	Tmax:31.0°C; Tmin: 20.5°C
Annual mean temperature trend	Tmax: Increasing (0.2°C); Tmin: Increasing (1.4°C)	Tmax: Declining (0.5°C); Tmin: Increasing (0.4°C)	Tmax: Declining (0.4°C); Tmin: Increasing (1.6°C)	Tmax: Declining (0.2°C); Tmin: Increasing (1.6°C)
Seasonal mean max temperature and trend	SWM: 31.6 (IT – 2.3); PM: 31.5 (DT – 0.3); Winter: 26.9 ((DT – 0.2); Summer: 31.6 (DT – 0.8)	SWM: 32.0 (DT – 0.7); PM: 32.2 (DT – 0.5); Winter: 27.6 (DT – 0.3); Summer: 33.4 (DT – 0.9)	SWM: 32.2 (DT – 0.1); PM: 31.1 (IT – 0.2); Winter: 26.1(DT – 0.5); Summer: 32.3 (DT – 0.9)	SWM: 32.6 (IT – 0.1); PM: 31.7 (DT – 0.1); Winter: 26.8 (DT – 0.2); Summer: 34.4 (DT – 0.3)
Seasonal mean min temperature and trend	SWM: 25.8 (IT – 0.9); PM: 24.4 (IT – 0.9); Winter: 14.4 ((IT – 1.8); Summer: 21.4 (IT – 1.7)	SWM: 25.8 (IT – 0.2); PM: 24.8 (IT – 0.2); Winter: 14.9 ((IT – 0.7), Summer: 22.4 (IT – 0.2)	SWM: 25.7 (IT – 0.6); PM: 23.7 (IT – 1.2); Winter: 12.8 (IT – 2.2); Summer: 20.2 (IT – 1.8)	SWM: 26 (IT – 1.2); PM: 24.4 (IT – 0.9); Winter: 13.7 (IT – 1.8); Summer: 21.6 (IT – 2.3)

IT – Increasing trend; DT-Decreasing trend; SWM – South west monsoon; NEM – North east monsoon; Tmax – Maximum Temperature; Tmin – Minimum Temperature.
*Note: For Khudaikali village, information was taken from the nearest meteorological station i.e., Rajshahi district

Thailand

Average annual rainfall of the country is 1564 mm, received in 128 days. Late rainy season (Aug-Oct) contributes to around 42% of annual rainfall, followed by 36% from early rainy season (May-Jul). Annual mean minimum temperature showed marginal increasing trend from 1970 to 2000. In the northeast region the annual rainfall varies from >2400 mm in eastern parts to 1000-1200 mm in western parts and annual average rainy days ranged from 100 to 139. Almost 80% of annual rainfall is received from May-Oct. Annual mean maximum and minimum temperature over this region ranges between 31.3 – 33°C and 19.7 – 22.5°C, respectively.

Chatturat district of Chaiyaphum province and Chok Chai district of Nakhon Ratchasima province were selected for in-depth analysis (Table 9d). In this region, rainfall analysis using 39 years of data (1970-2008) indicated that Chok Chai district receives an average annual rainfall of 1087 mm and Chatturat district receives 1115 mm per year. Both these districts get the major share (84-85 %) of annual rainfall from early and late rainy seasons (May-Oct). Annual and seasonal rainfall showed declining trend in Chok Chai district during 1970-2008, whereas in Chatturat district an increasing tendency is observed except in the early rainy season (May-July) during which a declining tendency was noticed (Limsakul et al. 2007; Manton et al. 2001; Kwanyen 2000). Studies on length of growing season revealed that medium duration rice varieties can be cultivated in both the districts as the moisture regime is conducive for 19 – 21 weeks. In the case of field crops, length of growing season ranges from 25-27 weeks in both districts and crops like cotton can be cultivated. The length of growing season is two weeks longer in Chok Chai district than Chatturat district for both rice and field crops. This might be due to the Chok chai district receiving a little higher amount of rainfall during the winter season than Chatturat district.

Viet Nam

Viet Nam is a tropical country, and is considered one of the five Asian countries most vulnerable to climate change impacts. It was observed that annual rainfall is slightly increased. Nevertheless, increasing tendency in rainfall was noticed during rainy season and decreasing trend during dry season (Nguyễn 2007). Annual mean temperature has increased by 0.1°C per decade but it has risen to 0.3°C per decade during certain months.

Ninh Thuan province in the southeast region of the country is semi-arid tropical areas which gets less than 700 mm rainfall per year (Table 9e). Phan Rang meteorological station which represents Phuoc Nam commune in Ninh Phuoc district receives normal annual rainfall of 763 mm (1979-2008). Around 58% annual rainfall is being received during rainy season (Sep–Nov) and remaining the 42% during dry season (Dec–Aug). Annual rainfall showed increasing trend at 10% probability level for the period 1980-2008 and no significant trend in seasonal rainfall. The variation of rainfall pattern showed that extreme events are likely to recur every decade. Conditional probability analysis for wet week showed that wet weeks (20mm rainfall/week) has 50% probability to last 10 weeks. This means farmers could raise only short-duration rainfed crops during the assured wet period of 10 weeks.

The analysis of number of rainy days per year, indicated that at all seasons except autumn, rainy days showed rising trend. However, the trend is insignificant. Meteorological drought analysis of the last 30 years revealed that only 50% of years recorded either mild (8 years) or moderate (7 years) drought indicating that every second year is rainfall deficient which negatively affects agricultural production. Severe drought never occurred during the study period at this station. Marginal decline in annual mean maximum temperature was observed and minimum temperature showed an increasing tendency from 1993-2008. However, there is no significant trend over the years in maximum and minimum temperature. Crop growing period is short, starting from late August to December.

Table 9d. Climatic trends of study regions in Thailand

Parameters	Chatturat district (Chaiyaphum province)	Chok Chai district (Nakhon Ratchasima province)
Annual rainfall	1123.6 mm (1970-2009)	1084.0 mm (1970-2009)
Annual rainfall trend	No significant trend	No significant trend
Seasonal rainfall	Summer (Feb-Apr) – 153.1 mm; Early rain (May-July)- 404.6 mm; Late rain (Aug-Oct) – 540.7 mm; Winter (Nov-Jan) – 24.8 mm	Summer (Feb-Apr) – 130.4 mm; Early rain (May-July)- 388.9 mm; Late rain (Aug-Oct) – 526.7 mm; Winter (Nov-Jan) – 38.0 mm
% contribution to annual rainfall	Summer (Feb-Apr) – 14 %; Early rain (May-July)- 36%; Late rain (Aug-Oct) – 48%; Winter (Nov-Jan) – 2%	Summer (Feb-Apr) – 12 %; Early rain (May-July)- 36%; Late rain (Aug-Oct) – 49%; Winter (Nov-Jan) – 4%
Seasonal rainfall trend	Summer (Feb-Apr) – no significant trend ; Early rain (May-July)- no significant trend; Late rain (Aug-Oct) – no significant trend; Winter (Nov-Jan) – no significant trend	Summer (Feb-Apr) – no significant trend ; Early rain (May-July)- no significant trend; Late rain (Aug-Oct) – no significant trend; Winter (Nov-Jan) – no significant trend
Annual rainy days	101 days	112 days
Annual rainy day trend	no significant trend	no significant trend
Annual max. and min. temperature	Average annual Tmax = 32.7°C: Average annual Tmin = 22.6°C	Average annual Tmax = 32.6°C: Average annual Tmin = 22.2°C
Annual max. and min. temperature trend	Tmax. and Tmin. showed significant increasing trend	Tmax. and Tmin. showed significant increasing trend
Seasonal max. and min. temperature	Winter: average Tmax = 30.8°C Tmin = 18.1°C Summer: average Tmax = 36.3°C Tmin = 24.7°C	Winter: average Tmax = 30.8°C Tmin = 17.1°C Summer: average Tmax = 35.8°C Tmin = 24.2°C
Seasonal max. and min. temperature trend	Winter: Tmax. and Tmin. had significant increasing trend; Summer: Tmax had significantly increasing	Winter: both Tmax. and Tmin. had significantly increasing trend; Summer:

	trend but Tmin had no significant trend; Early rain: Tmax had no significant trend but Tmin showed significantly increasing trend; Late rain: both Tmax and Tmin showed significantly increasing trend	Tmax had no significant trend but Tmin had sig. increasing trend; Early rain: both Tmax. and Tmin. had significantly increasing trend; Late rain: both Tmax and Tmin showed significantly increasing trend
Drought Probability	Mild – 23.6%; Moderate – 13.2% and Severe - Nil	Mild – 16.2%; Moderate – 5.4% and Severe - Nil
Heavy rainfall events (>90.1 mm/day)	No significant trend	No significant trend
Extreme temperature events (days with maximum temperature higher than 40.0 ^{O}C)	No significant trend	No significant trend
No. of dry spells/year (the rainy season period of less than 1 mm of rainfall per day for 15 consecutive days or no rainfall in a day for 7 consecutive days (unit: times/year)	No significant trend	No significant trend
Length of growing period (weeks)	Start – Rice – 21; Field crops – 15; End - Rice – 40; Field crops – 40; Duration - Rice – 19; Field crops - 25	Start – Rice – 19; Field crops – 15; End - Rice – 40; Field crops – 42; Duration - Rice – 21; Field crops - 27

Tmax – Maximum Temperature; Tmin – Minimum Temperature.

Table 9e. Climatic trends in the study region of Viet Nam

Parameters	Phan Rang Station (Ninh Phuoc district, Ninh Thuan Province)
Annual rainfall	763 mm (1979-2008)
Annual rainfall trend	Increasing at 10% level of significance (1980-2008)
Seasonal rainfall	Dry season (Dec-Aug) – 320 mm; Rainy season (Sep-Nov) – 443 mm
% contribution to annual rainfall	Dry season (Dec-Aug) – 42%; Rainy season (Sep-Nov) – 58%
Annual and seasonal rainy days	Increased but non-significant
Annual and seasonal temperature trend	No significant trend in Tmax and Tmin temperature
Drought	Mild – 27%; Moderate – 23%; Severe - Nil

Tmax – Maximum temperature; Tmin – Minimum Temperature

China

No long-term significant trend is observed in annual rainfall in China during the past 100 years. The annual precipitation trend over different regions in China from 1956-2001 showed decreasing trend in Yellow River Basin and North China Plain and increasing trend in Yangtze Basin, southeast coastal region, and most parts of western China. In addition, frequency of heavy rainfall events increased in the Chang Jiang Basin causing heavy damage to agricultural crops by flooding.

The climate characteristic of Guizhou province selected for the study falls under subtropical humid monsoon climate zone. There are 4 typical seasons in one year; namely spring from Mar to May, summer from June to July, autumn from Sep to Nov and winter form Dec to Feb of next year. In most parts of the province, the average temperature is around 15°C. The hottest month is July with a mean temperature of 22-25 °C and the coldest month is January with an average temperature about 3-6 °C. In a normal year, the main rainy season is from May-July.

Analysis of surface air temperature shows that annual mean surface air temperature in China increases significantly, and the trends of change reach 0.22°C/decade for the time period of 1951-2001 and 0.08°C/decade during 1905-2001 respectively (Table 9f). Annual mean temperature has risen by 1.1°C in the past 50 years. Warming is more significant from the early 1980s and the temperature has kept rising steadily. Seasonal mean temperature for almost all seasons in 1951-2001 has been rising over the years. Warming is also significant in spring and autumn, but it is very weak in summer. In addition, cold nights (minimum temperature less than 0°C declined significantly since 1950 but no trend was noticed in warm days (days with maximum temperature >35°C). Serious drought years have been experienced in the North Plain and northeast China frequently in the last 50 years in the country.

Table 9f. Climatic trends in the study regions of China

Parameters	Dajiang village (Luodian county)	Lucheba village (Pingba county)
Annual rainfall	1150 mm	1279 mm
Annual rainfall trend	Increased by 33 mm (2.9%) between 1959-1968 and 1999-2008	Decreased by 45 mm (-3.6%) between 1959-1968 and 1999-2008
% contribution to annual rainfall	Rainy season (May-Aug) – 67%	
Annual rainy days	150	192
Rainy days trend	Decreased by 22 days (-14.6%) between 1959-1968 and 1999-2008	Decreased by 11 days (-5.7%) between 1959-1968 and 1999-2008
Annual mean temperature	19.7°C (1959-2008)	14.2°C (1959-2008)
Annual mean temperature trend	Increasing 0.04°C/decade increased during 1959-2008	Increasing; 0.032°C/decade increased during 1958-2008;
Seasonal mean temperature	Winter (Dec-Feb) – 11.4°C; Spring (Mar-May) - 20.6°C; Summer (Jun-Aug) - 26.4°C; Autumn (Sep-Nov) – 20.3°C	Winter (Dec-Feb) – 5.3°C; Spring (Mar-May) – 14.7°C; Summer (Jun-Aug) - 21.8°C; Autumn (Sep-Nov) – 14.9°C
Seasonal mean temperature trend	Winter (Dec-Feb) – Increasing 0.5°C (1959-2008); Spring (Mar-May) - Increasing 0.2°C (1959-2008); Summer (Jun-Aug) - Increasing 0.1°C (1959-2008); Autumn (Sep-Nov) – Increasing 0.4°C (1959-2008)	Winter (Dec-Feb) – Increasing 1.1°C (1959-2008); Spring (Mar-May) - Decreasing 0.2°C (1959-2008); Summer (Jun-Aug) - Increasing 0.1°C (1959-2008); Autumn (Sep-Nov) – Increasing 0.4°C (1959-2008)

Tmax – Maximum Temperature; Tmin – Minimum Temperature.

Climate change projection – From bad to worse

In the preceding analysis, we see a marginal change in rainfall and temperature over the last four decades among the six countries studied. However, within each country there was evidence that even in the past there is a significant change in some of the regions studied. For example, in Andhra Pradesh state of India, there is evidence of significant increase in temperature. There is also a reduction in total rainfall, but found to not to be statistically significant. What is more important is to find out what the future holds for these countries and its people in terms of climate change. Here we have relied on the expertise of renowned climate data analysts and forecasters.

IPCC, is the authoritative body entrusted to undertake quantitative global climatic projections. Simulation output from different global climatic models from the IPCC Data Distribution Center and country reports on projections were the basis for the synthesis. The results showed that atmospheric temperature and associated rainfall variability will continue to rise in the years to come and will cause major impact on agriculture and other related sectors. The temperature increase will affect crop growth and productivity, thereby reducing yield. The temperature rise will also have negative consequences on physiological characteristic viz., crop duration, fruit setting, chilling requirement, pollination etc. Agriculture-based livelihood would face immediate risk of increased crop failure, loss of livestock and fish stocks, increasing water scarcities and production assets. According to the Millennium Ecosystem Assessment Report (WRI, 2005), potential climate change will impact nine other ecosystem, not just cultivation and that the nature of risk will increase and vary in the future.

Rainfall projections of the study countries are positive and are encouraging for regions where rainfall is already scanty. However, the distribution of rainfall has to synchronize to maximize benefit from this increased projection. Atmospheric temperature is expected to rise in all the regions and extreme temperature events could increase in frequency. Between maximum and minimum temperature, minimum temperature rise will be significant over the years. The magnitude of changes in these countries is given in Table 10.

The drastic changes in weather could pave the way for increased pests' infestation, stunted growth, and low yield, adversely affecting rural communities, pushing them to extreme poverty. These populations have constrained capacities to adapt to climate change, particularly marginal groups who have limited resources and little access to power. This will have compounding effects on global food security and employment.

Sadly, this information has been mostly held captive by the scientific, professional, and political elite groups, many of whom been apathetic and non-responsive over the decades to the imminent dangers that large segments of marginalized communities face. Those whose lives are most affected are not privy to this

Table 10. Climate change projections for Asia (Project partner countries)*

Climatic parameters	South Asia			Southeast Asia		
	India	**Sri Lanka**	**Bangladesh**	**Thailand**	**Viet Nam**	**China**
Rainfall	Andhra Pradesh Annual : 8% (2021-2050) ; 10 % (2071-2100); SWM : 6% (2021-2050); -6 % (2071-2100) Maharashtra Annual: 11% (2021-2050) ; 19% (2071-2100);SWM – 12% (2021-2050);13% (2071-2100) (Deviation from baseline average)	Southwest Monsoon rainfall will increase by 173 mm in 2025, 402 mm in 2050 and 1061 mm in 2100 compared to baseline year. Northeast monsoon rainfall will increase by 23 mm in 2025, 54 mm in 2050 and 143 mm in 2100 compared to baseline year.	Annual rainfall will increase by 3.8% in 2030, 5.6% in 2050 and 9.7% in 2100 compared to baseline year	No clear information is available for the country as a whole but there are positive and negative projections depending on the region.	Annual rainfall will increase by 1.6 to 14.6% by 2100 when compared to 1980-1999.	Annual rainfall will increase to 611 mm during 2050 when compared to 1950-2000 average of 467 mm
Temperature (Increment ^{o}C)	Andhra Pradesh (Max) Annual – 1.7 (2021-2050); 3.6(2071-2100); SWM – 1.5 (2021-2050); 3.8 (2071-2100) Maharashtra Annual – 1.8 (2021-2050); 3.4 (2071-2100); SWM – 1.4 (2021-2050); 3.2 (2071-2100) Andhra Pradesh (Min) Annual – 2.1 (2021-2050) ; 4.5(2071-2100); SWM – 1.7 (2021-2050); 3.8 (2071-2100) Maharashtra Annual – 2.2 (2021-2050) ; 4.5 (2071-2100); SWM – 1.5 (2021-2050); 3.4 (2071-2100)	Annual mean temperature will increase by 0.4°C in 2025, 0.9°C in 2050, 1.6°C in 2075 and 2.4°C in 2100 compared to baseline year.	Annual mean temperature will increase by 1°C in 2030, 1.4°C in 2050 and 2.4°C in 2100 compared to baseline year.	By the middle of the 21st century (2045-2065), average monthly maximum temperature is expected to increase by 3ºC-4ºC and average monthly minimum temperature is expected to increase by over 4ºC throughout the country.	At the end of century (2100) average annual temperature will increase between 1.1 -1.9°C and 2.1 -3.6°C.	Annual mean temperature will increase by 2.6 ^{o}C in 2050 over the base period average (1950-2000)
Sea level rise (cm)	48 by end of the century	-	30-100 by 2100	-	11.5 to 68 by 2100	-

Source: India : A1b scenario of HadCM3; NATCOM (2009), INCCA (2010); Sri Lanka: Samarasinghe, Director General of Meteorology, Sri Lanka Meteorological Department; Bangladesh: Agrawala et al., 2003; Thailand : Southeast Asia START regional Centre, Bangkok, 2010;China: ADB, 2009; Viet Nam: ISPONRE, 2009;SWM – South west monsoon, NEM – North east monsoon.

information for various structural and socio-economic reasons. Moreover, institutions closely associated with the wellbeing and livelihood of people in rural areas seem to be disjointed and interventions and programs are not informed by climate change projections. Thus, a stronger connectivity between the information generated, inferences from climate change, and various state and non-state institutions at different levels, is needed to make meaningful use of relevant information for preventive and mitigatory actions against the impacts of climate change.

Need for micro level information/Context

Global climate change now seems a reality and a major challenge for agricultural production systems. Most policies to address these challenges are based on aggregated/macro-level information, projections, or modeled scenarios, which do not offer concrete contexts at micro-levels, for instance how dryland farmers respond by way of adaptation measures. Aggregated information often do not offer inspiring lead lines due to information gaps and uncertainties.

This projects attempts to dovetail micro-level contexts with the macro-level contexts so as to downscale the approaches/information by way of focusing on regional and local landscape situations to develop regional policies. As an illustration, analysis was made from data on the rainfall pattern at different levels in India: National → State → District → Mandal/Tehsil →Village level. The village-level rainfall information was obtained from the ICRISAT's long-term panel data. The analysis could not be extended to other locations/countries due to paucity of datasets at local/micro-level. It was observed that rainfall recorded from macro to micro varied with an average coefficient of variation of 26% over the years (1971-2010). This clearly demonstrates that there is wide difference in the observed rainfall at different levels (Fig. 4). Similar revelations were made in the case of Thailand, where rainfall comparison was made at three levels viz., Country → Region→ Provincial (Fig. 5), where divergence of trend was clearly visible and there is a huge disconnect between macro and micro-level information/rainfall pattern. However, the policy and program formulation rely heavily on macro-level information at aggregated level, i.e., national and regional, possibly due to absence of micro- level information having local contexts. This could result in varied impacts of policies and program and many a times they fail to achieve the intended outcome and even misses the targeted foci. With strong evidence from the study, it is imperative to collect, disseminate, and consider the collection/gathering of micro-level information as a crucial initial step in formulating climate sensitive policies with a specific target orientation (MacCarthy et al. 2001). This could be achieved only through institutionalizing an efficient mechanism for collecting, collating, and channelizing micro-level information especially related to weather/climate indicators to the policy machinery of the country.

Here again the application of the principle of subsidiarity must be undertaken. Strengthening local institutional frameworks with engagement of the stakeholders therein using information in a rational manner to address local needs is the answer. The study undertaken in India and Thailand must be replicated in other locations to find more evidence in support of the approach to address climate change effects at local levels to identify the nuances experienced at local levels, which may be quite different from understandings derived from analysis at macro levels.

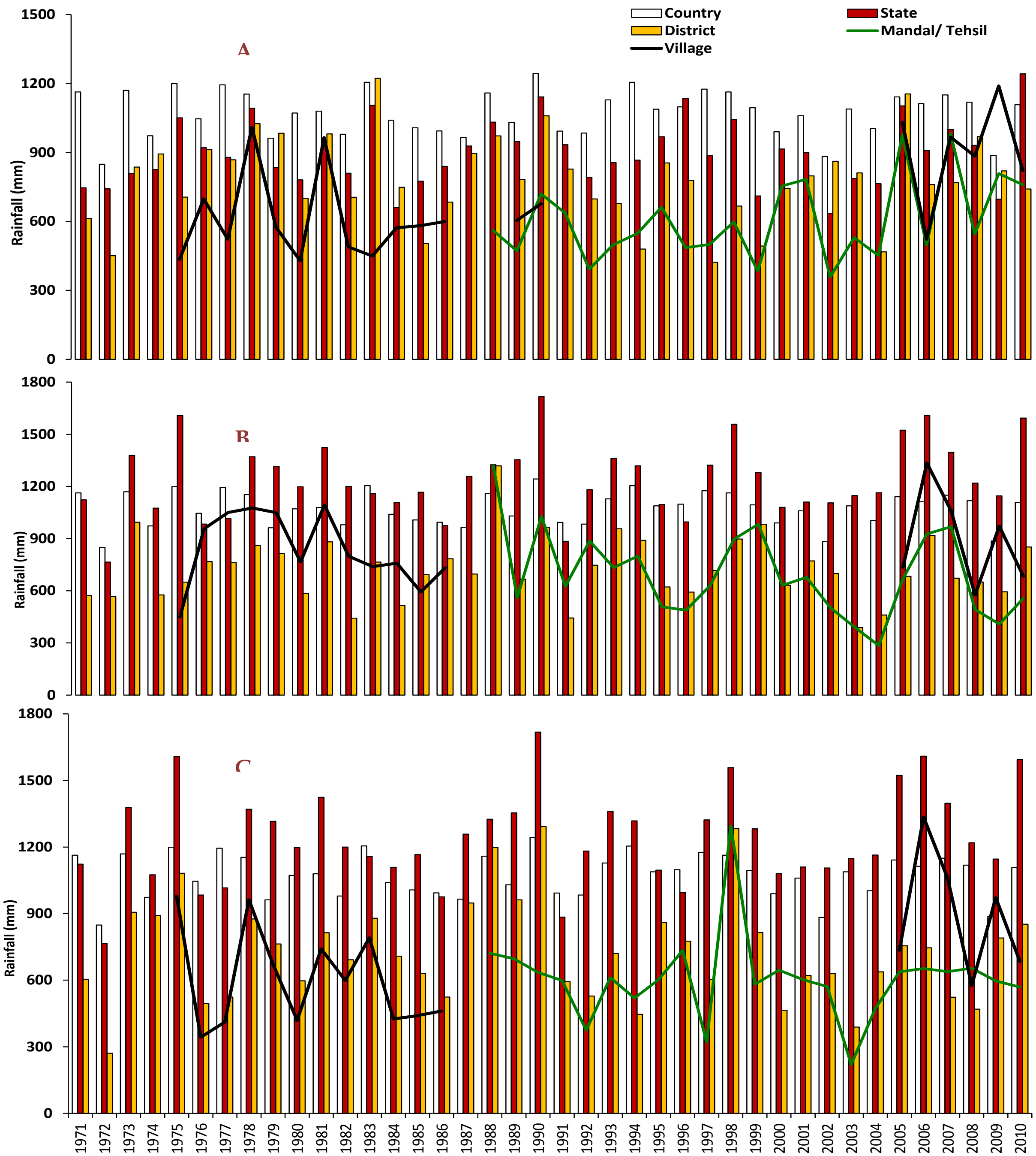


Figure 4. Divergence in the observed climate from macro to micro-level (Country → State→District→Mandal/Tehsil→Village) in Indian SAT region (A) Aurepalle, AP (B) Kanzara & (C) Shirapur, Maharashtra, India

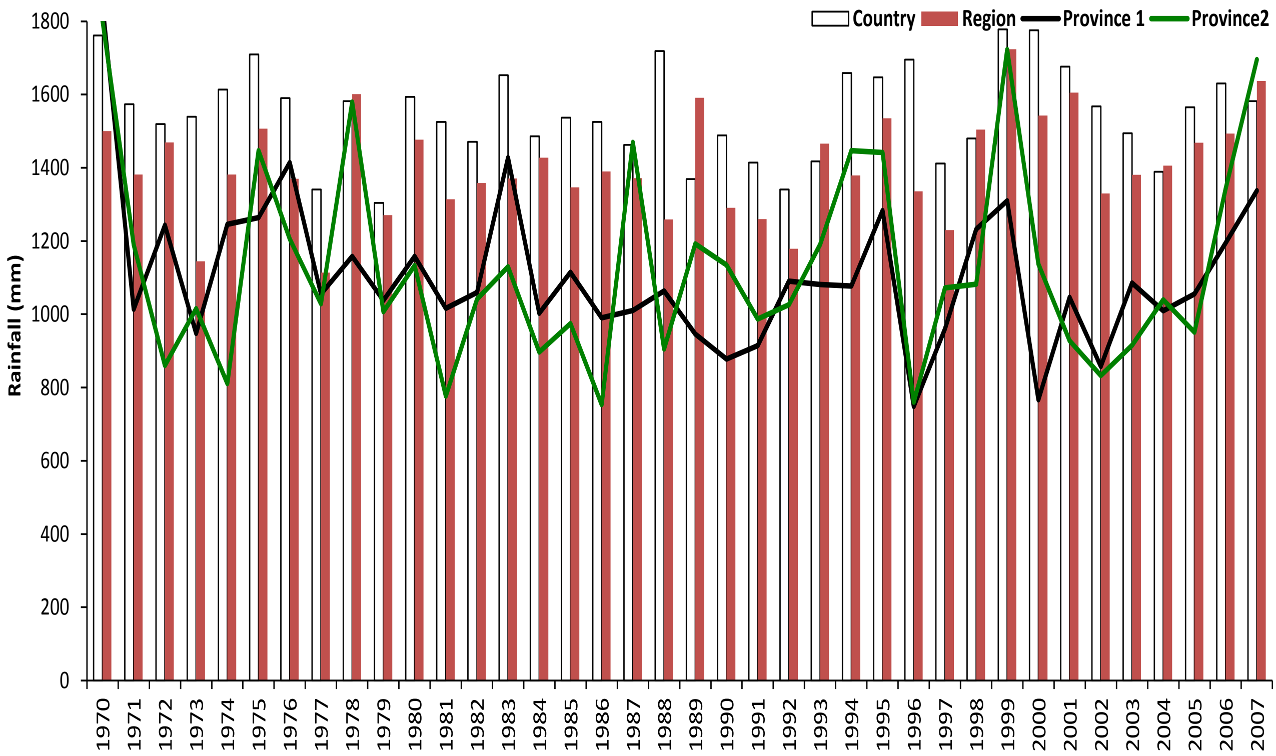


Figure 5: - Divergence in the observed climate from macro to micro level (Country → Regional →Provincial) Chok chai province in Thailand.

Several researchers have looked at climate change trends, drawn inferences and made recommendations on adaptation and mitigation strategies required to counteract expected deleterious effects. Studies generally look at the macro picture and draw inferences and apply them to the entire country or region. Our analysis clearly shows that this must be done with caution and with a clear understanding of the ground level variability and realities; and hence intra-country or intraregional differences in trends and impacts of climate related variables, understanding the intricacies of various drivers of change, rural socio-economic and political evolutionary pathways, rural infrastructure and their innate stress response behavior etc. are the necessary input to formulize strategies through policies and other support services (Smit and Pilifosova 2001).

Targeting vulnerable regions to climate change

Climate change vulnerability in the study domain

From the aforesaid analysis and inferences drawn, it is necessary to examine more closely those regions and populations who are likely to be affected mostly by climate change. Asia is a vast region with significant variability in development and hence ability to cope with the deleterious effects of climate change. Climatic impacts are geographically specific and have wide range of consequences on livelihoods, food security (FAO 2008), as well as quality and quantity of food intake. Currently, Asian countries are facing water-related stress and are expected to intensify in the future due to repeated incidence of drought and variability of precipitation. Several studies have projected that Asia will be most affected due to water stress of 1,700 cubic meter per person per year in 2025 and even worse during the later period. Isolated studies on country-level climate change vulnerability and resilience have been undergone using varied methodologies for India (Brenkert and Malone, 2005., O'Brien et al, 2004)) and other South Asian countries. To understand the climate change vulnerability, we need to understand the socio-economic and environmental and natural resources contexts, which decide different dimensions of vulnerability such as poverty, gender issues, income inequality, environmental degradation, and resource access, among others.

Assessing vulnerability in a developmental context

One of the key findings of the Fourth Assessment of Working Group II of the IPCC is addressing non-climate stresses, which can increase vulnerability to climate change. Another finding is sustainable development can reduce vulnerability to climate change by enhancing adaptive capacity and increasing resilience. Developing countries have lesser capacity to adapt and more vulnerable to climate change damages, just as they are to other stresses. This condition is most extreme among the poorest people (IPCC 2001). Thus, understanding the underlying development context, which ultimately decides the extent of vulnerability, is important in climate change research.

The table 11 shows the socio-economic and natural resources indicators of the selected countries with low development status as shown by low per capita GDP, lower HDI rank, low share of forest land, higher poverty incidence and a high share of agriculture in GDP. The core dimension of vulnerability comes from poverty. Poverty eradication is the primary objective of any development program in developing countries. About 907 million people, who are under nourished, live in developing countries. Of these, 65% live in only six countries: India, China, the Democratic Republic of Congo, Bangladesh, Indonesia, Pakistan and Ethiopia (FAO 2008).

Table 11. Socio-economic and natural resources indicators of the selected countries

Indicators	Bangladesh	China	India	Sri Lanka	Thailand	Viet Nam
Total land (1000 sq. km)-2009	144	9600	3287	65.6	513.1	331.2
Agricultural land (% to total land)- 2009	63.5	54.5	54.73	39.8	38.5	31.0
Forest land (% to total land)- 2009	10.0	21.3	20.61	28.6	37.0	41.2
Annual population growth, 2011 (%)	1.2	0.5	1.4	1.0	0.6	1.0
GDP growth, (Annual, %) – 2007	6.7	9.1	6.9	8.3	0.1	5.9
Share of Agriculture in GDP (%),2011	18	9.0	17	14	12	20
People living on < $1.25/day(%)– 2010 ppp	43.3	NA	32.7	NA	0.4	22.8
Human Development Index – 2011	146	101	134	97	103	128

Source: FAOSTAT (2011), World Bank (2012) ; UNDP (2011)
NA-Not available

With a very large population and relatively slow progress in hunger reduction, nearly two-thirds of the world's hungry live in Asia (583 million in 2007). China and India together account for 42% of the chronically hungry people in the developing world (FAO, 2008).

Synthesized information from the results of vulnerability analysis from the study countries are given in Table 12. The analysis further reinforces the need for targeting climate change impact mitigation and related policies and programs. A single encompassing formula will not be feasible, although region wide overview of collective action may be necessary. In this context, the intra country specific needs should be assessed in order to refine understanding to make locally relevant inferences, conclusions and recommendations.

India

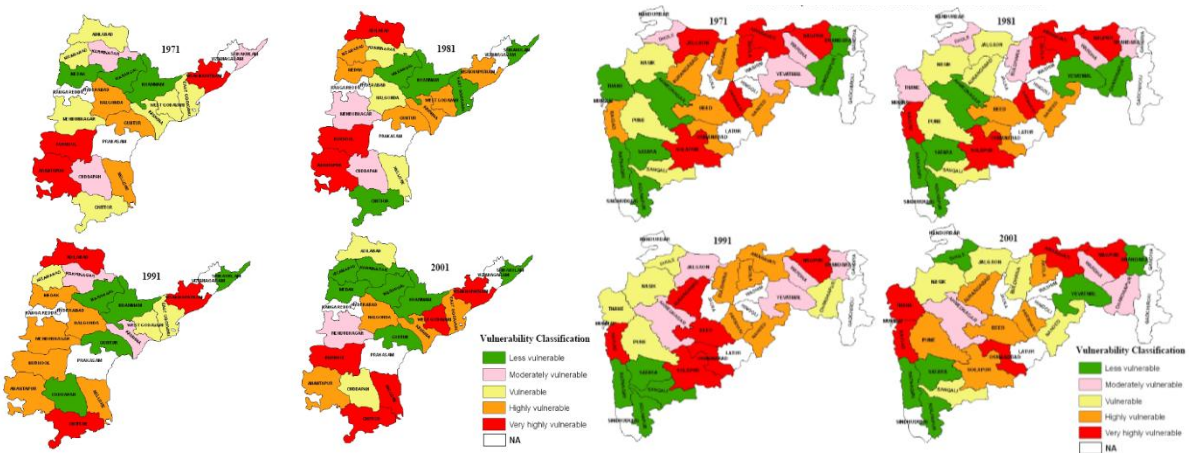
An important element to define priorities for implementing climate risk management actions, inform decisions and establish policy is the assessment of socio-economic vulnerabilities. This analysis has been extremely challenging to effectively link them to actual decisions and policies. A set of indicators were used for the analysis of vulnerability and these indicators were selected to cover multi-dimensional aspects of rural vulnerability. The districts of Andhra Pradesh and Maharashtra (major states of SAT-India), were taken as target region for index calculation. Analysis was done in these districts based on the given set of indicators and analysis of decadal trend. These districts were grouped under five major categories viz., less vulnerable, moderately vulnerable, vulnerable, highly vulnerable and very highly-vulnerable.

Majority of the districts (>60%) in both Andhra Pradesh and Maharashtra fall under vulnerable to very highly-vulnerable category. During the decadal analysis[12], the degree of vulnerability fluctuated greatly in both states, particularly, in Maharashtra, the number of districts accrued from vulnerable to very highly vulnerable groups (Figure 6).

[12] Decadal analysis was done for 1971, 1981, 1991 and 2001. The datasets for the year 2001 was taken as latest owing to unavailability of data such as population etc.

Figure 6. Decadal trends in number of districts of Andhra Pradesh and Maharashtra state falling under different vulnerability categories.

Maharashtra **Andhra Pradesh**



	Andhra Pradesh (N=19)				Maharashtra (N=25)			
	1971	1981	1991	2001	1971	1981	1991	2001
Less Vulnerable	3	5	5	7	7	6	4	6
Moderately Vulnerable	3	2	2	1	3	5	5	3
Vulnerable	7	3	3	2	3	6	5	5
Highly Vulnerable	3	6	6	4	6	3	5	6
Very Highly Vulnerable	3	3	3	5	6	5	6	5

Note: Data in the table indicates number of districts analyzed in the states of Andhra Pradesh and Maharashtra.

The SAT region is generally considered vulnerable with scanty rainfall, population, crop production and other socio-economic factors of the rural poor. Even though index approach is very much valuable for studying trends within the same region; it is very likely to be less robust for comparing the vulnerability of different regions. The main reason is that the importance of a selected variable varies with the region's information available at more disintegrated level (micro-level) and the location specific weights assigned for indicators. However, indexing will definitely provide information for tracking the regions where actions and policy level interventions are needed the most.

Table 12. Climate change vulnerability of selected study countries of Asia – A synthesis

	South Asia			Southeast Asia		China
	India	**Sri Lanka**	**Bangladesh**	**Thailand**	**Viet Nam***	
Vulnerability to climate change	1. Most districts of Andhra Pradesh and Maharashtra falls under (Vulnerable, Highly vulnerable and very Highly vulnerable). 2. The extent of vulnerability of districts varied over the decades.	1. Over the past 25 years there is no significant improvement in the vulnerability status of the study districts of Sri Lanka. Southern districts are identified as moderately to highly vulnerable 2. The vulnerability ranking fluctuated bi-dimensionally over the years.	1. Most flood prone and tidal prone districts are highly vulnerable 2. Vulnerability of coastal districts has increased over the years.	1. Northeast region of Thailand is highly vulnerable among other regions; and these regions are drier compared to other parts of the country. 2. Twelve provinces in the north east region falls under vulnerable, highly vulnerable and very highly vulnerable categories	1. Out of eight agro-ecological zones, five zones are comparatively 'Very Highly Vulnerable' (NWM, RRD, CHR, SER, MRD) and among other three NCR, SCR are 'Highly Vulnerable' and the NEM is 'Vulnerable'. 2. Mekong river delta, major rice bowl falls under very highly vulnerable zone.	The highly vulnerable the arid and semi-arid region of northwest (most parts of eastern Xinjiang, northern Qinghai, Gansu, Ningxia, Shaanxi, western Inner Mongolia); the Tibet-Qinghai plateau; the Karst uplands of southwest China (parts of Guizhou, Sichuan, Chongqing); and densely populated peri-urban coastal. Zones (IDRC and DFID, 2008)

* NWM-North West Mountainous area; RRD- Red River Delta; CHR- Central High Land; SER- Southeast Region; MRD – Mekong River Delta; NCR- North Central Coast; SCR – South Central Coast; NEM- North East Mountainous ; ψhttp://ehsjournal.org/http:/ehsjournal.org/michael-bittner/climate-change-vulnerability-country-rankings-maplecroft/2010/

Sri Lanka

An overall vulnerability was assessed considering all the components contributing to overall vulnerability such as agriculture, climatic, demographic, occupational and geographic. It was evident from the analysis that in 1977, Northeastern districts were categorized as the most vulnerable districts and the Northwestern districts as the least vulnerable. In 1977, study districts of Puttalam, Hambantota, and Anuradhapura were categorized very highly-vulnerable. However, using IPCC method, mixed trends of transition in degree of vulnerability were observed for districts of Sri Lanka from less-vulnerable to high and vice versa. In 2007, among the 22 districts analyzed only 10 were under moderately to less moderately vulnerable category and remaining 12 were vulnerable with varied degree. Considering the trends among the 3 study districts, Hambantota District was categorized as highly vulnerable in 1982 and it remained the same even in 2007(Fig. 7).

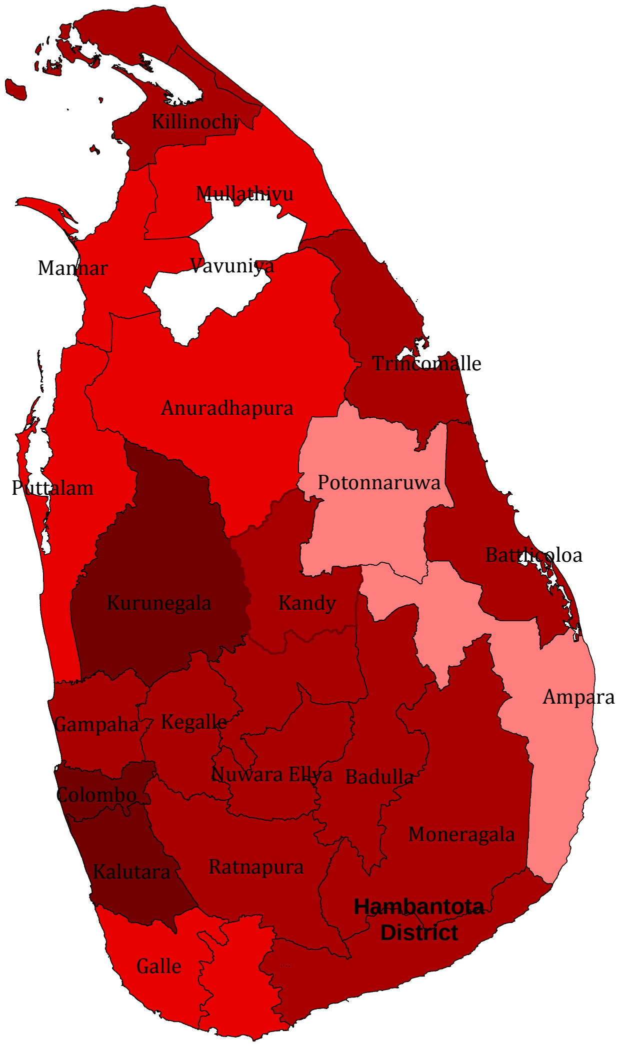


Figure 7. Regional vulnerability to climate change in Sri Lanka(2007)

Bangladesh

Of the six zones to which the country is divided, the mixed, low-flood, flood zones of Bangladesh observed a substantial reduction in vulnerability status compared to other zones in the country. These changes could be mainly due to significant improvements in the life and livelihood activities across these ecological zones during the period of analysis, with access to better irrigation and agricultural inputs, and flourishing economic activities such as fisheries and poultry that significantly changed much of the rural economic structure. The remaining agro-ecological zones are gradually moving towards a highly vulnerable status. The incidence of flood in flood prone regions is recently decreasing but accompanied by increasing incidences of cyclones, salt intrusion in the coastal belts and incidences of drought-like situations in the non-flood prone zone where many of the river ecosystems are gradually losing their natural flow in the other zones (including non-flood zones) are observed (FAO 2004). District wise analysis using IPCC method, revealed that the majority of districts, irrespective of the zone they belong, were vulnerable over the years and are most likely to get worsen in the future, even though a few may show improvements in certain indicators, considering the projected climatic scenario and the socio-economic conditions (Fig. 8).

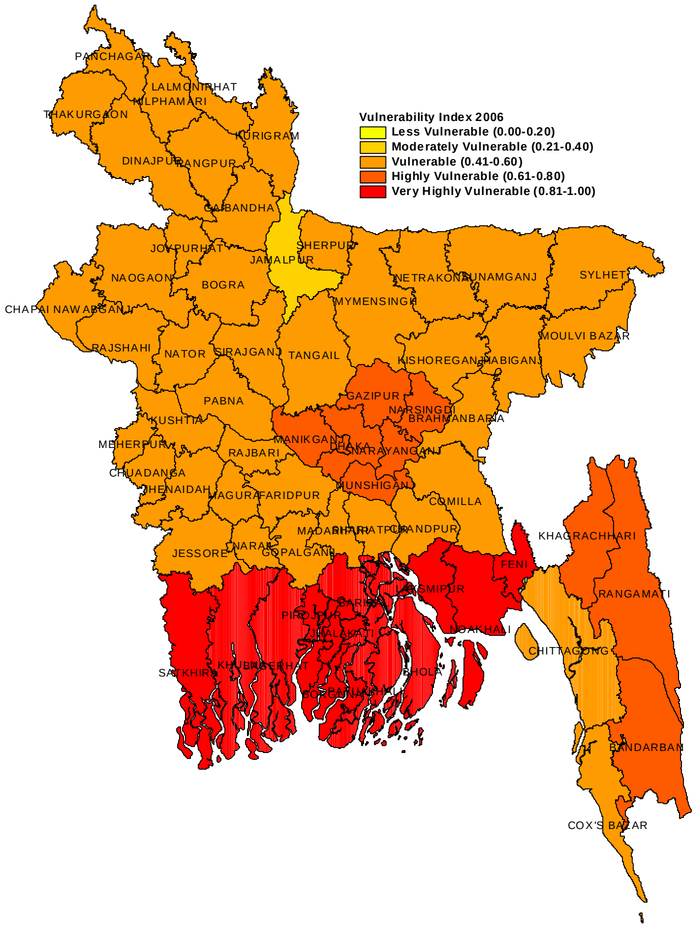


Figure 8. Regional vulnerability to climate change in Bangladesh (2006)

Thailand

In Thailand, the northeastern region is the poorest and most vulnerable to climate change. But within the northeastern region, the eastern provinces have the highest vulnerability index, i.e., Sakon Nakhon and Nakhon Phanom provinces in 2006 (Figure 9). Fertilizer use, crop yield, irrigated area, and cropping intensity are major determinants and are negatively correlated to vulnerability. A declining vulnerability trend was observed from eastern to western provinces of the northeastern region. The two selected provinces for in-depth analysis were among the most drought-prone areas of the region.

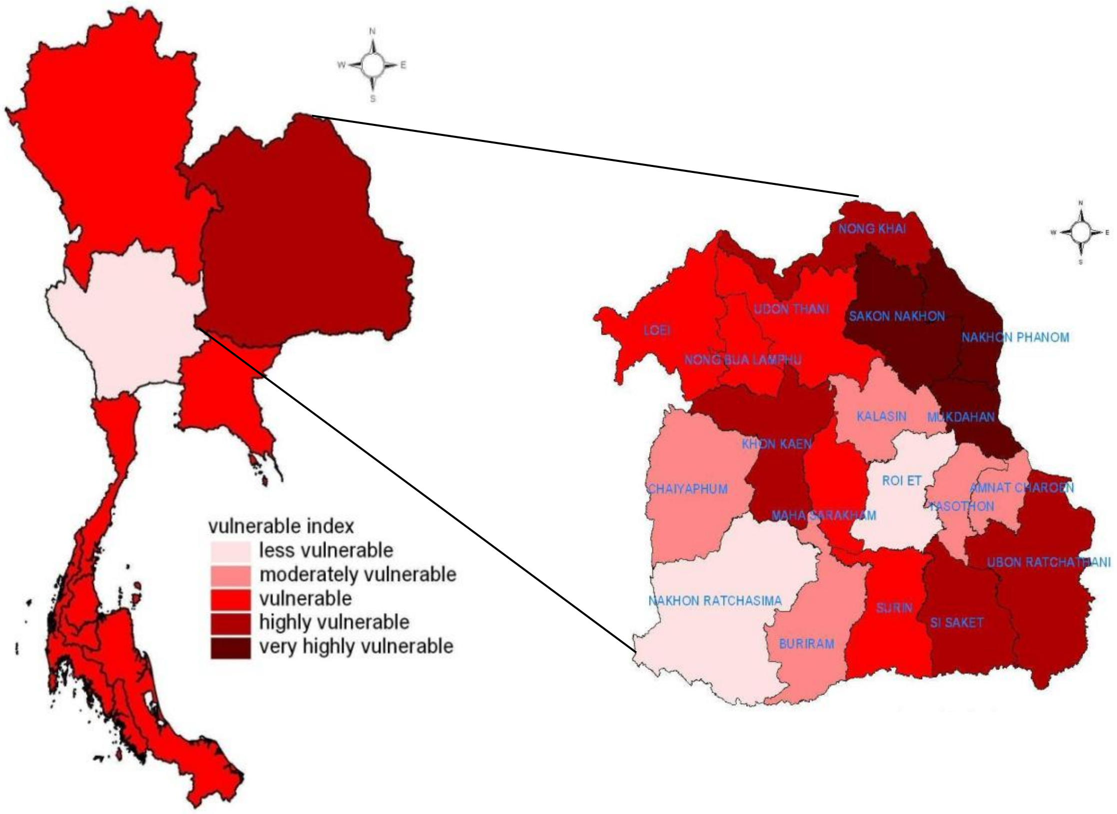


Figure 9. Regional vulnerability to climate change in Thailand (2006)

Viet Nam

Viet Nam is divided into eight agro-ecological zones from North to South, based on topography, climate, soil, geology and agronomy as: North East Mountainous Area (NEM); North West Mountainous Area (NWM); Red River Delta (RRD); North Central Coast (NCC); South Central Coast (SCC); Central High Land (CHR); South East Region (SER); Mekong River Delta (MRD).Total vulnerability index was computed based on the current datasets (2009) and climatic parameters. Analysis of aggregated data at regional level showed that five regions (RRD, NWM, SER, CHR, and MRD) are most vulnerable compared to other regions. The other two regions that are moderately vulnerable are NCC and SCC (Figure 10). The NEM falls in the vulnerable category. The sea level rise is an important indicator in computing vulnerability, which is not considered in this analysis especially for the zones bordered with coastal lines.

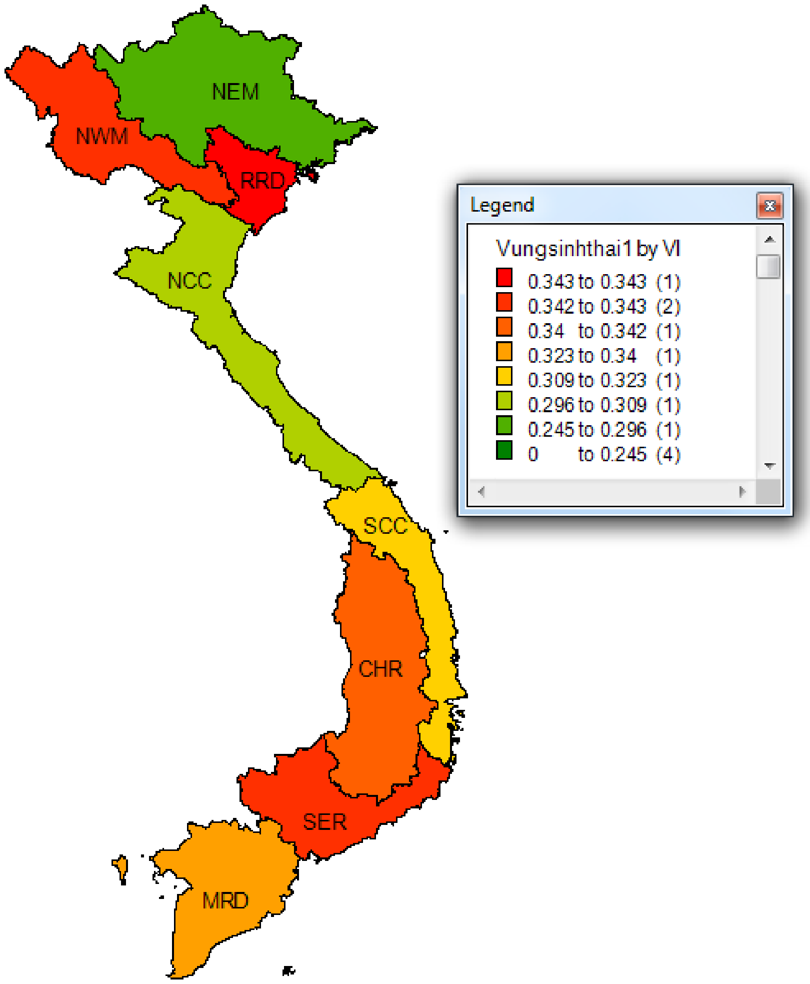


Figure 10. Viet Nam's regional vulnerability to climate change (2008)

China

China is the most populous country with a huge geographical area and diverse agro-ecological zones with regions highly vulnerable to natural disasters viz. earthquakes etc. Studies done on China's vulnerability to climate change identifies climate change impacts on sea level rise, water availability, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns are the major challenges in the future. The most vulnerable regions are the arid and semi-arid regions of northwest, and where a major sections of poor lives. The densely populated peri-urban and coastal zones are moderate to highly vulnerable.

Identification of vulnerable regions through socio-economic indicators and to understand household level linkages to poverty is the next step. Household linkages at vulnerable regions need to be explored to understand how farmer perceived these changes of cropping pattern, income levels and output and input markets, diversification etc. Household level survey and analysis give a clear picture of what has been happening in terms of adaptation strategies to climate change.

It is clear that the study countries in Asia are heterogeneous and the impact of climate change will vary from one location to other depending on various climatic conditions, as well as environmental and contextual factors. The latter will include historical, social, economic and governance status faced by the people and the institutional framework within which they function. The quality of life of people who have the ability to act in their interest greatly defined through acquired strengths and hence the coping people have. People's sense of realities is acquired strength that is gained through life experiences, learning, and wealth and one's own perceptions and values that will to a great extent provide the impetus to act. In the context of climate responsiveness, the values and perceptions that define their actions are of paramount importance to understand their adaptive behavior.

Farmer’s perception on agriculture and climate variability

Recent literature has highlighted that risks are meaningful, and their meanings are determined by perceptions influenced by socially-embedded beliefs and values (Adger 2000). Hence decisions regarding risk are based on the way of life or world view of the individual, household or community (Parthasarathy 2009). Individuals and groups rank risks in terms of their probabilities, their own coping strategies, ability and the willingness of the state to help them adapt and survive various crisis and disasters (Parthasarathy 2009). The role of technology, institutions, individual behaviour and social capital is crucial in determining adaptation to a particular situation. Sen (1985) has argued that human development and security are possible only if an individual gets his/her due entitlements and in turn nurtures his or her capabilities to build up an adaptive capacity.

Farmers have been facing the variability of rainfall and associated uncertainty in their rainfed crop production system from time immemorial. They have been continuously testing new crops and fine tuning their agriculture by practicing various adaptation measures. These autonomous adaptation measures are often in response to the real situations which are not the effect of a single variable. In fact they are usually complex and few or more factors are combined together like variability and uncertainty in rainfall, socio economic contexts, market complexities or government policies.

Scientists and policymakers have identified climate change as a serious future threat that needs immediate corrective actions (CCAFS 2010). It is presumed that climate change will bring in increased variability in rainfall, increased temperatures, and more often increased frequency of climate extremes such as droughts and floods across the globe. Since there have been few studies on farmers’ perceptions of climate change (Mertz et al. 2009; Thomas et al. 2007; Bunce et al. 2010), this study used a Q^2 approach. Fieldwork focused on four basic questions:

1. How do villagers perceive climate change?
2. How do farmers respond to climate changes or climate variability?
3. Which individuals or groups are most vulnerable?
4. What kind of adaptive capacities do they have that will help build resilience to effects of climate change?

The present global environment can be seen as a good panorama of climatic variants existing around us. Examining and understanding farmers reactions to the present adverse environmental conditions resulting from climate extremes and rainfall variabilities, it will provide insight on how people in other areas adversely affected by climate change must act, adapt and behave in order to successfully face the forthcoming climate change scenario.

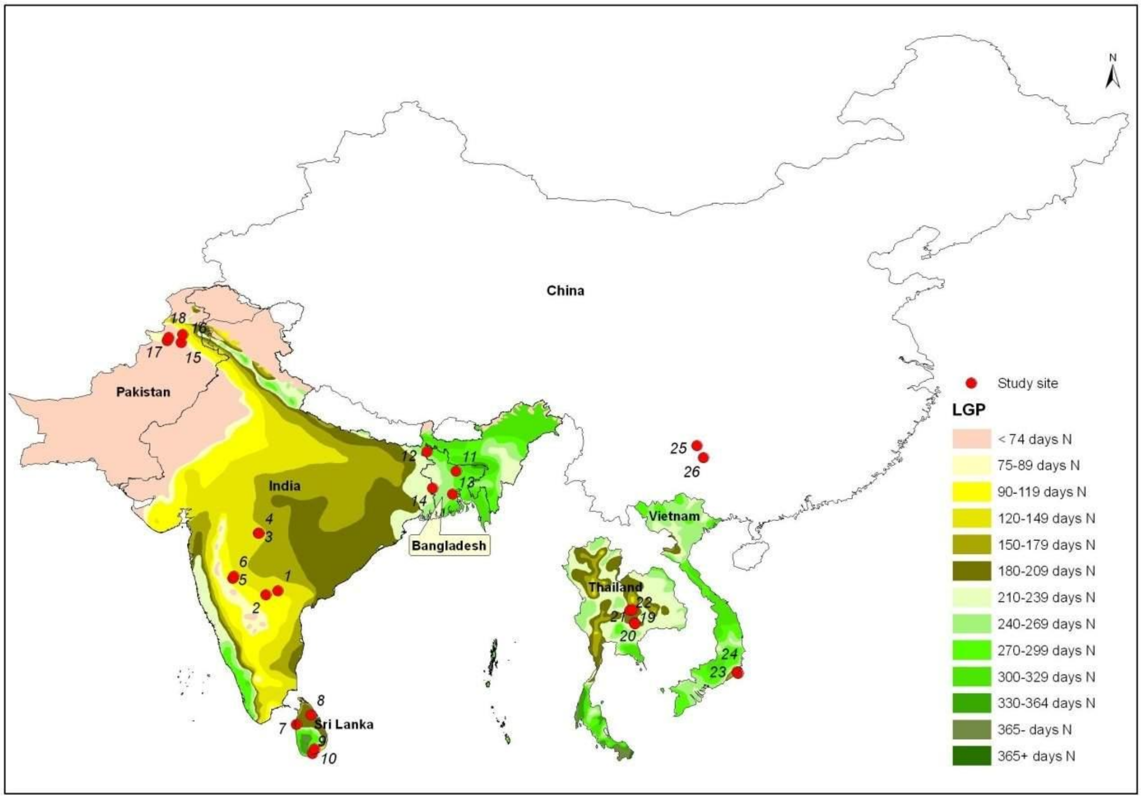


Figure 11. Location of study villages in South Asia, Southeast Asia and China

Table 13. List of study villages in South, Southeast Asia and China

Sl.No.	Country	Province/District	Village	Longitude	Latitude
	South Asia				
1	India	AP/Mahabubnagar	Aurepalle	78.6163	16.8643
2	India	AP/Mahabubnagar	Dokur	77.8500	16.5900
3	India	Maharashtra/Akola	Kanzara	77.3500	20.6600
4	India	Maharashtra /Akola	Kinkheda	77.3900	20.6400
5	India	Maharashtra /Solapur	Kalman	75.6600	17.6800
6	India	Maharashtra /Solapur	Shirapur	75.7200	17.8000
7	Sri Lanka	Puttalam	Mangalapura	79.8353	8.0342
8	Sri Lanka	Anuradhapura	Galahitiyagama	80.8167	8.6667
9	Sri Lanka	Hambanthota	Bata-Atha	80.9014	6.1099
10	Sri Lanka	Hambanthota	Mahagalwewa	81.0500	6.4000
11	Bangladesh	Mymensingh	Nishaiganj	90.4026	24.7492
12	Bangladesh	Thakurgaon	Boikunthapur	88.4590	26.0281
13	Bangladesh	Madaripur	Paschim Bahadurpur	90.1500	23.2300
14	Bangladesh	Chaudanga	Khudaikhali	88.8527	23.6430
	Southeast Asia				
15	Thailand	Chok Chai	Don Plai	102.1631	14.7322
16	Thailand	Nakorn Ratchasima	Kudsawai	102.1927	14.6662
17	Thailand	Chatturat	Tha Taeng	101.8456	15.5656
18	Thailand	Chaiyaphum	Nong Muang	102.0155	15.5997
19	Viet Nam	Phuoc Nam	Vu Bon	108.9134	11.4973
20	Viet Nam	Phuoc Dinh	Nho Lam	109.0056	11.4136
	China				
21	China	Guizhou	Lucheba	106.2700	26.4200
22	China	Guizhou	Dajiang	106.7210	25.6320

The present study tries to understand farmer's perceptions on various issues relating to agriculture and their adaptation strategies in India, Sri Lanka, and Bangladesh from South Asia, Thailand and Viet Nam from Southeast Asia and China. All the study villages are from marginal environments. The driest villages were Kalman and Shirapur from India and the rest of the four villages from India had 120 to 149 days of LGP. Nong Muang and upland village from Thailand and the two villages from Viet Nam have 150 to 179 days of LGP. The remaining villages from Thailand and all the villages from Sri Lanka had under 180 to 219 days of LGP. All the villages from Bangladesh fall under the comfortable zone of more than 210 days of LGP (Figure 11 and Table 13).

To capture farmer's perception on periodical changes in various bio-physical and socio-economic indicators and dynamics of natural resource use and management, institutions and policies etc. a detailed perception survey through a structured questionnaire was conducted. Representative samples of each group of farmers were drawn from the selected villages and their perceptions were recorded at interviews using the questionnaires. In addition, key informant interviews and focus group discussions (FGD) were conducted to corroborate the information acquired through individual surveys. Transect walks and other qualitative techniques were also used to supplement the information. In the case of India other unique data from the "Village level Studies" (VLS) - a classical longitudinal study of the ICRISAT initiated in the mid 1970's were also used for the set of six villages from India to enhance the understanding of the dynamics of agricultural development of the small holder farmers of the SAT region of India. The same template of the questionnaire and other methods were used in all the six countries comprising India, Sri Lanka, Bangladesh, Thailand, Viet Nam and China. The general characteristics of the study villages are presented in the following section.

General Characteristics of the Study Locations

India

The selected villages belong to different districts of Andhra Pradesh and Maharashtra. These villages are Aurepalle & Dokur (Mahabubnagar district, Andhra Pradesh), Kanzara & Kinkheda (Akola district, Maharashtra) and Shirapur & Kalman (Solapur district, Maharashtra). The villages are different from one another in agro-ecological and socio-economic characteristic like climate, soil type, cropping pattern, average household size and occupation among others (Walker and Ryan 1990). The villages receive a minimum annual average rainfall of around 750mm and majority of precipitation is received during June to September. Kharif (June-October) and rabi (October- March) seasons are the major cropping seasons of the SAT region. Rabi crops are primarily irrigated with minimal rainfall received during this season. Atmospheric temperature frequently rises to >40°C during summer months (March-May) in all three districts. The major soil type of Aurepalle and Dokur is red soils and major crops grown in these villages are rice, sorghum, castor, cotton and other minor crops. The major soil type of Akola district is medium black soil and pigeon pea; cotton, green gram, and soybean are also important crops grown. The major soil type in Solapur district is heavy deep black cotton soil and the important crops in this district are pigeon pea, cotton, sugarcane, sunflower, and black gram. Furthermore, livestock is an important component of farming system mainly comprising cattle and goats in all these villages irrespective of districts they belongs to. The winter (rabi) crops are grown with the help of water drawn from a variety of sources like surface water (canal) or groundwater (wells, tube wells, etc.) (Table 13a).

Table 13a. General characteristics of study villages in India

	Andhra Pradesh		Maharashtra			
Villages	**Aurepalle**	**Dokur**	**Kanzara**	**Kinkheda**	**Shirapur**	**Kalman**
Geographical locations	16.5° N lat 77 °50′E long		20.5° N lat 77.2° E long		18.32°N lat 76.15°E long	
Geographical area (ha)	1642	1371	600	527	1369	3087
Net cropped area (hectares)	1224	351	482	442	859	1888
Irrigated area (ha)	245	41	65	18	714	398
Average annual maximum temperature (°C)	33.3		34.2		34.3	
Average annual minimum temperature (°C)	21.8		19.4		20.5	
Rainfall (mm)	785		723		726	
Soil Type	Shallow to medium alluvial (Alfisols)		Medium black clay soil (Vertisols)		Deep Black soil (Vertisols)	
Cropping seasons	Kharif & Rabi					
Major crops	Paddy, sorghum, castor, cotton		Pigeon pea, cotton, green gram, Soybean		Sorghum, sugarcane, pigeon pea, sunflower and chickpea	
Number of households	766	519	319	189	546	486
Population	3562	2816	1427	876	1325	1127
Main occupation of the villagers (% of population)	Farming (70-80%)	Farming (60-70%)	Farming (75-85%)	Farming (85%)	Farming (50-60%)	Farming (70%)
Improved technologies partially adopted	High yielding cultivar, fertilizers, tractors, power sprayers and threshers		Hybrids, fertilizers, tractors, power sprayers and threshers. Combine harvester for different crops, Sprinkler and drip irrigation		High yielding cultivar, fertilizers, tractors, power sprayers and threshers. Cross bred livestock and poultry	

Note:*Kharif – (June-October); Rabi – (October – March)

Sri Lanka

Three districts namely, Puttalam, Anuradhapura and Hambantota from the dry zone of Sri Lanka were chosen for the study. Mangalapura village from Puttalam, Galahitiyagama village from Anuuradhapura district and Mahagalawewa and Bata-Atha villages from Hambantota district were selected. All these villages represent marginal environments with rain-fed agriculture. Mangalapura has 394 households and Galahitiyagama has 344; and Bata Atha and Mahagalawewa have about 484 and 225 households respectively. The average annual rainfall is around 1275 mm in Mangalpura and Galahitiyagama villages and in Bata-Atha and Mahagalawewa it is around 1234 mm. Average annual number of rainy days are 61 in Mangalpura and Galahitiyagama and 77 days in the other two villages i.e., Mahagalawewa and Bata-Atha. The average annual minimum temperature is 21 to 22 degrees in the villages and the maximum temperature is 34 degrees in Mangalapura and Galahitiyagama and about 31 degrees in Bata-Atha and Mahagalwewa. Major soils in these villages are Red and yellow Latosols and reddish brown earths.

Mangalapura village is predominantly rainfed with very little irrigated area irrigated by tube wells. Anuradhapura village has a small area irrigated by tanks and open wells. Bata Atha has a small area irrigated by a canal and open wells and Mahagalawewa has small tanks and open wells. In general most of the area in the study villages is rainfed. Major crops grown in Mangalapura are Cowpea, Water melon, Green gram, Chili, Manioc and Cashew. Paddy, Maize, Foxtail Millet and Chilies are commonly grown in Galahitiyagama. Sesame, Maize and Finger Millet are the common crops in Bata Atha village. Rice, Sesame and Finger Millet are common in Mahagalawewa. Yala (Mar-Aug) and Maha (Oct-Feb) are the two main cultivation seasons in Sri Lanka. Modern technologies such as high yielding varieties, fertilizers, power sprayers, tractors, water pumps, agro-wells and tube-wells can be seen in Mangalapura village. High yielding varieties, fertilizers, power sprayers, tractors, threshers, and harvesters are some of the modern technologies used by the farmers of Galahitiyagama village. High yielding varieties, fertilizers, sprayers, tractors and threshers are used by the farmers in Bata-Atha village. High yielding varieties, fertilizers, power sprayers, tractors, threshers, harvesters, and water pumps are the modern technologies that are adapted by some of the farmers in Mahagalawewa village (Table 13b).

Table 13b. General characteristics of study villages in Sri Lanka

General features	Puttalam district	Anuradhapura district	Hambantota district	
	Mangalapura	**Galahitiyagama**	**Bata-Atha**	**Mahagalwewa**
Geographical locations	8^0 01′ N 79^0 55′ E	8^0 22′ N 80^0 28′ E	6^0 10′ N 81^0 10′ E	6^0 10′ N 81^0 10′ E
Human population (no.)	1417	1179	1935	825
Total number of households	394	344	484	225
Average family size (no.)	3.6	3.4	4	3.7
Gross cropped area (ha)	1820	168	342	610
Literacy rate (%)	93.3	90.3	89	89
Percent Below poverty line	22.3	24.4	32.4	32.4
Average annual rainfall (mm) (2001-2008)	1275	_	1234	1234
Annual average number of rainy days	61	-	77	77
Average annual minimum temperature (^{0}C)	21	-	22	22
Average annual maximum temperature (^{0}C)	34	-	31	31
Soil type	Red Yellow Latosol	Reddish Brown Earth	Reddish Brown Earth	Reddish Brown Earth
Sources of irrigation	Tube wells	Tank and wells	Canal and wells	Tank and wells
Major crops grown	Cowpea, Water melon, Green gram, Chili, Manioc, Cashew	Paddy, Maize, Foxtail millet, Chili	Sesame, Maize, Finger millet	Paddy, Sesame, Finger millet
Main occupation of the villagers (Percent of population)	Farming (60-70%)	Farming (100%)	Sea Fishing (60-70%)	Farming (80-90%)
Cropping seasons		*Yala & Maha		
Improved technologies partially adopted	High yielding varieties, fertilizers, power sprayers, tractors, water pumps, agro-wells, tube-wells	High yielding varieties, fertilizers, power sprayers, tractors, threshers, harvesters	High yielding varieties, fertilizers, sprayers, tractors, threshers	High yielding varieties, fertilizers, power sprayers, tractors, threshers, harvesters, water pumps

*Yala (Mar-Sep); Maha (Oct-Mar)

Bangladesh

For the present study Khudiakhali village of Chuadanga district and Boikunthapur village of Thakurgaon district from the drought-prone zones and Nishaiganj village of Mymensingh district, and Paschim Bahadurpur village of Madaripur district from the flood-prone zones of Bangladesh were chosen to understand how farmers have been adapting to the increasing variability of rainfall.

Drought-prone Villages: Of the two drought-prone villages, Boikunthapur, is located about 12 km away from the Thakurgaon district headquarters and about 360 km north from Dhaka. The village has largely a plain landscape. Most of the lands of the village are either high or medium high (46.5% high and 47.2% medium high) and the remaining 6.3% are low and very low lands. Two small rivers, named Tangon and Shenua, flow near the village. The village has about 35 families, mostly smallholder and medium farmers. Major soils in the village are Loamy. Aman and boro rice, vegetables, maize and pulses are the common crops. The other drought prone village, Khudiakhali of Chuadanga district is located about 200 km away from Dhaka city. The village is reside by approximately 33 households, comprising 4.5 members each, on an average. Agriculture provides the basis of livelihoods for 80% of the population of this village whilst the rest are engaged in the entrepreneurship and services sector. Boro and Aman rice, vegetables, maize, jute, and tobacco are the major crops grown in the village, although betel leaf production became hugely popular in the last decade and half due to high profitability and better marketing opportunity.

Flood-prone Villages: Nishaiganj is located about 110 km north of Dhaka. The village has about 157 people, mostly engaged in farming or fisheries. The village in general has clayey, loamy, or sandy soils where Boro and Aman rice, jute and various common vegetables are grown. From the beginning of the year 2000, many farmers of the village have started aquaculture instead of rice and jute production. Fisheries can ensure better profitability in the face of declining rice and jute production due to changes in rainfall and its variability. Tube wells are the main source of irrigation. Paschim Bahadurpur, a flood-prone village, is located about eight kilometers west of Madaripur district sadar and 80 km Northwest of Dhaka. The village is mostly a plain-land. Farmers grow rice, jute, *kalai* (peas), *masur* (Red lentil), *khesari* (Lathyrus), *peas, kalijira* (Cumin), *dhania* (coridander), and vegetables, mostly for self-consumption (Table 13c). The villagers have to cross a two-km long earthen road, which becomes muddy during the rainy season and makes the lives of the villagers very difficult. Sometimes the villagers also use trawlers and boats to transport their produces to the local markets, during the rainy season. The village does not have access to electricity or any recognized educational institution.

Table 13c. General characteristics of study villages in Bangladesh*

Characteristics	Flood Prone								Drought Prone							
	Mymensingh District				Madaripur District				Chuadanga District				Thakurgaon District			
	Nishaiganj				*Paschim Bahadurpur*				*Khudiakhali*				*Boikunthapur*			
	1987-88	**2000**	**2004**	**2010**	**1987-88**	**2000**	**2004**	**2010**	**1987-88**	**2000**	**2004**	**2010**	**1987-88**	**2000**	**2004**	**2010**
Human population (no.)	114	138	160	157	68	168	162	170	106	132	135	132	114	138	136	140
Total number of households	20	30	32	35	19	30	30	34	20	30	30	33	20	30	31	35
Average family size	5.7	4.6	5	4.5	3.6	5.6	5.4	5	5.3	4.4	4.5	4	5.7	4.6	4.4	4
Extreme poor (%)	45	33	12.5	5	10.5	36.7	23.3	15	50	10	10	7	35	23.3	13	10
Soil type	Clayey, Loamy, and Sandy				Clayey -loam				Clayey and Sandy loam				Loamy			
Main sources of irrigation	IM, DTW	IM, LLP, DTW	DTW, STW, LLP	DTW, STW, LLP	STW	LLP	LLP	LLP	IM, STW	STW	STW	STW	STW	STW	STW	STW
Major crops grown	Boro, Aman, jute, and vegetables				Aman, Boro, pluses, vegetables, spices, and jute				Betal leaf, Boro, Aman, Jute, maize, tobacco, vegetables				Boro, Aman, maize, pulses, spices, vegetables			
Cultivable area (in hectares)	6.4	14.59	14.22	8.00	11.08	13.42	14.06	15.0	6.5	9.57	11.47	13.0	17.9	26.5	19.83	20.0
Average annual rainfall 2001-08 (mm)	1859															
Extinct or nearly extinct crops	Linseed, arahar, shati, futi and local variety of banana.				Indigo, betel leaf, watermelon.				Linseed, mustard seed, kaun and varieties of dal (pulse).				Jute, barley and aus paddy.			

IM- Indigenous method, DTW- Deep tube well, LLP- Low lift pump, STW- Shallow tube well.
*The census details is based on the sampled households

Thailand

Chok Chai District in Nakhon Ratchasima Province and Chatturat District in Chaiyaphum Province in the northeast region representing dry areas in Thailand are chosen for the study. Don Plai (DP) and Kud Sawai (KS) villages in Chok Chai district are mainly villages with a majority in lowlands and with little irrigation from Lum Chae Dam, whereas Nong Muang (NM) and Tha Taeng (TT) villages from Chatturat district are mainly uplands with some irrigated areas from small and medium reservoirs that are not active in the dry season. These also have less paddy fields than the first two villages. Among the lowland villages, DP has a larger population with 266 households and KS village has 176 households. Upland villages NM and TT have 257 and 96 households, respectively. Lowland village DP is the largest with a geographical area of 1072 hectares and the smallest is the other lowland village with an area of 358 hectares. Net cropped area in DP and KS are 66% and 96% of total area, whereas in upland villages NM and TT net cropped area is 90% and 87%, respectively.

In general, lowland villages have a higher irrigated area. DP has an irrigated area of 50% and KS has 23%. The upland villages have very little irrigated area with NM and TT having only 3% and 16% irrigated areas respectively. Both the lowland villages are dominated by smallholder farmers, comprising 45% and 68% of households in DP and KS, respectively. In the upland villages, farmers with medium-sized landholding of 2-4 hectares of land dominate with NM and TT comprising 77% and 44% of households in the village. The average annual maximum temperature is around 32.5°C and the average annual minimum temperature is around 22.1°C. The average annual rainfall is about 1086 mm in the lowland villages and about 1114 mm in the upland villages. Both these districts have bimodal rainfall distribution pattern and thus create two distinct rainy seasons. One, during May to July, can be called early rainy season and the other (Aug to Oct) can be called the late rainy season. Cassava, vegetables, and fruits are cultivated all year round. In the lowland villages during the early and late rainy season, rice, cassava, and vegetables are grown. In the upland villages, rice, cassava, vegetables, maize and banana are grown in TT and NM. Fruits like mango and coconut are also common. Kenaf was common in the past in both the villages but is now disappearing. New technological improvements such as tractors, threshers, and new improved varieties are penetrating the lowland villages. In the upland villages tractors, threshers, new improved varieties, and organic fertilizers are becoming common (Table 13d).

Table 13d. General characteristics of study villages in Thailand

Study villages		**Chok Chai District**		**Chaiyaphum District**	
		Don Plai	**Kud Sawai**	**Nong Muang**	**Tha Taeng**
Demographic features	Population	1116	780	916	323
	No. of household	266	176	257	96
	Gender(female : male)	1 : 1	1 : 1	1 : 1	1.3 : 1
	Education	Mostly primary school	Mostly primary school	Mostly primary school	Mostly primary school
Main occupation (% of population)		Agriculture 83%	Agriculture 95%	Agriculture 100%	Agriculture 90%
Geographical locations		14.67° N lat 102.20 ° E long	14.72° N lat 102.13°E long	15.70° N lat 101.82 ° E long	15.64° N lat 101.74 ° E long
Geographic		lowland	lowland	upland	upland
Geographical area (ha)		1,072	358	800	466
Net cropped area (ha)		707 (66%)	342 (96%)	718 (90%)	405 (87%)
% Irrigated area (of net cropped area)		50	23	3	16
Landless HH (%)		11	12	3	5
Small HH (0-2 ha) (%)		45	68	0	4
Medium HH (2-4 ha) (%)		26	12	77	44
Large HH (>4 ha) (%)		18	8	20	47
Average annual maximum temperature (°C)		32.5		32.6	
Average annual minimum temperature (°C)		22.1		22.5	
Average annual rainfall 1970-2008 (mm)		1,086 (Average increase 0.29 mm)		1,114 (Average decrease 0.023 mm)	
Cropping seasons		Early rain (May-Jul) / late rain (Aug-Oct) / all year round (cassava, vegetables, trees)			
Major crops		Rice, cassava, vegetables, fruit	Rice, cassava, vegetables	Rice, cassava, kenaf, maize, vegetables, banana	Rice, cassava, vegetables, maize, kenaf, chilli, mango, coconut
Improved technologies partially adopted		Tractor, thresher, bio-extract, new varieties	Tractor, thresher, new varieties	Tractor, thresher, bio-extract, organic fertilizer, new varieties	Tractor, thresher, bio-extract, organic fertilizer, new varieties

Viet Nam

In Viet Nam, agricultural production is the important activity with the engagement of more than 73.41% of population. For this study, we selected Ninh Thuan province which is situated in the southeast region along the sea. Ninh Phuoc district was chosen in the Ninh Thuan province because of its predominantly semi-arid nature. In these districts, two communes, Phuoc Nam and Phuoc Dinh were selected and further two villages, one from each communes, namely Vu Bon village from Phuoc Nam commune and Son Hai village from Phuoc Dinh commune were selected for the study. The total geographical area in Vu Bon and Son Hai villages are 548 and 490 hectares, respectively. Net cropped area is 433 and 111 hectares in these villages. The average annual maximum and minimum temperatures are 31.7°C and 24.1°C. About 74% and 86% of the net cropped area is irrigated in Vu Bon and Son Hai villages. Average annual rainfall of the villages is 764 mm. Sandy and brown grey red soils dominate the villages. In Vu Bon, wet rice (July-Oct) and spring rice (Jan-May) are the main crop growing seasons. In Son Hai village, spring rice (Jan-Apr), summer rice (May-Sep) and autumn rice (Oct-Dec) are common growing seasons. Rice, maize, and beans are common crops in both villages. In addition, tobacco and some vegetables also are grown in Son Hai village. Drought tolerant varieties, fruit trees, and water conservation measures are favoured by the farmers of Vu bon. Aquaculture, goat and sheep rearing, and drought-tolerant varieties are common in Son Hai village (Table 13e).

Table 13e. General characteristics of study villages in Viet Nam

Study villages	**Vu Bon village, Phuoc Nam commune**	**Nho Lam village, Phuoc Dinh commune**
Geographical location	11ᴼ29′50,1″N, 108ᴼ54′48,4″E	11ᴼ24′48,9″N, 109ᴼ00′20,2″E
Geographical area (ha)	548.0	490.0
Net cropped area (ha)	433.0	111.0
Irrigated areas (ha)	321.5	96.0
Average annual maximum temperature (^{0}C)	31.73	31.73
Average annual minimum temperature (^{0}C)	24.09	24.09
Rainfall (mm)	764.0	764.0
Soil type	Grey soil, acrisol, semi-arid brown grey red soil	Sandy soils, acrisol, semi-arid brown grey red soil
Crop seasons	Spring Rice (Jan-May)- Wet Rice (Jul.-Oct)	Spring Rice (Jan-Apr)- Summer Rice (May-Sept)- Autumn rice (Oct.-Dec).
Major crops	Paddy, maize, bean, some vegetables, grape	Rice, maize, bean, tobacco
Number of household	491	277
Main occupation (%)	Farming (80-90)	Farming (60-75)
Improved technologies partially adopted	Drought tolerance crops, water conservation, fruit tree, livestock	Drought tolerant crops and tobacco, goat, sheep, aquaculture

China

In China, two counties namely, Pingba County from Central Guizhou and Luodian County from South Guizhou, were selected for the study. Pingba County has a general climate of subtropical monsoon zone with rainfall of 1100-1500 mm and the average temperature is 14-16℃. This area is dominated by mountains or hills. Only about 9.4% of area is flat or plain. The main crops in the county are rice, maize, rapeseed, wheat, tobacco, tea and some subtropical fruits. The second county selected is Luodian County from southern region of Guizhou province. The climate is subtropical monsoon with annual rainfall of 1200-1400 mm and temperature of 14-20℃. About 97.83% of land is mountainous or hilly and only 2.17% is plain or flat land. Main crops are rice, maize, rapeseed, wheat, sugarcane, and some tropical or subtropical fruits, such as orange, litchi, longan, and local banana. Soil types are red soils and yellow. One village from Pingba county namely Lucheba and another village from Luodian county namely Dajiang were selected for the study. Lucheba also has very little plain land and 340 households live in the village. In Dajiang, 417 households are present. Lucheba has 73 hectares of lowland and 93 ha of upland, whereas Dajiang has 80 hectares of lowland and 66.7 ha of upland. Lucheba has 0.49 and Dajiang has 0.35 hectares of farmland per household, respectively. In Lucheba, almost all farmland has irrigation potential and this is made possible by the state construction of reservoir and pipelines to supply water from 2009; irrigation reaches up to the farm gate of about 50% of the farmland. The remaining 50% of the area get supplementary irrigation by small tanks. In Dajiang, about 38% of the area is irrigated (Table 13f).

In short, the twenty six villages from where detailed information was gathered revealed that farmers tilling the soil over many generations have adapted to the vagaries of weather patterns and seasons and made a living dependent on land. The exceptions are the two flood-prone villages chosen for the study in Bangladesh that experience more rainfall and water availability than the others. Due to availability of water, the types of agricultural enterprises also differ significantly. The level to which market penetration has occurred also varied distinctly. The availability of service delivery agencies also differ, some villages have access to state education and health services, and have motorable roads, while other villages do not. Hence the presence of state institutions reflects the levels of penetration of the governance system in the respective country.

Table 13f. General characteristics of study villages in China

		Lucheba village (Central Guizhou)					Dajiang Village (southern Guizhou)				
Demographic features		Population	HH	Male	Female	Labor	Population	HH	Male	Female	Labor
		1360	340	700	660	710	1785	417	803	984	750
Geographical area (km^2)		Karst hilly area (7.2)					Karst mountainous area (12)				
Small HH(0-2 ha) (No.)		340					417				
Total farmland (ha)	Paddy	73.3					80.0				
	Upland	93.3					66.6				
Average farmland/HH (ha)		0.49					0.35				
Average farmland/person (ha)		0.12					0.08				

Dynamic changes in cropping patterns

As seen from the preceding overview of the study villages, there is great variability in the climatic conditions experienced as well as the types of cultivation undertaken by farmers. The level at which villages are integrated to the state will determine to a great extent the level to which the villages can benefit from information generated at the center, and the services presumably designed to benefit the people. A combination of the efficacy of the village level institutions, the environment, the community dynamics and household capacity will determine how effective the farmers are at making a living. Those who farm the land will adopt cropping patterns that "best fit" the farmers farming context.

India

Of the six villages studied, Kanzara is the most prosperous village. Traditionally, Kanzara village is in the cotton growing belt. Cotton has been grown in the village for centuries. Most of the farmers adopted BT Cotton, but soybean has fast replaced cotton after it was introduced in 2005 in the village; about 74% of the area during the kharif season is sown with soybean. Soybean is a cash crop and farmers are getting good remuneration from this crop. In the post-rainy season, wheat and vegetables are the main crops grown under irrigation. Shirapur is the next in rank in terms of prosperity. Traditionally, farmers used to grow, pigeon pea, sunflower, pearl millet, and sesame in the rainy season mostly as rainfed crops. With the improvement of irrigation facilities, along with the introduction of canals in 1996, farmers started shifting to cash crops and slowly abandoned food crops. The village now plants over 76% of cropped area with sugarcane. Fodder crops such as maize, grasses, and a little fodder sorghum gained importance of late as the dairy industry started to grow in the village. During the rabi season, farmers usually grow sorghum and wheat. Most of the area was used for sorghum cultivation during rabi in the 1970s and 80s. Even now, rabi season sorghum is the main crop for most of the farmers in Kalman.

During the kharif season, pigeon pea was the main crop in the 1970s and it remains to a major crop, currently occupies around 66% of the cropped area. In the 1970s, groundnut and pulses like mungbean and blackgram were common during the rainy season. However in recent times, the cropped area under pulses and groundnut decreased while that of vegetables and maize increased along with improved irrigation facilities. Rabi is the major season in Kalman and sorghum is the most prevalent crop. Wheat, chickpea, and vegetables are also grown under irrigated condition. Kinkheda comes under the assured rainfall zone. During the 1970s, cotton and cotton-based mixed cropping were dominant; groundnut and sunflower were other commonly grown crops in the village along with sorghum. But groundnut and sunflower almost disappeared in recent times. This is mainly due to wild pig menace. At present, soybean is the dominant crop and more than 50% of the cropped area in kharif is sown with soybean

Table 14a. Cropping Pattern in selected villaged in Andhra Pradesh and Maharashtra states of India

% of total cropped area	**Aurepalle**	**Dokur**	**Kanzara**	**Kinkheda**	**Shirapur**	**Kalman**	**Aurepalle**	**Dokur**	**Kanzara**	**Kinkheda**	**Shirapur**	**Kalman**
	Kharif						**Rabi**					
Cotton	73	3	8	5								
Castor + pigeon pea	6	24										
Paddy	14	52					51	40				
Maize					13	7	6					4
Sorghum + pigeon pea	3	4		4								
Pearl millet + pigeon pea	1											
Maize	1											
Vegetables	1				8	10	5		30	13		5
Soybean + pigeon pea				34								
Cotton + Pigeon pea				20								
Cotton + Green gram + pigeon pea				10								
Pigeon pea	1	11	6		3	65						
Ground nut						2	21	60				
Soya bean			74	20	1							
Green gram			5	4								
Sunflower						6	13					3
Black gram			3				3					
Sugarcane					75						21	
Wheat									67	50	7	4
Sorghum											70	76
Safflower							1					
Chickpea										37	2	5
Other pulses						5						
Others		6	4	3		5			3			3

as an intercrop with pigeonpea or soybean as a sole crop. The rapid spread of soybean is because of high prices offered to the produce (market-driven), less labor requirement, and most importantly, since it is a shorter duration crop. It is easier to have wheat as a second crop.

Wheat, chickpea, and vegetables are the common crops during rabi season in the irrigated areas. Farmers in Aurepalle used to grow sorghum, pearl millet and some pulses in their fields until the 1970s and paddy was grown around the wells. With time, cropping pattern has changed and now cotton has taken over of about 73% of cropped area in kharif. With the introduction of bore wells, paddy areas have increased and now occupy around 14% of the cropped area. Irrigated paddy cultivation is dominant in rabi season. Groundnut, sunflower, and maize are also grown during rabi season in the irrigated areas. Farmers in Dokur used to grow paddy in the irrigated situation; sorghum, groundnut, and pigeonpea are grown under rainfed situation during the rainy season in the 1970s. From 2000, farmers started castor cultivation due to uncertainty in rainfall and slowly castor cultivation increased with time. At present about 56% of cropped area is with paddy and the second most important crop is castor. Cotton cultivation along with sorghum was reduced with time (Table 14a).

Sri Lanka

Yala and Maha are the two major cultivating seasons in Sri Lanka. Yala season starts in March and ends in August, while Maha season starts in September and ends in February. Yala season gets rain from the southwest monsoon and Maha season gets rain from the northeast monsoon.
In Galahitiyagama village, farmers reported that cultivated areas for finger millet, black gram, and sesame have decreased over time, whereas those for okra, maize, paddy, and other crops (fruits) have increased in Yala season. In Maha season, cultivated area for paddy and foxtail millet has increased while those for chili, onion, finger millet, green gram, black gram, maize, and mustard were reduced. Average yield of chili, onion, finger millet, maize, okra, groundnut, and paddy have increased in Yala season. Average yields of chili, onion, finger millet, and green gram were reduced in Maha season.

In Mangalapura village, most of the farmers are following rainfed farming and irrigation facilities are almost non-existent. During the last four decades, most cultivated area for annual crops have decreased. Farmers were discouraged as yield of most of the annual crops reduced and sometimes crops failed due to spells of drought. The result is that over the last few decades farmers increased the area of perennial crops. In particular, the drought tolerant species like cashew was favored by farmers.

In Mahagalwewa village, over the period in the Yala season, cotton cultivation has decreased. Cultivated area for crops, such as finger millet, green gram, and cowpea has decreased. Paddy cultivation increased from 36% in the seventies to 41.4% in recent decades. In Maha season, more areas were used to grow crops in the recent years, particularly paddy, increasing from 31-44% of total area. Cotton cultivation disappeared in the recent times from as much as 17% of the area in the seventies.

In Bata Atha village, cultivated area of finger millet, green gram, sesame, maize and paddy declined while the area of cowpea and cashew increased in the Yala season. Average yields of chili, cowpea, groundnut, sesame, and tomato declined in the Yala season (Table 14b).

Table 14b. Cropping pattern and farmer's perception in the study villages of Sri Lanka

	Cropping Pattern						Farmers Perception*		
Crop	**Galayihitiyagama**		**Mahagalwewa**		**Bata-Atha**		**Galayihitiyagama**	**Mahagalwewa**	**Bata-Atha**
	1970(%)	**2008(%)**	**1970(%)**	**2008(%)**	**1970(%)**	**2008(%)**			
Chilli	27.8	6	2	1.2	12.4	19.6	MD	MID	MII
Onion	5.6	0.9	-	-	-	-	MID	-	-
Finger millet	16.7	12	14.3	8.9	7.4	11.8	MID	MID	MII
Black gram	2.2	0	-	-	-	-	MID	-	-
Maize	1.1	6	0.4	3	6.2	9.8	MII	MII	MII
Okra	0	3	-	-	-	-	MII	-	-
Groundnut	0	0.3	-	-	0	0	MII	-	NC
Sesame	5.6	0	10.2	11.8	18.6	29.4	MID	MII	MII
Pumpkin	2.2	0	-	-	-	-	MID	-	-
Paddy	33.3	65.9	36.7	41.4	31.1	49	MI	MII	MII
Other	5.6	6	20.4	17.8	8.7	13.7	MII	MID	MII
Cotton	-	-	2	1.2	-	-	-	MID	-
Green gram	-	-	6.1	3	2.5	3.9	-	MID	MII
Cowpea	-	-	6.1	5.9	0	0	-	MID	NC
Cashew	-	-	0.8	1.2	0	0	-	MII	NC
Manioc	-	-	0.8	3	6.2	9.8	-	MII	MII
Tomato	-	-	2	3	6.8	10.8	-	MII	MII

Crops	Galahitiyagama		Mahagalwewa		Galahitiyagama	Mahagalwewa
	Cropping pattern				Farmers Perception	
	1970	**2008**	**1970**	**2008**		
Chilli	1.6	1.1	2.2	1.7	MID	MID
Onion	1.6	0.3	-	-	MID	
Finger Millet	8.5	2.2	12.3	13.2	MID	MII
Green gram	6.4	1.6	10	10.3	MID	MII
Cowpea	0.5	0.5	-	-	NC	-
Black gram	1.1	0.5	-	-	MID	-
Sesame	0.5	0.5	13.4	18.8	NC	MII
Ground nut	0.5	0.5	0.6	0.9	NC	MII
Pumpkin	1.1	1.1			NC	-
Paddy	39.4	48.7	31.2	44.5	MII	MII
Maize	33	32.8	4.5	3.4	MID	MID
Foxtail millet	4.8	9.8	-	-	MII	-
Mustard	0.5	0	-	-	MID	-
Other	0.5	0.2	6.7	5.1	MID	MID
Cotton	-	-	17.8	0	-	MID
Manioc	-	-	0.2	0.3	-	MII
Papaya	-	-	1.1	1.7	-	MII
Tomato	**-**	**-**	**-**	**-**	**-**	**-**

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease,
.* major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase).

Bangladesh

Drought-prone Villages

Rice is the main crop in Boikunthapur village. Almost 76% of the area is under rice cultivation. It usually follows double-cropping system for boro and aman rice. Rice, maize, and other vegetables are the major crops. Boro rice cultivation is done by ground-water irrigation, mostly using shallow water-pumps, whereas aman cultivation is rainfed. Farmers used to produce Aus paddy but now shifted to Boro rice cultivation. Wheat was a popular crop in the village but is slowly being replaced by maize in recent years as it is a longer duration crop. Maize can be produced with less water supply. Demand for maize is increasing day-by-day.

In Khudiakhali, the lowlands are generally used for rice cultivation, whereas betel leaf is increasingly being grown in both low- and semi-high lands (about 40% of the village lands are currently under betel leaf cultivation). Even within rice production, the share of Boro paddy has been increasing and the traditional Aus cultivation has been reduced over the years. Tobacco is also getting popular in recent years. Most of the rice-cultivated lands follow a double-cropping system (Boro and Aman). Along with these, jute, maize, and vegetables are also grown in the village. Aus rice, mustard, and pulses like masur (Red lentil), and chola (chickpea) are now rarely grown due to low-productivity and less- profitability. In Khudiakhali, overall irrigated lands have increased from mere 11.07% in 1988 to 99.15% in 2004.

Flood-prone Village

Major agricultural activities at Nishaiganj village comprise fisheries and traditional agricultural activities like growing rice, jute, and vegetables. Among the most popular crops, rice is the dominant one grown in the lowlands. Farmers follow a double cropping system. Both Boro and Aman rice are grown. Boro rice is dependent on irrigation, mostly groundwater. Jute used to be popular but currently not commonly grown because of expansion of other crops and fisheries and lack of water bodies for retting. Vegetables like brinjal, pumpkin, tomato, and papaya are also grown. Cereal production is decreasing gradually. During the last fifteen years, fisheries have occupied lands suitable for rice cultivation. Jute and cereals have decreased significantly in the village. These changes have been highly facilitated by availability of inputs and easy marketing facilities along with exchange of knowledge about fish cultivation.

In Paschim Bahadurpur village, rice is a dominant crop. In addition, farmers produce masur (Red lentil), khesari (Lathyrus), pea, kalijira(Black cumin), dhania (Coridander), and vegetables mainly for self-consumption. Aman and Boro rice comprises 90% of total cereal production in the village. Earlier jute was a prominent crop but from late 1990s, farmers started to shift to rice and other crops due to lower profitability of jute. About 40% of farmers in the village are tenants. Pump owners for irrigation generally get one-third of the total produce while the remaining two thirds are distributed proportionately among owners and tenants. In such case of share-cultivation system, input costs are generally borne by all the parties.

Thailand

Average size of the landholdings varied from about 2 ha in village Kud Sawai (KS) to about 4.8 ha in Tha Taeng (TT) and 4 ha in Don Plai (DP). Villages DP and KS have more lowland and villages Nong Muang (NM) and TT have more of upland. In the villages DP and KS the area under rice is more that in villages of NM and TT. NM and TT being upland villages, more area is under cassava. In the upland village NM during the seventies 60% of the area was under rice. But in recent times rice area reduced from 60 to 31% and the cassava area increased from 30 to 49%. The rest of the area is diversified and is grown to horticultural crops. In village DP, medium and large-scale farmers diversified into cassava, and now almost all the medium and large-scale farmers grow this crop. It is the large-scale and medium farmers who are able to take advantage of the energy demand and the associated market advantage of the cassava villages of Thailand. It is interesting to note that roselle is a crop that yields fiber. It is a water intensive crop; more particularly, water is needed for extraction of fiber. In the seventies most of the villages, particularly KS, NM and TT, were growing this crop but during the nineties and more recently, the crop is not cultivated any more. (Table 14c).

Table 14c. Cropping Pattern in the study villages of Thailand

villages	1975-76			2007-08		
	Average size of landholding (ha)	**Proportion area under food grain production (%)**	**Proportion of rice: cassava: other crops growing area (%)**	**Average size of landholding (ha)**	**Proportion area under food grain production (%)**	**Proportion of rice: cassava: other crops growing area (%)**
Don Plai	NA*	NA	25 : 75: 00	4.0	65	51 : 28: 21
Kudsawai	NA	NA	70 : 30: 00	2.0	70	60 : 40: 00
Nong Muang	NA	NA	60 : 30: 10	3.1	28	31 : 49: 20
Tha Taeng	NA	NA	20 : 43: 27	4.8	20	23 : 66: 11

* Not Available

Upland Villages

Village Nong Muang, Kenaf /Roselle used to be a popular crop in the seventies and nineties but in recent times most of the farmers gave it up. Particularly the small and medium farmers stopped growing it. This is mainly because Kenaf processing is water intensive and farmers started realizing the importance of water. Similarly in TT village Kenaf growing stopped in the recent decades. Growing cassava increased with time by all categories of the farmers in the village. Almost all the small, medium and large farmers grow cassava in past of their lands in the recent times.

Viet Nam

In the Phuoc Nam commune, hybrid maize area reduced with time, and was more recently replaced by inbred local maize varieties. Hybrid maize went down to 5%in the area, and inbred maize area increased from 3% to 15%. Rice area decreased from 53% to about 19% due to lack of sufficient water and uncertain dry spells. Farmers have switched over to neem tree cultivation in a limited way. In the Phuoc Dinh commune, rice area is very small and farmers switched over to aquaculture twenty years ago. Tobacco and legumes occupy a significant area, and about 27% of the area is under tobacco and 13% is under legumes. Increase in aquaculture in recent years is seen as an adaptive measure as some of the areas were affected by salt intrusion. Farmers started aquaculture in such areas (Table 14d).

Table 14d. Cropping pattern and farmer’s perception in the study villages of Viet Nam

Commune	**Phuoc Nam (%)**			**Phouc Dinh (%)**			**Phuoc Nam**	**Phouc Dinh**
Crop	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**Farmer's Perception**	
Paddy	53.6	17.4	19.4	0.7	0.7	0.7	MD	NC
Hybrid maize	7.8	8.4	5.2	1	1	0.7	MID	MID
Bred-maize	3.2	9	14.9	6.5	4	3	MII	MID
Red-onion	3.7	7.4	11.7	3.5	1.9	2	MII	MID
Legume	11	3.2	2.3	13.7	14.3	13.1	MID	MID
Vegetable	6.7	16.9	10.3	3.9	2.9	2.2	MII	MID
Sesame	2.8	5.3	2.5	4.3	3.1	2.8	MID	MID
Sorghum	1.3	2.1	3.3	1.5	2.3	1.3	MII	MID
Grapes	8.1	15.2	15.7	3.1	2.1	2.3	MII	MID
Tobacco	0.2	0	0	20.7	27.6	27.5	MID	MII
Watermelon	1.7	2.7	1.5	3.6	2.5	2.5	MID	MID
Fruit	0	0	0	2.1	1.4	1.3	NC	MID
Neem	0	12.5	13.1	0	0.8	1.1	MII	MII
Jatropha	0	0	0	0	1.9	1.9	NC	MII
Xi-ro	0	0	0	5.6	7.2	7.5	NC	MII
Aquaculture	0	0	0	29.9	26.4	30.2	NC	MII

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception cropping pattern change; * Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase).

China

In Lucheba village there used to be two crops a year in earlier decades. It used to be rice-oilseeds or corn-oilseeds cropping system. It gradually changed to three crops a year with the addition of vegetables. The latest trends show that the cropping intensity further increased tremendously. By 2009 about 72% of the area shifted to vegetables and the current year saw disappearance of all the other crops. At present, farmers can harvest four crops a year of vegetables. In Dajiang village, farmers still grow rice and maize in the rainy season on 26 and 58% of the land. In about 7% of their land maize+ soybean is grown as mixed crops. This is a good adaptation practice to minimize risk of yield loss due to prolonged dry spells. In the dry season about 32% of the area is sown with winter vegetables and this area used to be sown with oilseeds or kept fallow. Farmers are increasing the cropping intensity or switching to more profitable/cash crops such as vegetables (Table 14e).

Table 14e. Cropping Pattern and farmer's perception in study villages of China - 2009

	Lucheba village (central Guizhou)		**Dajiang Village (southern Guizhou)**	
Crops	**Area (%)**	**Magnitude of change***	**Area (%)**	**Magnitude of change***
Rainy season				
Paddy	3.6	MD	26.2	NC
Maize	32.0	MD	58.2	MD
Sweet Potato	2.0	MD	0.7	NC
Groundnut	1.4	MII	0.7	MII
Maize +soybean	12.0	MD	7.2	MD
Maize + oilseed	20.0	MD	-	-
Winter season				
Wheat	4.0	MD	0.7	MID
Oil seed	20.0	MD	0.7	MID
Potato	6.8	MD	-	-
Green manure	12.0	MD	-	-
Feed crops	4.8	MI	0.1	MII
Tea	12.0	MD	-	--
Vegetables (total)	72.0	MI	32.8	MI
Tomato	13.6	MI	-	-
Chillie	40.0	MI	18.2	MI
Chinese Cabbage	16.0	MI	-	-
Cucumber	2.0	MI	-	-
Cowpea	1.4	MI	-	-
Kidney Bean	-	-	3.6	MI
Soybean (vegetable)	-	-	7.3	MI
Fresh Maize	-	-	3.6	MI

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on cropping pattern change. * Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase).

These village studies have provided insights to the present situation with regard to cropping patterns and how they have changed over time. The changes are associated with several factors, including the changes in rainfall, availability of markets, prices as well as new technologies and support systems. These changes include (i) complete change of crops, i.e., seasonal as well as in some instances, perennial or semi-perennial crops, abandoning traditionally cultivated crops, (ii) adopting mixed cropping systems (iii) increasing cropping intensity, (iv) growing shorter duration crops, (v) adopting new enterprises such as aquaculture, (vi) using devices to increase water availability such as water pumps. Depending on the context, agronomic, environmental, institutional and governance, farmers adopt a range of practices to adapt to situations for sustainable living. Some of these changes can be attributed to climate changes while others are due to other contextual factors and their interactions. Unraveling these relationships requires analysis to identify the factors attributable to the adaptation strategies such as changes in cropping patterns.

Livestock developments in the study location

Farming systems (and adjusting to them) provide opportunities for farmers to adapt to climate related changes that impact their livelihoods. Although not pervasive in all the study villages in Asia, many benefits are expected from livestock keeping. Livestock raising and management is crucial for an efficient utilization of farm outputs. Mixed crop-livestock systems are increasingly seen as a sustainable and environment friendly adaptation strategy that conserves the resources efficiently, maximizes profits and is a promising option for the farmers, especially the resource poor farmers (Thornton, et al. 2011). The following section deals with the livestock situation in the study villages.

India

In all the study villages, the population of local indigenous cows decreased with time. These cattle are low producers of milk. Farmers perceived a decrease in the population of the bullocks, which might be due to increased mechanization of farm activities.

Aurepalle

There was no change in the population of cross-bred cows and at present the village has about 420 exotic cows. The population of buffaloes decreased probably due to pressure and poor management of the grazing lands. At present there are 872 buffaloes in the village. The livestock in the village is dependent on grazing on the common grazing lands. Farmers perceive 30% of the feed requirement of the local cows and buffaloes is met through grazing. The rest of their diet comes from stall feeding. Farmers also perceived a decrease in the population of goats and sheep over time, indicating a possible degradation of common grazing lands over the period, as the animals are completely dependent on grazing.

Dokur

The population of buffaloes saw a major increase and at present there are about 145 buffaloes in the village. In 2008, decrease in the population of goats and sheep with time was observed in the village.

Kanzara

These cows were dependent on grazing for 75% of their feed requirement. There are only 11 exotic cows in the village and very few buffaloes are present in the village now.

Kinkheda

Farmers perceived a decrease in the population of the bullocks, which might be due to increased farm mechanization . There are only 6 exotic cows in the village and only 20 buffaloes. Farmers perceive that about 70% of the feed requirement of local cows is dependent on grazing. About 60% (for bullocks) and 50% (for buffalos) feed requirement is met by grazing. This indicates that relatively more stall feeding and supplementation with concentrates etc., is done for buffaloes and bullocks as compared to local cows. However, there is a scope for improving the milk yield by improving feed management. Goats are reared entirely by grazing in the common lands.

Shirapur

The population of cross-bred cows is more in this village and there are about 219 cross-bred cows here. Buffaloes are also present in large numbers and at present there are 189 buffaloes in the village. The population of buffaloes is increasing due to the improved markets for milk in the village. Farmers also perceived a decrease in the population of goats over the years.

Kalman

There are about 190 improved cross-bred cows in the village. This is a good number among the study villages and the farmers in the village are trying to improve milk yield and dairy incomes. Buffaloes are present in good numbers in the village and at present there are 155 buffaloes here. The population of buffaloes decreased probably due to grazing pressure and poor management of the grazing lands. Farmers also perceived a decrease in the population of goats and an increase in the sheep numbers with time. Farmers felt that 75% of the feed of buffaloes and 70% of feed for local cows comes from grazing. Goats are 100% dependent on grazing. About 90% of the feed requirement of sheep comes from grazing.

Dairy farming is a better option for efficient resource utilization and improved income (Shirapur village, Maharashtra, India)

Sri Lanka

In Galahitiyagama village the present survey shows that there are about 185 cows and 140 buffaloes. There are also about 80 goats and 210 poultry in this village. Farmers perceived that there was a major increase in the population of livestock from the 1970s to 2008. Of the studied villages, this is the only village where the livestock population increased with time. The other villages showed a decrease in the population of livestock. In Mangalapura there are about 180 cows and no buffaloes. There are about 37 pigs and poultry numbers crossed 1000. Farmers perceived that there was a major decrease in all these livestock numbers with time, except for the goat population, which saw an increase. Farmers perceived that there was no goat rearing in the past in the village. The scenario is most striking in Bata-Atha village. During the seventies there were about 2500 cows and 1750 buffaloes in the village. Farmers perceived a drastic reduction in their numbers, and by 2008 there were only 30 cows and 58 buffaloes in the village.

Although farmers were aware about the services such as vaccination, medicines and artificial insemination, the actual service they received was marginal, which could be one of the reasons for the neglect of livestock. Most of the farmers who carried out livestock activities in a limited scale have not used the inputs brought from markets. Whatever was available was fed to the livestock and the livestock was dependent on common grazing sources. Perhaps the absence of milk societies and collection centers and the low demand for milk products may be a reason for arriving at such a situation. Poultry based activities are also on a very small scale, only for household needs of eggs. Most of the dairy output was for household consumption (Table 15a).

Table 15a. Farmers' perception on dynamics of livestock in the study villages of Sri Lanka

	Galahitiyagama		**Mangalapura**		**Bata-Atha**	
Livestock population (no)	**2008**	**FP***	**2008**	**Perception**	**2008**	**FP***
Cattle	185	MI	181	MD	30	MD
Buffaloes	140	MI	0	MD	58	MD
Goat	80	MI	76	MII	-	-
Poultry	210	MI	1040	MD	-	-
Pig	-	-	37	MD	-	-

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on trends in livestock population.* major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase).

Thailand

Livestock is not a major activity in the study villages in Thailand. Most farmers raise livestock for their household consumption. Occasionally they use them for a little supplementary income. Chicken rearing is the most popular activity among the villages, especially in Don Plai and NM. Cattle are the second most favored except in KS. There are no buffaloes in the study villages. A few swine can be seen in NM and TT villages (Table 15b).

Table 15b. Estimated numbers of farm livestock in study villages of Thailand as perceived by resident farmers

Livestock population(nos.)	Don Plai	Kud Sawai	Nong Muang	Tha Taeng
Cattle	100	13	300	300
Buffaloes	35	-	-	-
Poultry	2,600	300	1,000	500
Swine	-	-	20	20

Viet Nam

Buffaloes, cattle, goat, sheep, pigs and poultry are commonly found farm animals in Vu Bon and Nho Lam villages. Cattle are the main livestock in Vu Bon village, and sheep in Nho Lam village. There were about 866 cows in Vu Bon and 500 cows in Nho Lam villages. Farmers perceived that there was an increase in all types of livestock in Vu Bon village. The perception in Nho Lam is that except for small ruminants all the other animals increased in number in recent times. Farmers perceived that due to shortage of fodder meat yields of goat and sheep were marginal and they were not profitable. As a result, their numbers decreased. Additionally, during 2007-08 there was a fall in the prices of sheep and goat in the local markets (Table 15c).

Table 15c. Estimated numbers and perceived trend of farm livestock in study villages of Viet Nam

Livestock population (nos.)	Vu Bon Village, Phouc Nam Commune		Nho Lam Village, Dinh Commune	
	Population	FP*	Population	FP*
Buffalo	12	MID	0	-
Cow	866	MI	500	MII
Goat	155	MII	1500	MD
Sheep	650	MII	3000	MD
Pig	352	MID	30	MII
Poultry (head)	1760	MI	5000	MID

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on trends in livestock population.* major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase).

China

Unlike in the case of Thailand, cattle and buffaloes are reared in Lucheba and Dajiang villages for commercial purposes. Buffaloes are used for farm operations like tillage etc. Farmers perceived that the buffalo numbers decreased in recent times. This was mainly due to increased mechanization with the introduction of mini tractors and tillers. Farmers perceived that the number of goats increased in the mountainous areas of Dajiang village for the purpose of increasing farm incomes (Table 15d).

Table 15d. Estimated numbers of farm livestock in study villages of China as perceived by resident farmers

Livestock population(no)	Lucheba Village (central Guizhou)	Dajiang village (southern Guizhou)
Cattle	60	60
Buffalo	20	50
Goats	0	2000
Pigs	650	830
Poultry	3000	5000

While livestock continue to play an important role in the socio-economic lives of the farmers, the purposes for which they are reared vary significantly. The rearing of large ruminants is dependent on availability of fodder mostly obtained from common grazing land in the localities. Livestock is understood to supplement household income. Mechanization, depleting common grazing land and market prices contribute to the continuity of livestock as an important component of the farm enterprise. In many of the study villages poultry and cattle rearing is done for household consumption. There is evidence that there is a decline in buffalo rearing mainly due to shrinking grazing land and non-availability of fodder as well as increased farm mechanization. Clearly, attributing changes in livestock composition in the villages will require analysis of primary data to test correlations.

Historical evolution and current status of input markets

Farmers' adaptive behavior is closely related to the types of farming practices they adopt. Cropping patterns, livestock rearing and diversifying income sources are general strategies. Changing the crops they grow, livestock they rear will require a complete change in the types of inputs, they require and a change in the markets in order to sell their products. A well-functioning and fair market operating at close proximity to the villages will enable them to optimize enterprise restructure provided other requirements are met.

Availability of inputs and the distance the farmer has to travel to access these inputs or in other words, the distance of the input markets as well as the access and availability of output markets are crucial for the farmers to choose the crops that he grows. The following is an analysis of the situation in the study villages, based primarily on farmers perceptions.

India

Farmers of Aurepalle village perceived that seeds have been available in the village from 1970 onwards. However, fertilizer, agrochemical and fodder markets were 10 kms away till 1990, but during the last decade all these are available in the village, indicating a major improvement over time. In Dokur, seeds have been available in the village from 1970 onwards. Fertilizer, agrochemical and fodder markets are 7 kms away at Devarkadra, the mandal headquarters. In Kanzara village, seeds have not been available in the village from 1970 onwards and the nearest markets are 10 kms away. Similarly fodder markets are 10 kms away from the village. Fertilizers and agrochemicals were available at around 10 kms from the village till the nineties. During the last decade there was a major improvement and these commodities are now available in the village. In Kinkheda the markets for seeds, fertilizers, agrochemicals and livestock feed are not available in the village. The situation did not change over the years. Seed, fertilizer, agrochemical and fodder markets were 12 kms away from the village. In Shirapur village, farmers perceived that important inputs like seeds, fertilizers and agrochemicals are not available in the village. For these inputs farmers used to go to markets that are 12 kms away during seventies and nineties. At present new markets have emerged 3 kms away from the village. In Kalman village, inputs such as seeds, fertilizers, agrochemicals and cattle feed were available in markets that were 15 kms away from the village. There was a major improvement over time and now they are available in the village (Table 16a).

Table 16a. Dynamics of input markets in the study villages of India

	Access in the village (Yes/No)			If No, Distance from the village (Km)		
Aurepalle	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Seed	Yes	Yes	Yes	0	0	0
Fertilizers	No	No	Yes	10	10	0
Agrochemicals	No	No	Yes	10	10	0
Cattle feed	No	No	Yes	10	10	0
Shirapur						
Seed	No	No	No	12	12	3
Fertilizers	No	No	No	12	12	3
Agrochemicals	No	No	No	12	12	3
Cattle feed	Yes	Yes	Yes	0	0	0
Kanzara						
Seed	No	No	No	10	10	10
Fertilizers	No	No	Yes	10	10	0
Agrochemicals	No	No	Yes	10	10	0
Cattle feed	No	No	No	10	10	10
Dokur						
Seed	Yes	Yes	No	0	0	7
Fertilizers	No	No	No	7	7	7
Agrochemicals	No	No	No	7	7	7
Cattle feed	No	No	No	7	7	7
Kinkheda						
Seed	No	No	No	12	12	12
Fertilizers	No	No	No	12	12	12
Agrochemicals	No	No	No	12	12	12
Cattle feed	No	No	No	12	12	12
Kalman						
Seed	No	No	Yes	15	15	0
Fertilizers	No	No	Yes	15	15	0
Agrochemicals	No	No	Yes	15	15	0
Cattle feed	No	No	Yes	15	15	0

Sri Lanka

Most villages in the vulnerable regions in Sri Lanka are not in the developmental pathway as far as agriculture is concerned. Infrastructure is the key to development of any sector including agriculture. Most of the villages are neglected and even access to seed or seed shops are available in a radius of 10 to 30 kms from the village, except in Mahagalawewa, where the seeds are available within the village. Generally, in all four villagers, the farmers have to travel outside the village to obtain farming inputs. The situation is the same for inputs like fertilizers, agro-chemicals or cattle feed. Farmers have to face considerable hardships to have access to these inputs, and this is probably an impediment to effective adaptation of improved management practices in agriculture (Table 16b).

Table 16b. Accessibility of input markets in the study villages in Sri Lanka, distances in km estimated by villagers

Distance(Km)	**Galahitiyagama**			**Mangalapura**			**Mahagalwewa**			**Bata-Atha**		
Input	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Seed	V	0-20	0-20	10-30	10-30	10-30	V	V	V	0-10	0-10	0-10
Fertilizer	0-20	0-20	0-20	10-30	10-30	10-30	0-15	0-15	0-15	0-10	0-10	0-10
Agro Chemicals	0-20	0-20	A	10-30	10-30	10-30	0-15	0-15	0-15	0-10	0-10	0-10
Cattle feed	0-20	-	A	10-30	10-30	10-30	0-15	0-15	0-15	0-10	0-10	0-10
Others(Machineries)	-	-	-	10-30	V	V	-	-	-	-	-	-

Note: V = In the village

Thailand

There were no shops in DP village to sell inputs in the seventies. More recently, 3 shops came up in the village that sells all the inputs like seed, fertilizers and agro-chemicals. For cattle feed, the farmers still have to go up to 7 kms to buy it. KS village has a shop selling fertilizers that came up recently, but farmers have to go and buy seed, agrochemicals and cattle feed from some distance away. Farmers in NM village have to go and buy inputs in the nearby markets that are 9 to 21 kms away. In another upland village, TT farmers had to travel 15 kms to get seed, fertilizers and other inputs during the seventies to nineties. Recently the village saw the coming up of shops that sell seed and fertilizers. However, the situation is still difficult for agro-chemicals or cattle feed (Table 16c).

Table 16c. Trends in accessibility of input markets in the study villages of Thailand

Distance(km)	Don Plai			Kud Sawai			Non Muang			Tha Taeng		
Items	**Distance From the Village (km)**			**Distance from the village(km)**			**Distance from the village((km)**			**Distance from the village(km)**		
	1970	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Seed	7	7	0	-	-	28	B	B	21	15	15	0
Fertilizers	7	7	0	-	-	6	NU	NU	9-21	15	15	0
Agro Chemicals	7	7	0	-	2	2	NU	NU	9-21	15	15	15
Cattle feed	7	7	7	-	-	5	NU	NU	2	15	15	15

Note: NU=Not used, B-Borrowed.

Development of output markets at micro level

Availability and accessibility of markets for selling their produce is an important factor in achieving maximum returns. It is the availability of the markets that largely influences the farmer's decisions in choosing the specific crop that they grows. The following section deals with the farmer's perception of the availability and types of transactions that the farmers make regarding their agricultural outputs in the study villages.

India

Andhra Pradesh

Farmers in Aurepalle and Dokur villages stated that food grains and pulses and oil seeds were sold in the villages during the seventies but with time and farmers they also started selling in the markets available 10 kms away (Table 17a). Food grains and pulses were sold mainly to fellow farmers, whereas oilseeds were sold to local agents. Vegetables were sold in the village till 1990, but during the last decade they also started selling in the nearby market 10 kms away. They sold mostly to fellow farmers and local retailers. Milk is sold in the village to retailers. Live animals are sold in the village and nearby market 7-10 kms away in both the study villages. They were mostly sold to fellow farmers during seventies and in recent times local agents also started buying them. Poultry and eggs and forest produce are sold in the village mostly to local farmers and retailers. In general, markets do exist both in the village and at a distance of 10 kms away from the village.

Maharashtra

In Kanzara, Kinkheda, Shirapur and Kalman, farmers perceived that food grains and pulses and oilseeds were sold in the village and nearby markets 10-15 kms away from seventies till now. Food grains and pulses were sold mainly to fellow farmers, whereas oilseeds were sold to local agents. Other agricultural commodities are sold in the village and nearby markets, which are 10 -12 kms away (Table 17a). They sold these commodities to local agents and retailers. In earlier periods they sold the milk at a distance of 10-12 kms from the village, but since the nineties they sell the milk in the village to retailers. Live animals are sold in the village and in a nearby market 10-12 kms away. They were mostly sold to fellow farmers during the seventies, and in recent times local agents also started buying the produce. Poultry, eggs and non-timber forest produce are sold in the village mostly to local farmers and retailers, and recently local agents have also started buying the forest produce. In general, markets are located 10-12 kms away from the village.

A typical village market in Shirapur village, Maharashtra, India

Local agents purchase oilseeds from the farmers. Vegetables are sold in the village as well as in the nearby markets at a distance of 12 kms. Vegetables are sold to fellow farmers and retailers. Milk has been sold in the village to retailers since the seventies. Live animals are sold in the village and at nearby markets that are 12 kms away. They were mostly sold to fellow farmers during the seventies, and since the nineties, local agents also started buying them. Poultry and eggs and non-timber forest produce are sold in the village mostly to local farmers and retailers. In general, markets did exist in the village but formal markets were available at a distance of 12 kms from the village.

Table 17a. Periodical changes in accessibility of output markets in the study villages in India (Kms from village)

	Kanzara			Shirapur			Aurepalle		
	Ave. dist. to sale point(Km)			**Ave. dist. to sale point(Km)**			**Ave. dist. to sale point(Km)**		
	1970	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Food grains & Pulses	10	10	10	12	12	12	0	10	10
Oil seeds	10	10	10	12	12	12	10	0	0
Vegetables	0	10	10	12	12	30	0	0	10
Other agricultural commodities	10	10	10	12	12	12	10	10	10
Milk	10	0	0	0	0	0	0	0	0
Live animals	10	10	10	1	1	1	0	10	10
Poultry & eggs	-	0	0	0	0	0	0	0	0
Forest products				N.A.	N.A.	N.A.	0	0	0
	Kalman			**Kinkheda**			**Dokur**		
	Ave. dist. to sale point(Km)			**Ave. dist. to sale point(Km)**			**Ave. dist. to sale point(Km)**		
	1970	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Food grains & Pulses	15	15	0/15	12	12	12	0	0	7
Oil seeds	15	15	15	12	12	12	0	0	7
Vegetables	35	35	35	12	12	12			
Other agricultural commodities	15	15	15	12	12	12	NA	NA	NA
Milk	-	-	-	12	12	12	0	0	7
Live animals	35	15	15	12	12	12	7	7	7
Poultry & eggs	0	0	0	1	1	1	-	-	-

Sri Lanka

In Galahitiyagama, during the seventies, farmers travelled up to 20 kms to sell their outputs. During the nineties oilseeds and vegetables were sold in the village itself. In recent times almost all the outputs of the farmers are being sold in the village. This is mainly due to the arrival of the wholesalers in the village and agents also are active in buying the outputs from the farmers. In Mangalapura village during the seventies most of the outputs were sold 30 kms away in Puttalam town by the farmers, and in recent times wholesalers have been appearing in the village to buy the outputs from the farmers. In Mahagalawewa the situation has not changed much since the seventies. Most of the outputs of the farmers are being sold at a distance of 10 kms from the village even now. except for poultry and dairy products. The situation is in Bata-Atha village. Dairy and poultry products were sold by the farmers in the village, but most of the other outputs like cereals, pulses, oilseeds and other agricultural commodities are sold at a distance of 10 kms from the village. In general, in most of the villages the farmers have to travel away from the village to a distance of 10 to 30 km to sell their produce. Infrastructure for output markets are not well developed even in the recent times. Well-developed infrastructure will help the farmers to plan their strategies of crop production in advance, as it reduces the risk and uncertainty of marketing (Table 17b).

Table 17b. Trends in accessibility of output markets in study villages of Sri Lanka, proximity in km.

Average distance (Km)	**Galahitiyagama**			**Mahagalwewa**			**Bata-Atha**		
Output	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Food grains and pulses	0-20	0-20	A	0-10	0-10	0-10	0-10	0-10	0-10
Oil seeds	0-20	A	A	0-10	0-10	0-10	0-10	0-10	0-10
Vegetables	0-20	A	A	0-10	0-10	0-10	A	A	0-10
Maize	0-20	0-20	A	-	-	-	-	-	-
Other agricultural commodities	0-20	0-20	A	0-10	0-10	0-10	0-10	0-10	0-10
Milk	A	A	A	A	A	A	A	A	A
Live animals	A	A	A	A	0-10	A	A	A	-
Poultry and eggs	A	A	-	-	A	-	A	A	A
Cotton	-	-	-	A	A	A	-	-	-
Gingelly	-	-	-	0-10	0-10	0-10	0-10	0-10	0-10

Note: A= In the Village

Thailand

Rice is sold in the village itself to the mills in the recent times, cassava is sold at a distance of 25 kms in Don Plai village and sugarcane is sold at a distance of 40 kms to the sugar factories. In Kud Sawai rice and cassava are sold at a distance of 3 to 28 kms from the village by the farmers to mills and wholesalers. In Nong Muang, rice is sold at a distance of 2 to 21 kms from the village and cassava were sold at a distance of 21 kms from the village during the seventies and nineties, and in recent times cassava is being sold at a distance of 7 kms where mills have come up. In Tha Taeng, rice is being sold at a distance of 15 kms and cassava is being sold at distance of 20 kms from the village. Sugarcane is being sold at a distance of 60 kms from the village to a sugar factory. Most of the other products are being sold at a distance of 15 kms. Kud sawai and Tha Taeng villages are mostly rainfed and upland in nature and markets are also not developed well around these villages, so farmers often have to travel 15 to 20 kms to sell their products (Table 17c).

The means to dispose of produce at a reasonable price at close proximity to the farm is a great advantage and helps to minimize transport and storage costs for farmers. With income enhancement it is probable that the adaptive capacity will improve. The availability of markets at close proximity and the relationship between incomes and ability to adapt to climate change is for the most part a complex causal relationship. The qualitative analysis clearly indicates the benefits of markets being at the "door step" as opposed to being far away. The availability of local markets greatly enhances the income earning capacities, thereby helping to mitigate climate shocks.

Table 17c. Accessibility of output markets in the study villages of Thailand.

	Don Plai			Kud Sawai			Nong Muang			Tha Taeng		
Output market	**Distance from the village (Km)**			**Distance from the village(Km)**			**Distance from the village(Km)**			**Distance from the village(Km)**		
Items	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Rice	-	-	-	3-28	3-28	3-28	2-21	2-21	2-21	15	15	15
Cassava	25	12	25	5-27	5-27	5-27	21	21	7	20	20	20
Chilli	-	-	-	-	-	-	-	-	-	15	15	15
Sugarcane	-	-	40	-	-	-	-	-	100	60	60	60
Maize	-	-	-	-	-	-	-	-	-	15	15	15
Cow (live animal)	-	-	-	-	-	-	-	-	7	-	-	-
Chicken	-	-	-	-	-	-	-	-	7	15	15	15
Wild vegetables and mushrooms	-	-	-	-	-	-	-	-	21	15	15	15
Vegetables (Mint, Basil, Brassica)	-	-	-	-	-	-	-	-	-	-	-	15

Dynamics of occupational portfolios in the villages

Accessing markets for different agricultural inputs and services as well as supplying different produce indicates a well differentiated village economy and diverse social relationships and networks that are likely to withstand climate shocks and changes. Such a situation also implies a higher level of development of the village economy, and reflects the presence of related institutions and various state agencies as well as regulatory bodies in the infrastructure. Farmers with multiple income sources are an indication of higher socio-economic status and also have the ability to deal with risks. The village level analysis examines this situation to draw appropriate inferences.

India

Information about the occupation will give insights to farmer's income sources. The share of agriculture in the occupational basket varied from just 21% in Dokur to 27% in Aurepalle village of Andhra Pradesh in 2007. Farm work has a share of 2% in Aurepalle to 18% in Dokur. The level of migration is as high as 30% in Dokur. The share of livestock and sheep rearing varied from 2% in Aurepalle to 5% in Dokur. Non-farm work varied from 6% in Dokur to 16% in Aurepalle. In general the occupations are not dominated by agriculture-based activities anymore. There is an element of diversification that is visible (Table 18a).

18a. Trends in occupational differentiation in the study villages of India*

	Aurepalle (%)		Dokur (%)	
	2001	2007	2001	2007
Agriculture	36.0	27.0	18.0	21.0
Farm work	6.0	2.0	11.0	18.0
Business	5.0	5.0	2.0	2.0
Caste occupation	11.0	2.0	3.0	5.0
Regular job	5.0	7.0	4.0	3.0
Migration	11.0	13.0	37.0	30.0
Livestock and sheep rearing	5.0	2.0	5.0	5.0
Non-farm work	6.0	16.0	6.0	6.0
Others	15.0	26.0	14.0	10.0

In the four villages chosen for the study there are several changes in the types of agricultural activities undertaken within the reference periods of 1970 - 2008 (Table 18b).

Fine cereal based farming ranged from 8.6% to as low as 1% among the villages of Akola district. Coarse cereal based farming ranged from 5.6% to 1% in 2008 in this district. Coarse cereals have decreased in this district from their levels in the seventies.

Pulse cultivation ranged from 10% to 6.2%. Pulse cultivation in this district was almost at the same level during the last four decades. Oilseed cultivation ranged from 8%to zero among the villages of Akola district. Cotton cultivation ranged from 11 to 6%. Cotton cultivation decreased drastically from their levels of the seventies. Dairy farming as an occupation varied up to 2.3%. Goat and sheep rearing varied from a minimal level to 4.7%. About 14 to 18% of the occupation was through agricultural labor in this district. There was a reduction of this fraction in the occupational basket from the seventies level. About 3.9 to 6.7% comes from business. Contribution of service varied from 1% to as high as 11% in Akola district. Villages in Solapur district had very little fine cereal cultivation. Coarse cereal cultivation varied from 11 to 12.7%. The cultivation of coarse cereals decreased from their levels in the seventies. Pulse cultivation varied from 2 to 10.9%. Sugarcane cultivation is prominent in one of the villages of this district. Contribution of dairy farming varied from 4.7 to 5.9% in this district. A growth in the dairy sector was observed in the last four decades. Contribution of agricultural labor varied from 6.9 to 17.8%. Contribution of business varied from 12.4 to 7.4%. The contribution of business has increased over the years in this district. The share of salaried service varied from 8.4 to 23%. This share has increased significantly during the last four decades (Table 18b).

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Part-time business to cover the risks associated with agriculture
(Petty shops in Aurepalle village in Andhra Pradesh, India)

Table 18b. Trends in the distribution of population in agriculture enterprises in the study villages of India

	Persons engaged in different agriculture enterprises (%)											
	Shirapur			Kanzara			Kinkheda			Kalman		
Farm	1970	1990	2008	1970	1990	2008	1970	1990	2008	1970	1990	2008
Fine cereal based farming	2.4	1.8	1.9	1.5	5.8	8.6	0.9	2.8	1.0	3.7	3.2	1.2
Coarse cereal based farming	33.0	25.1	11.0	7.3	6.8	1.0	12.2	12.8	5.6	15.2	14.4	12.7
Vegetables	1.6	1.8	1.3	0.8	2.6	0.0	0.3	0.3	0.3	0.0	0.0	0.0
Pulses cultivation	7.0	3.6	2.0	5.7	11.2	6.2	10.4	10.2	10.2	10.8	11.0	10.9
Oilseeds cultivation	3.4	1.4	0.2	4.4	1.3	8.1	3.8	0.5	0.0	0.0	1.7	1.2
Cotton cultivation	0.0	0.4	0.0	19.5	20.3	6.1	27.3	28.3	11.5	0.0	0.0	0.0
Sugarcane	0.0	0.0	11.4	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dairy	2.9	5.2	5.9	0.3	0.5	0.3	2.3	1.8	2.3	1.8	2.6	4.7
Goat/Sheep farming	5.7	5.6	4.4	0.9	1.9	1.5	4.9	4.7	4.7	0.3	0.3	0.5
Agricultural labor	17.7	18.9	17.8	44.5	30.5	18.2	28.8	22.6	14.0	24.4	12.7	6.9
Others (Farm)	3.7	3.2	2.2	0.0	0.0	8.0	0.0	0.8	28.5	0.0	0.0	0.0
Business	5.8	8.8	12.4	0.0	4.6	3.9	2.4	3.2	6.7	11.5	9.5	7.4
Service	6.1	15.2	23.2	0.0	1.2	1.0	6.7	13.2	11.7	13.1	21.0	8.4
Out migration	0.0	0.0	0.0	0.6	0.0	0.7	0.0	0.0	0.3	2.8	0.0	0.0
Others (Non-farm)	10.7	9.0	6.4	14.6	12.8	36.5	0.0	0.0	3.5	16.4	23.6	45.4

Sri Lanka

Fine and coarse cereals find a prominent place in all the villages, except in Mangalapura where coarse cereals are not popular with the farmers. Vegetable and pulse cultivation was important to the farmers in all the villages as more than 50% responded across the villages. (Table 18c) Oilseed cultivation found favor with majority of the farmers in Mahagalawewa and Bata-Atha villages. During the seventies about 38% of the farmers were into cotton cultivation, but in recent times they discontinued it. Many of the farmers also diversified into fruit cultivation in Mangalapura and Bata-Atha villages. A sizable number of farmers were into coconut and cashew cultivation in Mangalapura village. Dairy farming is important for Galahitiyagama village as more than 40% of the farmers said that they are into cattle rearing. Goat and poultry farming were marginally present and less than 10% of the farmers follow it in all the villages except Mahagalawewa. These are only for self-consumption. Working as a farm laborer was a part of the occupation portfolio of most of the farmers. More than 30% of the farmers reported this to be true in the seventies in Galahitiyagama and Mangalapura villages. Even in recent times about 25 and 28% of the farmers perceived it. In Bata Atha village more than 45% of the farmers are working as farm labor in recent times.

Table18c. Farmer's perception and trends in distribution of different agricultural enterprises in the study villages of Sri Lanka

	Galahitiyagama				Mangalapura				Mahagalwewa				Bata-Atha			
Primary Occupation	**Percentage of Farmer Involved**			**FP***	**Percentage of Farmer Involved**			**FP***	**Percentage of Farmer Involved**			**FP***	**Percentage of Farmer Involved**			**FP***
Agriculture	**1970**	**1990**	**2008**		**1970**	**1990**	**2008**		**1970**	**1990**	**2008**		**1970**	**1990**	**2008**	
Fine cereal based farming	98	100	98	NC	56	38	14	MD	88	88	82	MID	40	40	30	MID
Coarse cereal based farming	90	95	97	MII	14	2	4	MID	70	70	68	MID	60	58	36	MD
Vegetable cultivation	85	82	65	MD	92	66	52	MD	48	48	40	MID	60	62	50	MID
Pulses cultivation	60	57	47	MID	84	54	30	MD	48	48	40	MID	60	62	50	MID
Oilseed cultivation	20	17	18	MID	16	8	6	MID	58	62	62	MII	82	84	46	MD
Cotton cultivation	-	-	-	-	6	2	0	MID	38	8	0	MD	0	0	0	-
Fruits	7	5	8	MII	60	62	70	MII	14	14	16	MID	30	38	42	MII
Coconut cultivation	-	-	-	-	32	32	40	MII	-	-	-	-	-	-	-	-
Cashew cultivation	-	-	-	-	46	66	84	MI	-	-	-	-	-	-	-	-
Dairy	62	40	40	MD	8	10	10	MII	16	10	4	MID	10	6	0	MID
Goat farming	13	7	7	MID	12	10	6	MID	0	0	2	MII	6	4	0	MID
Poultry	20	7	5	MID	22	20	16	MID	-	-	-	-	14	8	2	MID
Bee keeping	2	0	0	MID	8	2	2	MID	-	-	-	-	2	2	2	NC
Labor	35	33	25	MID	36	36	28	MID	0	2	4	MII	10	36	46	MI
Business	5	7	7	MII	10	16	18	MII	2	6	8	MII	12	24	24	MII
Service	7	15	27	MI	34	38	38	MII	2	2	2	NC	0	4	6	MII
Out migration	3	8	23	MI	2	4	30	MI	4	6	6	MII	4	8	8	MII

Note: NC=No Change, NU=Not used, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on trends in agricultural enterprises.

* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase).

Thailand

More than 90% of the farmers are in agricultural production in most of the villages. In Don Plai about 83% of the farmers are in agricultural production. About 25% of the farmers in Don Plai and 33% in Kud Sawai responded as working as farm labor. In the upland villages of Nong Muang and Tha Taeng 58 and 48% of the farmers work as farm labour at some point. These numbers are more in the uplands as the upland farmers need income diversification due to higher risk and uncertainty in agricultural production.

Very few farmers are partly working as labor in the non-farm sector in all the villages. About 3 to 13% of the farmers are also into part time business in these villages. Farmers perceived that there was a major increase in these activities in the recent times. A fraction of the farmers ranging from 3 to 8% have salaried occupations as a fraction of their occupational basket. They perceived that these numbers increased over time. About 33% of the farmers indicated that they are also into temporary out migration to enhance their incomes in all the villages except in Tha Taeng (Table 18d).

Table 18d. Farmer's perception on changes in occupations in the study villages of Thailand-2008

Primary occupation	**Don Plai**		**Kud Sawai**		**Nong Muang**		**Tha Taeng**	
	%	**FP***	%	**FP***	%	**FP***	%	**FP***
Agriculture	83	MII	95	MII	100	MII	90	MII
Labor								
-Agricultural Labor	25	MD	33	MD	58	MD	48	MD
-General Labor	5	NC	10	MI	3	MID	3	MI
-Factory Labor	-	-	-	NC	0	NC	0	MD
Business	8	MI	13	MI	3	MI	5	MI
Service	5	MI	8	MD	5	MI	3	MI
Others -Out migration	33	MI	33	MD	33	NC	0	MD
- Sale of fuel wood, forest products	5	MD	0	MD	3	MD	15	MII

Note: NC=No Change, NU=Not used, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on occupational.

* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase); Total percentage exceeded 100 because there were multi-occupation households; *percentage of sampled respondents.

China

China is different from the rest of the Asian countries. Here occupational diversification is restricted by governmental policies. Everybody has to register at the location of their stay and it is not be much possible to move geographically for livelihood earnings except few instances of labour migration. This reduces the chances of diversification and building a diversified occupational basket in the villages. However the adaptation strategy of the farmers is to intensify crop production and climate proof their agriculture by increasing the irrigation potential. Lucheba experienced this through the development of a reservoir and piped water supply at the farm gate (Table 18e).

The occupational diversity picture that emerges from the study villages is very clear. In the South Asian villages especially in India and Sri Lanka, agriculture has ceased to be the mainstay of the rural family. Wage labour, state employment, and migration have added more sources of incomes to the households. However, in Thailand and China in the study villages, people mostly remain farmers. However, in China, due to state control, villagers find it difficult to migrate or change their occupations compared to other countries. Diversifying income may be a strategy that has developed over time facilitated by the institutional environment to adapt to the changing context of life to ensure required levels of incomes for survival and meet changing family needs and aspirations.

Table 18e. Occupational trends of study villages of China - 2008

Primary Occupation	Lucheba Village (central Guizhou)	Dajiang Village (southern Guizhou)
Agriculture	68	70
Labor	8	15
Business	18	12
Service	2	1
Caste	-	-
Others	4	2

*values are in %.

Farm Income - tracking diversification at micro level

Occupation diversification is closely related to income diversity. It was observed that in the study villages in India and Sri Lanka, there is considerable diversity of sources of incomes. The diversity of occupations and sources of income are closely associated with market penetration and the presence of various state institutions. In the South Asian countries the situation is similar, especially in India and Sri Lanka, whereas in Thailand and China the income sources are fewer while agriculture remains the main source of income. Diversifying the sources of income indicates a reduction in risk and vulnerability.

India

It is important to understand the income sources / portfolio of the farmers to appreciate the measures that farmers adopt in response to the ground situation. The proportion of income from agriculture in the income portfolio of the farmers remains important. During the last four decades farmers have diversified their incomes into non-farm sources to reduce their exposure to the risk of climatic uncertainties. In Aurepalle it came down from 59 to 42%. In Dokur the share of agriculture in the income portfolio is the lowest and is only 28% at present. The story of Dokur village in Mahabubnagar district of Andhra Pradesh is a case of natural resource degradation. During the seventies farmers derived 96% of their income from Agriculture and by 2007 the contribution of Agriculture came down to as low as 28%. Income from non-farm sources in this village increased from just 3% in the seventies to as high as 58% in 2007. This increased dependence on non-farm sources is mainly due to increased variability in rainfall and associated yield losses.

Most of the natural resources such as ground water were over exploited for a decade in the nineties and the result was the drying up of common resources like tanks and ponds as well as dug wells. These developments drove the farmers towards adaptation measures such as going for the non-farm sources such as petty part time business, salaried incomes, non-farm labour earnings etc. In Dokur family income contributions from migration has also shot up with time. Shirapur village has seen the development of irrigation facilities through the construction of a canal and a dam. As a result farmers adapted the growing of cash crops and sugarcane is grown on more than 70% of the area. In Shirapur village 83% of income was from agriculture sector in the seventies. It came down to 59% by 2007. During the same period, income from non-farm sources shot up from 17 to as high as 37%. Almost 89% of the income was derived from Agriculture in seventies in Kalman village but farmers have diversified their income sources during the last several decades and in 2007 their income from Agriculture decreased to just 41%. During the same period income from Non-farm sources increased from just 10% in seventies to as high as 55% in 2007. In Kanzara income from agriculture decreased from 87% in seventies to 66% in 2007. During the same period non-farm income increased from 12 to 26%. In Kinkheda Income from Agriculture decreased from 96 to 61% by 2007. This coincided with the increase of non-farm income from 4 to 35% by the year 2007. In recent times farmers have diverse income portfolios where they diversified into Business and non-farm activities apart from diversification within the agriculture sector. The trend is similar in all the villages. In general farmers are diversifying their income portfolio and they see this trend as an essential adaptation measure to address the increasing risks in agriculture due to variability in rainfall and associated risks of crop loss or failure due to soil moisture stress in rainfed agriculture (Table 19a).

Table 19a: Dynamics of income sources of farmers in the study villages of India

Income source (%)	**Aurepalle**		**Dokur**		**Shirapur**		**Kalman**		**Kanzara**		**Kinkheda**	
	1975	**2007**	**1975**	**2007**	**1975**	**2007**	**1975**	**2007**	**1975**	**2007**	**1975**	**2007**
Agriculture	59	42	96	28	83	59	89	41	87	66	96	61
Non-farm	11	41	3	58	17	37	10	55	12	26	4	35
Caste occupation	29	13	1	5	-	1	1	2	1	1	-	2
Govt. welfare programs	-	4	-	3	-	2	-	-	-	3	-	2
Others	-	1	-	5	-	1	-	3	-	3	-	-

Diversify occupation into non-farm labor to reduce the risk of uncertainty in farm income. (Kinkheda village in Maharashtra, India)

Sri Lanka

Farmers perceived that the proportion of income from cereal based farming in their agricultural income had increased with time. During the seventies vegetable cultivation had a share of 45% in the total agricultural incomes and in the recent times it has decreased to 16.9%. This is mainly due to reduced irrigation sources and the village tanks which were a source of supplementary irrigation are drying up frequently due to insufficient runoffs. In recent times farmers have diversified their incomes into non-farm sectors and business, and outward migration and earnings from service are the major sources of diversification. Recently, income diversification has reduced the risk of rainfall variability through reduced dependence on agricultural incomes. This is seen as an effective adaptation measure by the farmers (Table 19b).

Table 19b. Changes in income sources of farmers in a study village of Sri Lanka

	Galayitiyagama Village	
	Percentage (%)	
Crop/Livestock activity	**1970**	**2008**
Cereal Based Farming	28.0	50.2
Vegetable cultivation	45.2	16.9
Pulses Cultivation	18.7	22.3
Oilseeds cultivation	6.1	7.9
Dairy	0.7	1.7
Goat Farming	0.8	0.8
Poultry	0.4	0.3

Thailand

Farmers have responded to the circumstances and diversified and changed their income sources over time. Depending on the resource availability different groups of farmers responded and adapted differently. In the lowland village of Don Plai, landless farmers used to earn more than 97% of their income from cattle farming during the seventies. In recent times they completely abandoned cattle rearing and started cultivating rice as tenants. Similarly smallholder farmers were also relying heavily on cattle in the seventies and nineties but in the recent decades their incomes are mostly derived from rice and vegetable cultivation. For the medium and large-scale farmers the situation was similar during the seventies but in the recent decades their major share of income stems from cassava cultivation followed by rice. In another lowland village Kud Sawai the landless farmers were not dependent on cattle during the seventies. But in the recent times most of the farmers diversified into incomes from cassava and rice growing, while large-scale and medium farmers derive a small part of their income from poultry. Most of their agricultural income arises from cassava and rice. In the upland village of Non Maung large farmers diversified incomes into cassava and rice and in recent times derive 20% from cassava and 11% from rice. About 50% of their income comes from cattle. And medium farmers derive 38 and 36% from cassava and rice and about 22% from cattle. In another upland village Tha Taeng cattle is not a prominent income source but in the recent times medium and large farmers derive some income from it. Large-scale farmers derive 71% of their incomes from vegetable cultivation and medium farmers get about 21% of their income from vegetables. Cassava gives 12 and 24% of the incomes for large and medium farmers. In general incomes from rice form a major share in the lowland villages and other crops like cassava form a major share in the upland villages. Farmers in all the villages diversified their agricultural income in the recent times (Table 19c).

Table 19c. Changes in income sources of farmers among different land holding categories in the study villages of Thailand

Farmer group	**Landless**			**Small**			**Medium**			**Large**		
Percentage (%)	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
Don Plai												
Rice	3.0	26.0	100.0	21.0	50.0	82.0	80.0	32.0	37.0	19.0	28.0	42.0
Sugarcane	-	-	-	-	-	-	-	-	-	-	7.0	2.0
Maize	-	2.0	-	5.0	-	-	-	-	-	5.0	2.0	-
Cassava	-	-	-	-	47.0	0.0	20.0	33.0	55.0	15.0	35.0	42.0
Fruit crops	-	-	-	-	-	-	-	13.0	-	-	5.0	-
Vegetables+herbs	-	-	-	-	-	16.0	-	-	-	-	-	-
Trees	-	-	-	-	-	-	-	-	-	-	-	-
Others (neem etc.)	-	-	-	2.0	-	-	-	-	8.0	5.0	5.0	-
Cows	97.0	72.0	-	73.0	2.0	-	-	22.0	-	54.0	12.0	11.0
Poultry	-	-	-	-	1.0	-	-	-	-	3.0	6.0	2.0
Fisheries	-	-	-	-	-	2.0	-	-	-	-	-	-
Kudsawai	-	-	-	-	-	-	-	-	-	-	-	-
Rice	-	26.0	46.0	28.0	35.0	62.0	39.0	35.0	83.0	27.0	28.0	41.0
Sugarcane	-	-	-	-	-	-	-	-	-	-	-	-
Maize	-	-	-	-	-	-	-	-	-	-	-	-
Cassava	100.0	5.0	54.0	4.0	20.0	22.0	4.0	4.0	-	12.0	29.0	58.0
Fruit crops	-	-	-	-	-	-	-	-	2.0	-	-	-
Vegetables+herbs	-	-	-	-	-	-	-	-	9.0	-	-	-
Trees	-	-	-	-	-	-	-	-	-	-	-	-
Others (neem etc.)	-	-	-	9.0	-	-	-	-	-	-	-	-
Cows	-	69.0	-	59.0	46.0	14.0	57.0	61.0	-	60.0	42.0	-
Poultry	-	-	-	-	-	2.0	-	-	6.0	1.0	1.0	1.0
Nong Muang	-	-	-	-	-	-	-	-	-	-	-	-
Rice	-	-	-	-	-	12.0	36.0	39.0	38.0	4.0	7.0	11.0
Sugarcane	-	-	-	-	-	-	-	-	4.0	-	2.0	4.0
Maize	-	-	-	-	-	-	-	-	-	-	2.0	1.0
Cassava	-	-	-	11.0	23.0	39.0	19.0	41.0	36.0	3.0	7.0	20.0
Fruit crops	-	-	-	-	-	-	-	-	-	-	1.0	2.0

Vegetables+herbs	-	-	-	-	-	12.0	10.0	8.0	1.0	3.0	3.0	4.0
Trees	-	-	-	-	-	-	-	-	-	-	-	8.0
Others (neem etc.)	-	-	-	89.0	21.0	-	18.0	12.0	-	4.0	4.0	-
Cows	-	-	-	0.0	56.0	38.0	18.0	0.0	22.0	86.0	75.0	50.0
Poultry	-	-	-	-	-	-	-	-	-	-	-	-
Fisheries	-	-	-	-	-	-	-	-	-	-	-	-
Tha Taeng	-	-	-	-	-	-	-	-	-	-	-	-
Rice	97.0	-	-	3.0	-	-	2.0	2.0	11.0	6.0	4.0	5.0
Sugarcane	-	-	-	-	-	-	-	-	-	3.0	-	-
Maize	-	-	-	-	-	-	-	4.0	14.0	33.0	8.0	6.0
Cassava	3.0	-	30.0	-	-	27.0	5.0	6.0	24.0	19.0	19.0	12.0
Fruit crops	-	-	-	-	-	-	1.0	-	-	-	-	1.0
Vegetables+herbs	-	-	70.0	-	-	73.0	-	15.0	21.0	5.0	40.0	71.0
Trees	-	-	-	-	-	-	-	-	-	-	-	-
Others (neem etc.)	-	-	-	10.0	-	-	60.0	39.0	5.0	16.0	7.0	3.0
Cows	-	-	-	87.0	-	-	33.0	34.0	23.0	15.0	22.0	2.0
Poultry	-	-	-	-	-	-	-	-	-	2.0	-	-
Fisheries	-	-	-	-	-	-	-	-	-	-	-	-

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Viet Nam

Farmers in rainfed areas in Viet Nam diversified their income sources. The share of income from crop production increased from 10% during the nineties to about 22% in recent times. This income mainly came from the cultivation of the food crops, cotton, grapes and other crops. Income from livestock activities from cattle and poultry increased rapidly from 26% in the nineties to about 61% in recent times. In the recent times 18% of the income came from salaried service and other non-farm sources. In general income diversification is seen among the farmers as a measure to reduce risk of uncertainty in rainfall on agriculture (Table 19d). The data confirmed presence of trend in crop diversification from traditional food crops to more high value crops viz. grapes cotton, vegetables etc.

Table 19d. Dynamics of sources of income of farmers in the study villages of Viet Nam

	Phuoc Nam Commune		
	1990	2008	FP*
Income sources	%	%	
Crop Production	10.3	21.8	MII
a) Food crops	39.0	28.6	MID
b) Cotton	4.6	0.0	MID
c)Grape	56.0	65.0	MII
d)Other crops	0.4	6.4	MII
Live stock	25.9	60.6	MI
a) Cattle	2.0	0.8	MID
b) Poultry	98.1	99.2	MII
Services and other sources	63.8	17.6	MD
Total	100.0	100.0	

Note: NC=No Change, NU=Not used, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on changes in income sources.
* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase);

China

Out migration and changing of work place is not possible in China as the population has to register at a place for their work. Over the period of last 20 years, the share of income from farm agriculture has remained more or less the same in Lucheba village but fraction of income that came from the livestock decreased from 36.4% twenty years back to about 17% in the recent times. Off-farm income increased its share from 9% twenty years back to about 31% in the recent years. In Dajiang village the share of income from agriculture decreased from 46 to 35.5% in the last twenty years. Similarly income from the share of livestock decreased from 48 to 36% and off-farm income increased from just 6% to about 29% in the last twenty years. In general income diversification among the farmers of marginal areas in China took place with an increased share coming from non-farm income (Table 19e).

Table 19e. Changes in the sources of income of farmers in the study villages of China

Total Income share (%)	**Lucheba (30 households)**		**Dajiang (30 households)**	
	20 years ago	**2008**	**20 years ago**	**2008**
Farm Income	54.5	51.7	45.8	35.5
Animal Breeding Income	36.4	17.3	47.9	35.9
Off-farm Income	9.1	30.9	6.3	28.6
Total	100.0	100.0	100.0	100.0

Farming continues to be major source of income
(A study village in China)

Land management practices - What farmers are doing at micro level

Soil management practices that improve the water holding capacity of the soil and conserve soil moisture are important adaptation measures against variability in rainfall in rainfed agriculture. Practices such as organic matter incorporation through green manure, composting as well as incorporating crop residues and mulching will improve soil properties and serve as moisture conserving measures.

India

Aurepalle

Several soil management measures to conserve moisture and improve soil quality were listed and discussed with the farmers to their perceptions and adaptation status of these measures. More than 30% of the farmers in the village used green manure and incorporated crop residues in the soil during the early period but there is a major decrease in the practice during recent years. (Table 20a) Similarly composting was followed by more than 70% of the farmers during the early period from 1970 to 1990 but there is a major decrease in the farmers using compost and only a little above 20% of the farmers are using compost now. Farmers in the village are aware of conservation tillage but very few farmers practice it. Keeping the land fallow was practiced by more than 20% of the farmers earlier but in recent times very few people leave the land fallow for one season in the recent times. Minimal tillage is being practiced by about 18% of the farmers. One of the major factors that emerge out of this information is that organic inputs to the soil reduced over the years and this is adversely affecting the soil and subsequently this will lead to unsustainable productivity growth.

Dokur

About 7% of the farmers used green manure during the seventies and a major decrease was observed during the recent decade (Table 20a). Farmers in the village are aware of conservation tillage but very few farmers practice it. Keeping the land fallow was practiced by 3% of the farmers during the seventies and it increased slightly in recent times. The practice of bunding the field has increased recently. One of the major factors that emerge out of this information is that most of the farmers were not aware of organic input methods to the soil and whatever meager measures were followed earlier were reduced over the years This is adversely affecting the soil and subsequently this will lead to unsustainable productivity growth.

Table 20a. Farmer’s perception on land management practices in the study villages of India

	Kanzara			Shirapur			Aurepalle			Kalman			Kinkheda			Dokur		
Practices	**Household practicing (%)**		**FP***	**Household practicing (%)**		**FP**	**Household practicing (%)**		**FP**	**Household practicing (%)**		**FP**	**Household practicing (%)**		**FP**	**Household practicing (%)**		**FP**
	1970-90	**1990-08**		**1970-90**	**1990-08**		**1970-90**	**1990-08**		**1970-90**	**1990-08**		**1970-90**	**1990-08**		**1970-90**	**1990-08**	
Mulching	-	-	-	0	23	MI	-	-	-	0	30	MI	-	-	-	-	-	-
Green manuring	-	-	-	20	8	MID	33	0	MD	10	25	MII	-	-	--	7	2	MID
Composting	74	23	MD	80	60	MD	74	23	MD	70	40	MD	80	40	MD	-	-	-
Incorporating crop residue	10	38	MI	20	55	MI	32	6	MD	45	65	MII	10	38	MI	-	-	-
Conservation tillage practices	2	10	MII	-	-	-	1	3	MII	60	90	MI	2	10	MII	6	4	MID
Bunding	12	65	MI	80	100	MI	8	28	MI	10	30	MI	12	65	MI	7	20	MII
Fallow	28	5	MD				28	5	MD	30	5	MD	28	5	MD	3	6	MII
Fallow strips	-	-	-				-	-	-	-	-	-			-	-	-	-
Drainage channels	10	60	MI	70	25	MD	1	2	MII	-	-	-	10	60	MI	13	23	MII
Contour ridges	0	10	MII	-	-	-	0	0	NC	-	-	-	0	10	MII	-	-	-
Zero tillage	-	-		-	-	-	2	10	MII	-	-	-	-	-	-	-	-	-
Minimal tillage	-	-		-	-	-	4	18	MII	-	-	-				-	-	-
Agro-forestry	-	-	-	-	-	-	-	-	-	-	-	-				-	-	-
Wind barriers/ alley cropping	15	5	MID	18	28	MII	-	-	-	-	-	-	15	5	MID	-	-	-
Planting grasses/ savanna grasses	-	-	-	5	8	MII	0	8	MII	-	-	-	-	-	-	-	-	-
Constructing stone walls	-	-	-	-	-	-	2	9	MII	-	-	-	-	-	-	1	6	MII
Plantation of shrubs and trees	-	-		-	-	-	0	3	MII	-	-	-	-	-	-	0.1	1	MII

Note: NA=Not available, NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on land management practices.
* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase);

Kanzara

Farmers are aware of mulching, use of green manure and composting to conserve moisture and improve soil fertility. These practices saw a major decrease over time. They are also aware of the practice of incorporating crop residues into the soil. This practice saw a major increase over time. One of the factors that emerged out of this information is that organic inputs to the soil reduced over the years and this is adversely affecting the soil. Bunding the field and preparing the drainage channels have seen a major increase and more than 70% of the farmers are following them (Table 20a).

Kinkheda

Farmers perceived that the practice of mulching and using green manure decreased with time. They felt that composting was followed by about 80% of the farmers during the early period from 1970 to 1990, but there is a major decrease in the farmers' use of compost, and only 40% of the farmers are using compost now. Incorporation of crop residues was followed by 10% of the farmers during the first period (1970-1990)(Table 20a), and with time more farmers started following this in recent times more than 35% of the farmers practice this measure. Farmers felt that 10% of the farmers follow conservation tillage. The practice of bunding was practiced by just 12% of the farmers earlier; this practice found increased acceptance and 65% of the farmer's now bund their fields. The practice of keeping the fields fallow has reduced. Now more farmers are using drainage channels.

Shirapur

Mulching was non-existent during seventies to nineties, but recently gained favor with farmers, and they perceive that about 23% of the farmers practice it. Use of green manure saw a major decrease with time, and barely less than 10% of the farmers follow it these days. (Table 20a). Farmers perceived that more than 80% of the farmers followed composting in the early periods and they felt that there is a major decrease in the farmers following the practice now. Incorporating crop residue has increased over a period of time and they felt that about 55% of farmers follow this practice now. Farmers are not aware of practices like contour ridges, zero tillage, minimal tillage and agroforestry. Farmers perceive that bunding was a common practice even during earlier periods from the seventies to the nineties, with about 80% of the farmers following it. In the recent times there was a major increase in the farmers following it and almost every farmer is following it now. One of the major factors that emerge from this information is that organic inputs to the soil might have reduced over the years and this is adversely affecting the soil.

Kalman

Mulching was not practiced during period (1970-1990). (Table 20a). In recent times this practice increased and the farmers perceive that about 30% of the farmers use it. Use of green manure also increased in recent times and about 25% of the farmers practice it now. Composting was followed by a large number of farmers in the earlier period. There was a reduction in the farmers practicing it in the recent times and now only 40% of the farmers follow it. The practice of incorporating crop residues has increased in the recent times. More farmers follow conservation tillage practices now. Most of the farmers are aware of bunding and farmers perceive that this practice saw a major increase over time and about 30% farmers practice it now. Farmers using drainage channels decreased over time and farmers perceive that only 10% of the farmers practice it now.

Sri Lanka

In Galahitiyagama, the practice of mulching, use of green manure, composting, incorporating crop residues in soil, conservation tillage practices and drainage channels have increased during the period of study. The majority of the farmers said that they are practicing bunding of their fields. According to majority of respondents, awareness on all the practices have increased from 1970 to 2008. In Mangalapura farmers perceived that among the land management practices, mulching, use of green manure, composting and incorporating crop residue and to some extent bunding their fields saw a minor increase over the period from 1970 to 2008. Other practices were not common with the farmers. In Mahagalwewa, mulching, use of green manure, composting, bunding, and drainage channels saw a minor increase during the period from 2007 to 2008. Similar trends were seen in Bata-Atha village (Table 20b).

Table 20b. Farmer's perception on land management practices in the study villages of Sri Lanka

Land Management Practices	Galahitiyagama	Magalapura	Mahagalwewa	Bata-Atha
Mulching	MII	MII	MII	MII
Green Manuring	NC	MII	MII	MII
Composting	MII	MII	MII	MII
Incorporating crop residue	MII	MII	NC	NC
Conservation tillage practices	MII	NC	MII	MII
Bunding	MII	NC	MII	MII
Fallow	NC	NC	NC	MD
Fallow Strips	NC	NC	NC	MD
Drainage channels	MII	NC	MII	MII
Contour ridges	NC	NC	MII	MII
Zero tillage	NC	NC	-	NC
Minimal tillage	NC	NC	MII	NC
Agro- forestry	MII	MII	MII	MII
Wind barriers/alley cropping	NC	NC	-	NC
Planting grasses/Sawana grasses	NC	NC	MII	NC
Construction of stone walls	NC	NC	MII	MII
Plantation of shrubs and trees	NC	NC	MII	MII

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on land management practices.

* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase);

A typical unprotected irrigation water supply well dug by a farmer at Mangalapura, Puttalam District, Sri Lanka

Thailand

Farmers in upland villages, particularly those with the least possibility of irrigation, as seen in Tha Taeng village, are increasingly adapting organic matter incorporation measures in the recent decades as compared to the 1970's. More than 60% farmers are practicing these measures. In the lowland villages, due to the land position, moisture gets accumulated in the rainy season and more often standing water also accumulates in these soils. Villages that have predominantly lowlands, farmers seem to prefer methods that will store the rainwater in their fields. This can be seen through the fact that 80 and 67% of the farmers in Don Plai and Kud Sawai villages practice bunding in the last few decades. Incorporating crop residues is followed by about 42 and 31% of the farmers in DP and KS villages in the recent decades. Farmers perceived that only 19 and 18% of the farmers followed this during the seventies. In DP village composting practice increased from 26% during the seventies to 42% in the recent decades. In comparison all these practices are followed by a higher number of farmers in the upland villages of NM and TT (Table 20c).

Among the sample villages studied, a range of practices in land management were observed as adaptation strategies to the low or uncertain availability of water for agricultural purposes. The practices varied due to the level of dependency on rainfall and the types of practices adopted reflecting in the differences of farmer experiential knowledge, access to information and penetration of scientific / technical knowledge to the villages.

Table 20c. Trends in land management practices in the study villages of Thailand

	Households Practicing*							
	1970-1990				1990-2008			
Practices (%)	**Don Plai**	**Kud Sawai**	**Non Muang**	**Tha Taeng**	**Don Plai**	**Kud Sawai**	**Non Muang**	**Tha Taeng**
Mulching	6	11	4	34	16	17	9	40
Use of green manuring	10	2	4	9	18	8	7	25
Composting/Manuring	26	43	21	52	42	16	50	59
Incorporating crop residue	19	18	33	34	42	31	46	64
Conservation tillage practices	18	34	41	46	31	40	47	60
Bunding	74	62	74	66	80	67	74	74
Fallow	44	66	60	60	38	60	60	65
Drainage channels	53	53	59	70	71	65	59	80
Contour ridges	11	7	2	11	12	6	3	13
Zero tillage	5	13	5	5	3	5	4	0
Minimal tillage	22	36	27	38	32	32	29	27
Agro-forestry	17	5	8	24	14	8	9	28
Wind barriers/alley cropping	3	1	5	15	4	2	9	14
Planting grasses/Sawana grasses	0	8	7	19	2	5	9	20
Construction of stone walls	0.3	0.7	0.7	0.6	1	10	3	8
Plantation of shrubs and trees	23	24	22	27	19	25	26	23

* Total number of households sampled in each village is 40.

Farmer's perception of climate variability

Farmers have been devising and practicing various adaptation measures in response to adverse and unpredictable climatic variability like erratic rainfall, as well as moderate and severe droughts and several other socio-economic shocks such as market movements or absence of supportive institutions. The following section deals with the farmer's perception of climatic variability during the last four decades. Farmers knowledge of the environment is based on individual as well as their collective experiences. Gathered through the household surveys and FGDs, as perceptions, this information is the basis on which they will decide their adaptation strategies to short term weather situations and long term climate change.

India

Farmers in all the villages had similar perceptions about climate variability. When asked about their observation on the behavior of the weather elements, farmers perceived that the quantum of rainfall decreased over the last few decades, arrival of southwest monsoon progressed during period 1 (1970-1990) and delayed during period 2 (1990-2008). Distribution of rainfall was perceived to be skewed during period-1 and erratic during period 2. Farmers perceived that there was an increase in temperature during period 1970-'90 and a major increase in temperature during period 1990-2008 (Table 21a).

Table 21a. Majority of sampled SAT-Indian farmers' perceptions on climate variability in the study villages of India

Villages	Rainfall		Temperature		Intensity of rainy days		Arrival of monsoon		Distribution of rainfall	
	1970-1990	**1990-2008**	**1970-1990**	**1990-2008**	**1970-1990**	**1990-2008**	**1970-1990**	**1990-2008**	**1970-1990**	**1990-2008**
Kanzara	MID	MD	MII	MI	MID	MD	On time	Delayed	Less erratic	Erratic
Shirapur	MID	MD	NC	MI	MID	MD	On time	Delayed	Uniform	Erratic
Aurepalle	MID	MD	MII	MI	MID	MD	On time	Delayed	Less erratic	Erratic
Kalman	MII	MID	MID	MII	MII	MID	On time	Delayed	Less erratic	Erratic
Kinkheda	MID	MD	NC	MII	MID	MD	On time	Delayed	Less erratic	Erratic
Dokur	MID	MD	MII	MI	MID	MD	Delayed	Delayed	Less erratic	Erratic

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on climatic variability.

* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase)

Sri Lanka

Farmers perceived that there was a decrease in annual rainfall, intensity of rainfall, number of rainy days, early arrival of southwest and northeast monsoons and an increase in the duration of dry spells both in Yala and Maha cultivation seasons in all the villages. Farmers perceived that the annual temperature had increased. The perception is the same in all the villages (Table 21b).

Table 21b. Farmer's perception of climate variability in the study villages of Sri Lanka

	Yala & Maha Seasons							
	Galahitiyagama		Mangalapura		Mahagalwewa		Bata-Atha	
Climatic Variability	**1970-2000**	**2000-2008**	**1970-2000**	**2000-2008**	**1970-2000**	**2000-2008**	**1970-2000**	**2000-2008**
Quantum of Rainfall	NC	MID	NC	MID	MID	MID	MID	MID
Intensity of Rainfall	NC	MID	NC	MID	MID	MID	MID	MID
Distribution of Rainfall	NC	MID	NC	MID	MID	MID	MID	MID
Number of rainy days	NC	MID	NC	MID	MID	MID	MID	MID
Arrival of Monsoons-Northeast	NC	MID	NC	MID	MID	MID	MID	MID
Arrival of Monsoons-Southwest	NC	MID	NC	MID	MID	MID	MID	MID
Rainfall outside the rainy season	NC	MII	NC	MII	MII	MII	MID	MII
Onset of Rainfall	NC	MID	NC	MID	MID	MID	MID	MID
Withdrawal of Rainfall	NC	MID	NC	MID	MID	MID	MID	MII
Longer dry spells	NC	MII	NC	MII	MID	MII	MII	MII
Temperature (hotter or colder)	NC	MII	NC	MII	MII	MII	MII	MII

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on climatic variability.
* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase);

Bangladesh

Drought-prone Villages

Farmers perceived that in Boikunthapur the onset of the rainy season has gradually been getting delayed, which induced many farmers to try non-traditional crops like maize in place of wheat. The village has in some cases experienced rainfalls in the off-seasons too. Farmers perceived that in Khudiakhali rainfall quantum and the number of rainy days have declined (one third on an average) in the village. In addition, the farmers observed that incidences of rainfall in the off- season has become less in recent years. Normal onset of the rainy season is getting delayed by about a month in . The village, as a result of its semi-high topography, has faced only a few events of floods and none of them in recent years. The last time that flood submerged the village was in 2004. Farmers in Boikunthapur and its neighboring villages felt that summer is now becoming hotter and temperature in the winter is falling along with very thick fogs and mists. General observations by the farmers in Khudiakhali, are that average temperature has been rising during the summer over the last three decades. Since the last 5 to 6 years, the degree of rising temperature has been quite high. Over the last decade, drought spells have increased in the area. With such combination of temperature rise, inadequate rainfall and resulting drought, water level of the river has decreased in the dry season and people are forced to use diesel operated water pumps to cultivate betel leaf and other crops, which also increase their production costs. Local people observed that the water depth of the river is at the lowest level in the decade. The groundwater and other surface water sources have also depleted.

Flood-prone Villages

In Paschim Bahadurpur farmers perceive that the intensity and frequency of rainfall has decreased significantly for the last 30-35 years. The villagers said that the extent of rainfall in the dry season has decreased remarkably in the last ten years. They think that the on-set of the rainy season is gradually getting delayed and the duration is also getting shorter. According to the villagers, number of rainy days is decreasing over the years. Farmers in Nishaiganj felt that average maximum temperature is increasing over the last 10-12 years and the average minimum temperature is increasing, although not very significantly. The villagers from Paschim Bahadurpur observed that temperature is gradually getting warmer every passing year.

Thailand

The actual annual rainfall increased by 3.4% during 1970-1990 and decreased by 3.6% for the lowland villages of Don Plai and Kud Sawai. The actual values for both the villages are the same because the data is from a single meteorological station representing both the villages. Farmers perceived that the annual rainfall saw a minor increase in both the periods in Don Plai and farmers in Kud Swai perceived a minor decrease. The actual annual rainfall in the upland villages saw a decrease in the first period and an increase of 3.5% in the second period. Farmers in both the villages perceived the annual rainfall to witness a minor decrease in both the periods. The actual annual temperature decreased by 0.81 in the first period and increased by 0.88 degrees centigrade from 1990 to 2008. Farmers perceived it as a minor and major increase in both the periods. It may not have been in great magnitude but the farmers perceived correctly about the latest period. The actual annual temperature in the upland villages of Nong Muang and Tha Taeng decreased by 0.81 degrees in the first period and increased by 0.91 degrees centigrade in the latest period. Farmers perceived it as a major increase in the first and second periods. If not the magnitude the trend in the latest period was correctly perceived by the farmers. The actual arrival of the monsoon was earlier by 3.1% in the first period and late by 1.6% in the later period. Farmers perceived that there was no change in the first period and a major delay in the second period. Disregarding the magnitude the farmers correctly perceived the change in the onset of monsoon in the latest period. In general, farmer's perception about the variability was nearer to the actual observations in the recent period. They were able to recall their latest observations in the recent two decades correctly (Table 21c).

Table 21c. Farmer's perception of climate variability in the study villages of Thailand

	Don Plai			Kud Sawai			Nong Muang			Tha Taeng		
	1970-1990	**1990-2008**	**FP***	**1970-1990**	**1990-2008**	**FP**	**1970-1990**	**1990-2008**	**FP**	**1970-1990**	1990-2008	**FP**
Change in actual annual rainfall (%)	3.4	-3.6	MID	3.4	-3.6	MID	-3.3	3.5	MII	-3.3	3.5	MID
Change in actual annual temperature (%)	-0.81	0.88	MII	-0.81	0.88	MII	-0.85	0.91	MII	-0.85	0.91	MII
Average actual deviation of monsoon (%)	-3.1	1.6	MII	-3.1	1.6	MII	-2.4	-0.5	MII	-2.4	-0.5	MII

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on climatic variability.
* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase);

Viet Nam

Data is available from only one meteorological station to represent both the villages. Rainfall increased by 14.8% from 1970 to 1990 (period-1) and by 28.3% during the 1990-2008(period-2). Farmers perceived that the annual rainfall saw a major increase during the first and second periods. The actual number of rainy days in the first period decreased by 9.4% and during the second period the number of rainy days increased by 1.7%. Farmers perceived a minor increase in the number of rainy days in the first period and a minor decrease in the second period in Vu Bon village. In Nho Lam village, farmers perceived a minor increase in the first period and a major decrease in the second period. In both cases the farmers were not able to perceive the reality. The reasons need to be clarified through further interpretation. The actual change in annual temperature saw a decrease by 1.5 degrees centigrade. Farmers perceived that there was a minor increase in the temperature during the second period. In general there was a deviation of the farmer's perception and actual observation (Table 21d). The differences between farmers' experiential knowledge and perceptions compared with the inferences drawn from meteorological data need more analysis to identify the reasons for the divergence. The local variability in climate data compared to those collected at a single point needs closer examination. Further, the reliability and validity of information collected must also be closely examined.

Table 21d. Farmer's perception of climate variability in the study villages of Viet Nam

	Vu Bon Village			Nho Lam Village		
	1970-1990	**1990-2008**	**FP***	**1970-1990**	**1990-2008**	**FP**
Change in actual annual rainfall (%)	14.8	28.3	MII	14.8	28.3	MI
Change in actual day with rains (%)	-9.4	1.7	MID	-9.4	1.7	MD
Change in perception in rainy day*	1	-1	MID	1	-2	MD
Change in actual annual temperature (%)	-	-1.5	MII	-	-1.5	MID

Note: NC=No Change, MI=Major Increase, MII=Minor Increase, MD=Major Decrease, MID=Minor Decrease, FP= farmers perception on climatic variability.
* Major decrease (>20% decrease), minor decrease (<20% decrease), no change, minor increase (<20% increase), major increase (>20% increase);

China

In Lucheba village the actual annual rainfall increased by 2% during the 1991 -2008 period. Farmers perceived it as a 5% increase. In Dajiang village the actual rainfall increased by 0.9% during 1991-2008 and the farmers perceived it as an increase of 5%. The actual annual temperature increased by 1.6% in Lucheba village whereas the farmers perceived it as an increase of 5%. In Dajiang village the actual annual temperature decreased by 3% in recent times, whereas the farmers perceived it as an increase of 5% (Table 21e). In all of the study locations the farmers' experiences of long term trends matched the findings of the climate data analysis. Their ability to recall key extreme events also matched the data recorded for the past forty years in the respective countries.

Table 21e. Climate variability in the study villages in the study villages of China

	Lucheba Village (Central Guizhou)		**Dajiang Village (Southern Guizhou)**	
Change in perception and actual climate	**1970-90**	**1991-2008**	**1970-90**	**1991-2008**
Change in actual annual rainfall (mm)	1274	1299+2%	1147	11.57+0.9%
Change in perceptual annual rainfall (%)	0	-5	0	5
Change in actual annual temperature (%)	14.13	14.35	20.1	19.5
Change in perceptual annual temperature (%)	0	5	0	5
Change in GWL	Not Known			
Average actual deviation of monsoon (%) (May-Sep)	72.69	75.09	74.26	74.11
Perceptual deviation of monsoon	Progressed	Delayed	Progressed	Delayed

Dynamics of sources and availability of water for irrigation

Water is the most important input in crop production. To insulate crop production from the uncertainties of rainfall, the role of alternate sources of water is critical. Common property sources such as tanks and ponds mostly depend on the rainfall runoff or the catchment area to fill up. Other private sources such as open wells and tube wells tap the ground water to cater to the needs of irrigation. Sustainable management of groundwater resources is critical to long term use of these resources.

India

Aurepalle

Tank irrigation was common during the 1970s and 80s. The perception varied from 10% as perceived by large-scale farmers, to 18% as perceived by marginal farmers as those dependent on irrigation. Since the 1900s there has not been water in the tanks to irrigate, and the tanks dried up. Over time, the catchment area farmers started following water conservation measures like bunding their fields. The result is that rainfall runoff is considerably reduced and there is almost no water that comes into the tank. In addition, rainfall intensity decreased, which resulted in reduced runoff (Mohan Rao Personal communication). Open wells in the village were the major source of irrigation during the 1970s. Perception varied from 82% by marginal farmers to as high as 90% by large-scale farmers and those dependent on irrigation wells. During the nineties perception about the irrigated area catered to by the wells was more consistent between the groups of farmers. In the recent decade perception varied from 5 to 6%. Use of wells came down drastically in the recent decade and only about 5% of the irrigated area is catered to by open wells. This is mainly because the ground water table has receded drastically due to over exploitation, and as a result most of the wells dried up. During the seventies ground water exploitation by deep tube wells was non-existent, but in the recent decade there was an enormous increase in the number of tube well sunk in the village, and more than 90% of the irrigated area is being irrigated by tube wells. (Table 22a).

Dokur

Dokur village has a bigger tank than Aurepalle and the command area of the tank used to be more than 400 acres. Tank irrigation was very important during the 1970s and 80s; 62 to 74% of the area is catered by the tanks. During the nineties the area catered to by tanks came down drastically and farmer's estimate this to be about 17 to 30%. During the recent decades tanks are no more used for irrigation by the farmers. The catchment area of the tanks was obstructed over the period. Farmer's perception about the proportion of irrigated area catered to by open wells during the seventies varied from about 34 to 23% area. All groups of farmers perceived that the importance of open wells has increased and that more of the irrigated area was catered to by open wells during the nineties. This increased dependence on wells coincided with the decrease in tank irrigation. In the recent decade the area irrigated by wells has decreased drastically. This is mainly because the ground water table has receded drastically due to over exploitation, and as a result most of the wells dried up. In the nineties farmers across different groups perceived that about 8 to 13% of the irrigated area was catered to by tube wells. During the recent decade there was an enormous increase in the numbers of tube well in the village and farmers perceived that more than 85 to 93% of the irrigated area is being irrigated by tube wells. (Table 22a).

Kanzara

The irrigation canal is the major source of water in this village. Farmers perceive that about 54 to 57% of the irrigated area is watered by canal irrigation. During the last decade all categories of farmers perceived that more than 62% of irrigated area was provided water by the canals. During the seventies open wells were the only source of irrigation and all the farmers expressed this. During the nineties 42 to 46% irrigated area was perceived to be catered to by open wells. Farmers perceived that the number of open wells increased from 46 in seventies to 108 at present. However, in the course of time, about 73 wells dried up. For all practical purposes, the numbers of functional wells remain similar throughout the period. During the last decade farmers started installing tube wells. Farmers perceive that only 5 to 6% of the irrigated area is catered to by tube wells. (Table 22a).

Kinkheda

From the 1990s the canal has been a major source of irrigation for this village. Farmers perceived that the proportion of the irrigated area watered from the canal during the nineties varied from 90 to 92%. During the early nineties canal water was available even during post-rainy season (rabi). Wells in the village also contribute to irrigation in the village. The number of open wells increased with time and now about 42 wells are present in the village. Irrigation by canal water is restricted to the fields that are geographically situated around the canal. But irrigation by wells has the advantage of catering to the water needs of the fields irrespective of their geographical location. Due to the adverse water situation, about 15 open wells have already dried up. Farmers perceive that wells were the only source for irrigation in the seventies. With the advent of the canal farmers felt that the proportion of irrigated area catered to by the wells decreased and in nineties it was perceived to be 8 to 10% by different groups of farmers. These numbers slightly increased during the recent decade and so have the number of wells in the village. Farmers perceive that recently only two bore wells were installed in the village and only large-scale farmers expressed that about 1% of the irrigated area is catered to by the tube wells. (Table 22a).

Shirapur

A canal was constructed in the village during the nineties, which serves as a major source of irrigation. In the recent decade all the groups of farmers expressed that the irrigated area catered to by canals increased. It varied from 32 to 36%. Wells in the village were an important source of irrigation during the seventies. It catered to about 95 to 98% of the irrigated area. With the arrival of the canal, irrespective of the group of farmers, all the farmers perceived that the share of wells in irrigation decreased during the nineties. It varied from 34 to 50%. During the seventies ground water exploitation using deep tube wells was very limited. In the nineties perception about the irrigated area catered to by bore wells varied from 23 to 37%. At present a drastic lowering of the ground water table in the village and the first casualty is the drying up of the village open wells. (Table 22a).

Check dam and canals in 1990's opened the way for surface water use to climate proof agriculture in Shirapur village, Maharashtra, India

Kalman

Farmers perceive that almost the entire irrigation needs of the village were taken care of by the wells during the 1970s. In recent times alternate sources of water and the contribution of water from the wells to irrigate came down to about 50% despite the fact that the number of open wells increased over time. This is mainly because the ground water table has receded drastically due to over exploitation and as a result most of the wells dried up or else the yield from open wells reduced. In the nineties all groups of farmers felt that about 10 to 13% of the irrigated area was catered to by the tube wells. During the last decade there was an enormous increase in the tube well numbers in the village. Farmer's perception of the proportion of irrigated area catered to by tube wells varied from 40 to 50%. This increase in the use of tube wells is leading to over exploitation of the ground water in an unsustainable way and the result is a drastic lowering of the ground water table in the village. Farmers are drilling deeper and deeper for the exploration of ground water through installation of new tube wells (Table 22a).

Table 22a. Periodical trends in water availability in study villages of India

			Farmers Category			
Kanzara			**Marginal**	**Small**	**Medium**	**Large**
Canal	Area irrigated (%)	1970	0	0	0	0
		1990	56	56	57	54
		2008	65	62	67	63
Wells	Area irrigated (%)	1970	100	100	100	100
		1990	42	44	43	46
		2008	29	31	27	32
Tube wells	Area irrigated (%)	1970	0	0	0	0
		1990	1	0	0	0
		2008	6	6	5	5
Shirapur						
Canal	Area irrigated (%)	1970	0	0	0	0
		1990	29	29	28	27
		2008	33	32	36	36
Wells	Area irrigated (%)	1970	95	95	95	98
		1990	34	42	36	50
		2008	30	34	29	40
Tube wells	Area irrigated (%)	1970	5	5	5	2
		1990	37	29	36	23
		2008	37	33	36	24
Aurepalle						
Tank	Area irrigated (%)	1970	18	15	15	10
		1990	0	0	0	0
		2008	0	0	0	0
Wells	Area irrigated (%)	1970	82	85	85	90
		1990	86	83	84	85
		2008	6	6	6	5
Tube wells	Area irrigated (%)	1970	0	0	0	0
		1990	14	18	16	15
		2008	94	95	94	95
Kalman						
Wells	Area irrigated (%)	1970	100	100	100	100
		1990	87	88	90	90
		2008	50	52	60	60
Tube wells	Area irrigated (%)	1970	0	0	0	0
		1990	13	12	10	10
		2008	50	48	40	40
Kinkheda						
Canal	Area irrigated (%)	1970	0	0	0	0
		1990	90	92	92	90
		2008	90	89	89	89
Wells	Area irrigated (%)	1970	100	100	100	100
		1990	10	8	8	10
		2008	10	11	11	10
Dokur						
Tank	Area irrigated (%)	1970	65	75	74	72
		1990	29	20	30	23
		2008	0	1	0	0
Wells	Area irrigated (%)	1970	35	24	26	24
		1990	63	66	59	67
		2008	13	14	7	8
Tube wells	Area irrigated (%)	1970	0	0	0	0
		1990	8	13	11	10
		2008	87	85	93	92

Sri Lanka

Most of the villages in the marginal environments in Sri Lanka are rainfed and quite often there is no other source of irrigation. An irrigation canal is present in Mahagalwewa village and a majority of the farmers felt that there was no change in the quantum of water used for irrigation from the canal in the last 4 decades. Irrigation from the wells was partially sufficient in Galahitiyagama. Tube wells were not present in Galahitiyagama and very few were present in Mahagalwewa and they were insignificant. In general, irrigation infrastructure, whether collective or private, was very limited in these villages and their potential was limited. Since most of their agriculture is rainfed, farmers are prone to high risk of uncertainty in rainfall, which has led to increased exposure to spells of water stress and crop loss (Table 22b).

Table 22b. Farmer's perception on sources of water availability in study villages of Sri Lanka

	Galahitiyagama		Mahagalwewa	
Sources	**1970**	**2008**	**1970**	**2008**
Canal	-	-	No change	No change
Tank	Partially sufficient	Partially sufficient	No change	No change
Wells	Not Practiced	No change	No change	Totally insufficient
Tube Wells	Not Practiced	Not Practiced	No change	No change
Water Sheds/ Ponds	Not Practiced	Not Practiced	No change	No change
Others (Tap Water)	-	-	Not Practiced	No change

Supplementary water source in a village in Puttalam district, Sri Lanka

Thailand

There are various sources available for irrigation in the villages in Thailand. The river is one of the major sources across the villages. In low land villages like Don Plai and Kud Sawai the river is close to the fields. In the upland villages like Nong Muang, the river is situated but at a distance from the village and the fields. Only very few farms located at the boundary of the village have some access to the river water for irrigation. During the recent times farmers using water from rivers varied from 57% in Kud Sawai to 24% in Nong Muang. Farmers accessing water from the irrigation canal varied from as high as 87.6% in Don Plai to 6% in Nong Muang. In the upland villages like Nong Muang and Tha Taeng, tube wells, wells and tanks are not important for irrigation. Water sources like these that use either ground water or runoff have not been explored. Very little area is irrigated in the upland villages and due to the topography of most of the land; water does not get accumulated even in the rainy season (Table 22c).

Table 22c. Trends in available water sources in the study villages of Thailand

	Don Plai			Kud Sawai			Nong Muang			Tha Taeng		
Sources*	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**	**1970**	**1990**	**2008**
River	50.6	45.7	34.7	47.0	53.8	57.1	18.4	19.5	24.6	44.5	46.4	43.4
Irrigation canal	1.2	8.9	87.6	6.3	25.8	36.7	0.0	1.7	6.3	5.1	13.0	25.9
Tank	1.3	2.5	16.2	0.0	4.5	7.0	2.3	2.3	4.1	0.0	0.0	3.1
Wells	9.4	4.8	3.2	12.6	12.6	1.5	9.3	9.3	7.3	7.0	6.7	6.1
Tube wells	19.4	13.3	5.5	8.9	14.6	11.0	8.0	8.1	0.6	10.1	13.1	7.1
Pond	31.9	30.9	17.4	26.6	36.8	42.7	27.3	34.8	39.6	23.3	24.9	19.8

*% of sampled households

Viet Nam

The studied villages represent marginal environments in Viet Nam. Both Vu Bon and Nho Lam villages have a canal system for irrigation. It can be seen that in both the villages the percentage of area irrigated increased with time. The main source of irrigation in both the villages was the canal system. In Vu Bon village during the nineties some wells came up and about 10% of the area is irrigated by the wells. It seems that even though the data shows that there was a decrease in rainfed area with time in both the villages, in reality farmers seem to abandon the rainfed area and stopped cultivating it, and the statistics did not take into consideration the rainfed area to estimate the percentage of area irrigated in the recent times. (Table 22d).

Table 22d. Trends in available water sources in the study villages of Viet Nam*

	Vu Bon Village			Nho Lam Village		
Item	**Area Irrigated (%)**					
	1970	**1990**	**2008**	**1970**	**1990**	**2008**
Canal System	50.0	75.0	85.0	40.0	60.0	80.0
Tanks	-	-	-	-	10.0	10.0
Wells	-	10.0	15.0	-	-	-
Tube Wells	-	-	-	-	-	-
Water shed/pond	-	-	-	-	10.0	10.0
Rainfed	50.0	15.0	0.0	60.0	30.0	10.0

China

The selected villages represent marginal environments in China. From the seventies and until recently, most of the crop lands were dependent on rainfall in both the villages. In 2009 the government built a large reservoir near Lucheba village and started supplying water directly to the agricultural farms in Lucheba through a pipeline from the reservoir and water tanks near the farms, and then by supplying water from the tanks through pipelines to the fields. Through this system, at present 50% of the area is being irrigated and the remaining 50% of the area is being irrigated by tanks. In Dajiang village about 5% of the area is irrigated by tanks and about 32% of the area is irrigated by pumping water from the rivers. This way the lowlands and flat lands are being irrigated. In general, the villages are seeing a development of irrigation infrastructure and this is a good adaptation measure to insulate agriculture from the uncertainties of rainfall and associated dry spells during the crop season (Table 22e).

Table 22e. Existing sources of water availability in the study villages of China

	Lucheba Village (central Guizhou)		Dajiang Village(southern Guizhou)	
	ha	**% of total farmland**	**ha**	**% of total farmland**
Tank	80	50.0	10	5.5
Pipe irrigation system	80	50.0	112.8	61.7
Pump Irrigation	-	-	60	32.8

Water is the most important resource that determines production and sustainability of livelihoods. A range of local and external sources of water are seen around the villages. Some do not have access to any form of water other than ground water that gets depleted during a severe drought. On the other hand, through state intervention many villages are provided with water through tanks, canals and wells. Most villagers perceive state sponsored water supply schemes both for home use and irrigation as the most suitable and reliable source.

Sociological Perspectives

India

The following study was made in semi-arid villages of India to bring out the sociological perspective of different groups and communities in the villages, and to distil their views and understand the following: a) their perceptions on climate change; b) vulnerability and adaptation capacity based on their perceptions; and c) adaptation strategies and the associated constraints emerging at the technological, institutional and the socio-economical level of the farmers in the SAT.

For this study, purposive sampling was used to understand and identify perceptions of climate change and subsequent adaptation practices. The sample was separated into large-scale, medium, and smallholder farmers, landless labourers and women. The rationale for this categorization was that each group had different levels of vulnerability and adaptive capacities based on their resource base. Focus group discussions (FGD) and individual interviews were carried out with all categories of farmers, landless labourers and women using semi-structured questionnaires. Among the farming group, sufficient care was taken to interact separately with the first (older) and the second (younger) generation farmers in order to appreciate the differences and similarities in their perceptions and adaptation behaviour. The information gathered was triangulated by means of narratives, timelines and transect walks. A total of 21 FGDs, and 52 individual interviews were conducted.

The analysis process, based on grounded theory, helped to tap the diverse perspectives of different groups and provide insights and develop an in-depth understanding of the issue by probing, clarifying and listening to stakeholders talk about the topic in their own words. Grounded theory is a well-established qualitative method for developing theories and conceptual frameworks in a way that is both inductive and deductive based on long-term fieldwork (Strauss and Barney, 1967). The process was iterative where attempts were made to keep clarifying the understanding of climate change among the respondents. It gave the freedom to the respondents to give their own interpretation of "why" and "how" the phenomenon was happening and "what" they were doing based on their understanding. Key issues that emerged during the first round of data collection were incorporated into the analytical framework and further rounds of elicitation carried out to gain a deeper understanding of the subject. This process helped generate explanations regarding the impact and the adaptations, the role of institutions, technology, participation and collective action that were grounded in the context of climate change.

a) Do the farmers perceive climate change or variability

The farmers perceive climate variability rather than climate change. Analysing these villages it was found that the effects of climate variability were most felt in the villages of Kanzara and Kinkheda in Maharashtra and Dokur in Andhra Pradesh. In the case of the two villages of Maharashtra, the farmers were increasingly beginning to feel the variability in climate over the past five years. There was consensus on this account in Dokur, which was already grappling with drought conditions for the last 18 years. Farmers felt that there had been an increase in temperatures. The farmers also perceived that there have been significant variations in the quantum and distribution of rainfall over the years. They believed that the rainfall was more intense, with fewer rainy days, and an extremely erratic distribution. It was claimed that as compared to the 1970s, when the number of rainfall days were 68 on an average, it had currently reduced to an average of 45 days across the six villages[13] Most of the respondents expressed concern about the off-season rains in the months of May, September and November, that were becoming common in these parts including the villages of Aurepalle, Shirapur and Kalman. For the villagers, the fact that the months of June, July and August did not bring much rain both in quantum and distribution especially in the past five – six years indicated that climate had become more variable, rather than suggesting a consistent change.

b) Constraints to adaptation and vulnerability

The Capability Approach states that one of the factors that influence a person's or group's capabilities to adapt, is the variations in social climate. Simply put, it means that the conversion of resources into function is influenced by social and institutional conditions. According to the approach, wealth or resources alone cannot act as a good indicator for judging an individual's capacity to adapt rather it depends a lot on actual opportunities that a person has than the means (Sen, 1985, 1999; Nussbaum, 2000).The actual opportunities could be in the form of financial access, infrastructure facilities, education and learning, new technologies and practices, social relations and institutions. The adequate utilization of these depends to a large extent on the implementation will and efficiency of the local administration along with the conditioning of socio-cultural factors. The adaptive capacities of individuals or groups are thus influenced by these factors which in turn constrains their capabilities. For instance, in the case of Dokur, the watershed program that was started by the government in 1999 was seen as a positive step in water conservation. However, it was stopped in 2003 without any follow-up to revive it. The community attributed these failures in assistance to the lack of political will and prevalent corruption in the existing system; accentuating that there is a close relationship of risk to power. Groups that have less power and lack of access to resources are unable to determine public perceptions as to what constitutes risk. As a result, public policy responses are shaped by those who are powerful, and policies rarely reflect the needs of the less powerful and articulate sections (Tierney 1994). As an example, the respondents in all the six villages and especially Shirapur complained that there was a dearth in the formal information sources and the guidance in terms of the kind of

[13] The perception of the farmers' seemed quite accurate as this information was confirmed by the first generation ICRISAT resident investigators working in these villages. In addition, the climatic data obtained from the district level concurred with the description of the years of the extreme events by the farmers.

seeds available, shorter duration varieties which were both drought resistant and yet profitable to grow. There was a need expressed as the respondents believed that because of lack of government's initiatives in this regard, most people were ignorant and were continuing farming practices without being aware of what they were using. The respondents of Shirapur mentioned that the canal was an important source of irrigation for them; however there were complaints of malpractices and mismanagement of the water distribution when it came to the village. The influence of the central authorities was most often conflicting with the needs of the locals, which was influencing the water being diverted for industrial use. The issue of poor governance emerged very strongly in Kanzara with respect to the functioning of the Gram Panchayat, as it was considered to be of very little service to them when it came to agricultural aid, especially during climatic shocks. This was a common observation in all the six Indian SAT villages. However, the respondents of Aurepalle and Shirapur pointed out that the probable reason was the limited resource base that the Gram Panchayat had access to, which did not allow them to aid the farmers adequately. The labourers accused the Gram Panchayat of being inefficient regarding the implementation of the National Rural Employment Guarantee Scheme (MGNREGS). A similar concern was shared in Kinkheda regarding the implementation of one of the government schemes called The Pradhan Mantri Gram Rojgaar Yojana[14] (Prime Minister's package for rural employment). The respondents felt that even though the written formalities were complete, the scheme was yet to be put into practice. The medium group of farmers, especially in the villages of Kanzara, Shirapur and Aurepalle, felt that lopsided preferences of the government were an impediment in working better preparing to meet the challenge of the increasing climatic variability.

With regards to formal financial accessibility, other than in Aurepalle, none of the villages under the study had microfinance institutions or private bank establishments. In addition, the need for a co-lateral, negative attitude of the bank and co-operative officials towards smallholder farmers, labourers and women, emerged as deterrents towards approaching these formal institutions for aid. This has led to a high dependence on private moneylenders in the villages and higher incidence of exploitation of smallholder farmers and landless laborers while obtaining credit. Though most of the women relied on their self-help groups (SHGs) for credit and savings, it was observed that the SHGs were running and being managed better in the AP villages as compared to the Maharashtra villages. The Public Distribution System (PDS) no doubt had emerged as one of the most important institutions contributing to adaptive capacity in all the villages. However the point of concern on certain occasions was the quality of the food grains that were made available in the shop. Since there were limited or practically had no choice on getting subsidized food, the community was accepting what was on offer. It was interesting to note however, that in Kinked, the smallholder farmers and the laborers

[14] The program with an objective to provide additional employment wages in rural area in India. This targets the nature, creation of community assets with special emphasis on women, schedule casts, scheduled tribes and parents of children withdrawn from hazardous occupation.

complained that the large-scale and medium farmers were getting the food grains at subsidized rates due to the non-transparent manner in which the local government is distributing the Below Poverty Line (BPL) cards, issued by the central government[15].

The willingness to act together and collectively towards management and access to resources, plays a vital role in increasing or decreasing community or individual capabilities, which goes a long way in determining the resilience level of the community. A key constraint to adaptation was the lack of institutional arrangements for providing access to input and output markets. The reasons they cited were, i) the lack of storage facilities in the villages and the need for finances; as most of the farmers were not very rich, they had to sell their produce immediately after harvest; ii) most importantly they did not have a co-operative of their own with the help of which they could negotiate better prices for themselves. The reason for the absence of the co-operative and storage facilities was attributed to the lack of collective will to create one. A noticeable practice of dairy farming was done in majority of villages viz., Aurepalle, Dokur and Kanzara. However in Kanzara the respondents shared that as an alternate livelihood, it was taking time to be accepted because of the requirement of high investments for the care and maintenance of the animals. In addition, the lack of disposition to work collectively had prevented the villagers from starting a milk co-operative. Similarly, though a co-operative had already started in Dokur, there were complaints of insincerity and lack of commitment from the community as the reasons for its failure in the past. In all the villages it was pointed out that the commonality regarding collective action was the coming together for a wedding, funeral or festivals, which were as part of the cultural and social norms that a community is bound to. However, in Kalman, Kanzara and Shirapur, some form of collective action existed among the farmers for the maintenance of the irrigation canals; otherwise it would hamper water supply to the fields. Barriers to collective action in the villages were cited as mutual distrust and the fear of exclusion and dominance of particular groups.

In all the six villages, the small farmers and labourers emerged as the most vulnerable group. In case of Aurepalle, although becoming a farm servant was supposed to be a livelihood option for smallholder farmers, it appeared as one of the significant reasons for higher vulnerability among them as they got bound to the farmers who they were working for. In Kalman and Kinkheda, the lack of access to formal financial sources and inadequate information about the schemes and benefits available made the laborers and the smallholders dependent on middlemen and the moneylenders who most often than not were misleading them into farming and non-farming practices that were detrimental to their livelihoods, making them susceptible to future climatic shocks. In the case of Kanzara there is a strong possibility that the medium farmers will be the next group to slip into the high risk category as this group appears to depend purely on its own resource base without

[15] It was claimed that the local government had been distributing the BPL cards to the non BPL group; as a result of which they were benefiting from the same The BPL members on the other hand were being forced to buy the grains at a regular price without any subsidies.

any external help from the local government structure. In Dokur, on the other hand, respondents were unanimous that dryland farmers were the most vulnerable group, because their yields are continually affected unless there was adequate rain at the right time and the right amount. However, they did agree that the labourers, though migrating, were also equally vulnerable as they depended a lot on the farm labour, which was dependent on the harvest that the farmers received.

c) Adaptive capacity and behavior

In the villages of SAT India, though the farmers displayed significantly higher levels of adoption of new technologies[16], some of the farmers spoken to in the study villages practiced certain methods that were learnt as part of the farming practices over time.

Box 3: Responses from different strata of SAT- farmers in the study villages of India

School Teacher (Kalman)

When the rains come and it is time for sowing, everyone and all the farmers are in a rush to sow the seeds in the fields. My father always tells me to wait for a few days before I should sow. On asking the reason he told me that the incidence of birds and other creatures eating the seeds are higher during the first few days so it is always better to wait a few days and sow after the farmers have sown.

Second Generation Farmer (Kalman)

Sorghum, the moment it reaches 2-3 feet, the farmers start watering the crops and as a result of which the stalks become thick and heavy and are not conducive for fodder. We do not buy fodder, we use the stalks of the sorghum to feed our cattle and if the stalks are too thick then the animals don't eat them. But if they are small and thin then they eat them. So we keep the stalks thin and small so we use less water. Also if the stalks are big in size and if some uncalled for rains come then the pods tend to fall off easily which doesn't happen if the plant is short and thin in size

Second Generation Farmer (Kanzara)

I don't burn my fields after the harvesting of wheat. The reason why I don't burn my land but till it instead, even though it takes more effort, is because the fertility of the soil gets compromised if burnt. I let the natural heat burn the remains of the wheat post harvesting during the summers as the stubs of the wheat plant is rich in silicon which is good for the soil

It was claimed that the rate of migration among the labourers had increased by 30-40% because of persistent droughts. The large scale farmers were still actively involved in agricultural activities though members of their families were migrating outside the village to look for work as a supporting livelihood strategy. Some of the existing dairy farmers had started the process of creating a milk co-operative by collecting and disseminating information among fellow members and looking forward to the organization being a representation of both men and women milk producers[17]. In the case of Kanzara the instances of in-migration were more than the instances of out- migration. The construction of the airport near Aurepalle and the presence of industries like the sugar factory and the Maharashtra Industrial Development Corporation (MIDC) in Shirapur, had led to traditional coping

[16] New technologies are defined as those technologies which have been introduced to them at some point after the 1950s in India. They include the tractors, fertilizers and pesticides and the more recent hybrid and the short duration seeds.

[17] There is a milk co-operative which is about 5 kms away from the village. The milk is sold to the nearby hotels @ Rs.15/- to Rs.12/- per liter depending on the fat content. The quality of milk is measured based on its fat content. The villagers sell the milk directly even to those traders who come from the cities.

strategies being integrated through diversification of occupations. There was temporary migration taking place to the nearby airport village, nearby towns and the city of Hyderabad, Solapur, Pune and Mumbai. This was especially true in the case of the poor or smaller farmers and the youth who did not mind leaving their farms to pursue other sources of income even during normal years. Often they joined existing people who had earlier left their villages over a given period of time. In the case of Shirapur, some of the respondents had government jobs with fixed salaries. Both the villages displayed the trend of starting small businesses through petty shops and accessories or roadside hotels either in the village itself or on the outskirts. Like in Shirapur, in Kalman, the rate of migration was more to cities like Pune and Mumbai predominantly among the youth. The reasons were access to transport and better wages being paid outside the village as compared to within the village for the labour work[18]. The migrations were mostly short term especially in the event of a loss suffered due to a climatic shock (drought).

In the Maharashtra villages, it was seen that the farmers in Kanzara and Kinkheda had taken to adoption of new, high yielding varieties and short duration crops. The diversification had taken place mainly towards soybean and vegetable growing like coriander, spinach and onions as their growing periods were relatively shorter as compared to food crops. The short growing period allowed the farmers to use the fields to grow more crops both in the rabi and kharif season, and further the high price of soybean that they were getting in the market. An interesting observation was that some of the farmers had used the delayed and less rains to their advantage by intensifying growing cultivation of vegetables like brinjal and cucumber, which grew well under the mentioned conditions. Some of the farmers continued to grow cotton in spite of water shortage as they believed that it was still the most commercially viable choice at their disposal. In Shirapur, it was claimed that the presence of irrigation had reduced the impacts of climate change on agriculture, though efficiency of water usage needed to be improved. The majority of farmers had diversified into growing sugarcane for the last 8-10 years. Among the food crops, pigeon pea and sorghum were grown for subsistence. There were about 3-4% of the farming community who had diversified into horticultural produce, though the production of grapes had drastically reduced as it was found to be highly susceptible to the erratic climatic conditions. In Kalman, some of the medium scale farmers were exploring possibilities of poultry farming. Many farmers were diversifying into growing drumsticks, tomatoes and onions as they were not only less water consuming but also gave good returns in the market. The commonalities in case of Aurepalle and Dokur were in the shift that the farmers had made to short duration paddy seeds[19] since 1995. It was interesting to note though that in Aurepalle, despite this shift along with sunflower and maize, they were continuing to grow groundnut and BT cotton. The government provided subsidies on drip

[18] In the village it is Rs.70 per day but outside the village in the nearby areas or village it is Rs. 80/- on a daily basis for work like road construction work, laying bricks and even maintenance and expanding of the canal work
[19] Unlike the traditional paddy seeds which took almost six months to get ready for harvesting, these seeds would mature and be ready for harvesting in less than four months.

irrigation system to grow groundnut and encouraged the farmers to get back into groundnut growing even though it was water intensive. Like in Kanzara, since BT cotton was perceived to be the most commercially viable crop, most of them had shifted to allocating certain parts of their farms to growing cotton.

A common observation across all the six villages, irrespective of the differences in soils, was that most of the farmers were experimenting depending on the resilience of the crop in terms of what worked and what did not; examples of the same were the short duration pigeonpea and sorghum seeds. It should be noted however, that most of the farmers interviewed acknowledged that in addition to climatic conditions, the reasons for diversifying were the commercial values received for the crops in the market. Particularly worth mentioning were the strong sense of awareness among the farmers regarding the conservation of water and the need for water harvesting to raise the depleting water tables. The villagers in Dokur felt that the revival of the watershed project which was suspended in 2003, would go a long way in solving water shortage problems at least with respect to farming. The suggestion of pricing of water to ensure optimal use of the same in Shirapur was evidence enough of the consciousness for the requirement of judicious usage of water.

The role of institutions is significant in increasing adaptive capacities was observed across the six villages. It was observed that the government programs in the Andhra Pradesh villages; Aurepalle and Dokur were running more efficiently than they were in the four Maharashtra villages. Most of them were quite useful to most members of the village particularly to the labourers and smallholder as compared to the ones in Akola and Solapur. The government had appointed two people from each village as Aadarsh Raitu (Ideal Farmers) for Rs.1000/- (US$ 20) per month to serve as government's agents in the village to inform the community on the subsidies and schemes regarding agriculture. Particularly worth noting was, though the labourers and the small farmers completely relied on the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and the Public Distribution System (PDS), the medium scale farmers were using and benefiting from the same. It can also be assumed that the community themselves, irrespective of socio-economic status, has acquired the use of government programs as a long term adaptation strategy. Though there were governance and accountability issues particularly in the Akola villages of Maharashtra, the small farmers were nevertheless making use of the subsidies given by the government in an attempt to increase their resource base by digging wells and using fertilizers for their fields, though they were also preparing to migrate out if the climatic situations got worse. The main role of government assistance claimed for the labourers and the smallholders farmers had been the provision of support programs like the PDS and the MGNREGS as an aid towards building the adaptive capacities of the mentioned groups against risks including climatic shocks. It was for reasons such as these that the farmers did not mind depending on the input supplier for advice on the varieties available and if the variety was high yielding, short duration as well as drought resistant it worked in favour of the farmers. In the Akola villages, the second generation farmers were also quite forthcoming when it came to asking for advice from the Krishi Vigyan Kendra

(KVKs), which are the agricultural extension service providers designated by the Government of India. However, there was no mention of seeking any form of assistance from the KVKs in the remaining four villages. An interesting observation made in the six villages was that in spite of the uncertainty of rainfall and the potential threat of climate variability increasing in the coming years; the first generation farming community still preferred agriculture over any other form of livelihood. Though crop insurance was not very popular among the farmers because of the lack of understanding of the implementation process, it was acknowledged by the respondents that it was a good mechanism against the variability of climate. The farmers who had taken crop insurance in Maharashtra villages in the last six years had done so as a possible safety against the increasing erratic and uncertainty of the weather conditions.

Women across the study villages were totally dependent on the SHGs not only for financial assistance but as a platform to negotiate access to technology and credit, especially in the Mahabubnagar villages; in the case of Shirapur and Kalman it was more for acquiring credit for non-farming activities like meeting household expenses and starting petty business; whereas in Kanzara and Kinkheda the credit was used for farming activities. This reliance on SHGs was in spite of the fact that they were not running as efficiently as they should be, as compared to Dokur and Aurepalle villages. Dairy farming was emerging as a potential source of livelihood in the study villages; in the case of Shirapur, a particular entrepreneur in the village who had established a milk dairy for collective marketing was offering loans to the small farmers which were paid back through delivery of milk.

Though the co-operatives were not so multidimensional in the six SAT-Indian villages, they played a vital role in financial assistance for the farming community. The medium scale farmers especially, depended on the co-operatives for financial aid as compared to the women who relied completely on their SHGs for any financial assistance, be it for farming or non-farming purposes. For information the second generation farmers in Kanzara were forthcoming about approaching the KVKs, unlike the first generation farmers, though the first choice for counsel on agricultural inputs and crop variety was ICRISAT. It was established in all the villages that social capital was an important factor when it came to the adaptive capacity of a group or individual. It was established in all six villages that social capital was an important factor when it came to the adaptive capacity of a group or individual as, i) it was a source of finding livelihoods on migration to the cities and other places outside the villages, and ii) when there was a bad year or a climatic shock, the first reaction had always been to approach their most trusted people who could be in the form of friends, relatives, parents and even local moneylenders. When asked about the recovery period from a climatic shock, the respondents were of the opinion that the average time frame was at least two years for a farming community and three-four years for a non-farming community, assuming that the year following the climatic shock was a favourable one (Table 23).

Drawing from the studies carried out in the six countries, the key (i) adaptation measures adopted by the villages and enabled by state agencies, (ii) main constraints faced by farmers and agencies, and the (iii) opportunities for optimizing adaptation were synthesized. This synthesis provides the information base from which key conclusions are drawn and policy directives recommended.

Table 23. Recovery period of Various Groups w.r.t Climate Shock/Bad Year

Category of Respondents	**Time Span to recover***			
	Dokur	**Kanzara**	**Aurepalle**	**Shirapur**
Big Farmer	2-3	1-2	1-2	1-2
Medium Farmer	2-3	2-3	2-3	3-4
Small Farmer	3-4	4-5	2-3	3-4
Laborers	3-4	3-4	2-3	3-4
Women	Dependent on Household	Dependent on Household	Dependent on household	Dependent on household

*This is assuming only if the following year is a normal year or a favorable year
Source: Farmer FGDS in Kanzara and Dokur 2009

The preceding sections highlighted important micro level findings of the project on the farmers perceptions on various issues such as the farmers perceptions on climate variability and in response to the key changes that the farmers have introduced in their cropping patterns; the development of input markets and how the farmers are affected;, the status of output markets and farmers perception on marketing their outputs; the options that the farmers have in diversifying into livestock and the way the farmers are using them; the path of diversification of incomes of farmers with time and how farmers have been doing in the practice of better soil management practices over the last four decades; and other issues. The following sections bring out key adaptations that the farmers have been practicing in the last four decades and the farmers' perceptions on the constraints to adaptations in India, Sri Lanka, Bangladesh in South Asia, and Thailand and Viet Nam in Southeast Asia and China.

Predicting future crop needs - results from simulation studies

A range of crops in various combinations and rotations are grown in villages in the semi-arid regions of Asia. The scientific evidence and farmers' experiential knowledge articulated as perceptions indicate clearly the prevalence of long-term trends in climate change. Due to the manner in which nations are carved out of geographically contiguous regions, often analysis does not match eco-systems or agro-climatic conditions, territories that could have similar climatic experiences. On the other hand, when predicting accurately the impact of changes on moisture availability and temperature on crop productivity what can be done are micro-level studies from which inferences may be drawn to homogeneous regions? Simulations require long term reliable data. Such data are not available except for a few locations.

Indian Context

To understand the impact of future climate change on the crop production, simulation modeling is an important tool. Crop growth simulation models will dynamically simulate the crop growth and yield of any specific crop under a given set of weather, soil and crop parameters that are user defined. In an attempt to understand the crop growth and yields in the study locations in India under future weather conditions, CMS CERES-Sorghum and CROPGRO-Groundnut models, which are a part of the DSSAT v4.5 (Jones et al., 2003) were used to simulate kharif and post-rainy sorghum and groundnut yields. The major components of these models are vegetative and reproductive development, carbon balance, water balance and nitrogen balance. The models need input of daily weather data (maximum and minimum temperatures, rainfall and solar radiation), crop- and cultivar-specific parameters and soil profile data on physical and chemical properties. The models simulate growth and development using daily time step from sowing to maturity, and ultimately predict yield. Cultivar-specific coefficients (genetic coefficients) for sorghum, crop variety CSV 15 and for groundnut JL 24 were used as inputs to the models to simulate their growth and yield in the targeted environments. Crop yields were simulated for 40 and 80 kg/ha of nitrogen for sorghum during kharif season in Mahabubnagar (Andhra Pradesh) and Akola (Maharashtra), and 40 kg/ha of nitrogen during rabi season in Solapur (Maharashtra) district of India. In case of groundnut the crop was simulated for the kharif season in Anantapur district of Andhra Pradesh with an input nitrogen of 18 kg/ha. These simulations were carried out in Mahabubnagar and Anantapur districts in the state of Andhra Pradesh, and Akola and Solapur district in Maharashtra.

The baseline climate data as well as the future projected climate data values of maximum and minimum temperatures and rainfall predicted by the UKMO-HADCM3 GCM model for the SRES A1B scenario for the study districts in India for 2030, 2050 and 2080 were collected from the CIAT portal and used for the study as inputs to the model.

To understand the impact of climate change, long-term simulations for four different scenarios for two crops and four districts were performed. They are, a) Baseline weather data without climate change; b) Weather data of 1980-2010 period without climate change; c) Baseline weather data with projected changes in temperature (T) and rainfall (R) incorporated; and d) Baseline weather data with projected changes in T, R and CO_2 incorporated. This study brought out the following points.

Sorghum: Productivity of both kharif and rabi (post-rainy) sorghum will decrease by shortening of its life cycle (crop duration) and decreased crop growth due to increased water and temperature stress. If this is associated with an increase in CO_2 with climate change, it will minimize the yield reductions (Table 24). Progressive increase in the climate change decreased the crop duration of kharif sorghum by 11% in both the locations. The yields decreased by 18% in Mahabubnagar and 10% in Akola district by the year 2080 in a scenario where the effects of increased temperature, rainfall as well as elevated CO_2 are taken into consideration. In fact, there was actually some beneficial effect due to the elevated CO_2.

Groundnut: Productivity of groundnut is also affected in the same way as that of sorghum, except that its crop duration will decrease or increase depending upon the current temperatures of the sites and future climate change. At both Mahabubnagar and Anantapur sites the crop duration somewhat increased with climate change because of the resultant above optimum mean temperatures (>28^{o}C), which slowed down phenological development in groundnut. Increase in CO_2 with climate change will be more beneficial to groundnut than to sorghum, and its benefit could be as high as 24% increase in pod yield with climate change (Table 24). In spite of the beneficial effect of CO2 groundnut yields will be adversely affected because of direct and indirect effects of high temperatures and increased water stress. The traditional growing environments in Anantapur showed a potential reduction of 8, 10 and 13% in the yields in the years 2030, 2050 and 2080 when the combination of temperature and rainfall, as well as increased CO_2 are considered. In Mahabubnagar district a small benefit due to the increase in CO_2 can be seen.

It is concluded in the business as usual scenario that climate change impact on food crop productivity is imminent in South Asia (DFID, 2011), and to enhance crop productivity in the future climates we will need sorghum and groundnut genotypes with a range in crop duration (short to long duration) with high yield potential and tolerance to high temperature and drought stress (Craufurd and Wheeler 2009; Challinor et al. 2007). As different regions will be affected differently by climate change, the deployment of new genotypes will vary with the target region. The study has also shown that agronomic management, especially the dates of sowing and nutrient management, will have to be reworked to optimize the yields towards higher productivity.

These studies suggest the importance of simulations for other crops and locations in order to assess future trends in production levels. Such estimates can provide objective information of greater accuracy for planning effective mitigation to prepare for crop yield losses. It will to be correct simply to extrapolate these estimates to the national extents cultivated or total yields reported without considering the local variability in cultivation contexts.

Table 24:- Impact of future changes in temperature (T), rainfall R and carbon dioxide (CO2) on the yield

Time period	Climate change	Maturity		Grain Yield (% Change)	
		Days	Change	N = 40kg/ha	N = 80kg/ha
Kharif Sorghum in Mahabubnagar					
1980-2010	Nil	110		3038 (kg/ha)	3586 (kg/ha)
2030	T + R	106	-4	-8	-12
2030	T + R +CO2	106	-4	-6	-9
2050	T + R	103	-7	-15	-21
2050	T + R +CO2	103	-7	-10	-15
2080	T + R	99	-11	-24	-32
2080	T + R +CO2	99	-11	-18	-25
Kharif Sorghum in Akola					
1980-2010	Nil	111		3765 (kg/ha)	4305 (kg/ha)
2030	T + R	107	-4	-6	-5
2030	T + R +CO2	107	-4	-4	-3
2050	T + R	104	-7	-11	-11
2050	T + R +CO2	104	-7	-7	-7
2080	T + R	101	-10	-15	-18
2080	T + R +CO2	101	-10	-10	-11
Rabi Sorghum in Solapur					
1980-2010	Nil	109		1556	-
2030	T + R	103	-6	-7	-
2030	T + R +CO2	103	-6	-3	-
2050	T + R	99	-10	-14	-
2050	T + R +CO2	99	-10	-5	-
2080	T + R	95	-14	-22	-
2080	T + R +CO2	95	-14	-11	-
Groundnut in Anantapur					
1980-2010	Nil	108		1354	-
2030	T + R	108	0	-18	-
2030	T + R +CO2	108	0	-8	-
2050	T + R	109	1	-24	-
2050	T + R +CO2	109	1	-10	-
2080	T + R	112	4	-31	-
2080	T + R +CO2	112	4	-13	-

Drawing from the studies carried out in the six countries, the key, (i) measures adopted by the villages and enabled by state agencies (ii) main constraints faced by farmers and agencies and the (iii) opportunities for optimizing adaptation were synthesized. This synthesis provides the information base from which key conclusions are drawn and policy directives recommended.

Viet Nam context

Using an integrated modeling framework, the impacts of climate change on water resources, especially availability of water, and the yields and production of major crops[Ψ] in Viet Nam were computed. Crop simulations indicated that temperature rise is the main factor that causes crop yield decline in Viet Nam under the climate change conditions. This is primarily due to the situation that some crops already grow near or above their optimal thermal ranges. Yield reductions varied widely across crops and agro-ecological zones and under different climate change scenarios. For rice, the worst yield reductions are about 12% in the Mekong River Delta and about 24% in the Red River Delta (Table 25). Across zones, Central Highlands tend to have the highest crop yield decline under the studied climate change scenarios. Country-wide, rice yield decreases between 10% and 20% in 2050 with and without CO_2 fertilization. By 2050, climate change might reduce annual rice production by 3.1 to nearly 6.7 million metric tons. Sea level rise can seriously affect rice production in the Mekong River Delta. By 2050, nearly 0.5 million ha of rice cultivation area may be lost due to increased inundation and salinity intrusion. This can result in a rice production loss of about 2.7 million metric tons, accounting for more than 14% of the Mekong Delta's present rice production or more than 7% of national rice production in 2007 (Zhu T and Van Trinh 2010).

Table 25. Predicted impact of climate change on crop productivity in Viet Nam*

Agro-ecological Region / River Basin	Projected features of the future climate (2050)		Quantifying impacts on crop yield (%)	
	Annual Temperature (°C)	Annual Rainfall (%)	Rice	Other crops[Ψ]
Northwest	1.3 to 2.2	-12.7 to 19.4	-11.1 to -28.2	-5.9 to -23.5
Northeast	1.3 to 2.2	-11.8 to 13.5	-4.4 to -39.6	-2.7 to -38.3
Red River Delta	1.3 to 2.2	-9.2 to 10.1	-7.2 to -32.6	-4.1 to -32.9
North Central Coast	1.4 to 2.0	-7.0 to 10.0	-7.2 to -32.6	-4.1 to -32.9
South Central Coast	0.9 to 1.6	-9.7 to 5.7	-8.4 to -27.0	-4.0 to -20.9
Central Highland	0.9 to 1.6	-5.6 to 6.0	-11.1 to -42.0	-7.5 to -45.8
Southeast	1.0 to 1.5	-5.0 to 6.3	+4.3 to -8.8	-3.0 to -22.7
Mekong River Delta	1.0 to 1.5	-6.3 to 6.3	-6.3 to 12.0	-3.4 to -26.5

* Range of possible impacts on yield.
[Ψ] Major crops includes Maize, cassava, sugarcane, coffee and vegetables

Analyzing economic impact of climate change – farm revenue

a) Impact of climate change on net revenue of rice and other major crops in Andhra Pradesh, India

The present study is aimed to quantify the impact of climate change on agriculture in Andhra Pradesh districts of India by employing the Ricardian modeling approach. The study focused on the changes in net revenue of a) paddy crop and b) major 14 crops (Appendix 3) due to change in climate variables. The dataset for the present study included three types of panel data i) climatic ii) crops area and production and iii) socio-economic. The study included 14 major crops grown in over 20 districts of Andhra Pradesh for 39 years during the period 1970-2008. The climatic variables included the temperature and precipitation during the four seasons, viz., south west, north east, winter (Jan-Feb) and post-winter (Mar-May). Crop variables included were area and production under each crop. The technological variables were fertilizer consumption (N, P, K), density of tractors and pump sets etc. These data were collected from various government department published sources. Other socio-economic variables including demographic and infrastructural variables were used as control variables in the model.

Table 26: District wise marginal impact of climate variables on the net revenue per ha for rice (US$/ha)

Region*	TSW	TNE	TW	THW	RSW	RNE	RW	RHW
Adilabad	-1.94	-0.77	2.90	0.20	-0.01	0.00	-0.01	0.01
Anantapur	-4.20	-0.50	2.87	3.37	-0.01	0.00	-0.02	0.01
Chittoor	-3.03	-0.65	2.94	4.03	-0.01	-0.01	-0.01	0.01
Cuddapah	-2.88	-1.04	2.85	2.29	-0.01	0.00	-0.02	0.01
East Godavari	-1.16	-2.96	2.86	2.64	-0.01	0.00	-0.01	0.01
Guntur	-0.83	-2.92	2.78	1.12	-0.01	0.00	-0.01	0.01
Hyderabad	-2.56	-1.65	2.82	0.92	-0.01	0.00	-0.01	0.01
Karimnagar	-2.44	-0.59	2.90	1.05	-0.01	0.00	-0.01	0.01
Khammam	-1.26	-2.77	2.81	1.08	-0.01	0.00	-0.01	0.01
Krishna	-1.01	-2.87	2.81	2.11	-0.01	0.00	-0.01	0.01
Kurnool	-2.22	-2.32	2.74	0.62	-0.01	0.00	-0.02	0.01
Mahabubnagar	-2.47	-2.19	2.76	0.55	-0.01	0.00	-0.02	0.01
Medak	-3.22	-0.70	2.87	1.20	-0.01	0.00	-0.01	0.01
Nalgonda	-2.52	-1.13	2.87	1.54	-0.01	0.00	-0.01	0.01
Nellore	-0.67	-2.88	2.78	1.48	-0.01	-0.01	-0.01	0.01
Nizamabad	-3.06	-1.07	2.86	0.81	-0.01	0.00	-0.01	0.01
Srikakulam	-3.59	-0.06	3.08	6.27	-0.01	0.00	-0.01	0.01
Visakhapatna	-1.95	-1.84	2.92	3.31	-0.01	0.00	-0.01	0.01
Warangal	-1.73	-1.98	2.83	0.72	-0.01	0.00	-0.01	0.01
West Godavari	-0.87	-3.15	2.82	2.53	-0.01	0.00	-0.01	0.01
Total	**-2.18**	**-1.70**	**2.85**	**1.89**	**-0.01**	**0.00**	**-0.01**	**0.01**

*TSWM: Temperature south west monsoon; TNEM: Temperature north east monsoon; TWP: Temperature Jan-Feb; THWP: Temperature Mar-May; RSWM: South west monsoon precipitation; RNEM: North east monsoon rainfall; RWP: Rainfall Jan-Feb; RHWP: Rainfall Mar-May.

The analysis revealed that the south west and north east monsoon temperatures have a decreasing effect on the net revenue across all the districts, though impact varied across the districts and the differential impacts depend on the location (Table 26). At aggregated level, for instance, in Andhra Pradesh, one degree rise in temperature during the southwest monsoon resulted in decrease of US$2.18 per ha. Similarly temperature rise during northeast monsoon will have the maximum adverse effect in the West Godavari Region, which is predominantly a rice growing region with an impact of US$3.17 per ha. However, temperature has a positive effect on rice crop net revenue during the remaining two seasons. In the case of rainfall, southwest and northeast monsoons too have a negative effect, but the impacts were not substantial.

Table 27: - Marginal impact of climate variables on the net revenue from major crops$^{\Psi}$ in districts of Andhra Pradesh, India (US$/ha)

Region	**TSW**	**TNE**	**TW**	**THW**	**RSW**	**RNE**	**RW**	**RHW**
Adilabad	0.71	0.03	0.58	0.19	0.01	0.01	0.04	0.01
Anantapur	-5.54	0.09	-0.08	1.59	0.02	0.00	0.05	0.01
Chittoor	-2.31	0.06	1.57	1.88	0.02	0.00	0.04	0.01
Cuddapah	-1.89	-0.02	-0.49	1.11	0.02	0.00	0.05	0.01
East Godavari	2.88	-0.42	-0.33	1.26	0.01	0.00	0.04	0.01
Guntur	3.77	-0.41	-1.95	0.59	0.02	0.00	0.04	0.01
Hyderabad	-1.00	-0.15	-1.13	0.50	0.01	0.01	0.04	0.01
Karimnagar	-0.69	0.07	0.75	0.56	0.01	0.01	0.04	0.01
Khammam	2.60	-0.38	-1.26	0.57	0.01	0.01	0.04	0.01
Krishna	3.28	-0.40	-1.28	1.03	0.01	0.00	0.04	0.01
Kurnool	-0.08	-0.29	-2.82	0.37	0.02	0.01	0.05	0.01
Mahabubnagar	-0.75	-0.26	-2.43	0.34	0.02	0.01	0.05	0.01
Medak	-2.83	0.05	0.07	0.63	0.01	0.01	0.04	0.01
Nalgonda	-0.90	-0.04	-0.04	0.78	0.02	0.01	0.04	0.01
Nellore	4.22	-0.40	-1.96	0.75	0.02	0.00	0.04	0.01
Nizamabad	-2.39	-0.03	-0.15	0.45	0.01	0.01	0.04	0.01
Srikakulam	-3.86	0.18	4.58	2.87	0.01	0.00	0.04	0.01
Visakhapatna	0.67	-0.19	1.20	1.56	0.01	0.00	0.04	0.01
Warangal	1.28	-0.22	-0.86	0.42	0.01	0.01	0.04	0.01
West Godavari	3.68	-0.46	-1.08	1.22	0.01	0.00	0.04	0.01
Total	**0.04**	**-0.16**	**-0.36**	**0.93**	**0.01**	**0.00**	**0.04**	**0.01**

*TSWM: Temperature south west monsoon; TNEM: Temperature north east monsoon; TWP: Temperature Jan-Feb; THWP: Temperature Mar-May; RSWM: South west monsoon precipitation; RNEM: North east monsoon rainfall; RWP: Rainfall Jan-Feb; RHWP: Rainfall Mar-May.

$^{\Psi}$The major crop includes

Further, it can be deduced that most of the marginal effects of temperature during the first three seasons are negative; implying that one unit increase in the respective climate variables will decrease the net revenues. For example, southwest monsoon temperature and Jan-Feb temperature have a strong negative impact on many districts. Anantapur district has the most negative marginal net return of US$5.54 during the southwest monsoon season (Table 27). Rainfall in all seasons had positive marginal impacts in all districts even though they are small. The analysis revealed that climate variables do have significant negative effects on crop revenue for Andhra Pradesh districts, a major state falling under the semi-arid zone of India. Among the climate variables, the southwest monsoon season temperature and rainfall seem to have a significant effect on crops. The impacts were not uniform across the districts. The impact was profound in Anantapur district for rice and all the major crops. It is hoped that these findings will help policy makers, planners and extension workers to formulate suitable adaptation strategies relating to technology, crop management practices and other related strategies to nullify the negative effects of climate variables on agricultural production.

b) Impact of climate change on farm revenue in northeastern region of Thailand

An economic analysis on the impact of climatic variables on net revenue from major crops (rice, cassava, maize, mungbeans, etc.), and also an analysis specifically for rice and cassava, were done for the northeastern region of Thailand. These two crops, i.e., Cassava and rice, are major crops cultivated in this region. Ricardian approach (Mendelsohn et al. 1994) was adopted as the framework for analysis. Climatic and socio-economic data were collected from all 19 provinces constituting the northeast region of Thailand. The analysis showed that relationship between climate (especially rainfall) and crop net revenue varied in crop types and seasonality. Increasing rainfall in winter will be harmful for crop production because it is the period of harvesting. However, high rainfall in summer is beneficial. It is also found that the relationship of rainfall on crop and the resultant net revenue from rice in early rainy season is a hill shaped curve since excess rainfall can cause flooding and crop damage. The overall econometric results showed that the effect of coefficients of climatic variables is statistically significant with non-linear relationships. The negative impacts of temperature on net revenue rise with increase in annual temperature. The estimates highlighted that an overall rise in temperature by 1°C will reduce the net revenue by US$0.21 to US$ 1.58/ha (Table 28). Furthermore, 1mm rise in rainfall enhances the net revenue by US$0.001 - 0.01/ha. The impact of temperature on cassava is higher than rice, and cassava has a slightly better advantage from increased rainfall than rice.

Table 28. Marginal Impact of Climate Change on Net Revenue[@] of major crops, rice and cassava in the Northeast Region of Thailand, Year 2001-2008.

	Marginal Net Revenue Of major Crops Ψ	Marginal Net Revenue Of Rice	Marginal Net Revenue Of Cassava
Climatic Factors			
Winter Temperature(°C)	-1.29	-0.95	-1.64
Summer Temperature(°C)	0.72	1.72	1.3
Early Rain Temperature (°C)	-0.41	-0.02	-0.99
Late Rain Temperature(°C)	-0.61	-0.95	0.61
Overall Temperature	-1.58	-0.21	-0.72
Winter Rainfall(mm.)	-0.01	-0.01	-0.06
Summer Rainfall(mm.)	0.004	0.01	0.004
Early Rain Rainfall(mm.)	0.01	0.001	0.06
Late Rain Rainfall(mm.)	0	-0.005	-0.001
Overall Rainfall	0.01	0.001	0.004

[@]US$/ha; Ψ Crops includes rice, maize, mungbeans, cassava, sugarcane, millet, oil palm, soybeans, groundnuts, coconuts, sesame, castor beans, garlics, shallots, onions, potatoes, chillies, tomatoes, baby corn, pineapples, longans, rambutans, durians, mangosteens, lichees, tangerines, longkongs, guavas, lemons, bananas, coffee, para rubber, pepper, tobacco, and orchids.

Adaptation measures - how the farmers are practicing at micro level

A summary of the adaptation measures is presented below, drawing from the conceptual frame presented. The summarizing is at the four levels of action required, i.e., household, community and national (macro)

Figure 12: A framework for synthesizing adaptation strategies at ground level and enabling conditions.

The strategies adopted at the house holds level are a result of several factors as presented in the conceptual model elaborated in Figure 12.

It is well known and widely accepted that farmers are rational and also conservative, and the majority are risk aversive. The prevailing array of practices adopted by farmers in each village is unique and specific to the location, with some commonalities in the regions. The practices adopted at present are a result of the following factors:

At the household level:

i. Intergenerational knowledge transfer based on primarily experiential learning
ii. Household resource base – savings, assets, wealth, skills and competencies, social contacts

Community Level:

i. Leadership
ii. Collective ethos guiding action for community interests
iii. Groups addressing common needs
iv. Penetration of external agencies

v. Resource base – land, water, forests, infrastructure

National / Governmental:

i. State agencies with extended mandates to the periphery
ii. Supporting legislation and institutions that enable households and communities to act considering local context
iii. Resource transfer to periphery

Global / Regional

i. International agreements and conventions
ii. Interagency programs
iii. Regional initiative and programs

The situation in each of the countries and study locations is elaborated below and a template summarizing specific adaptation strategies classified by levels of action are presented in Table 29.

Table 29:- Summarized information on adaptation strategies or initiatives adopted at different level among the partner countries

Sl. No.	Adaptation strategies adopted at different level of organization	India	Sri Lanka	Bangladesh	Thailand	Viet Nam	China
	Household level:						
1	**Intergenerational knowledge transfer based on primarily experiential learning:**						
	Adopt improved varieties and short duration crops	√	√	√			
	Substitute cash crops for cereals	√		√			
	Drought tolerant crops i.e., cotton, sorghum	√				√	
	Dug tube wells to supplement water supply.	√				√	
	Adaptation improved short varieties duration crops	√					
	Reduce high water requiring rice cultivation.	√					
	Adopt mixed cropping including glow water required crops i.e., castor and pigeon pea	√			√		
	Shifting to mono-cropping of soybeans	√					
	Increase sugar cane or other high value cultivation (canal irrigation)	√			√		
	Delayed cultivation to conserve rain water	√					
	Income diversification (Dairy, fish farming)	√	√	√		√	
	Wheat cultivation during rabi with supplementary irrigation	√					
	Change from seasonal to perennial crops				√		
	Changing traditional / seasonal crops to short duration cash crops/high value cops		√				√
	Farm mechanization		√				
	Adaptation of hybrid varieties		√				
	Work as labour					√	
	Diversification to non-farm income source	√			√		
	Migration	√		√			
	Enriching soil fertility through organic amendments (organic manure,				√		

2	**Household resource base – savings, assets, wealth, skills and competencies, social contacts**						
	Reduction of personal expenses	√			√		
	Community Level						
3	**Leadership**	√	√				
4	**Collective ethos guiding action for community interests reflected in groups addressing common interests;**						
	Establish self-help micro-credit groups.	√	√		√		
	Kinship support systems		√		√		
5	**Penetration of external agencies**						
	Establishing milk collecting centers	√					
6	**Resource base – land, water, forests, infrastructure**						
	National/Governmental						
7	**State agencies with extended mandates to the periphery**	√			√		√
8	**Supporting legislation and institutions that enables household and communities to act considering local context**						√
							√
9	**Resource transfer to periphery**						
	Input subsidies during peak requirement periods		√				√
	Global / Regional						
10	International agreements and conventions	√	√	√	√	√	√
12	Regional initiatives and programs	√	√	√	√	√	√

India

Adaptation measures exercised by the farmers in the six villages shown below are elicited from interactions with the farmers through various means. Most of these adaptation measures are autonomous and the farmers chose them to address the changing situations, and it may not necessarily be due to climate variability but quite often a complex situation arising out of a combination of reasons.

<u>Aurepalle</u>

- Adaptation of improved varieties and short duration crops and varieties.
- Farmers slowly went for cash crops in the place of cereals as an adaptation measure. At present dominated by cotton cultivation on more than 70% of the area.
- During the last decade farmers in the village rapidly formed as many as 45 various self-help groups (SHGs). Notable among them are a few micro finance groups to get easy access to capital for their farm inputs and other needs. This is a viable adaptation strategy to the increasing risk of agriculture.
- In the recent decade three new milk collection centers came up in the village and this is seen as evidence that an increased diversification of incomes away from the traditional crop production is an adaptive measure that will reduce the risk of income loss due to increased variability of rainfall and droughts.
- Water for "on demand irrigation" eliminates the risk associated with the variability in rainfall. Farmers recognize this as an important adaptation measure. The recent decade saw the rapid increase in the tube well numbers in the village. At present there are about 212 tube wells in the village. Over the decades exploitation of ground water has rapidly increased.

<u>Dokur</u>

- Adaptation of improved varieties and short duration crops and varieties.
- Dokur has more than 50% of area growing rice. The rice area decreased with time and more drought tolerant crops like castor are adopted by farmers in the village.
- Mixed cropping is adopted and at present castor + pigeonpea is one of the mixed cropping systems that the farmers practice in this village.
- In the recent decade 15 various farmer associations and 32 self-help groups including micro-finance groups came up in the village and they are seen as effective adaptation strategy to cope with the risk from increasing rainfall variability, and droughts.
- In the recent decade the farmer's incomes diversified and a new milk collection center came up in the village. The recent decade saw the rapid increase in the tube well numbers in the village and at present there are about

220 tube wells in the village. Over the decades exploitation of ground water has rapidly increased.

Shirapur

- Adaptation of improved varieties and short duration crops.
- Farmers in Shirapur have chosen sugarcane and now it is grown on more than 70% of their lands. This gives assured cash incomes a ready market, due to the sugar mills that came up near the village.
- About 70% of the rainfed area is sown with sorghum in the post rainy season with no crops grown on these lands during the rainy season to allow it to conserve moisture during the rainy season. Post rainy season sorghum is grown on residual and stored soil moisture.
- In the recent decade, as many as 15 self-help groups came up in the village to cope with the risk from increasing rainfall variability and droughts.
- Farmers in this village see dairy activities as diversification of incomes and as an adaptive measure to reduce the exposure to increased risk of rainfall variability and droughts.
- The recent decade saw the rapid increase in the tube well numbers, and at present there are about 350 tube wells in the village. Over the decades exploitation of ground water has rapidly increased.

Kalman

- Adaptation of Improved varieties and short duration crops.
- Most of the farmers grow pigeonpea under rainfed conditions during the rainy season. They have adapted improved short duration cultivars.
- More than 70% of the cropped area is sown with sorghum during the post rainy season as it can grow on the residual soil moisture.
- In the recent decade as many as 39 self-help groups came up in the village as an effective adaptation strategy to cope with the risk from increasing rainfall variability and droughts.
- The recent decade saw an increased number of milk collection centers and a new milk cooperative in the village. Farmers see the diversification of incomes into dairying and others as an adaptive strategy to cope with the risk of depleted incomes due to increased variability of rainfall and droughts.
- The recent decade saw rapid increase in the tube well numbers, and at present there are about 160 tube wells in the village. Over the decades exploitation of ground water has rapidly increased.

Kinkheda

- Adaptation of improved varieties and short duration crops
- To address the variability of rainfall, majority of the farmers grow mixed crops to reduce their risks of crop failure. More than 60% of the area in the rainy season is under mixed crops of soybean and pigeonpea or cotton and pigeonpea.
- Wheat is grown on the lands with supplementary irrigational facilities during the rabi season.
- In the recent decade as many as 11 self-help groups came up in the village as an effective adaptation strategy to cope up with the risk of increasing rainfall variability and droughts.
- Farmers recognize the importance of irrigation in reducing the risk of variability of rainfall. Exploitation of ground water is not so rapid in this village.

Kanzara

- Adaptation of improved varieties and short duration crops.
- Farmers changed from growing sorghum and cotton and slowly shifted to growing soybean. At present soybean is grown as a sole crop as well as mixed crop on more than 70% of the area in the village. Farmers chose modern short duration and drought tolerant soybean varieties to increase their income.
- As many as 4 different farmers associations and 14 self-help groups came up in the village in the recent decades and farmers see them as an effective adaptation measure to cope with the risk associated with the increasing rainfall variability and droughts.
- The recent decade saw an increase in the milk cooperative in the village and farmers see it as an adaptive measure to address the increased risk due to increased rainfall variability and droughts.
- In this village there was a rapid expansion of the number of open wells in the recent decade (about 108 at present) irrigation is seen as an important adaptation measure by the farmers.

Sri Lanka

Major adaptation strategies followed in the villages to reduce the risk of variability in rainfall are as follows.

Mangalapura Village

- Change from seasonal crop cultivation to perennial crop cultivation,
- Providing subsidy to input requirements.
- Use of short duration varieties, hybrids and drought tolerant varieties.

- Establishment or strengthening of kinship ties.
- Diversification of means of livelihood by marginal and small farmers.

Gaalahitiyagama Village

- Changing from traditional crops to short duration cash crops is a major adaptation.
- Adapted a short duration hybrid maize variety (Pacific) as a cash crop.
- Input subsidies at the peak requirement period.
- Introduction of mechanization and adaptation of hybrid varieties.
- Establishing kinship ties to aid at difficult times.

Bata-Atha village

- Input subsidies provided at the peak requirement period for cultivation.
- Diversification of means of livelihoods by marginal and smallholder farmers.
- Shifting from seasonal crop cultivation to short term cash crops.

Bangladesh

Adaptation to climate change is seen as a strategy to face changes in climatic variables and minimize their impacts on the life and livelihood activities. Adaptation measures are usually taken to address the uncertainties in the weather elements such as rainfall. Farmers at the micro level have been facing these rainfall variabilities from season to season. They are adjusting their agriculture to best address the variability. This study tried to capture the farmer's adaptation measures in the marginal environments.

Drought Prone Villages

Boikunthapur and Khudaikhali Villages

- Farmers are turning to irrigation based Boro rice and maize cultivation to address rainfall variability.
- Jute cultivation saw a major decline due to uncertainties in rainfall and non-availability of water bodies for jute retting.
- Traditional crops like mustard and other cereals are on the decline.
- Temporary migration of smallholder and marginal farmers is increasing.
- Contribution of income from non-farm activities is increasing.
- Cultivation of traditional cereals and oilseeds were partly replaced by betel leaf cultivation.

Flood prone villages

Nishiagunj Village

- Farmers have diversified with fish cultivation or aquaculture in their fields.
- Traditional cultivation of rice got reduced and fish cultivation replaced most of the rice cultivation.
- Jute cultivation has declined drastically in the recent times.

Paschim Bahadurpur Village

- Farmers are no more cultivating jute as it needs plenty of water for processing.
- Jute is replaced by several pulses, vegetables and tobacco.
- Wheat cultivation has also declined due to farmer's perception that the winter duration has decreased.
- Due to increased rainfall variability, Aus rice cultivation has declined.
- Better access to micro-finance is seen as another adaptation measure by the farmers.
- Improved mechanization in recent times.

Thailand

Lowland villages

Migration was very high in Don Plai village during the severe drought of 1981-82 the most unforgettable tragedy to the farmers of DP village. They recollect that all the able bodied villagers left the village leaving the very young and old in the village. The entire rice crop was lost.

Adaptation measures that the farmers of DP and KS villages followed over the years that came up during the FGDs are shown below.

- Decreased their personal expenses.
- Medium and large land holders store rice for their own consumption instead of selling in the markets.
- Temporary migration in times of extreme events.
- Income diversification through handicraft making (in KS village) and working as factory labor.
- Grow less water-demanding crops such as cassava, or short duration crops like maize.
- Delayed planting of rice

- Change from transplanting to broadcasting of rice
- Shift cassava growing to marginal lowlands to prevent the effect of longer dry spells.
- Small and large farm holders access loans to invest in better inputs and irrigation.
- Soil improvement using organic matter and crop residues.
- Increasing crop intensity as the irrigation potential has improved due to construction of canals.

Farmers' adaptation strategies in the upland villages

- Farmers reduced their personal expenses.
- They sometimes borrow money from their friends and relatives.
- Digging and deepening wells in the village.
- Change from transplanting to broadcasting rice.
- Growing Kenaf/Roselle was stopped due to less availability of water for processing.
- Increased irrigation facilities on a fraction of land encouraged sugarcane growing as a cash crop. Switched to short duration crops like maize.
- Income diversification from non-farm sources like silk weaving etc.
- Access to loans from coop-societies and banks to invest in agriculture.
- Soil improvement through organic inputs and incorporation of crop residues.
- Increasing crop intensity through growing vegetables (TT village).

Viet Nam

Farmers in both Phuoc Nam and Phuoc Dinh communes have followed the adaptation measures described below.

- Shift to less water demanding crops
- Investments to establish cash crops and on increased irrigation infrastructure by large farmers
- Diversification into livestock, especially poultry, for reducing risk
- Improving water sources by deepening wells, desilting ponds and tanks.
- Shift to aquaculture in Phuoc Dinh commune.
- Working as farm labor to supplement the farm income (specially marginal and smallholder farmers)

- Diversifying into part time business and salaried service to supplement income.

China

Among all the countries, China has a different path and the government has a decisive role in the farmers' adaptation measure. In the rest of the countries, most of the adaptation measures that the farmers have implemented are autonomous. In the case of Chinese farmers almost all the adaptation measures are guided by the government and seem to go towards climate smart measures. The following are some of them that have evolved from the study.

Protect and increase the forest cover around the villages

Government planned to transform around 60% of the land around Lucheba and Dajiang villages into forests. Now the forest coverage is close to 40% around Lucheba and 20% around Dajiang. It was estimated that one growing tree could absorb 18.3 kg of CO_2/annum. If there is roughly 2t of CO_2 emission per farmer in one year, to balance that 110 trees, or 0.13 hm^2 of forest land is estimated to be needed. Based on these calculations the government is planning an afforestation drive.

Saving power and developing several alternate renewable power sources.

Installation of biogas tanks: The government estimates that one tank could save 700 kwh of electric power per year if one hour of biogas per day is used. By that it could reduce 1.5 ton of CO_2 emission, which is estimated as equal to single farmer's carbon emission. About 75% of the households are covered by biogas installations.

- Saving power by installing power efficient lamps.
- Reduction in the use of coal.
- Reduction in the use of firewood.
- Saving gasoline in farm operations.
- Using solar power.

Government is taking initiatives in the implementation of all the above measures.

Enhancing infrastructure development

Government is improving the infrastructure for irrigation.

- An irrigation and drainage system has been developed by the government in Lucheba village to supply water through a pipeline to the farm gates in the village

- Increase and improve the farm mechanization to increase cropping intensity
- Construction of small water tanks

  About 300-400 small water tanks (store 4~6 m^3 water) were constructed in Lucheba village since 2003, which provide water for supplementary irrigation for the crops.

- Changing cropping system by increasing the cropping intensity.

  Farmers have increased cropping intensity by shifting from traditional cereal production to vegetable cultivation and taking three to four crops in a year.

Constraints to adaptation as perceived by the farmers

Adaptation to any change in the system is essential to sustain the productivity and profitability for the farmers. Usually, the changes in the system be it physical, economical, sociological or political, do not come as an isolated phenomenon specific to that field. In a real situation the changes are usually manifested in a complicated way. Quite often there will be a combination of changes ranging from physical to economic to administrative. Farmers usually go for autonomous adaptations in response to these complex changes keeping in view their adaptive capacities and optimizing their resources. Quite often the disadvantaged sections like marginal and smallholder farmers are kept away from adapting such measures due to several constraints. The following are some of the identified constraints across the villages in each country and across the selected countries in Asia.

India

The interactions with the farmers in the study villages and longitudinal panel data highlighted the following constraints faced by the farmers in adaptation of suitable measures.

Box 4: Adaptation constraints experienced by Indian SAT farmers

Field level
- Non-availability of drought varieties
- Difficulty in supplementary irrigation

Farm Level
- Lack of access to information on climate
- non-availability of potential technologies including improved varieties
- No capacity for crop diversification

Institutional Level
- Access to credits against risk
- Efficient co-operatives/association tackling risks
- Efficient governance
- Lack of incentives to adopt soil and water conservation practices
- Lack of efficient market access to the produce

Technological level
- Decreased ground water availability
- Lack of improved technology to recharge ground water
- Lack of water efficient crop varieties.
- Lack of information on Water efficient crops

Social Level
- Labor shortage
- Population increase
- Fragmentation of farms
- Lack of collective approach
- More efficient infrastructure viz., roads, hospitals, veterinary clinics etc.

Economic level
- Lack of availability of non-farm income during drought period

Bangladesh

About the possible adaptation measures against climatic vulnerabilities most of the respondents have reported some barriers to adaptation. There have been studies identifying the policies to improve the resilience in Bangladesh (Khatun and Nazrul Islam 2010) through policy suggestions. Constraints identified from the studies from Bangladesh are listed below:

Inadequate infrastructure

Poor infrastructure is the major obstacle to adaptation. Better roads and communication facilities and marketing opportunities are identified as important drivers of adaptation.

Lack of suitable seeds

To minimize the negative consequences of droughts, floods and water-logging, soil salinity and salt intrusion, climate-tolerant seeds are considered very effective. To adapt to such adversities new varieties of crops should be made available for the farmers.

Inadequate irrigation facilities

Rainfall variability has forced farmers to depend more on irrigation for cultivation. But inadequate irrigation facilities are a major concern. Due to non-availability of water farmers have restrained themselves from rice (mostly *aus* variety), jute or cereal cultivation in many villages. According to the villagers, improved irrigation facilities (using ground or surface water) can enhance their adaptation capacity and increase their productivity.

Lack of credit facilities

Several NGOs and Micro Finance Institutes such as BRAC[20], Grameen Bank[21], ASA[22] and other local NGOs are currently working in rural Bangladesh and provide micro-credits. But no NGO provides credit to cope with the climate extremes, floods or drought. Due to the lack of institutional credit, after the incidence of climatic catastrophe the villagers had to take loans from informal channels, which leave them in perpetual debt traps.

Crop insurance

According to the farmers, introduction of crop insurance system may help them reduce the climate related risks. Although the government has given permission to privately own enterprises to set up 'crop insurance' schemes, there is a need to take the initiatives comprehensively to cover most vulnerable areas of the country.

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[20] BRAC, based in Bangladesh, is (as of May 2010) the world's largest non-governmental development organization; Bangladesh Rural Advancement Committee.

[21] Grameen Bank is a microfinance organization and community development bank in Bangladesh that makes small loans to the without collateral.

[22] A NGO based in Bangladesh for micro credits; Association for Social Advancement.

Lack of agriculture extension services

The local agriculture officer generally does not visit villages to provide expert suggestions to farmers on better adaptation practices that can be easily adapted by the farmers. It is very important to strengthen and make available proper extension services at village-level to undertake and implement adaptation policies successfully.

Thailand

Based on the interactions with the farmers and the farmers' perceptions on adaptive capacities, the following barriers were identified that need to be addressed for creating an enabling environment for adaptation to change (Table 30) (Adaptation Knowledge Platform, 2010a).

Table 30. Barriers to adaptation and reasons in Thailand

Barriers to adaption	Reasons
Don Plai	
• Recommended adaptation strategies not within priority needs of farmers eg. producing compost • Small landholding farmers	• Income generation activities most important • Lesser opportunity to change cropping pattern
Kud Sawai	
• Many small landholding farmers • Most cropping areas are very low flood plain • Hard to adopt new methods or recommendation in improving soil fertility eg. compost and bio-fertilizer production and usage	• Less opportunity to change cropping pattern and cost limitation • A few rice varieties available and suitable for both area and market needs • Lack of knowledge and not realize the importance of soil improvement
Nong Muang	
• Lack of water source in the dry season • Lack of better crop production technology especially for rice which needs more water eg., drought tolerant varieties • Little innovation on alternate sources of income in the village	• The village and growing areas are higher than natural river (Chee River) and the existing water sources have not recovered after the rainy season • Deep ground water level • No access to seed supply and technology • Temporary migration is easier as the road is in the village
Tha Taeng	
• Hard to adopt new methods or recommendation in agriculture and need successful evidence • Large farm holders ignore onset of rainfall in planning to grow crops but more consideration is given to crop types and land suitability	• Too risky to lose income • Got used to the former practice • Having large areas provides easy decision making in growing various types of crops without awareness of climate variability

Viet Nam

Discussions with farmer groups, local authorities in Phuoc Nam and Phuoc dinh communes highlighted the following constraints to adaptation by the farmers (Table 31).

Table 31. Micro level constraints to adaptation in Viet Nam

Barrier	Reasons
Technical	Technologies are available but the farmers were not able to afford them, some are not effective, and lack of subsidies makes them inaccessible.
Financial	Financing is available but due to lack of collateral for borrowing farmers are not able to use them.
Social	Low education level, small farm sizes, remote and inaccessible areas
Economical	Low profits, high investment for adaptation, higher risk of crop failures.
Institutional	Little or no attention to smallholder farmer

China

Barriers to adaptation

China is still a developing country. In poor areas, especially in rural areas, farmers still live under low standards of living. For them ecosystem protection and perception of climate change are not high priorities. So there is a need to create awareness among the farmers on climate change and related implications, adapt and take appropriate action to mitigate climate change.

There are still some conflicts between agri-production and ecosystem protection, such as to open sloping wasteland, increase runoff and soil erosion, increased goat numbers on hilly and marginal lands that increases grazing pressures and destroy young trees and grasses, and cause heavy erosion.

Economic Barriers

Farmers' income is still at a low level, and they do not want to invest in adoption measures. A lot of financing is needed for rural development, rural infrastructure construction, transportation, communication, power supply and technical support and so on. This would be a long time development. This means rural development will have to take place gradually.

Technological Barriers

Technological advancements such as new drought tolerant crop varieties, modern water saving management technologies new environmental friendly power sources and power saving technologies are needed by the farmers.

Infrastructural barriers

Rural roads, water supply and drain system, rural communication, drinking water system, ecosystem protection and agricultural machinery need to be developed.

Barriers in policy

Government policy still plays important roles in rural development in China. To mitigate impact of climate change, policies are needed to adjust to suit the changed situation. For example, it was suggested that the biogas tank project is no longer needed for addition of new tanks in the two villages. There is a need to repair and manage them. But government funds are allocated to construct new tanks. The "Save power lamp" project needs more support in rural areas and needs more subsidies in rural areas than in cities. For the solar water heater project, only 13% of government funds are allocated, which is not enough. Installation of solar water heater in rural areas is much easier than cities because the farmers' have independent houses as dwelling units.

Farmers perceived that afforestation needs more protection, needs to make clarifications on such forest ownership and needs to improve planting technology and planting quality.

Opportunities for mainstreaming adaptation and enhancing resiliency for climate change

The following section details various options that will empower farmers by enhancing the income and livelihoods and cushion them from various shocks and weather aberrations. These opportunities emerged from understanding the perceptions of the farmers that were elicited in the 26 study villages across South Asia, Southeast Asia and China. Though enumerated under each of the countries that participated in the study, the list may be considered as a menu of options for further assessment, modification and adoption by any entity.

India

- Development and diffusion of drought tolerant and short duration crop cultivars.
- Common property resources (CPRs) like tanks may be revived by collective action and suitable incentives for proper management and facilitating the flow of runoff into them.
- Advance information on the weather will help the farmers to implement timely management options and minimize losses due to adverse events. More accurate crop-weather advisories will help the farmers achieve this.
- Weather/crop insurance programs shall effectively help in tackling climate risks.
- Weather based agro-advisories at the micro level are to be planned. This would help to gear up to take protective measures in the future
- Crop planning for all good/bad weather situation be made, which would act as a ready reckoning to take decisions
- Diversify and improve income sources through livestock using adaptable breed through efficient management
- Improved technologies like new crops that will be more profitable, shorter in duration and require less water; improved water and crop management options will help the farmers to stabilize their production.
- Farmers, and particularly the smallholder and marginal farmers, are given credit/loan on easy terms and a high subsidy be given on the interest that they have to pay on the loans. This will help the resource poor farmers to succeed in practicing suitable adaptation measures.
- Establishment of efficient co-operatives and associations/groups to tackle the critical needs of farmers like resource mobilization, marketing their outputs and efficient natural resource management.
- The present governance structures that monitor and administer the welfare activities are perceived by farmers to be more bureaucratic and difficult to approach and less transparent. There is a need to reform them for smooth flow of funds and information to the farmers.
- Soil and water conservation practices are important in bringing long-term sustainability of the systems. But the immediate gains for the farmers are not visible. Farmers must be given incentives to adopt such practices.

- Market access for the outputs of the farmers is not direct for many villages. Usually either the local agents act or the farmers have to go a long distance with their produce. A better access will help the farmers in earning more margins.
- Suitable technologies should be made available to the farmers that will reduce the water use at the present levels. Farmers are facing a drastic reduction of ground water levels and suitable technologies that will reduce field water losses will help the farmers to reduce their water use.
- Suitable technologies to improve water productivities of the crops and development of cultivars that are less water demanding are made available to farmers.
- Building road connectivity, markets and information gateways to assist farmers.
- Creating institutional arrangements to encourage farmers towards collective action in management and use of natural resources (Shiferaw et al. 2009)
- Creating opportunities in the non-farm sector in and around the villages to help the farmers diversify their incomes.

Bangladesh

- Farmers identified the need for better infrastructure such as roads, marketing infrastructure
- Development and diffusion of new varieties that are drought tolerant, short duration in nature, flood tolerant rice cultivars and salinity tolerant cultivars
- Farmers perceive that improved and increased irrigation potential through surface and groundwater sources will improve their production sustainability and productivity.
- At present credit facility is not available to cover the risk of extremes like droughts and floods. This is leading the farmers into perpetual debt traps. Creating easy access to credit and a high component of subsidy on the interest will help the resource poor farmers.
- Farmers feel that crop insurance will help them cover the risks but the present scheme of crop Insurance is with the private players and the farmers perceive that it is not universal in its coverage. A universal Crop Insurance scheme will help the farmers.
- A better extension infrastructure that will improve the access by farmers should be transparent and proactive in their reach to the farmers in every village and particularly the most vulnerable villages. The local knowledge on adaptation strategies on income diversification, floating garden, duck rearing, constructions of canal and embankment (non-farm labour) etc. (Anik, et al. 2012; Nargis and Hossain 2006)

Thailand

- Farmers do not adopt practices like organic matter incorporation due to lack of immediate returns. A suitable incentive mechanism must be in place to motivate farmers to adopt such practices that will help in enhancing soil fertility and improve water holding capacities of soil.
- Farmers perceive that their landholdings are small and the risk associated with new adaptation practices deter them from accepting change. Suitable technology demonstrations on the farmers field will help in improving farmers knowledge and help in their decision making process.
- Development of rice varieties that are flood tolerant with local characters are needed for lowlands.
- The upland villages need drought tolerant short duration rice varieties as well as water harvesting technologies that will help in increasing supplementary irrigation potential.
- Innovations in alternate sources of income that will help the farmers to diversify their incomes are needed.

Viet Nam

- Subsidies to the farmers to better adapt technologies like improved varieties etc. will help the resource poor farmers particularly the smallholder farmers.
- Farmers feel that fine tuning the technologies to be location specific will help in better adaptation.
- Farmers do not have access to credit through formal channels due to the reason that collaterals are a precondition for loans. Access to loans on easy terms and a subsidy on the interest on loans will help the farmers to go for a higher rate of adaptation.
- It is perceived that the smallholder farmers are neglected by the system because they are resource poor and usually are not able to get into the mainstream to be able to afford availing any incentive. Preconditions for availing any type of benefits should be relaxed liberally in case of smallholder farmers, so that they are able to get the necessary help.
- Better training facilities to improve knowhow on climate change and adaptation.
- Farmers feel that lower profits and higher risk of crop failures due to uncertainty in rainfall discourage them from investing in crop production. It will be appropriate to introduce crop insurance schemes and subsidize the premiums of resource poor smallholder farmers. This will help them in getting assured that in the event of a crop failure a minimum return is guaranteed and they will be able to venture into practicing better adaptation practices.

China

- Development and introduction of new drought tolerant varieties and water saving technologies will help the farmers in better adaptation.
- Developing alternate sources of power and subsidizing it for the farmers will help in adapting climate friendly technology by the farmers.
- Providing water supply and drainage systems, better agricultural machinery on subsidized terms and ecosystem protection methods on state subsidies will help the farmers.

Road Map for Action and Way Forward Towards Climate Resilient Agriculture in Asia

Background

Ensuring sufficient food for the ever increasing global population through improved productivity and increased resource use efficiency continues to be a key challenge in this century. Since the competition for natural resources like water and land is increasing, compounded by the challenge of climate change and associated variability of weather and its impact on agriculture, the challenge appears to be even more daunting (Shiferaw and Bantilan, 2004). The global community must produce more using less natural resources under uncertain climate conditions in agriculture. Agriculture production systems are also to be environment friendly by reducing carbon emissions. Indeed this is a daunting task. To achieve this task of paving the way for a "climate smart agriculture", several measures must be taken, including enabling policies, institutions and infrastructure in place, and farm communities better informed and empowered with necessary resources. As a response to impacts of climatic extremes and the initiatives to tackle the expected impacts countries have come up with strategies and plans eg, India (NAPCC 2008; NATCOM, 2009), Bangladesh (BCCSAP, 2009; NAPA, 2005), Sri Lanka (NCCASS, 2010; NATCOM 2000), Thailand (MONRE 2008b), Viet Nam (MONRE 2008a) and China (NCCP 2007). However, these strategies and plans are not properly oriented to cater to the regional or local specific needs. These programs may be implemented with a downstream approach to have maximum response where the targeted stakeholders receive maximum benefits (Table 32).

The ADB-funded project on "Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience" builds its strength from the grassroots and a need based approach that it has followed in providing science-based solutions and pro-poor approaches for adaptation of agricultural systems to climate change for the most vulnerable people in semi-arid regions of Asia. The project had envisioned the identification and prioritization of the sectors most at risk and development of gender equitable agricultural adaptation and mitigation strategies including 'best fit' technologies as an integral part of agricultural development in the most vulnerable areas (Smit and Pilifosova, 2001). The climate characteristics were studied in detail, vulnerable regions identified and farmer's responses were elicited from villagers. It is essential that the future needs of the farmers in Asia to successfully implement adaptation measures against climate change/variability, and to improve agricultural productivity and incomes of the farmers, be addressed.

Table 32. National Initiatives on climate change resilience

Country	Initiatives
Bangladesh	Submitted the initial national communication in 2002 to UNFCCC[23]. The National climate change strategy and action plan was drafted in 2008. It constitutes a) food security, social protection and health b) Comprehensive disaster management c) Infrastructure d) Research and knowledge management e) Mitigation and low carbon development f) Capacity building and institutional strengthening. National Plan for Disaster Management released in 2010.
India	Submitted First National communication to UNFCCC in 2004 and second national communication in 2012. National action plan on Climate change (NAPCC) was released in 2008. It identifies eight missions in the area of Solar Energy, Enhanced Energy Efficiency, Sustainable Agriculture, Sustainable Habitat, Water, Himalayan Ecosystem, Increasing forest cover and Strategic Knowledge on Climate Change. ICAR has launched a major project entitled, National Initiative on Climate Resilient Agriculture (NICRA) during 2010-'11 in the 11th national plan in conjunction with the proposed NAPCC. To achieve coherence between strategies and action at national and state level. State level action plan on climate change (SAPCC) were drafted to enable to address existing and future climate risks and vulnerability. 14 out of 28 states have drafted SAPCC and further planning is underway towards implementation.
People's Republic of China (PRC)	Initial national communication to UNFCCC was submitted in 2004. The country issues national action plan to address climate change in 2007.
Sri Lanka	Submitted first national communication in 2000 and second in 2012 to UNFCCC. In 2010, a National Climate Change Adaptation Strategy for Sri Lanka (2011 to 2016) was drafted with a definite framework for action.
Thailand	Submitted first national communication in 2000 and second in 2011 to UNFCCC. In 2008, Thailand's strategic plan on climate change released underling the proposal of 6 strategies to tackle climate change. Capacity building, Promoting GHG mitigation activities, supporting research and development, Raising awareness and public participation, Building research capacity, supporting international cooperation are the strategies drafted to address its impacts.
Viet Nam	Submitted first national communication in 2003 and second in 2010 to UNFCCC. The national action plan on climate change (2012-2020) was approved in 2012.

[23] United Nations Framework Convention on Climate Change; Parties to the Convention must submit national reports (national communication) on national circumstances and other details on the implementation of the Convention to the Conference of the Parties (COP).

The project has successfully collected and analyzed primary data from 22 villages from six countries across Asia along with secondary data to understand climatic variability, farmers' perceptions and vulnerability to climate change. Keeping in view the results and future needs of the farmers in these countries to successfully implement the adaptation measures to address climate change and improve agriculture productivity and incomes, certain strategic measures are to be in place. An attempt was made to pull together all the necessary aspects for action to achieve the above goal. The set of actions were grouped under different categories, a) policies and strategies, b) tools and technologies, c) Financing for transformational change and d) partnerships for smart agriculture. The following list is *indicative* and is neither *exhaustive* nor *specific*. The idea is to suggest policies/strategies to create an enabling environment for the farmers in South and Southeast Asia to address climate variability and also to address socioeconomic problems resulting from changing weather patterns.

a) Policies and strategies to minimize climate change impacts for a "Climate Smart Agriculture"

It is very important that all the initiatives that are considered to address adaptation and mitigation to climate change must be integrated with government policies that address agriculture, food production (Klein et al. 2005) and livelihood. This will ensure effective mainstreaming. The measures identified should be sustainable based on location specificity and adaptation gains.

- ✓ ***Integration of climate change initiatives (such as NAPAs'[24], NAPCC[25], NICRA[26], NDMA[27]etc.) with the national agricultural policies/programs (food security, disaster management, natural resource conservation technology adoption, livelihood enhancement etc.) to encourage rural communities to concede to proposed adaptation measures to address climate change impacts.***

Response to climatic shock may not be good, but identifying these and work towards improving their capacity to adopt these during the time of climatic emergencies (Eriksen et al., 2011). There is a need to implement measures that will enable the farmers to invest in adaptation measures (short duration varieties, soil and water conservation technologies, crop management practices, replenishing the feed and fodder management etc) to mitigate the negative climate change effects. An example

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[24] National Adaptation Programs of Action identifies priority activities that respond to their urgent and immediate needs to climate change by which further delay would increase vulnerability and/or costs in the future
[25] National Action Plan on Climate change
[26] National Initiatives for Climate Resilient Agriculture
[27] National Disaster Management Authority

can be to encourage farmers by giving subsidies on interest on loans for implementing adaptation measures. Subsidies on weather based crop insurance – a measure to tackle the climate risks associated with extreme weather events. Development of strong collective initiatives such as co-operative movements will improve economic status and help facing climate shocks.

- ✓ ***Prioritizing regions of climate change vulnerability in arid and semi-arid tropics; preparation and implementation of comprehensive district-wise (local level) agriculture and livelihood contingency plans[28] of actions for effectively managing the climate risk.***

From meso-level data analysis, the regions vulnerable to long-term climate change need to be identified. Regional crop-contingency plans i.e., district-wise, which will be a response to anticipated climate change developed on an annual basis, with sufficient flexibility. In all study countries, regional level plans exists and identifying vulnerable sectors and regions is a pre-requisite. (For example in Viet Nam master plan in response to climate change in Ninh Thuan and Ninh Phuoc district were drafted with rounds of revision and prioritization exercises).

- ✓ ***Encourage crop and livelihood diversification[29] and ensure rural income flow; managing the common property resources (ponds, wells, tanks, grazing land, etc.) judiciously by community participation enabling long term sustainability.***

Increasing dry spells in the wet seasons; delayed monsoons and other climate change related effects require tailoring a location specific cropping calendar and developing suitable crop management techniques through research and interaction with the farmers.

The farming income is not considered sufficient to cover the increasing risks due to uncertainty and variability in rainfall and occurrences of extreme events like droughts floods etc. Farmers are increasingly looking for diversification to high value crops and other income generating enterprises from traditional agriculture to cushion the risk associated with agricultural production and income loss. Farmers need an enabling environment that creates or assists in innovation by the farmers to diversify their income sources. This could be achieved through rural developmental agencies. Hence, revamping of rural developmental agencies such as SFDA[30], DRDA[31] focused towards small farmers in India, policies on sustainable development[32], livestock production[33], irrigation[34] and fisheries & aqua cultural

[28] Includes state/district level contingency plans, disaster management plans and other reliefs.
[29] Enable opportunities to diversify more into high value crops, livestock and other non-farm income sources.
[30] Small Farmer Development Agency
[31] District level Rural Development Agency
[32] Decision No 153/2004/QĐ-TTg, on Direction of Sustainable Development in Viet Nam.

development etc in Viet Nam and its programs is a must in all the countries of study. In India, evoking the focus of these rural development agencies to farm and non-farm evenly is a must.

- ✓ ***Support to implement pasture conservation and better feed and fodder management[35] approaches for improved productivity of livestock, fisheries, poultry and other enterprises.***

There is a need to improve feed and fodder management to enhance fodder quality and availability to improve livestock productivity. Cereal based systems particularly coarse cereals are slowly being replaced with other cash crops in villages in India, China, Bangladesh, Thailand, Sri Lanka and Viet Nam. As a result the availability of dry fodder to feed the livestock population has become an issue. Options for improved fodder management and availability will ensure a healthy development of livestock sector in the villages for the farmers to diversify their income options. There are several state/district/national level livestock/poultry/fisheries programs officially being implemented in the region, however, time have come to relook the impacts of these programs & policies on livelihood and ensuring better effectiveness and efficiency.

- ✓ ***Ensure equitable in access of government support/relief programs such as Antyodaya[36] program, food security programs in India, VGF[37] program, CIP etc in Bangladesh etc.[38] This programs focusses on food security, agricultural and enterprise subsidies, rural finances, poverty reduction programs, technology adoption support etc.***

All groups of farmers must be able to get loans under easy conditions. This will enable small and disadvantaged farmers to implement adaptation measures to address climate change. This is true only if there is no recurrence of drought in this period. In reality droughts recur in the time span and many of these farmers fall into perpetual debt traps. Access to finance on easy terms and highly subsidized interest will help them come out of the debts.
Support in terms of subsidies must be given for choosing adaptation measures and innovative technologies to address climate change impacts as well as productivity improving measures of watersheds, integrated water and nutrient management

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[33] Decision No 10/2008/QĐ-TTg on Strategy of Livestock Production Development up to 2020.
[34] Decision No 1590/QĐ-TTg on Strategy of Irrigation Development up to 2020.
[35] Programs/schemes on dairy development; development of small ruminants; fodder and feed development; livestock entrepreneur programs etc.; In India, the concerns of demand for fodder and pasture are on with 12th plan call for rehabilitation of pasture and fodder resource on the country. The National livestock development board and other public livestock enterprises in Sri Lanka.
[36] Schemes under the program included land allotment, agriculture and land development, animal husbandry, village and cottage industries, wage employment, old age pension and housing subsidy, etc.
[37] Vulnerable Group Feeding program
[38] Government of Bangladesh's country investment plan (CIP). This CIP has identified 6 focus areas to continue their effort to achieve Millennium Development Goals (MDG).

options for efficient use of resources like land, water etc. as well as any other inputs. This is mainly because farmers in vulnerable areas do not have any social safety nets and require support to sustain and continue crop production. Easy access to support mechanisms like government interventions in terms of knowledge flow and/or financing options might help.

- ✓ ***Strengthen and empower the final beneficiary i.e., farmers to make them meaningful partners. Supplement their traditional/experiential knowledge with valid scientific knowhow and technology options, engage them more meaningfully in climate information management systems, provide incentives to farmers to adopt natural resource conservation measures and support to improve the existing indigenous technologies that are eco-friendly.***

Although the farmers had a wealth of information and experience in dealing with climate change variability and the harsh realities of moisture stress, they were still lacking in knowledge on accessing information and taking optimum use of services provided by the governments. Often they are unaware of their entitlements, reliefs on offer and other government support programs and thus fall prey to ignorance and consequences of extreme climate conditions. In vulnerable areas, farmers also lacked social capital and the organizational capabilities. They are often passive suppliers of information to the state and research establishments, but not integrated as valuable and active stakeholders in the climate change debates or intervention programs. The concept of "climate change schools" could have sufficient potential for sharing information and knowledge (indigenous knowledge) etc. The weather data collected at local levels once synthesized centrally, must go back to the farmers as useful outputs, so that they can and are assisted to make effective use of inferences drawn. The study also call for strengthening extension program and institutionalizing effective mechanism of information dissemination through Agricultural Technology Centre (KVK[39], ATMAs'[40] in India) in every block/mandal/sub-country level.

- ✓ ***Prioritize investment in training officials, extension and local development workers to make them more effective change agents in assisting farmers and strengthening institutions to improve climate adaptation capacity at local levels.***

Officials' responsible for the farmers' socio-economic well-being may be educated on climate change and mitigation through a series of awareness programs. Such programs may be conducted at the village level and required incentives need to be provided. To illustrate, it is observed that the Common Property Resources (CPRs)

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[39] Krishi Vigyan Kendra' is a district level institution engaged in transfer of latest agricultural technologies to the end users for bridging the gap between production and productivity

[40] Agricultural Technology Management Agencies in addressing the constraints faces by extension system

like grazing lands have degraded over the last several decades due to lack of collective action in managing them. It will be appropriate for extension officials to educate the farmers on low moisture availability in their eco-system and the way to mitigate the problem. Necessary to emphasize on capacity building for the government employees dealing with farmers problems in particular and agriculture in general. The lack of needed competitiveness in understanding climate change related implications and experience is highly recommended for all the partner countries particularly for Viet Nam and Thailand. Moreover, various stakeholders involved in nation building through agriculture development are not well aware about global policies, decisions and other related information.

b) Tools, technologies and infrastructure for "Climate Smart Agriculture"

- ✓ ***Increasing the density of weather observatories; establishing rain gauges at village level; enabling access and efficient management of weather related information (Remote sensing and GIS) and repository.***

Weather especially rainfall is variable across the regions. Analysis of single station data may not represent the accurate climate resources. Micro level weather data analysis using micro level data showed a decreasing trend in the rainfall compared to the positive trends at a district level. This feature was observed in two selective project locations in India and Thailand. Village level rainfall observations are important in characterizing the environment at micro level. Therefore, there is a need to increase the density of network of weather stations for better interpretation of variability of weather parameters and for accurate planning for improved and sustainable agricultural production.

Typhoons and flash floods as well as drought events are common in the Asian countries. In the event of increased frequencies of extreme weather events, agricultural production gets affected considerably. The best way to reduce the impact is to prepare the farmer well in advance to manage the situation in order to minimize the losses. Weather-based agro advisories benefit the farming community in ensuring effective agricultural operations. In spite of best efforts to alert the farmers, extreme weather events often causes huge losses subjecting the farmer to extreme hardships. To save the farmer from the weather hazards, weather insurance is quite beneficial. To cope with disasters such as typhoons, flash foods or droughts, identification of geographical boundaries for such events followed by preparation of regional crop-contingency plans must be put in place. These will form ready-reckoners to meet out any eventuality. They should be prepared to meet out the year-to-year variability. Modern tools such as 'Remote Sensing and GIS' should provide an excellent opportunity to analyze spatial land use and land cover changes to climate change. There have been initiatives[41] from the government on this front in the study countries to improve the infrastructure and database on climate information and to use advanced methods.

- ✓ ***Institutionalize continuous mechanism to collect and collate micro level information (climate, crops, socio-economic, natural resources etc.) and efficiently transmitted to be used as an input in formalizing macro level policies***

Most of the macro level policies are formulated with inputs from aggregated level. The aggregated information and existing micro level information could be highly diverse. There is a pressing need of having micro level information on climate, crops, socio-economics, natural resources, governance, trends and efficiencies etc. especially in the context of climate change issues. Micro level information need to be collected and collated to be accessed and used by various national/regional, governmental/non-governmental and other developmental agencies for efficient planning.

- ✓ ***Blending of farmers' traditional/indigenous knowledge on resource conservation, coping strategies etc. and with advanced technological interventions (varieties, crop management, community resource conservation, rainwater harvesting and storage etc.) for coping against climate change and associated stress***

Farmers have inherited the knowledge of managing and understanding the climate through their ancestors. Hence, there is a need to utilize this ancient wisdom[42] along with modern knowhow. For effective utilization of the modern technologies, combining traditional knowledge may improve the reliability and acceptability.

- ✓ ***Encourage investment in research and development of locally adaptable crops, management practices, input sources etc., Decision support systems (DSS) and models for analyzing the impacts of climate change and mitigation strategies in the semi-arid tropics in view of future climate scenarios***

With the changes and increasing variability of weather patterns, and introduction of new crops and varieties, the pest and disease behavior is likely to be altered in any given location. There is a need to identify such location and crop specific pest and

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[41] In India, Indian meteorological department (IMD), and allied department are greatly involved in enhancing weather information by improving weather station density across the country.

[42] On weather prediction, water conservation and storage, cultivation practices viz., organic farming, natural pesticides etc.

disease incidence and approaches to manage such situations developed. For example in Maharashtra (India), introduction of sugarcane in Shirapur and soybean in Kanzara and improved and short duration pigeon pea in Kalman villages brought in new diseases and pests that needed different management practices from the normal. Improved on-farm water harvesting and water conservation measures are useful in rainfed agriculture, similarly improved technologies like drip irrigation and precision timing of irrigation will reduce the risk associated with the variability of rainfall (Rockstorm et al. 2010; Lundqvist and Falkenmark 2010; Barron et al. 2010).

Incorporating organic matter or mulching to increase the water holding capacity of soils, in-situ water storage using different devices are time tested measures adopted by farmers such as cover cropping, mulching, composting etc. The different techniques adopted by farmers in the region provide an array of options for field validation in other countries and subsequent adoption.

- ✓ ***Encourage adoption of location specific conservation techniques (cover cropping, in situ moisture conservation, rain water harvesting, ground water recharge techniques, locally adapted cropping mixture etc.) for water efficient agriculture and demonstration of these available technologies[43] in the farmers' field.***

Incentives or support must be given for choosing adaptation measures and innovative technologies to address climate change impacts as well as productivity improving measures for efficient use of resources like land, water etc. as well as any other inputs. For example modern technology and external support by government in India and also non-government organizations in Sri Lanka and Bangladesh helped the farmers in many villages to harvest groundwater through agro wells and tube wells. In the recent decades there has been a rapid, uncontrolled expansion in the number of tube wells in many villages resulting in the receding of the ground water table. Such "tragedy of the commons" should be avoided through collective action, regulation by external agencies or systems of incentives and disincentives. The ground situation is sometimes aggravated due to low levels of education of farmers. This acts as a barrier to preventing over-harvesting of ground water as practiced in Ninh Thuan province in Thailand. Thus improving the knowledge of farmers may be a first step before adopting other measures. Thus calls for sensitivity to local socio-economic contexts when addressing mitigatory measures.

[43] Support in soil and water conservation, soil health, irrigation, fertilizer etc.

- ✓ ***Managing climate risks effectively through weather-based agro-advisories, and developing equally accessible innovative weather insurance products[44].***

In the event of increased frequencies of extreme weather events, agricultural production gets affected considerably. The best way to reduce the impact is to prepare the farmer well in advance to manage the situation in order to minimize the losses. Weather-based agro advisories come in a big way to benefit the farming community on timely agricultural operations. In spite of the best efforts to alert the farmers, extreme weather events often cause huge losses subjecting the farmer to extreme hardships and weather insurance can be an effective strategy to offset the losses. In order to prepare the weather insurance products for different agro climatic regions, research efforts on crop-weather relations need to be strengthened.

- ✓ ***Harnessing non-conventional energy[45] sources in agriculture and other allied sectors***

The use of non-conventional sources of energy, such as bio-fuels, solar energy and wind power in agricultural operations is very limited where there is more effective state interventions such as in the case of China, successful interventions in the rural areas has been possible, with high levels of adoption. In order to reduce the GHG emissions from the different sources, more research is required to estimate the emission levels and on measures to restore the balance.

c) Financing and partnerships for transformational change

- ✓ ***Enabling environment to attract public and private finances to invest in "Climate Smart Agriculture"***

Increasing the level of state financing for promoting climate smart agriculture is a priority, considering the long term goals of minimizing food insecurity, reducing carbon emissions and mitigating climate change effects. Public investment in the field of agriculture research and development must be increased. The focus should be to invest in tools and technologies as well as policies. For example, the National Initiative for Climate Resilient Agriculture (NICRA) is a major research and capacity building national project launched by the Government of India and ICAR to develop location specific tools and technologies and capacity building.

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[44] Weather based insurance schemes; government support through subsidies on premium. When weather indices are differ from the guaranteed indices of major crops a payment equal to the deviation/shortfall is payable to all insured farmers.

[45] The progressing demand and initiatives by the respective governments are existed. These are well highlighted in the related policies and strategies, National action plans etc.

- ✓ ***Encouraging the role of the non-governmental organizations, public and philanthropic organizations for enhancing adaptation preparedness among the local community.***

Along with the government efforts, NGOs are also important for the development of the rural community. For example in Thailand, Oxfam has undertaken some work on climate change adaptation with local communities in Yasothan province and in BRAC in Bangladesh.

There is a need to generate partnerships between public funding and financing from foundations and charitable private institutions for investment into smart agriculture promotion (Vermeulen et al. 2012; Vogel et al. 2007). Many NGO and other research organizations funded by various societies and trusts have been doing commendable job in various sectors. Their involvement in conducting research to manage climate change threats may be encouraged and enabling environment must be created.

- ✓ ***Forging international/regional partnerships for developing tools and technologies adaptable to suit local requirement through pooling finance and intellectual resources***

International partnerships among neighboring countries that share similar eco-systems as well as similar agricultural practices might be useful in sharing financial and intellectual resources to develop appropriate tools and technologies[46]. The technologies generated at various locations in the world may be collected and identified for its suitability to other regions. The SAARC[47] being a potential platform for cooperation and exchange of tools, technologies, skills, finance and other related resources to combat climate change and enhancing resilience in south Asia. Similar platform could be entertained in Southeast Asia and China.

[46] Drought, flood and salt tolerance varieties, robust methodologies to predict climate change impacts, resource conservation technologies, innovative safety nets etc.

[47] South Asian Association for Regional Cooperation (SAARC) with an objective of providing promotion of economic and social progress, cultural development within the south Asia region.

Summary and Conclusions

The primary focus of the study was to look at the farmers adaptation strategies against climatic variability. Based on the evidence and understanding of the farmers, traditional and current adaptation strategies against weather variability were identified. The report has attempted to document some indicative possibilities to substantiate the global agenda on climate change. Current policies are resonating a disconnect since they are aggregative, top down, highly macro level studies. They are often coupled with uncertainties and information gaps, thereby vitiating or obstructing the adaptation or mainstream into the policies/programs affecting the marginal environments in the developing world.

As a prelude, the report delved on climatic characteristics at a fairly micro level, corroborated the same with the village level data sets drawn from the longitudinal panel maintained at ICRISAT and Bangladesh. The utility of long term panel was heightened by the extent, identification and facilitation of effective adaptation to climate change in the micro level context since the impacts are felt at local/ landscape/village level. Further, in order to prioritize the region/sectors and thereby various programs and management's action/ informed decisions the vulnerability analysis was undertaken not only with just climatic indicators, but the critical indicators reflecting the adaptive capacity and sensitivity were incorporated across six countries in Asia. The approach, holistic in nature was the first of its kind revealing the targeting approach at a fairly micro level, i.e., provincial level. It is anticipated that the approach will suitably aide in characterizing and targeting the poor and marginal environments from socio economic perspective.

The global community has recognized climate change as a potential threat to human survival. The impacts of climate change are not spatially similar and Asia's rural poor are more challenged by its consequences. Along with the African continent, Asia is also rated as highly vulnerable to climatic changes. This six country regional synthesis report has tracked the climatic trends, identified vulnerable regions to climate change and undertaken a quantitative and qualitative analysis of farmers' perception, adaptation strategies, and constraints faced. The analysis has helped identify a set of recommendations. These recommendations may be integrated into the country specific policies for climate resilient agriculture and rural households. Climate trends were analyzed at country and regional level which reiterated an increasing atmospheric temperature and high rainfall variability. Regions or locations experienced frequent occurrence of extreme events viz., droughts, floods etc. However, these were often not captured in the country level analysis. Very high variability in distribution of rainfall was observed with no drastic reduction of quantum of rainfall in the study regions. For five countries climate vulnerable regions were identified and the most vulnerable demarcated. The villages for in-depth study were chosen from the most vulnerable regions.

The detailed village studies undertaken in the 22 locations, provides a comprehensive understanding of farmers perceptions of climate change and how they have adapted to climate variability. They have successfully faced the extremes and adapted to the situations faced on location and also migrated as a means of survival. The climate shocks are compounded by other institutional failures or weaknesses such as those related to markets, information, regulations and state support schemes. Infrastructure, technology, supportive policies, market intrusion etc. have also helped farmers cope. In general farmers have been changing the farming systems, crops cultivates, invested in livestock or fisheries, adopted diverse methods to conserve moisture, managed savings, diversified incomes, relied on external support, etc. in order to adapt to the extremes and variability of climate conditions. In India, Bangladesh, Sri Lanka and Thailand, the total precipitation, duration of the seasons have been perceived to be changed for the worst. Farmers have experienced an increased temperature which matched the findings of the meteorological data analysis. Salt water intrusion is also a common problem experienced in Bangladesh and Viet Nam.

Delaying commencement of land preparation and cultivation is a strategy adopted by farmers to adapt to the situation faced by the delayed monsoons. In some locations complete crop substitution is also practiced as in the case of Bangladesh where villagers have given up wheat for maize. Continuous water stress is handled by farmers by shifting from seasonal crops to perennial tree crops such as cashew (eg. Sri Lanka) that grow under water stress conditions.

Farmers in the coastal areas have shifted from agriculture to aquaculture to adapt to flooding and also salt water intrusion. This was seen in Bangladesh and Viet Nam study villages.

Expanding non-farm sources of income ranging from wage work to regular employment is a common strategy adopted by many in all countries other than China to cope with the long term uncertainties of rainfall. Expanded off farm incomes is in the range of 20-60% of total incomes according to the study.

Where the state service institutional system is well developed and spread, developing irrigation infrastructure enables farmers respond in an extremely positive manner. In the case of China a 400% increase in cropping intensity has been reported due to improved irrigation to remote villages in vulnerable rural areas. Efficient state intervention has also enabled farmers to adopt renewable energy sources at household level and for communities to undertake afforestation as a carbon fixing project having major macro environmental implications.

Irrespective of the wealth of farmers, longitudinal sociological studies done in Indian villages showed that it takes anywhere between 1 to 4 years to recover from the impact of the droughts. Poor farmers take the maximum period of time to recover. The SAT region is witnessing droughts recurrences at a shorter span than in the past.

Poor and marginal farmers get into perpetual debt traps in these vicious cycles of drought recurrences in these marginal environments.

Certain limitations which need to be addressed are presented below:

(a) There is a crucial need for collection, analysis and dissemination of reliable information on climate-response related variables (including farmer's perceptions) in diverse micro-level spatial contexts;
b) Preparation of area-specific inventories of indicative production and resource use options (possibilities) for dryland agriculture to match with the opportunities and constraints;
c) The search for indicative adaptation options (Fraser, 2007) for the above inventory should focus on (i) prevailing farmer's practices in different areas with varying degrees of vulnerability (eg. water scarcity or aridity) and other environmental constraints; (ii) agricultural R&D and location specific scientific results; (iii) formal and informal institutions and support systems including infrastructural changes with specific focus on success stories and visible failures.
d) The first three factors above should help in building an inventory of multiple and diverse options out of which farmers would have the flexibility to choose and use depending on the varying climatic conditions in their micro level contexts.
e) The overarching suggestion incorporating points (a) to (d) is to diagnose and understand farmers' adaptation strategies against climate variability with a focus on the dynamics of adaptations, and improving resilience to change.

The present study brought forth many observations that show that the farmers across Asia have demonstrated autonomous adaptation to the complex combination of physical, economic, social and political environment. This study has identified the most vulnerable sections of the farming community that are not able to cope equally well compared to relatively resource rich farmer groups. In order to address the issues brought out by the grass root level insights, the formulation of appropriate recommendations have been made. The array of interventions developed by farmers as farm level technologies need to be scientifically evaluated and up-scaled for wider adoption facilitated by the state.

This will enable the government to (a) create an conducive environment for the farmers to absorb adaptation strategies, (b) develop technological inputs and tools as appropriate adaptation measures, (c) create and strengthen the existing institutional infrastructure to assist the farmers towards an equitable adaptive capacity and (d) streamline the governance structures to smoothen the flow of information and resources to the farmers and be responsive to their needs.

The implementation of the above overarching suggestions highlighting dynamism, diversity and flexibility would need both enhancement and reorientation of the capacities of the farmers and rural communities, as well as the institutional arrangements and innovations supporting them. There should also be an effort directed at strengthening collective actions and formal and informal networks to ensure equity (Rodima-Taylor et al. 2011a, 2011b)

Stemming from the grass root and need based approach, the study elicited the farmer's perception and practices, their natural resource base, current and potential adaptation practices in the form of adjustment in their farming and non-farming systems and practices. In order to ameliorate the local level constraints, strategies to respond to climate change/variability must be mainstreamed into the development agendas of all countries keeping the following aspects in mind.

1. Adaptation strategies should incorporate diversification as a key element in terms of interventions as well as systemic support - (i) local level efforts (horizontal) at information management and institutional coordination as well as (ii) working with national level bodies and aggregates (vertical).
2. Since income sources, options, and opportunities to adapt are increasingly recognized as vital, adaptation strategies must to have a strong dynamic orientation thus recognize as requiring continuous change.
3. In keeping with the emerging evidence on convergence between development and adaptation processes, adaptation should be an integral part of development strategies[48].
4. Requisite space for grass root level understanding of adaptation strategies help in better and pragmatic bottom up approaches. This understanding is reinforced by details from field studies (eg. ICRISAT VLS panel data).
5. Adaptations to be effective not only call for individual household level understanding and capacities, but a strong element of collective action and institutional support on the one hand and proactive approach of the formal public and private agencies.
6. Encouraging conservation of community resources through appropriate support and imparting timely awareness and logistics to enhance adaptation.
7. Finally, the development policies for diverse agro-climatic regions need to have explicit and effective support for integrated adaptation strategies. The purpose of this study is also to sensitize and induce the same.

[48] Suggested by Halsnaes and Verhagen (2007).

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Annexure

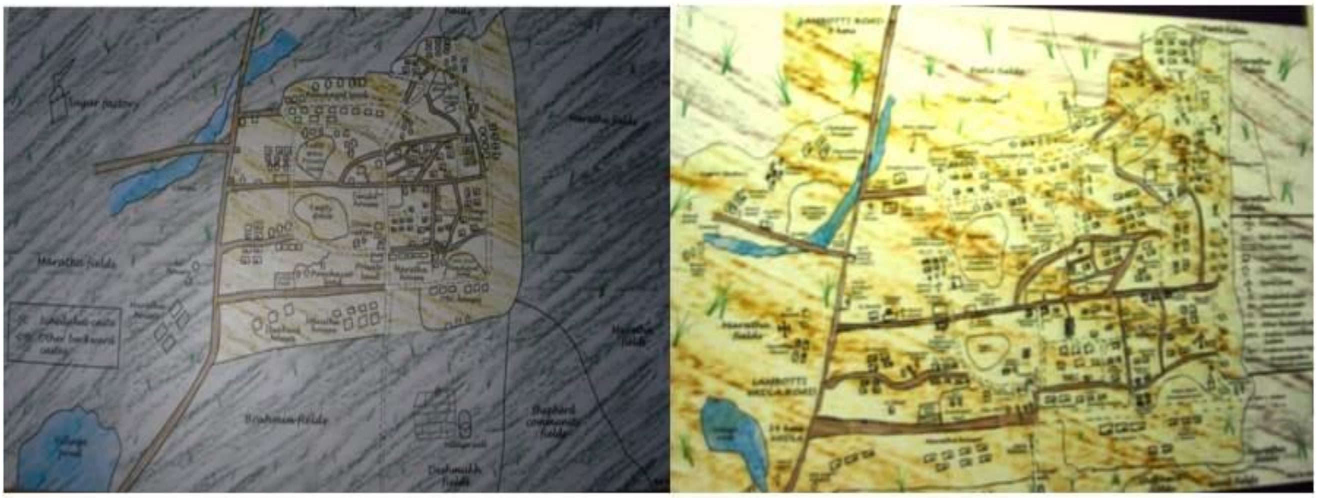
Annexure 1.Regional climatic trends in the targeted countries of South Asia

		South Asia		Southeast Asia		
Country	**India**	**Sri Lanka**	**Bangladesh**	**Thailand**	**Viet Nam**	**China**
Region name	Andhra Pradesh and Maharashtra States	Dry zone	Flood prone (Mymensingh and Madaripur) and drought prone (Thakurgaon and Rajshahi)	Northeastern region	Ninh Thuan Province	Guizhou province
Annual rainfall trend	Annual rainfall of AP increased significantly of about 96 mm during 1871 – 2010 period. No significant trend is observed in Maharashtra state.	-	Decreasing trend is noticed in drought prone areas and in flood prone areas.	No significant trend in annual rainfall showed in the past 40 years.	-	Decreasing tendency is seen at 10 mm / decade.
Seasonal RF trend	No significant trend was noticed in both the states of Andhra Pradesh and Maharashtra.	-	-	No significant trend was noticed in winter, early and late rainfall but significant increasing trend was observed in summer ($p<0.05$).	-	Rainfall declined by 63 mm during spring and by 20 mm in autumn. Contrarily, increasing trend was observed in summer (63 mm) and in winter (5 mm) during past 50 years.
Annual rainy days trend	-	-	Decreasing trend was noticed in both in drought and flood prone areas	No significant trend was noticed	-	Decreasing in the past 50 years.
Annual temperature trend	-	-	-	Tmax increasing by 0.96 °C in 39 years. Tmin increasing by 1.0 °C in 39 years.	-	Increasing by 0. 1°C in the past half century.
Seasonal	-	-	-	Tmax. increased in	-	Seasonal mean

temperature trend				winter (1.6°C in 39 years) and late rain (1.1°C) but no significant trend in summer and early rain. Tmin showed significant rise in all 4 seasons, winter by 1.8°C, summer by 0.96 °C, early rain by 0.69°C, late rain by 0.86°C in 39 years.		temperature showed an increasing trend in autumn (0. 2°C) and in winter (0.5°C). Decreasing trend was seen in spring (0.3°C) and in summer (0. 1°C).
Length of growing period	Lowest growing period (< 10 weeks) is observed in Anantapur region and highest (> 25 weeks) in north coastal Andhra. Lowest growing period (90 days) is noticed in south part and highest (150-180 days) in western and eastern parts of the State. Growing period is around 120-150 days in central parts of the state.	-	-	-	LGP range from 110-140 days for spring rice, 105-110 for summer rice	-

Annexure 2. Social and resource map of Indian study villages

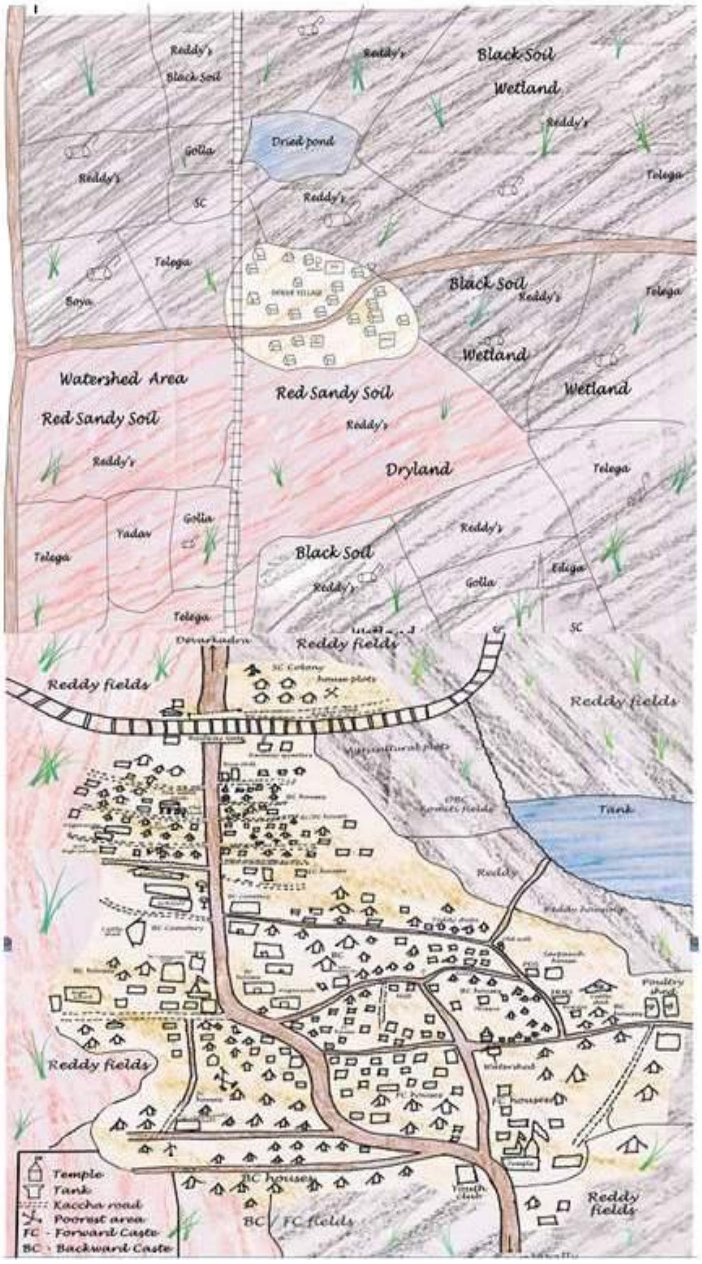
Shirapur



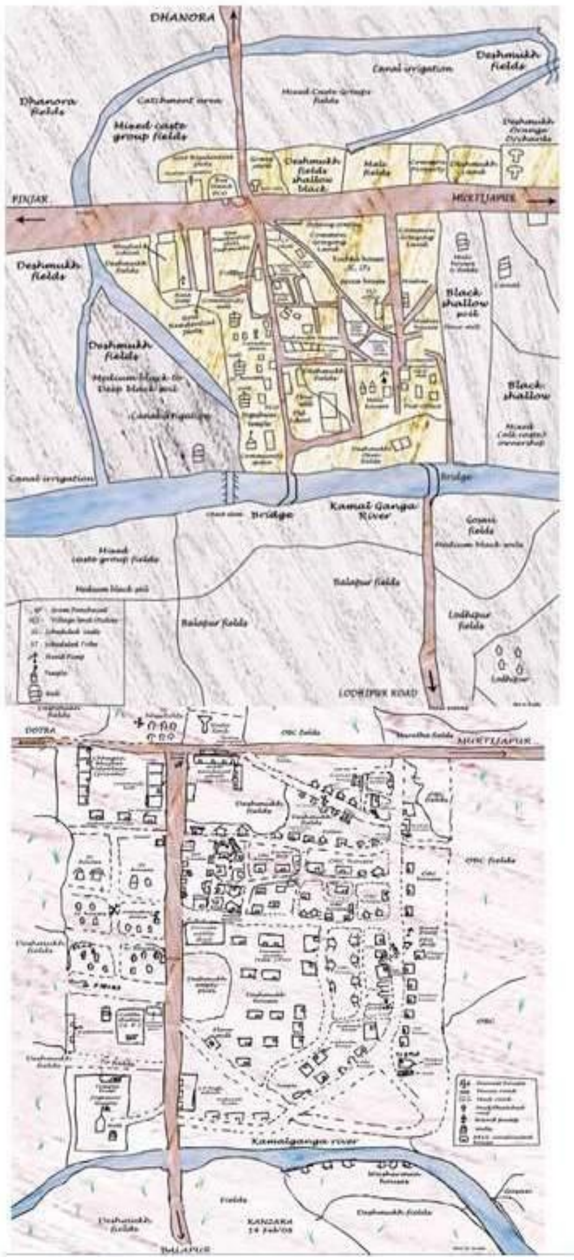
Aurepalle

Sources : BVJ Gandhi, 2008

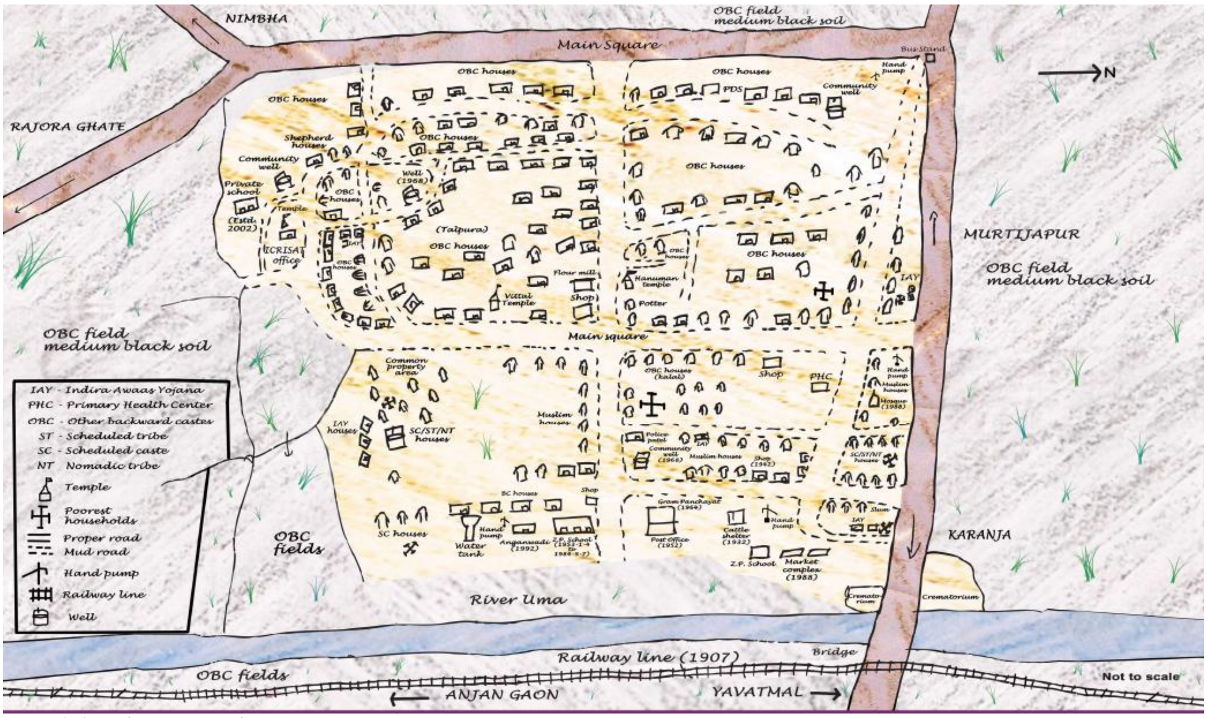
Dokur



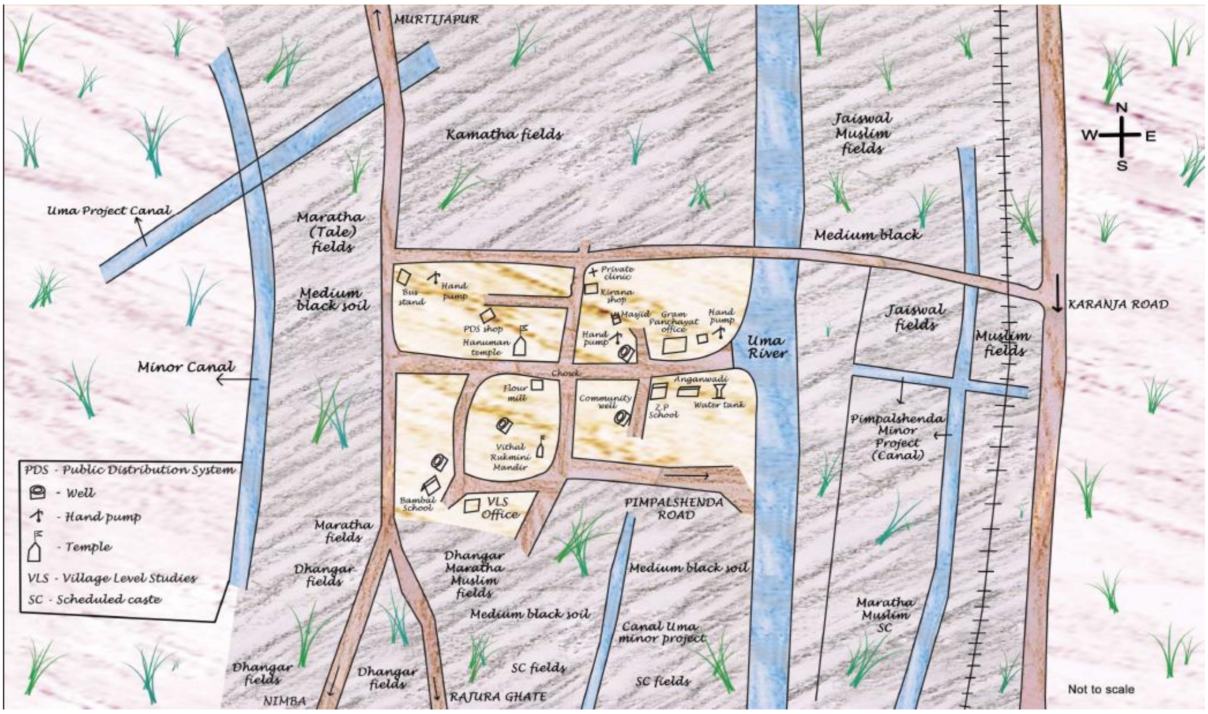
Kanzara



Sources: BVJ Gandhi, 2008

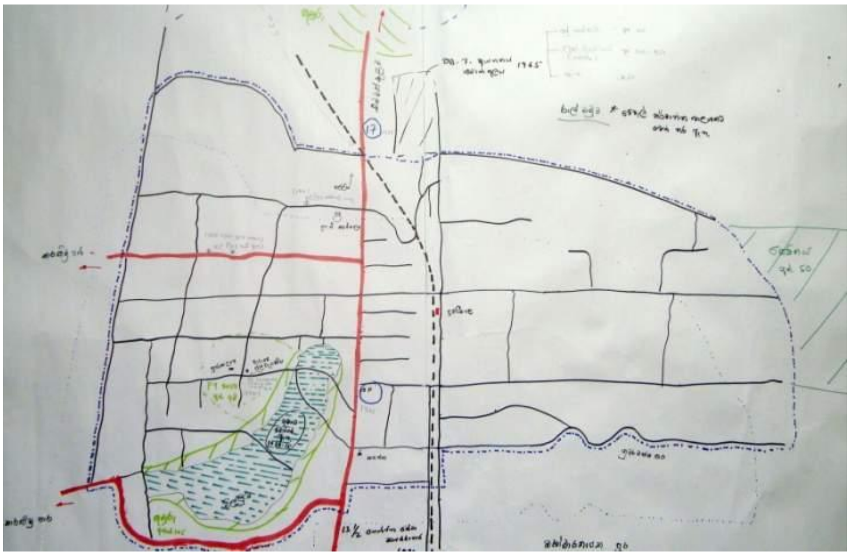


Kinkheda Social Map

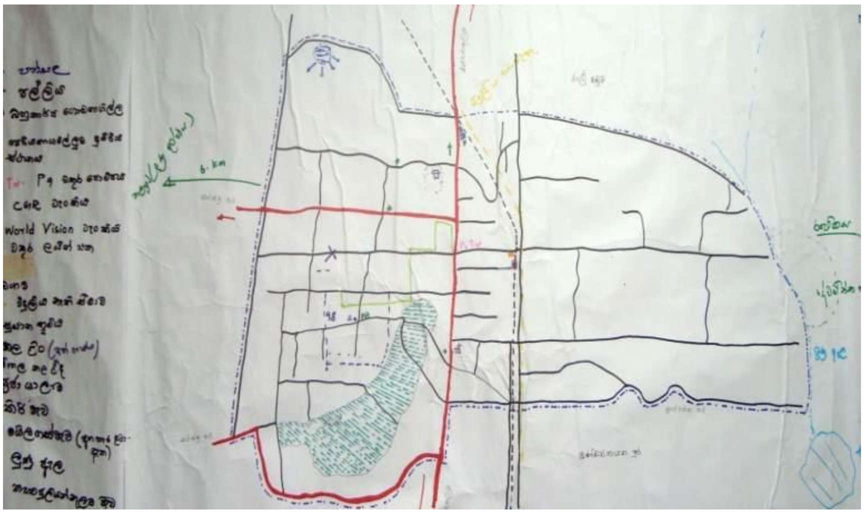


Kinkheda Resource map

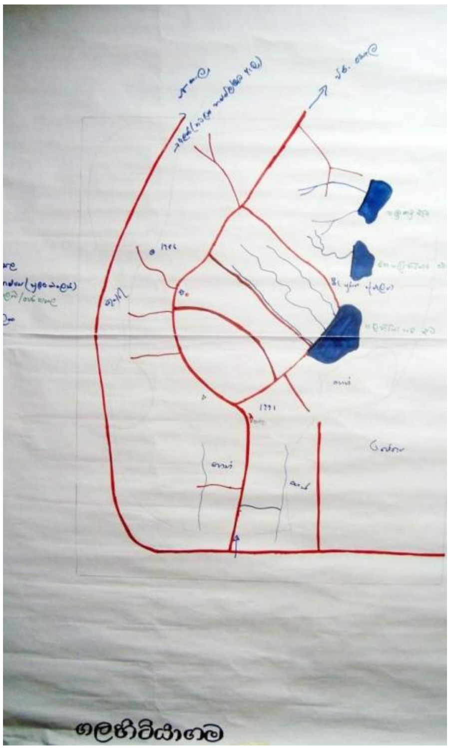
Annexure 3. Social and resource maps of Sri Lanka study villages



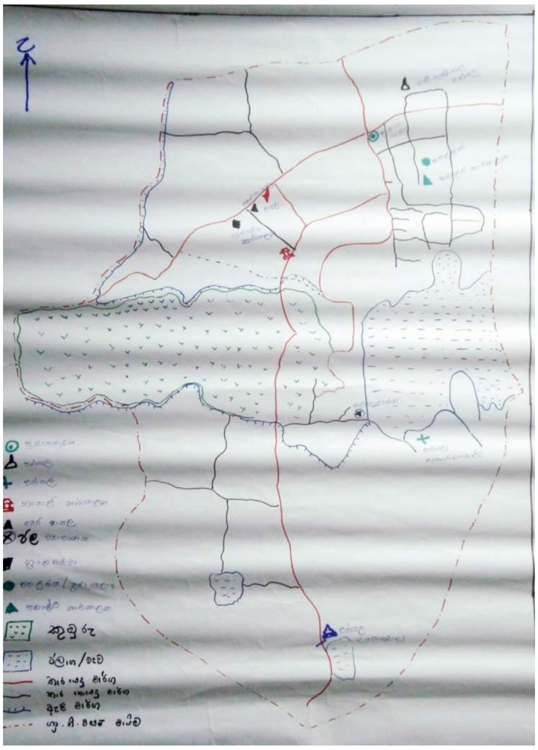
Social map of Mangalapura



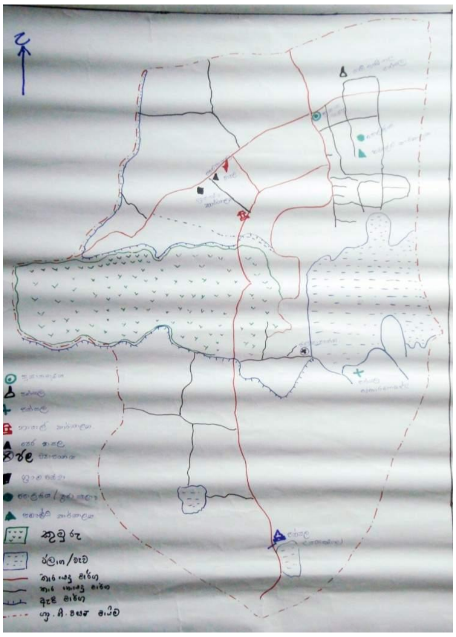
Resource map of the Mangalapura



Social map of the Galahitiyagama

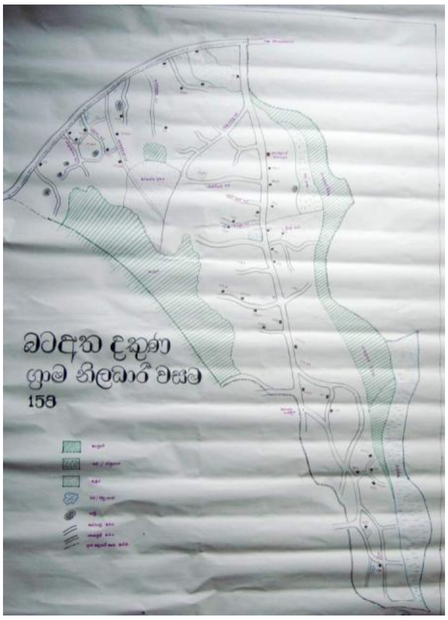


Resource map of the Galahitiyagama



Social map of the Mahagalwewa

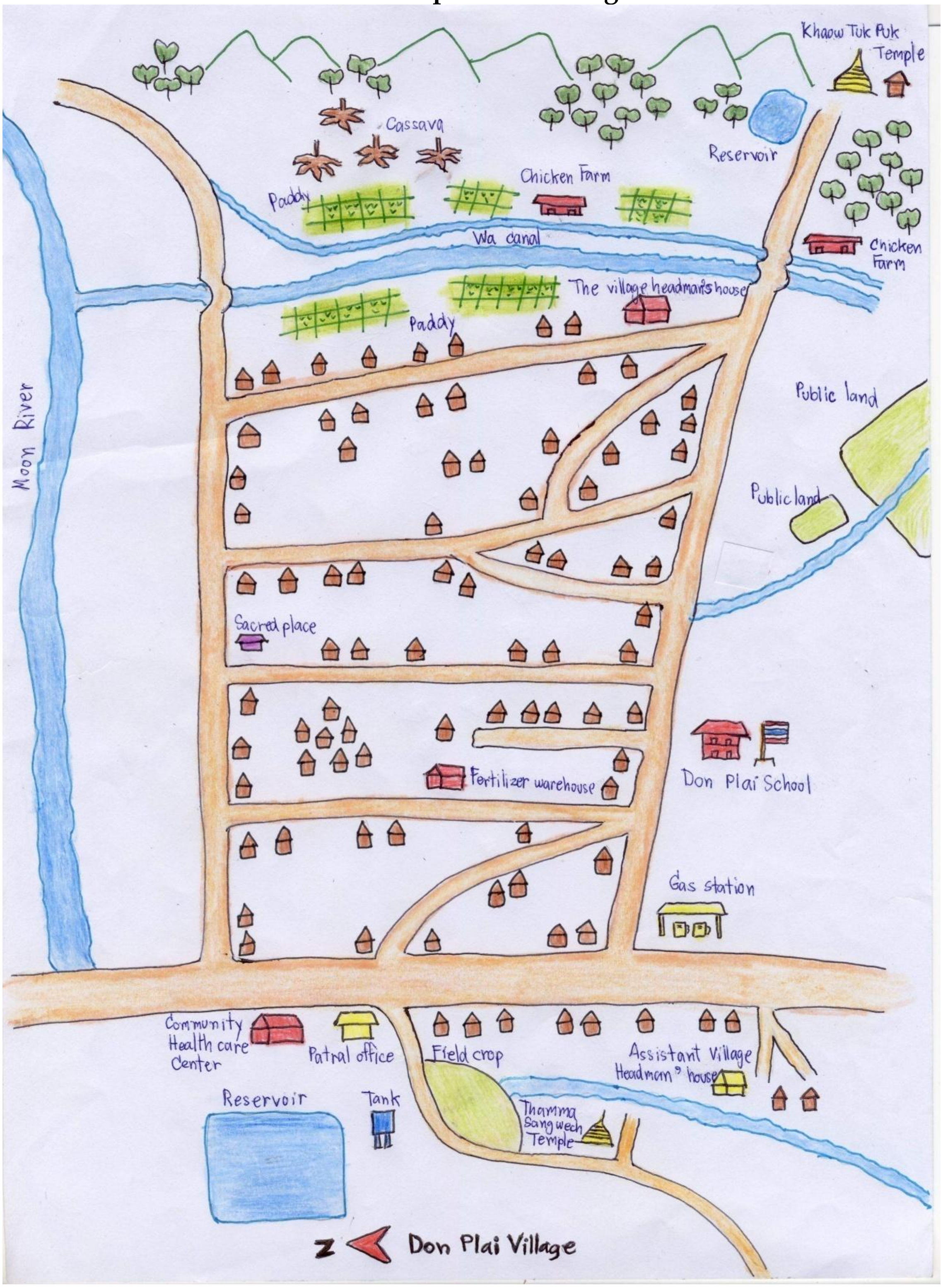
Resource map of the Mahagalwewa



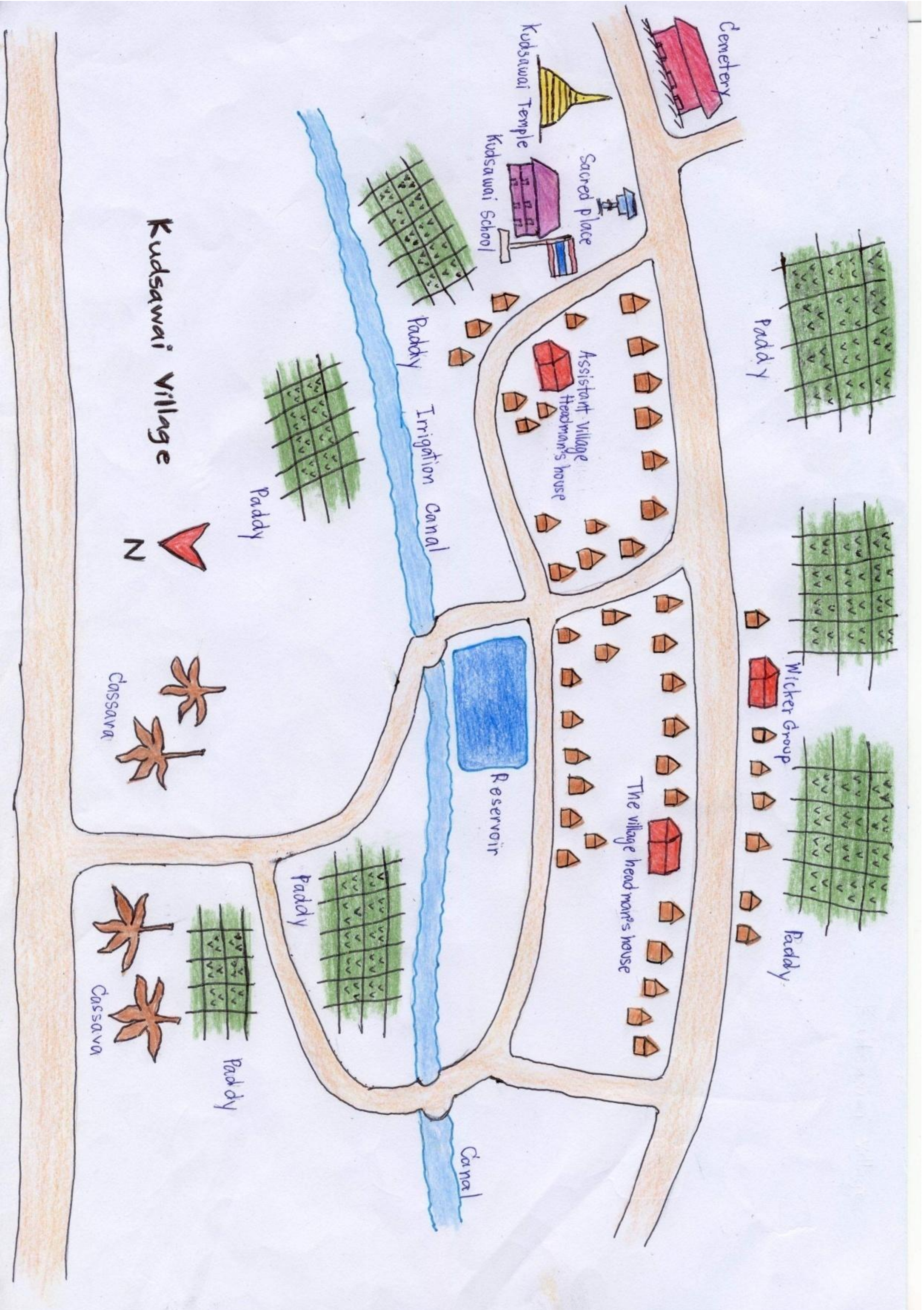
Social map of the Bata-Atha

Resource map of the Bata-Atha

Annexure 4. Social and resource map of Thai villages



Social and resource map of Don Plai (DP) village, Chok Chai district, Nakhon Ratchasima Province.

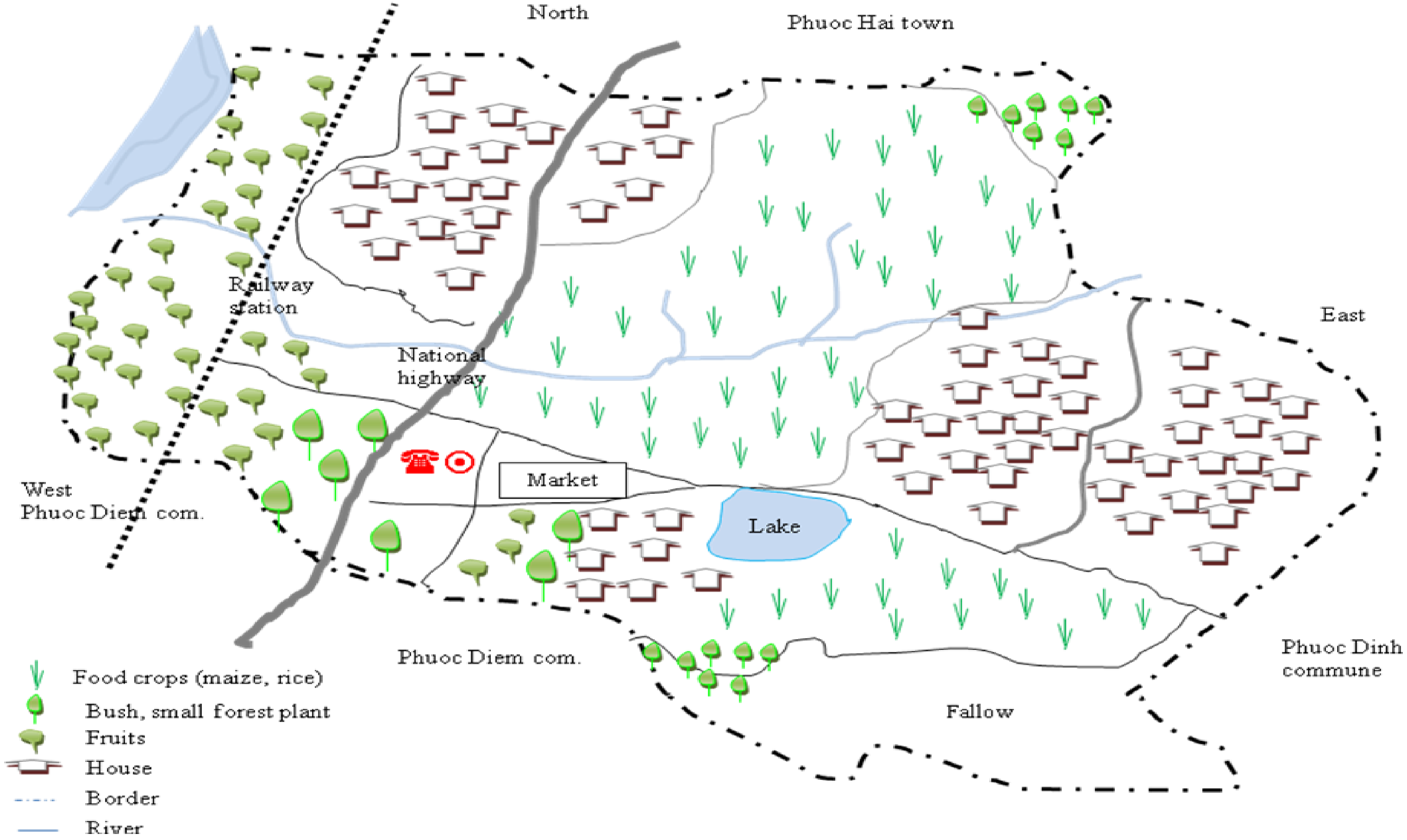


Social and resource map of Kud Sawai (KS) village, Chok Chai district,Nakhon Ratchasima Province.

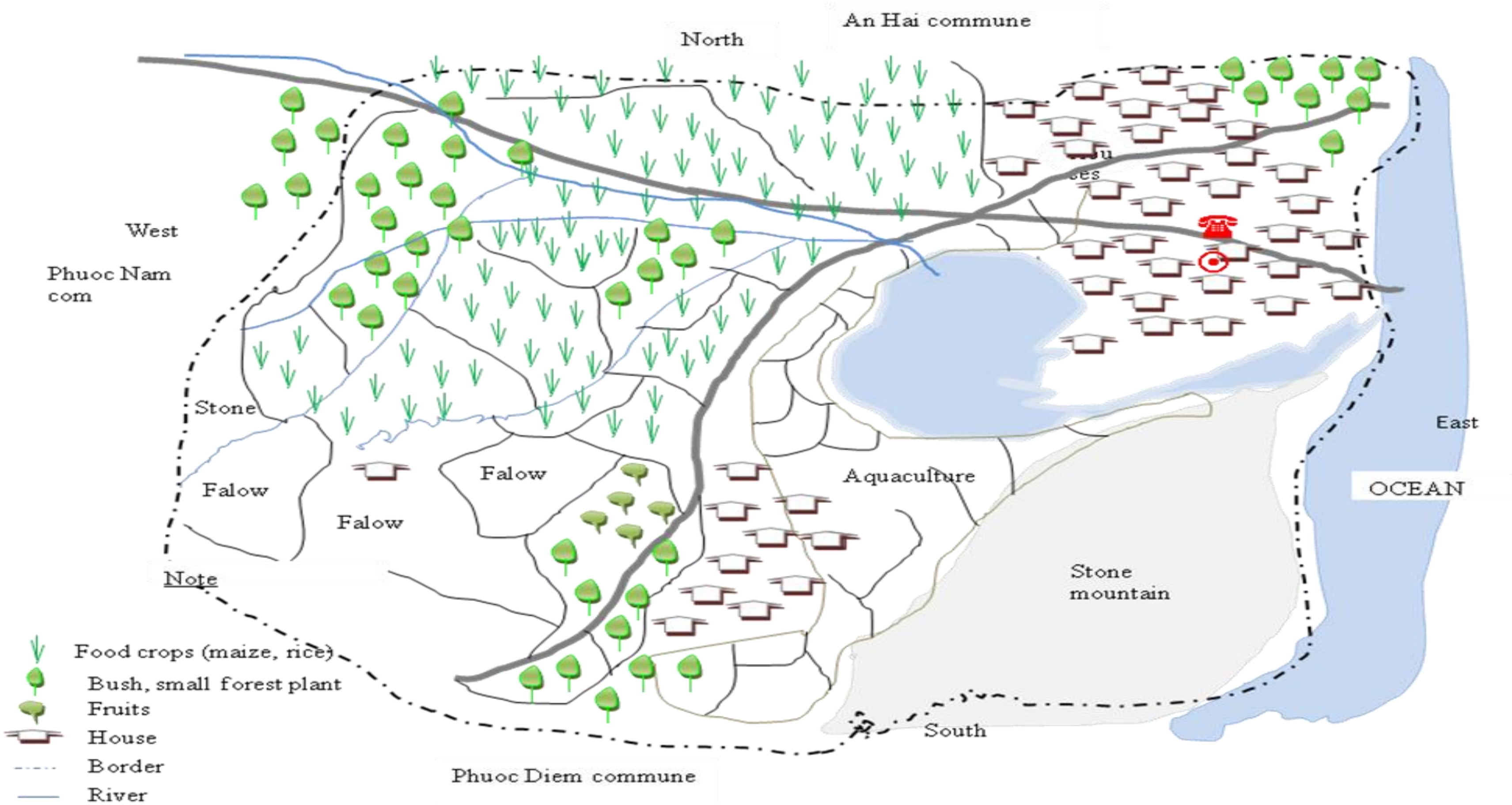
Social and resource map of Nong Muang (NM) village, Chatturat district, Chaiyaphum Province.

Social and resource map of Tha Taeng (TT) village, Chatturat district, Chaiyaphum Province.

Annexure 5. Social map of Viet Nam study villages



Social map of selected village in Phuoc Nam commune, Ninh Phuoc district, Ninh Thuan province



Social map of selected village in Phuoc Dinh commune, Ninh Phuoc district, Ninh Thuan province

Annexure 6:- The crop wise area distribution in Andhra Pradesh & climate reponse curves

The Major crop and the area grown in Andhra Pradesh during the period 1970-2008

Sl.No.	Crop (Andhra Pradesh)	Average area in ha.
1	Rice (paddy)	3685
2	Sorghum	1428
3	Pearl millet	305
4	Maize	398
5	Finger millet	177
6	Chickpea	159
7	Pigeonpea	317
8	Other Pulses	1117
9	Groundnut	1744
10	Sesamum	166
11	Castor	280
12	Other Oilseeds	2514
13	Sugarcane	209
14	Cotton	698

About ICRISAT

ICRISAT
Science with a human face

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT is supported by the Consultative Group on International Agricultural Research (CGIAR).

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About Project

Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience (ADB RETA: 6439)

Aim

to provide science-based solutions and pro-poor approaches for adaptation of agricultural systems to climate change for the rural poor and most vulnerable farmers in semi-arid regions

Expected outputs

- Improved understanding of climate variability and adaptation-coping strategies of the rural poor
- Best practices and institutional innovations for mitigating the effects of climate change
- Strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation