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project

Developing research options to mainstream climate adaptation into farming systems in Cambodia, Laos, Bangladesh and India

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2 Executive summary

Climate change is impacting throughout Asia, with shifts in rainfall patterns, changing temperature regimes and increased climate variability. Since many Asian economies depend more on agriculture than those of developed countries, and have less resilient institutions, they will be more heavily affected by climate change. The poorest farmers bear the brunt of climate change because they live in the more vulnerable areas. Changes in the quantity and timing of rainfall due to climate change are likely to be felt more immediately than temperature shifts and as such require more immediate attention. Climate change impact is likely to be exacerbated where policy environments and capacity to respond are weak. The impacts of climate change will amplify the current food security crisis.

In response to this ACIAR took a decision in 2008 to establish a dedicated *Climate Change Initiative.* This new initiative is to proceed in two stages. The first stage of the initiative will emphasise farm level adaptation to climate change, with an emphasis on more efficient use of water resources in Cambodia, Lao PDR, Bangladesh and Andhra Pradesh in India. This scoping study was commissioned by ACIAR to underpin the design of the first stage of the *Climate Change Initiative*, and the objectives of the scoping study were to:

1. Assess the constraints and opportunities to climate adaptation at the farm level in the four target countries
2. Assess the ability of selected farming systems modelling tools to adequately capture biophysical and socio-economic dimensions of rice-based cropping and mixed crop-livestock systems prevalent in the target
3. Develop benchmarking methods and data collection (survey) protocols to underpin a framework to assess impacts of adaptation

The study was carried out by CSIRO through its Climate Adaptation Flagship, in collaboration with a range of partner organisations in the above four countries. Extensive consultations with key government and non-government stakeholder organisations as well as with relevant international and national research institutions were carried out in the course of several scoping missions. Awareness raising and planning workshops were also held during each mission. A framework to benchmark adaptive capacity was developed and piloted in Bangladesh and Andhra Pradesh.

Recommendations to ACIAR in relation to future investment into farm level adaptation research were extracted from the review of:

- Existing knowledge with respect to projected climate change and its likely impacts
- Key priorities and policies relevant to adaptation to climate change
- Current donor funded activities
- Extension and agro-meteorological services in each country
- The current knowledge base with respect to farm level adaptation.

These recommendations were clustered into seven domains that are generally applicable to all four countries, followed by a set of country specific considerations.

A. *Climate science research priorities*

1. Better understanding and managing for current climate variability at local scales should be considered as a more important entry point for farm level climate adaptation for ACIAR than allocating effort to refining national level climate projections.

2. A more sophisticated statistical analysis of historical climate datasets should be undertaken to determine characteristics of climate variability (all four countries) and to determine/confirm trends in climate change (Cambodia, Lao PDR).

3. Explore the utility of statistical downscaling methods to ‘localise’ climate change projections and apply these methods in regions or locations of interest and where more detailed farm level adaptation research is envisaged.
4. Development of innovative ways of communicating climate uncertainty and variability, tailored to the different communication skills and needs of policy makers, government and non-government extensionists and smallholder farmers.
5. Evaluation of seasonal climate forecasts currently generated in Cambodia, Lao PDR and Bangladesh with respect to their current forecasting skill and with respect to options for improving their reliability and extending their lead times.

B. *Improving the assessment of climate change impacts on rice based farming systems*

6. Future impact assessments need to better reflect local conditions of farming systems and to the extent possible take into account ‘local’ climate variability and climate change.
7. More emphasis should be given on assessing opportunities and avenues to maximise positive impacts of climate change.
8. A scoping study should be considered by ACIAR to assess the direct and indirect impacts of climate change on livestock performance.
9. ACIAR should continue to invest in the further development of APSIM and in particular support its extension to fully capture rice crops in rice-based cropping systems.
10. In the context of wider application in food security and livestock intensification research, ACIAR should consider supporting the redesign of IAT to achieve greater versatility and more user friendliness.

C. *Research to underpin government and donor supported adaptation programmes*

11. ACIAR’s investment in climate adaptation research should consider targeting the gap between national scale climate change vulnerability and impact assessments, and the demonstration of adaptation interventions at the household and community level.
12. The ACIAR emphasis on adaptation research should be to demonstrate the development of multi-scale adaptation strategies that enable policy makers to deliver more effective climate adaptation programs elsewhere.
13. ACIAR should ensure its future adaptation research projects are explicitly linked to other donor funded adaptation projects where there are clear opportunities for outscaling of adaptation strategies and where there is a high likelihood of application of outputs generated by the ACIAR projects.
14. As a key input to policy formulation and the design of adaptation programmes, ACIAR should consider supporting research that also determines the limitations to adaptation.

D. *Understanding adaptive capacity as the base for developing technical adaptation options*

15. A high priority should be accorded to social research aimed at understanding adaptive capacity in conjunction with the evaluation of technical adaptation measures.
16. A focus of social research should be the development of more rigorous tools and frameworks to assess adaptive capacity at a range of scales (household to national policy levels).

17. Greater emphasis should be placed on supporting research into the integration of social and biophysical sciences by using the insights obtained from the adaptive capacity analysis to inform the choices of technical adaptation options requiring further evaluation.
18. Adaptation research should be underpinned by the quantification of the financial and economic costs and benefits of adaptation and a determination of the incentives that will encourage smallholder farmers to adapt to longer term climate change.

E. Enhancing the role of farming systems research in selecting and evaluating farm level adaptation options

19. Any evaluation of adaptive farm management practices (crop density and planting dates, choice of alternate crops or varieties, nutrient and water management, cultural practices, livestock nutrition and management, etc.) should be conducted using farming systems models that are capable of capturing farming practice realities and that are used in a participatory mode, soliciting farmer input to scenario definition and output assessment.
20. Capacity building in participatory farming systems modelling and in depth training of appropriately selected and institutionally supported researchers should be undertaken in conjunction with farming systems modeling to evaluate farm level adaptation options.
21. Crop and farming systems scenario modelling should be carried out to inform the prioritisation of breeding programs developing the next generation of climate-resilient crop varieties.
22. The evaluation of farm level adaptation options should also take into account their efficiency in terms of unit use of input factors (e.g. water productivity, nitrogen use efficiency, fuel/energy use per unit biomass produced) to ensure that adaptation does not inadvertently lead to future maladaptation.

F. Research into improved water management as a key to buffering climate impacts

23. ACIAR should commission a scoping study to assess the technical, economic and environmental feasibility of government and donor supported implementation of integrated drainage networks to mitigate the impacts of flooding.
24. A more systematic assessment of ground water resources in terms of quantity and quality, and their sustainable use for supplementary irrigation should be carried out in primarily in Cambodia and Lao PDR.
25. A focus of the climate adaptation research in Bangladesh should be the determination of spatial and temporal dynamics of salinity intrusion as a result of climate change and the implications of these changed dynamics for the adaptation of crop and water management.

G. Strengthening the capacity of information delivery systems

26. All farm level adaptation research activities should be designed with a significant capacity building component to enhance the skills of government and NGO extension workers in the provision of advice to farmers on farm level adaptation options.
27. The design of effective dissemination pathways and the packaging of seasonal forecast information into farmer friendly advisories should be piloted in Bangladesh and Lao PDR.

Whilst most of the above recommendations are relevant to all four countries studied, the balance and emphasis across these recommendations varies between each of the countries, depending on ACIAR country priorities, opportunities to link with other donor projects and the level of research capacity in country.

In Cambodia and Lao PDR it is proposed that the focus of ACIAR's adaptation research portfolio should be on assessing adaptive capacity to inform local level choice and testing of crop, nutrient and water (irrigation) based adaptation techniques as the basis for the development of more general adaptation strategies to underpin national and provincial planning and policy making. In Cambodia this should be located in Prey Veng and Svay Rieng, while in Lao PDR the proposed geographic focus is Savannakhet Province.

Bangladesh offers the best prospects for the further refining, testing and validating of an extended APSIM-ORYZA model because it is possible to draw on several high quality datasets not available elsewhere; so the further development of APSIM-ORYZA as a critical enabling tool to analyse adaptation scenarios is seen as the highest priority for ACIAR's climate adaptation portfolio in Bangladesh. Resources permitting, there are also two additional project options which revolve around addressing salinity intrusion and flooding in the SW of Bangladesh and mitigating the impact of drought in the NW of Bangladesh.

In India, based on stakeholder feedback, a clear preference is given to further refining the use of seasonal climate forecasting in farmer decision making and using this as an entry point to adaptation. These actions should be underpinned by a better understanding of adaptive capacity and a stronger level of engagement with policy stakeholders at central and state government levels.

3 Background

3.1 ACIAR Climate Change Initiative

Climate change is impacting throughout Asia, with shifts in rainfall patterns, changing temperature regimes and increased climate variability. Since many Asian economies depend more on agriculture than those of developed countries, and have less resilient institutions, they will be more heavily affected by climate change. The poorest farmers bear the brunt of climate change because they live in the more vulnerable areas. Changes in the quantity and timing of rainfall due to climate change are likely to be felt more immediately than temperature shifts and as such require more immediate attention. Climate-change impact is likely to be exacerbated where policy environments and capacity to respond are weak. The impacts of climate change will amplify the challenge to maintain future food security.

Apart from being directly impacted by climate change, agriculture is a major source of greenhouse gas (GHG) emissions, thus contributing to climate change. Ruminant livestock, particularly cattle, are major producers of methane, a potent GHG. In addition, nitrous oxide emissions arising from intensive fertiliser use, burning of crop residues and methane emissions from paddy rice fields are also very significant contributors, while energy consumption through tillage operations in field preparation and chemical inputs contributes indirectly.

In recognition of the above, ACIAR has in the past maintained a diverse portfolio of projects relating to prediction of seasonal climate variability, adaptation of farming systems and research in GHG emissions and agricultural mitigation. To date, climate-related projects in ACIAR have not been grouped under a dedicated climate-change program, but have been distributed and managed cross-sectorally, mainly through the natural resource management cluster of programs (Land and Water Resources, Soil Management and Crop Nutrition, and Forestry), but also involving the Crop Improvement and Management, Agricultural Systems Management and Livestock Production Systems programs.

In 2008-09, ACIAR took the decision to build on this existing and past project portfolio by establishing a dedicated *Climate Change Initiative.* This new initiative will proceed in two stages. The first stage of the initiative will emphasise farm level adaptation to climate change, with an emphasis on more efficient use of water resources particularly in the lower Mekong Basin and South Asia. It will provide the main thrust of the initiative. The plan is to expand this into a second stage with funding from part of a wider initiative involving AusAID and other agencies involved in a new program “Food Security through Rural Development” announced by the Australian government in its 2009/2010 budget.

As part of the first stage, ACIAR is implementing two major adaptation projects, one targeting farm level adaptation options in Cambodia, Lao PDR, Bangladesh and India, and a second project focussing on the Mekong Delta in Vietnam. This scoping study was commissioned in December 2008 to specifically assist in the design of the former project. Scoping and design of the Vietnam project is occurring through a separate process led by ACIAR. A further expansion of ACIAR investment into policy and climate change mitigation as well as additional adaptation research will be informed by a broader study being carried out by NCCARF.

3.2 Scope of study

Cambodia, Laos, Bangladesh and India are among the most vulnerable countries in Asia (Yusuf and Francisco, 2009; Cruz *et al.,* 2007). Their vulnerability to climate change arises out of a combination of socio-economic factors (very low institutional and community capacity to adapt) and their high exposure to climate risks (flooding in floodplain areas of the Mekong and in Bangladesh; increased drought more generally). While other Asian countries are also very vulnerable, other parts of the Australian aid programme are already addressing adaptation issues in these countries (e.g. AusAID in the Pacific Islands and Indonesia; ACIAR in Vietnam). Hence this study was constrained geographically to Cambodia, Laos, Bangladesh and India, and within India, to Andhra Pradesh in order to align with ACIAR's Subprogram 2 on water resource management centred on that State.

A feature of the selected countries is their dependence on large areas of **rainfed**, rice-based cropping systems to provide the mainstay of food security. This is in contrast to **fully irrigated** rice-based cropping systems, with a much lower inherent risk because of more certain access to irrigation water. Rice is the main staple crop in all four countries, with annual rice production in 2007 in India, Bangladesh, Cambodia and Laos PDR being 144.6, 43.1, 6.7 and 2.7 M tons, respectively (FAOSTAT, 2009). With an anticipated change in rainfall regimes, rainfed farming systems are confronted with the challenge of not just maintaining productivity in an environment of global change, but of increasing rice production to match the growth in population. This scoping study will primarily be focussing on rainfed areas without or with locally-sourced small-scale irrigation. Issues specifically relating to large scale irrigation schemes, as well as forestry and fisheries have been excluded from the analysis of this study.

The objectives of the scoping study reported here were to:

1. Assess the constraints and opportunities to climate adaptation at the farm level in the four target countries. This will include an analysis of the policy environment and drivers of change and an evaluation of the extent and efficacy of current agro-meteorological and extension services in the context of climate change adaptation. This task will also involve an assessment of other donor-supported programs and potential for linkages to Australian climate adaptation programs. All the above information will provide the backdrop against which a program of activities will be designed that will maximise climate change adaptation impacts of ongoing ACIAR work.
2. Assess the ability of selected farming systems modelling tools (APSIM and IAT) to adequately capture biophysical and socio-economic dimensions of rice-based cropping and mixed crop-livestock systems prevalent in the target regions in the context of climate variability and climate change. Data constraints and modelling gaps will be identified and scoped (e.g. potential need for more robust rice crop modules; lack of paddy soil modules; ability to integrate livestock components).
3. Develop benchmarking methods and data collection (survey) protocols to underpin a framework to assess impacts of adaptation. It is anticipated that this framework will then be developed and tested in selected countries as part of this study.

The study was carried out by CSIRO through its Climate Adaptation Flagship, in collaboration with a range of partner organisations in all four countries. It draws upon the expertise of a range of CSIRO researchers, and past and current ACIAR climate research, farming systems and systems modelling projects. Extensive consultations with key government and non-government stakeholder organisations as well as with relevant international and national research institutions were carried out in all four countries in the course of several scoping missions. Awareness raising and planning workshops were also held during each mission. The framework to benchmark adaptive capacity developed as part of Objective 2 was piloted in Bangladesh and Andhra Pradesh. A list of stakeholder organisations consulted and a summary of the missions undertaken is given in section 13.

4 Projected climate change and anticipated impacts on agriculture

Over the past 15 years the climate change debate has tended to focus on the science underpinning climate change impacts and the policy implications and responses required to achieve a reduction in greenhouse gas emissions (GHG) emissions through abatement. More recently and in particular since the 4th IPCC assessment on climate change, there is a growing realisation that climate change is already occurring and will continue to occur irrespective of the level of GHG abatement. As a result adaptation to inevitable climate change has gained much more prominence. This is particularly the case in most of the developing nations, as their climate change footprint (with the exception of India and China) is small, but these countries stand to be the worst affected by the impacts of climate change.

In its 4th Assessment, the IPCC states that there is more reliable evidence of decreasing crop yields in Asia due to a rise in temperatures and an increase in the frequency of extreme weather events (Cruz *et al*., 2007). In general, reports of observed temperature rise range from 0.68°C per century (India), 0.5 to 1.0°C for the period 1988 to 1998 (Bangladesh) and 0.1 to 0.3°C per decade for 1951-2000 (SE Asia). Observed changes in precipitation are less consistent, with increased intensity of rainfall in some areas and fewer rainy days in other areas (NW India, SE Asia), as well as a perceived intensification of El Nino related droughts in parts of South and SE Asia (Cruz *et al.,* 2007).

Regional climate projections as part of the 4th Assessment are summarised by Christensen *et al*. (2007). All of Asia is very likely to warm during this century; the warming is likely to be above the global mean in South Asia and similar to the global mean in SE Asia. It is very likely that there will be fewer very cold days in South Asia. Summer precipitation is likely to increase in South Asia and in most of SE Asia. An increase in the frequency of intense precipitation events in parts of South Asia is also very likely.

Despite the relevance of these findings for catalysing policy responses, such high level assessments are not very useful for the development of farm level adaptation programmes. The main reason for this is that for climate change to become relevant to farmer decision making would require a far greater level of location specific information, as well as a greatly increased level of certainty surrounding climate projections.

The high level of uncertainty is not only a result of the current limitations in GCMs, but a major additional source of uncertainty in climate change projections are the future global development trajectories captured in the suite of emissions scenarios generated by the IPCC commonly underpinning the GCM modelling (SRES; IPCC, 2000). These global (or so-called SRES) emission scenarios reflect a range of possible (and plausible) global development trajectories, but they are by no means certain or representative of a particular location or region. The inherent uncertainty originating from the inability of SRES scenarios to ***predict*** change trajectories, as well as the modelling uncertainties arising out of GCM limitations might well decrease somewhat as more data and knowledge is generated, but it is highly unlikely that sufficient certainty to enable predictions will be forthcoming in the near future. Consequently, it is suggested that activities aimed at understanding and addressing climate variability will be the best entry point to engage locally with farmers on adaptation to climate change.

Notwithstanding the above, the last 5 years have seen an increased effort in generating regional or country specific climate change projections with a higher spatial resolution (but not necessarily greater certainty), allowing for a more differentiated assessment of climate impacts. At a minimum, this information helps identify possible hotspot areas and cropping systems at greatest risk. The following sections attempt to summarise the present knowledge in this respect for the four study countries.

4.1 Cambodia

Most of the recent analyses of climate change in relation to Cambodia rely on Global Circulation Model (GCM) output and were conducted in the context of wider ranging Mekong Basin level assessments. There is very little published work on systematic analysis of historic rainfall data with respect to signals reflecting trends in climate change, although some analysis was undertaken as part of the Cambodia National Adaptation Programme of Action (NAPA).

Earlier regional work includes that of Hoanh *et al.* (2003), Snidvongs *et al.* (2003) and Ruosteenoja *et al.* (2003). All studies point to increases in temperatures and precipitation, with a likelihood of wetter monsoon seasons and less rainfall in the dry seasons. However spatial resolution of these studies is very low, overall uncertainty of projections very high and Cambodia specific conclusions are only very generic. In the context of the 4th IPCC Assessment, 52 more detailed country profiles were undertaken using re-gridded (2.5° x 2.5°) time series for different temperature and rainfall variables under three SRES emissions scenarios (A2, A1B and B1). One of these studies was for Cambodia (Mac Sweeney *et al.*, 2008). This study projects temperature to rise by 0.7 to 2.7°C by the 2060s and rainfall regimes to increase in mean annual rainfall, mainly due to wetter rainy seasons (-11 to +31%), partially offset by drier dry seasons (-54 to +35%). Shorter timeframe projections were not provided, possibly because no significant changes were detected. Also, there is no distinction between underlying climate variability and climate change signals, so these results need to be interpreted with caution.

More recently, Lacombe (2009) has used the regional climate model PRECIS to evaluate changes in 19 climate parameters for the period 1960-2049. PRECIS dynamically downscales output from the coarser level ECHAM4 model to a resolution of 0.2° x 0.2° and has recently been calibrated for Southeast Asia by the Southeast Asia START Regional Centre. This study allows some more spatially explicit conclusions to be drawn for Cambodia. Overall, total rainfall is not projected to change significantly, although there are indications of a reduction in total rainy days and a decrease in dry season rainfall. This implies a wetter rainy season with more intense rainfall events and a higher incidence of flooding. Average onset and end of the rainy season are predicted to shift by about 2 days every 10 years. Temperatures are likely to rise by about 2.3 to 2.8°C.

Climate change projections for individual sub-basins of the Mekong River Basin were generated by Eastham *et al.* (2008) in their assessment of climate change impacts on water resources. They sampled the output of 11 GCMs in order to reflect uncertainty bounds of projections. Sub-basin level projections of rainfall and temperature for the A1B SRES climate change scenario were obtained using statistical downscaling techniques. The median projected annual precipitation in most of Cambodia (Tonle Sap catchment) is expected to increase in a range of 200-300 mm, this increase diminishing a bit towards the eastern catchments in Cambodia (Kratie). Most of this change occurs during the wet season, while a small median decrease in dry season rainfall of about -10 to -14 mm is projected for the Tonle Sap in 2030. Temperature throughout the lower Mekong, including all of Cambodia is projected to be 0.7 to 0.8°C higher in 2030 compared to the 1951-2000 baseline.

In accordance with the earlier projections of Hoanh *et al.* (2003), Snidvongs *et al.* (2003) and Ruosteenoja *et al.* (2003), and those obtained more recently by Eastham *et al.* (2008), increased frequency and severity of flooding is seen by many stakeholders canvassed during the scoping study visits to Cambodia as the primary impact. Although increased incidence of drought (including within wet season drought spells) is also rated as highly likely, based on the climate change projections a change in wet season drought frequency is uncertain, whereas drier conditions in the dry season seem probable. As part of its 1st National Communication, Cambodia also conducted a survey-based assessment of vulnerability and adaptation in a number of case studies which examined the impacts of climate change on agriculture (rice production), forestry (forest types), human health (malaria) and coastal zone (sea level rise). The assessment of the effects of climate change on agriculture was conducted for rice cultivation, as it forms the backbone of traditional livelihoods and constitutes Cambodia's staple food source. Flood and rainfall patterns play a determining role in paddy cultivation and the absence of widespread irrigation and water harvesting schemes in Cambodia make this sector particularly vulnerable to climate change, especially due to the effects of flooding and drought. Based on data from 1996 to 2001, rice production loss in Cambodia was mainly due to the occurrence of flooding (more than 70% loss), followed by the impacts of drought (about 20% loss) and other impacts such as pest and diseases (10% loss) (MRC, 2009a). According to the NAPA report (RGoC, 2006a), the Provinces most likely to be affected by flooding are Kampong Cham, Prey Veng, Takeo, Kampong Thom and Battambang. Vulnerability to drought is most pronounced in Prey Veng, Battambang and Banteay Meanchey. There is some anecdotal evidence of observed changes, with villagers interviewed in the Stueng Siem Reap watershed reporting an increase in temperature alongside greater irregularity of rainfall (GTZ, 2008). Eastham *et al.* (2008) list projected impacts for sub–basins of the Mekong in Cambodia (Tab. 4.1).

Table 4.1: Summary of potential impacts of climate change on catchments of the Mekong Basin in Cambodia (Source: Eastham *et al.*, 2008)

Potential Impacts of Climate Change (2030)
Se San: Southern Laos, North-east Cambodia and Central Highlands of Vietnam Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Potential for increased flooding (not quantified).
Kratie: Southern Laos and Central Cambodia Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Frequency of extreme floods increased from 5% to 76% annual probability; Peak flows, flood duration and flooded area increased; Dry season minimum flows increased.
Tonle Sap: Central Cambodia Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Dry season water stress increased and remains high; High probability of increased flooding (not quantified); Seasonal fluctuation in Tonle Sap Lake area and levels increased; Minimum area of Tonle Sap Lake increased, areas of flooded forest permanently submerged and possibly destroyed reducing fish habitat; Net impact on capture fisheries uncertain; Maximum area of Tonle Sap lake increased with possible negative impacts on agricultural areas, housing and infrastructure.
Phnom Penh: South-eastern Cambodia Food scarcity due to population increase; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff increased; High probability of increased flooding; Flooded area increased.
Border: Southern Cambodia and South Vietnam Agricultural productivity decreased; Food scarcity due to population increase; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; High probability of increased flooding; Flooded area increased.

As part of an ongoing project building on the work by Eastham *et al*., (2008), CSIRO's Water for Healthy Country Flagship in collaboration with the MRC and IWMI is investigating the impacts of climate change at a finer spatial scale. This work also includes simple crop modelling using FAOs' AquaCrop model to assess the impacts of climate change on crop yields. While this study has yet to be completed, preliminary modelling suggests that in most of the case study areas crop yields are more likely to increase than decrease (Tab. 4.2), corroborating the general trend of increased crop productivity in most of the areas listed in Tab. 4.1.

The overall picture that emerges from the above is that climate change potentially offers opportunities as much as it represents possible threats to livelihoods. Increased wet season precipitation in the drier areas can be beneficial, especially if it goes with a reduction in frequency and duration of within season droughts. Conversely, in wetter areas, the concomitant increase in flooding might make rice cropping unviable in low-lying areas if they are too frequently inundated, requiring a more transformational change to production systems, e.g. shifting rice cropping into the dry season with irrigation. In comparative terms, the anticipated exposure to climate change impacts seems less severe than that of other countries (see Bangladesh below). However, vulnerability to climate change being the product of exposure and adaptive capacity, Cambodia still remains a highly vulnerable country given its relatively lower level of adaptive capacity (Yusuf and Francisco, 2009).

Table 4.2: Modelled impact of climate change on crop yields in the Lower Mekong for the SRES A2 and B2 scenarios (Mainuddin, *pers comm.)*

Country	Province	Yield change (%) from baseline condition			
		Including failed years		Disregarding failed years	
		A2	B2	A2	B2
Lao PDR	Savannakhet	10.3	-4.3	16.0	6.0
	Vientiane municipality	28.1	21.9	28.1	21.9
	Oudomxay	27.6	26.6	27.6	26.6
Thailand	Ubon Ratchathani	7.7	15.1	7.7	15.1
	Sakon Nakhon	17.6	11.4	17.6	11.4
	Roi Et	10.8	165.1	13.6	15.1
	Nakhon Ratchasima	16.5	27.7	22.5	37.8
Cambodia	Kampong Speu	**-14.2**	**-2.9**	0.6	13.7
	Battambang	2.7	**-3.0**	10.8	13.7
	Kratie	6.3	**-8.4**	9.0	**-1.1**
	Siem Reap	14.6	14.5	20.5	20.3
Vietnam	Gia Lai	6.4	**-10.1**	14.8	-5.5
	Kien Giang	11.9	**-6.8**	11.9	0.6
	Dong Thap	**-1.6**	**-11.0**	12.1	**-1.4**

4.2 Lao PDR

As for Cambodia, there is little information available in Lao PDR to identify future climate change trends based on the analysis of historical climate data and again, most of the recent analyses of climate change in relation to Lao PDR rely on GCM output generated for the Mekong Basin or other regional studies. In the studies conducted by Hoanh *et al.* (2003), Snidvongs *et al.* (2003) and Ruosteenoja *et al.* (2003) general climate change trends in Lao PDR portion of the Mekong Basin indicate increases in temperatures and little change or some increases in precipitation for most parts of Lao PDR, with a likelihood of wetter monsoon seasons and less rainfall in the dry seasons. Again, there is substantial uncertainty associated with these results. However, Snidvongs (2006) cited in the NAPA report (WREA, 2009) suggests a slight cooling of most of Laos for a 540 ppm CO_2 scenario, whereas temperatures are projected to rise fairly uniformly by 0.5 – 1°C under a 720 ppm CO_2 scenario. Annual rainfall is generally expected to increase across all of Laos by 100 – 200 mm and by 200 – 500 mm in the 540 and 720 ppm scenarios, respectively. However, these results should be interpreted with caution, as Snidvongs based this analysis on the output of one GCM only (CSIRO's Conformal Cubic Atmospheric Model, which has been found to represent climate in SE Asia fairly well).

More spatially differentiated results can be extracted from the study by Lacombe (2009). The PRECIS-derived projections for Lao PDR indicate that total rainfall is not predicted to change significantly although there are indications of some decrease in total in the central-south parts (Khamouane, Savannakhet, Saravane Provinces), but only in the SRES A2 scenario. Irrespective of scenario, most of Lao PDR is projected to experience a 2-day shift in onset and end of the wet season for each 10 year period of the studied climate change period (1960-2049). Temperatures are likely to rise by about 2.3 to 2.8°C.

These results are in contrast to the results obtained by Eastham *et al*. (2008) who based their analysis on ensemble outputs of 11 GCMs, allowing them to portray some of the uncertainty bounds around the median climate projections and making their projections more robust. In fact the median sub-basin level results obtained by Eastham *et al.* (2008) differ from Lacombe *et al.* (2009) with respect to rainfall, possibly due to a different choice of SRES scenario (A1B instead of A2 and B2 in Lacombe’s study) as well as the statistical downscaling used (in contrast to the dynamical downscaling used by Lacombe). The median projected annual precipitation in most of Lao PDR is expected to increase significantly, with distinct regional variations. In northern Lao PDR, median 2030 rainfall is estimated to increase by 50 – 100 mm. For some of the central Provinces (e.g. Vientiane) rainfall increase range between 100 – 200 mm, while other central and some southern Provinces median increases range between 200 – 300 mm (e.g. Boulikhamxay, Khamouane). Further south (Savannakhet, Champassak, Saravane) the range in increase is projected to be 100 – 200 mm.

Temperature rise across Lao PDR shows less geographical differentiation. For most of the country the projected 2030 median increase in temperature ranges from 0.7 to 0.8°C above the 1951 – 2000 baseline. Exceptions are some of the central north Provinces (Luang Prabang, Vientiane) with slightly higher increases (0.8 – 0.9°C), in contrast to Khamouane and Savannakhet, where the increase by 2030 is projected to be slightly lower (0.6 – 0.7°C).

In accordance with the above projections of higher rainfall over time, the main climate impact anticipated is an increased incidence and severity of floods. The NAPA report for Lao PDR (WREA, 2009) provides data on floods and their impacts, noting that severity of floods has been increasing, with the latest one in 2008 judged as the most severe to have affected Vientiane to date. In its regional synthesis report, the MRC (2009a) summarises the flood impacts as follows. From 1996 to 2005, floods and droughts have caused significant economic losses. Just in the areas of Vientiane plain and the Nam Ngum River valley, the losses from the 1995 flood amounted to more than USD 10 M. Significant damages to irrigation systems have occurred with nearly USD 9 M of losses between 2005 and 2007. The 2007 storms caused a loss of 34,751 ha of rainfed rice and destroyed USD 7 M of crops and USD 10.4 M worth of livestock. Floods and droughts are also thought to have led to an increase in disease outbreaks such as smallpox, malaria, diarrhoea, dysentery, dengue fever and pneumonia.

Chinvanno *et al.* (2006) surveyed 290 farm households in Vientiane Province and 160 farm households in Savannakhet Province with respect to farmer’s awareness of and ability to adapt to climate change. According to this study, *“Many farmers surveyed over the age of 40 years reported noticeable changes in the present climate pattern in comparison to the past 25 to 30 years. These noticeable changes include increasing variability in the dates of onset and end of the rainy season, changes in wind direction, changes in rainfall distribution pattern throughout the season, and an increase in thunderstorm activity. Thunderstorms, as far as the farmers’ observations are concerned, have increased in frequency, and their occurrence has extended throughout the rainy season in many study sites. In the past, they only occurred during the beginning and toward the end of rainy season. This observed phenomenon may be an indicator of changes in the regional high–low pressure front 5 during the rainy season, which no longer moves to a higher latitude after the beginning of the rainy season and moves southward again at the end of rainy season. The front now seems to stay within the region* *throughout the rainy season. Some farmers also noticed a change in wind direction pattern, which now varies throughout the season, unlike the old days, when farmers observed that clouds and rain always came from only a certain direction, which was more predictable"*.

Flooding at the end of the growing season before harvest of rice and midseason drought spells after planting were stated by farmers as being the most significant climate change related threats to their livelihoods (Chinvanno *et al.*, 2006). These impacts were also consistently voiced by all stakeholders at national and provincial level interviewed in the course of the scoping study visits. Extent of flooding varies from Province to Province and is mainly located in the major floodplain areas of the Mekong River and some of its larger tributaries, as well as in the vicinity of small dams. According to the NAPA report (WREA, 2009), during the period 1998 to 2005 the yearly average area of rainfed rice affected by flooding ranges from ~ 500 ha in the northern parts to ~24,000 ha in central Laos and ~10,000 ha in southern Laos. However, whilst the report states flooding has been exacerbated by climate change, the data provided does not indicate any significant statistical trends and it is quite possible that the variations observed are well within the bounds of natural climate variability. A recently initiated study funded by the ADB is looking at the impact of climate change on flood incidence in southern Laos, and it is likely that this study will provide further insights. Similarly, it is hard to conclude from the drought data presented in the NAPA report that incidence of drought is increasing as a result of climate change. Nevertheless, droughts within the rice growing season have the potential to significantly affect rice production. In the 2003 drought year, an estimated 23,770 ha of lowland, rainfed rice area was affected, with an additional 11,670 ha of upland rice also affected (WREA, 2009).

Irrespective of whether the current climate is already evidencing climate change impacts, the modeling conducted by Eastham *et al.* (2008) fairly consistently lists increased flooding as a likely outcome of climate change in most sub-basins of the Mekong within Laos, alongside increased discharge and runoff (Tab. 4.3).

Table 4.3: Summary of potential impacts of climate change on catchments of the Mekong Basin in Lao PDR (Source: Eastham *et al*., 2008)

Potential Impacts of Climate Change (2030)
Chiang Saen: China, Myanmar, Northern Laos Temperature and annual precipitation increased; Dry season precipitation increased; Annual runoff increased; Dry season runoff increased; Annual flows into Lower Mekong Basin increased by 30%; No reduction in dry season flow; Potential for increased flooding (not quantified).
Moung Nouy: Northern Laos Agricultural productivity decreased; Existing food scarcity increased; Temperature and annual precipitation increased; Dry season precipitation increased; Annual runoff increased; Dry season runoff increased; Potential for increased flooding (not quantified).
Luang Prabang: Northern Thailand and Northern Laos Agricultural productivity decreased; Existing food scarcity increased; Temperature and annual precipitation increased; Dry season precipitation increased; Annual runoff increased; Dry season runoff increased; Potential for increased flooding (not quantified)
Vientiane: Northern Laos and of North-east Thailand Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation increased; Annual runoff increased; Dry season runoff increased; Potential for increased flooding (not quantified)
Tha Ngon: Central Laos Agricultural productivity decreased; Existing food scarcity increased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff increased; Potential for increased flooding (not quantified)

Table 4.3 contd.: Summary of potential impacts of climate change on catchments of the Mekong Basin in Lao PDR (Source: Eastham *et al.*, 2008)

Potential Impacts of Climate Change (2030)
Nakhon Phanom: Central Laos and North-east Thailand Agricultural productivity increased; Existing food scarcity increased through population growth; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Potential for increased flooding (not quantified).
Mukdahan: Southern Laos and North-east Thailand Agricultural productivity unaffected; Existing food scarcity increased through population growth; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff increased; Potential for increased flooding (not quantified).
Ban Keng Done: Central Laos Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Potential for increased flooding (not quantified).
Pakse: Southern Laos and Northeast Thailand Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased Annual runoff increased; Dry season runoff increased; Potential for increased flooding (not quantified).
Se San: Southern Laos, North-east Cambodia and Central Highlands of Vietnam Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Potential for increased flooding (not quantified).
Kratie: Southern Laos and Central Cambodia Agricultural productivity increased; Food availability in excess of demand decreased; Temperature and annual precipitation increased; Dry season precipitation decreased; Annual runoff increased; Dry season runoff decreased; Frequency of extreme floods increased from 5% to 76% annual probability; Peak flows, flood duration and flooded area increased; Dry season minimum flows increased.

Again, as for Cambodia, whilst the increased likelihood of floods is a potential threat to rice production, the increase in river flow also offers adaptation opportunities through irrigation development, particularly in the lower rainfall and more frequently drought affected areas of central (Savannakhet) and southern (Saravane, Champassak) Laos. This is further corroborated by the crop yield impact modeling conducted by Mainuddin (Tab. 4.2), which indicates an increase in crop yields for Savannakhet due to higher rainfall.

4.3 Bangladesh

Changes of temperature and rainfall regimes in Bangladesh have been observed by a number of studies. The GoB NAPA report (MoEF, 2005) comes to the conclusion that a number of studies consistently report observed increases in temperature, with the strongest trend being that of increased minimum temperatures during the *rabi*[1] season, while temperature increases in the *kharif* season were deemed to be less pronounced. Overall, the mean annual temperature has shown a significant increase over the period of 1961-1990. The NAPA report makes no mention of any significant observed trends in rainfall, but does state that there is evidence of increased sea level rise (4.0 – 7.8 mm per year, depending on coastal location), but cautions that some of the observed sea level rise could be due to regional tectonic subsidence. There is also evidence of increased sea water intrusion inland. Partly this can be attributed to the observed changes in sea level

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[1] ***Kharif*** *and* ***rabi*** *are terms used in south Asia for autumn and spring harvested crops, respectively. Kharif is also known as the summer or monsoon crop, usually sown with the beginning of the first rains in July, while rabi season corresponds to the dry season.*

rises and higher frequency of storm surges, but some of the sea water intrusion is also likely to be caused by a reduction in dry season river flows, particularly from the Ganges River.

Basak *et al.* (2009) analysed temperature and precipitation data of all 34 meteorological stations of Bangladesh for the period 1976-2005. Despite only using simple linear regression techniques to determine trends, this analysis has shown that for the majority of stations yearly average maximum and minimum temperatures have increasing trends. The average increase in temperature was about 1°C from 1975-2005. Eighteen out of 32 stations showed a significant increase in the number of ‘hot’ days, while 13 stations showed a decreasing trend in the number of ‘cold’ days. The analysis of rainfall by the above authors for the same period showed an increasing trend of rainfall during monsoon and post-monsoon seasons, while a decreasing trend of total rainfall during winter was found for a significant number of the weather stations analysed. The pre-monsoon season (March-May) did not show any significant trends in total rainfall.

These observed trends are consistent with climate change projections for Bangladesh. The 4th IPCC Report states that monsoon rainfall in South Asia including Bangladesh, will increase, resulting in higher monsoonal river flows from Nepal, India, Bhutan and China into Bangladesh (Christensen *et al.*, 2007). The IPCC also forecasts sea level rises of between 0.18 and 0.79 m by 2070 – 2100, which could increase coastal flooding and saline intrusions into freshwater bodies across a wide coastal belt. While rainfall is projected to increase, it also projected to become more erratic, and the IPCC report suggests this may result in an increased frequency and intensity of droughts in the drier northern and western parts of Bangladesh. Finer resolution climate change projection modelling conducted for India (but also covering Bangladesh) either using time slice techniques with ECHAM4 (May, 2004) or PRECIS on a 50 x 50 km grid (Kumar *et al.*, 2006) has provided a higher degree of spatial resolution to climate change projections. In both studies, all of Bangladesh is projected to see significant increases in monsoonal rainfall, with higher intensity events. Unfortunately, neither of these studies provides any insight into the likelihood of increased drought incidence.

There is general consensus that Bangladesh belongs to the group of most vulnerable countries (UNDP, 2004), where climate change is likely to have severe impacts on all sectors (Mirza, 2002; Cruz *et al.*, 2007, MoEF, 2008). Bangladesh is already one of the most flood-affected countries of the world. The combined effect of increased monsoonal river flows and sea level rise is likely to significantly increase the incidence of flooding. Floods in Bangladesh are differentiated into four categories:

- Flash floods caused by overflowing of hilly rivers in eastern and northern Bangladesh (April-May and September-November)
- Rain floods caused by drainage congestion and heavy rains
- Monsoon floods in the flood plains of major rivers (during June-September)
- Coastal floods due to storm surges

Impacts of floods depend on the type above and the extent of inundation. Invariably, prolonged inundation with deep water levels leads to significant losses of the monsoon rice crops (*T. aman* rice). Paul and Rashid (1993) place these losses at about 0.5 million tons per annum on average. Examples of flood extent are provided in the NAPA report (MoEF, 2005):

- 1974: moderately severe, affected 58% or 83,519 km^2 of the country
- 1984: inundated area estimated 36.5% or 52,520 km^2
- 1987: inundated over 34.7% (>50,000 km^2)
- 1988: inundated 61% or 87,839 km^2 of the country

- 1998: inundated >100,000 km^2 (~75% of the land area)
- 2004: inundated 38% or 54,719 km^2 of the country

Climate change will increase the incidence and severity of floods as shown by modeling conducted by Mirza (2002). While the use of climate change scenarios from 4 GCMs as input to hydrological models demonstrates substantial increases in mean peak discharges of the Ganges, Brahmaputra and Meghna Rivers, uncertainty with respect to relative shifts of floods in their timing, duration and location in the individual rivers makes it very difficult to pinpoint precise impacts. However, during the scoping study trip to Khulna District, there was anecdotal evidence of farmers already shifting out of *T. aman* rice into various forms of *boro* rice in conjunction with fish and prawn farming during the monsoon, as growing *T. aman* rice was becoming too unreliable in some of the lower lying areas.

At the same time, increasing salinity intrusion in the SW coastal band is making it more difficult to grow *rabi* season crops, particularly in areas with a lack of groundwater for *boro* rice irrigation. Salinity intrusion is projected to affect the SW of Bangladesh more than other coastal areas, in part because of declining river discharge during the dry season. It is projected that the salinity isoline will move northwards by about 60 km by 2070 (MoEF, 2005).

Faisal and Parveen (2004) used the CERES crop simulation models to assess the impact of climate, CO_2 and rainfall change on future productivity of rice and wheat, Bangladesh's two main staple crops. Depending on the CO_2 level and temperature changes assumed, they found that the overall impact of climate change on the production of food grains in Bangladesh would probably be small in 2030. This is due to the strong CO_2-fertilisation effect that would compensate for impacts of higher temperature (shorter growth duration, spikelet sterility in rice), increased incidence of inundation and salinity increase due to sea water ingression. Conversely, in 2050, with even higher temperatures, the negative impacts of temperature, increased duration of inundation and salinity on crop physiology would negate the beneficial impacts of CO_2-fertilisation, leading to a projected reduction in production of rice and wheat by 8 and 32 %, respectively.

A summary and rating of likely severity of climate change impacts on different agricultural sectors is provided in Tab. 4.4. This illustrates the higher exposure of Bangladesh to climate impacts compared to Cambodia and Laos.

Table 4.4: Intensity and nature of impacts on different agricultural sectors (Source: MoEF, 2005)

Sectoral vulnerability context	Physical vulnerability context							
	Extreme temperature	Sea level rise		Drought	Flood		Cyclone and storm surges	Erosion and accretion
		Coastal inundation	Salinity intrusion		River flood	Flash flood		
Crop agriculture	+++	++	+++	+++	+	++	+++	-
Fisheries	++	+	+	++	++	+	+	-
Livestock	++	++	+++	-	-	+	+++	-

4.4 India (Andhra Pradesh)

In India there are many good quality, long-term climate datasets available, so that a number of studies have been able to analyse trends in temperature and rainfall regimes. Several recent reviews (e.g. Mall *et al.*, 2006; Rao *et al.*, 2008) have attempted to synthesise the large body of work in India.

At a whole of India level there are clear signals showing a general increase in temperatures. Whilst Rupa Kumar *et al.* (2002) state the rise as being 0.03°C per decade across all of India for the period 1901-2000, in recent years this trend seems to have accelerated to 0.22°C/10 years for the period 1971-2003 (Kothawale and Rupa Kumar, 2005), mainly due to an unprecedented warming in the last decade. Increasing temperature trends are particularly strong in the winter season and regional differences in warming have also been observed, e.g. with stations of southern and western India showing a rise of 1.06°C and 0.36°C/100yr respectively. An important aspect of the change in temperature regime is highlighted by Mall *et al*., (2006), who suggest that there was evidence of an asymmetry in the temperature trends in terms of day and night temperatures. The observed warming was predominantly due to an increase in maximum temperatures while minimum temperatures remained practically constant during the past century.

Rainfall trends are a lot less certain. Some authors maintain that any observed changes are within the statistical bounds of rainfall variability (Mall *et al.*, 2006), particularly if lumped at a whole of India level. However, data cited in Rao *et al.* (2008) indicates that depending on the region there are discernable trends. Over the 1901-2000 period, decreasing trends of summer monsoon rainfall have been observed in parts of northeast India, in contrast to increases of ~28mm/decade along the western coast of the peninsula. Rao *et al.* (2008) also provide some evidence of a shift in summer monsoon rainfall distribution in southern and central India, with a shift in peak rainfall by 2-3 weeks for parts of Karnataka in the decade 1991-2000 (Rajegowda *et al.* cited in Rao *et al.*, 2008). Similarly, a decreasing trend in pre-monsoon rainfall has been reported for Chhattisgarh. However, observational data is inconclusive with respect to whether there have been any changes in climate variability, although some studies state a higher incidence of droughts in more recent times (e.g. World Bank, 2008).

The above recorded trends are largely consistent with climate change projections for India. Again, there are numerous studies reporting climate change projections and an overview is provided in Mall *et al.*, 2006. Only the more recent studies are referred to here, as they are based on approaches yielding a higher spatial resolution than some of the earlier work. In a time slice experiment using ECHAM4, May (2004) compares present day rainfall (1970-1999) with 2060-2089 rainfall. This procedure allows for a higher spatial resolution (120 km grid cells) than conventional GCMs (300-500 km grid cells). The results of this study show that most of the Indian peninsula is projected to have higher rainfall during the monsoon due to an increased atmospheric moisture transport into the Indian region, with the Western Ghats and north-eastern India showing higher trends than central and southern India. Extreme rainfall events are also projected to increase in some regions. The intensity of heavy rains is expected to increase in both the 99.5% percentile and the 30-year return level, mainly in Bangladesh, north-eastern and north-western India. However, while ECHAM4 represents present day monsoon patterns fairly well, the projections depend on the particular scenario of atmospheric concentrations of GHG selected, which are also uncertain. May (2004) concludes that the changes projected will have the same structure for different emissions scenarios, but might vary in magnitude.

Rupa Kumar *et al*. (2006) used the regional climate model PRECIS to generate higher spatial resolutions of climate projections. They also found a general increase in monsoon rainfall by 2100, the increases being more pronounced for the A2 scenario than the B2 scenario. However, time series results provided in the same study indicate that there are marginal, if any changes in rainfall trends until 2030, and these changes are likely to be masked by the high inherent rainfall variability of the Indian monsoon. In fact, only the pre-monsoon (Mar – May) and post-monsoon (Oct – Nov) periods showed an increase in rainfall variability when future scenarios until 2100 were compared to the baseline, while variability during the monsoon either was similar, or less.

This study is also one of two found that makes explicit statements about climate change in Andhra Pradesh. Regional projections show monsoon rainfall increases of around 20-25% in the north-western parts of Andhra Pradesh by 2070-2100 for the A2 scenario, while monsoon rainfall across the entire northern half of Andhra Pradesh is projected to increase by 20-30% for the B2 scenario. Temperatures follow a similar geographic differentiation in Andhra Pradesh, with the northern half showing temperature elevations by 2070-2100 of up to 3 - 3.5°C for the A2 and 2.5 - 3°C for the B2 scenarios, respectively. In terms of the mean annual rainfall cycle, Rupa Kumar *et al*. (2006) also provide data for Andhra Pradesh indicating a shift to slightly less rainfall in June and July for the A2 scenario with subsequent higher rainfall in August and September. The pattern for the B2 scenario is less clear cut, but does also indicate higher rainfall in August and September. The rainfall shift towards less rain in June/July and higher rainfall in August/September is consistent with anecdotal evidence (GGSN Rao, *pers. comm*.) for Andhra Pradesh.

Slightly different results were obtained for southern Andhra Pradesh by a World Bank (2008) study investigating the impact of climate change on drought in Andhra Pradesh. This study focussed on the Pennar Basin, which covers part of Andhra Pradesh in the drier south west. Climate change modelling conducted by RMSI (2006; cited in World Bank, 2008) spanned four of the southern districts in Andhra Pradesh – Kurnool, Anantapur, Cuddapah and Chittoor. Average seasonal rainfall during the monsoon in all four districts is projected to increase by 12.7 – 26.0% for the A2 and 3.2 – 15.6% for the B2 scenario, respectively. This is in contrast to Rupa Kumar *et al*. (2006), whose projections did not indicate any major changes in monsoonal rainfall for southern Andhra Pradesh. However, the RMSI modelling baseline was scaled to observed rainfall data for the four districts and so is deemed a reasonably robust approach (S Priya, *pers. comm.).*

Considerable effort has also been undertaken by Indian researchers to quantify likely impacts of climate change on agriculture. A comprehensive review is provided by Shukla *et al.,* (2003). However, in relation to agriculture, the majority of this body of work has focussed in the implications of climate change on crop production. Crop simulation modelling has been used extensively, using a range of models (CERES-Rice, CERES-Wheat, CERES-Maize, CERES-Sorghum, CROPGRO, ORYZA1N, EPIC). Mall *et al.* (2006) have provided a comprehensive review of the crop modeling work. Results range between strong positive responses to largely negative yield responses, depending on the interactions between temperature and CO_2 changes, production environment, season and location in India. Much of the work has focussed on irrigated systems, where it has been demonstrated for rice that under optimum conditions of water and N supply, temperature effects will be more than compensated by CO_2–fertilisation, leading to significant yield increases even under pessimistic climate change scenarios (Aggarwal and Mall, 2002). Some of the modeling also shows that low-input systems are less sensitive to climate impact than high-input systems (Aggarwal, 2003). Conversely, in rainfed conditions of Andhra Pradesh, crop modeling using EPIC has tended to indicate a reduction in crop yields in the order of 0.1 – 0.2 t/ha for rice, 0.1 - 0.3 t/ha for groundnuts and little change for sorghum (World Bank, 2008).

Despite a wide range of simulated impacts (i.e. depending on scenarios, models used and assumptions, yields can either increase or decrease), the results exhibit a consistent pattern of response mechanisms:

- Crop yields are influenced by the interplay of three key climate parameters: (a) the level of carbon dioxide (termed carbon fertilization); (b) the temperature change; and (c) the level and distribution of precipitation. For most crops, elevated levels of carbon dioxide and higher precipitation rates (except where rainfall is excessive) promote crop growth. Since current temperatures throughout much of India are already high, these beneficial effects are offset by further warming.
- The overall impact of climate change on crop yields depends on the baseline conditions of these parameters and the balance of these conflicting forces. In arid locations where crops already suffer heat stress, a small increase in average temperatures can lead to a dramatic decline in yields. The same temperature change in a cooler climate zone could produce an increase in yields.

Typically the way the crop models have been set up in these studies does not make any allowance for ongoing adaptation by farmers, i.e. the studies assume that farmers are “myopic”, in that they do not respond to changing conditions, nor that they learn from past experiences. Moreover, invariably most of the modeling has relied on individual process variables (e.g. temperature only with all other variables constant) or on single–crop models, not easily applied to simulating crop rotations within a farming system and for multiple, interacting variables (CO_2, temperature, water, N). Hence the interactions between crops and the trade-offs involved are often not well captured, if at all. In most cases, the model parameterisation has also been conducted on the basis of researcher assumptions of average farmer practices or based on calibration data derived from controlled research station trials rather than true calibrations of farmer field practices. The clear implication is that broad generalizations of crop responses to climate change will be misleading if they do not take account of location-specific baseline climate and soil conditions.

5 Priorities and policies in relation to climate change adaptation

In broad terms, over the last 5 years, developing nations have tended to focus their climate change policy responses on compiling their 1st National Communications to the IPCC, on gearing up to qualify for the Clean Development Mechanism (CDM) and on initiating planning in relation to adaptation. Prior to 2003 there was little consideration of climate change given in policy formulation and most national planning and development programs are notable in their lack of reference to climate change. As of 2004/2005, the LDCs (in the case of this study Cambodia, Lao PDR and Bangladesh) were given capacity building support through the UNDP/GEF facility, which funded a series of National Adaptation Programmes of Activity (NAPA).

Arguably the most significant contribution of the NAPAs was to foster the establishment of institutional arrangements (e.g. the setting up of Climate Change Offices, National Climate Change Councils) and to start relevant government institutions planning in relation to climate adaptation. However, despite the NAPAs generating lists of priority or ‘no regrets’ actions, in general the NAPAs lacked a more strategic policy approach and little regard was given to integrating climate adaptation into the broader development agenda. Mainstreaming of climate adaptation across all relevant sectors and government institutions has yet to occur. The overall uncertainty of climate change projections, the lack of location specificity and the general absence of information on impacts and vulnerabilities at local scales could be seen as some of the impediments to taking a more strategic approach to planning for climate adaptation. The current state of play in each of the countries is reviewed in the following sections, together with a brief assessment of key developmental drivers in each country. Finally, the main adaptation priorities expressed by stakeholders during the scoping missions in each country are also briefly listed.

5.1 Cambodia

In 2004 the RGoC adopted the Rectangular Strategy for Growth, Employment, Equity and Efficiency as the framework for the country's socio-economic development (RGoC, 2004). Founded on good governance, peace, political stability, social order, macroeconomic stability, partnership and economic integration, the Rectangular Strategy focuses on critical development issues such as the enhancement of the agricultural sector, rehabilitation and construction of physical infrastructure, private sector development and employment generation and capacity and human resource development.

The National Strategic Development Plan (NSDP) was approved in 2006 and has been framed as the implementation of the Rectangular Strategy, linking the vision in the Rectangular Strategy to concrete goals, targets and strategies (RGoC, 2006b). The RGoC considers the NSDP as the single, overarching development strategy for pursuing prioritized goals and actions for the period 2006-2010. The NSDP highlights most essential strategies, targets and actions, but it leaves more details to be spelled out in sectoral and sub-national plans. However, with the exception of mentioning the intent of developing a National Adaptation Programme of Action (NAPA), there is no mention of climate change mitigation or adaptation policies.

Under the NSDP in the agriculture sector the focus is on intensifying crop production to increase yields and rural incomes, diversification of crops, improving fisheries management, sustainable management of forestry through reforms, environment conservation and carrying out of land reforms, particularly to ensure land tenure to the poor. These general directions have been further refined in the Strategy for Agriculture and Water (TWGAW, 2007). This strategy proposes five programs:

1. Institutional capacity building and management support program for agriculture and water resources
2. Food security support program
3. Agricultural and agri-business (value-chain) support program
4. Water resources, irrigation management and land program
5. Agricultural and water resources research, education and extension program

Whilst this strategy is noteworthy in that it attempts to integrate agricultural development with water resource management and planning, it makes little reference to climate change. This shortcoming has been recognised and the strategy document is in the process of being updated to reflect the implications of climate change on the agricultural and water sectors.

In October 2006 the RGoC established the National Climate Change Committee (NCCC) under the Ministry of Environment. The NCCC is a senior policy-making body operating as an inter-ministerial mechanism with the mandate to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programmes of the RGoC to address climate change. The NCCC is cross-sectoral and is composed of Secretaries and Under-Secretaries of State from 19 Ministries and government agencies whose mandates are relevant to climate change adaptation or mitigation activities. The NCCC meets at least twice yearly and more often if needed. It is supported by the Cambodian Climate Change Office (CCCO), which was established in 2003 within the Department of Planning and Legal Affairs of the MoE (www.camclimate.org.kh). The CCCO has the broad mandate of carrying out all technical activities related to the implementation of the UNFCCC, and all other assigned climate change-related tasks.

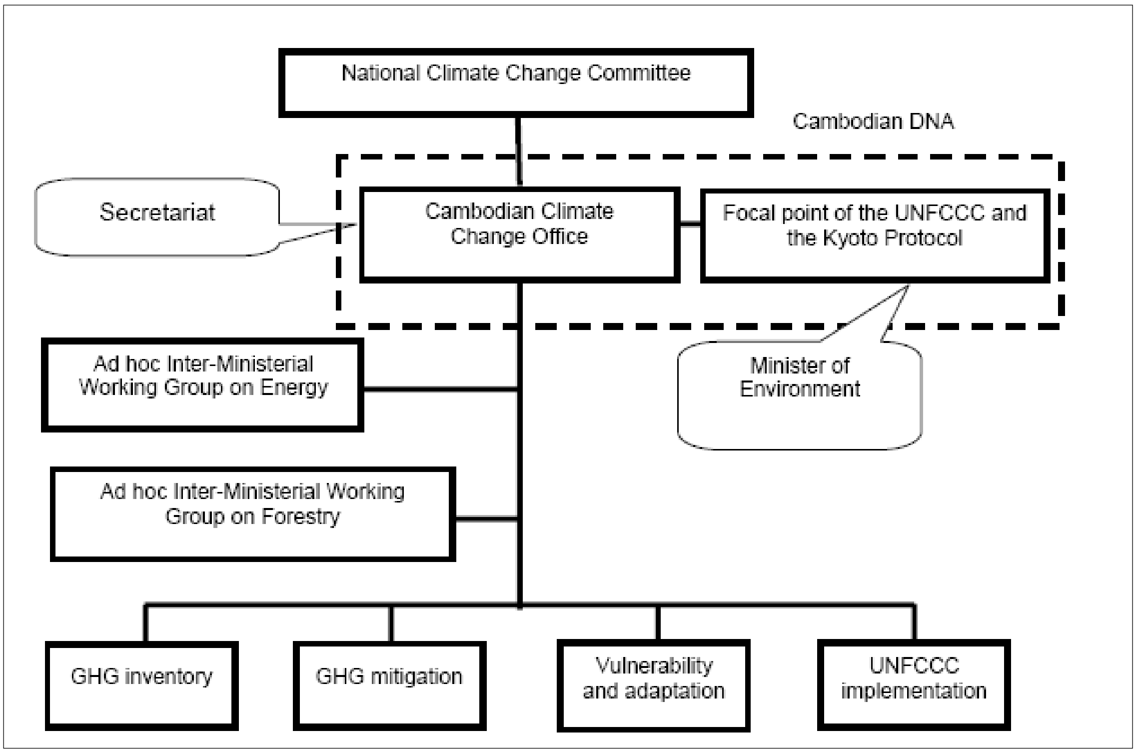

Figure 5.1: Cambodian institutional arrangements for climate change (Source: MRC, 2009a)

Specifically, the CCCO acts as the secretariat for the MoE in its role and climate change focal point and as the Designated National Authority (DNA) under the Kyoto Protocol for CDM activities. The CCCO's role is to facilitate and coordinate donor and private sector activities relevant to climate change. CCCO organises inter-ministerial technical working groups specialised in sectors (energy and forestry), and along climate change themes (GHG inventory, mitigation, vulnerability and adaptation, and UNFCCC implementation). The priority of the CCCO to date has been to raise awareness of climate change issues among other government agencies and to attract donor funding for adaptation and mitigation activities. An overview of the institutional arrangements concerning climate change is provided in Fig. 5.1.

So far no comprehensive national plan or strategy on climate change has been drawn up. However, from discussions with stakeholders in Cambodia, it clearly transpired that adaptation is accorded a much higher priority than mitigation. To date, the only explicit activity undertaken by the RGoC in relation to climate adaptation was the UNDP/GEF facilitated National Adaptation Programme of Action to Climate Change (NAPA) planning and reporting process. A NAPA report for Cambodia was prepared in 2006 (RGoC, 2006a). It proposes a total of 39 'no regret' adaptation projects. Of these projects, 9 agriculture/water resource projects were ranked as high priority and 10 projects as medium priority:

High priority agriculture and water resource related projects proposed

- Rehabilitation of a Multiple-Use Reservoir in Takeo Province
- Rehabilitation of Multiple-Use Dams in Takeo and Kampong Speu Provinces
- Development and Rehabilitation of Flood Protection Dikes
- Rehabilitation of Upper Mekong and Provincial Waterways
- Water Supply for Rural Communities Promotion of Household Integrated Farming
- Water Gates and Water Culverts Construction
- Development and Improvement of Small-Scale Aquaculture Ponds Development
- Improvement of Community Irrigation Systems

Medium priority agriculture and water resource related projects proposed

- Improving Farmers' Adaptive Capacity to Climate Change
- Cement Water Tanks Construction
- Introduction of Short-Period Rice Varieties in Areas Affected by Seawater Intrusion and Drought
- Establishment and Improvement of Farmer Water User Communities
- Development of Community Rice Banks
- Groundwater Extraction for Crop Cultivation
- Development of Community and Household Flood Safe Area
- Community Agro-Forestry in Deforested Watersheds
- Traditional Wooden Boat Distribution
- Promotion of Food Supplements in Household Cattle Raising

None of the actions/projects identified in the NAPA have been implemented yet, with the exception of a UNDP-supported project to integrate water resource planning into agriculture through the Ministry of Agriculture, Forestry and Fisheries (MAFF) and Ministry of Water Resources and Meteorology (MOWRAM; see section 6.1 for details). Strictly speaking, this project was not one of the listed priorities, but builds on the NAPA and aims to provide a policy framework for better integration of the no regrets actions proposed under NAPA.

What does transpire from NAPA is a focus on developing irrigation resources to buffer the effects of drought, particularly in the Tonle Sap and along the main Mekong floodplains. This priority was also consistently voiced by government and NGO stakeholders in Cambodia. In principle, prospects for achieving this seem good, as there is a good alignment between this goal and the RGoC’s overall priorities for agricultural development, as articulated in the NSDP and in the Strategy for Agriculture and Water, where the development of irrigation resources is seen as a key pathway to increase agricultural productivity, decrease the impacts of drought and to help improve rural livelihoods. Accordingly, rehabilitation of irrigation schemes is a very high RGoC priority, receiving substantial government and donor support. The rehabilitation target is 20,000 ha per annum, which apparently has been exceeded. However, in practice the problem with much of the rehabilitation work is that funds have usually only been sufficient to rehabilitate dams/reservoirs, headworks and the main and secondary channels. With the exception of a few cases (mainly NGO executed projects with smaller schemes and partial establishment of tertiary distributors, e.g. in Kampong Tom by GRET, in Prey Veng and Svay Rieng by CARE, and one 270 ha MOWRAM pilot in Pursat), no comprehensive tertiary distribution systems connected to primary and secondary channels have been built. In addition to bridging this gap, a number of other constraints need to be addressed to for this strategy to be effective. These include technical gaps (optimising the design of irrigation structures, lack of drainage management and integrated drainage systems, effective delivery systems to end-users, matching irrigation schedules to crop demands for Cambodian soil and climate conditions) and more importantly, institutional arrangements and capacity building (e.g. establishing water user groups in a cultural setting that does not have a strong tradition in irrigation and where social relationships have been traumatised by the Khmer Rouge period).

Ultimately, the intensification of agricultural production in Cambodia is not so much being driven by climatic impacts and some of the RGoC’s policies, but to a greater extent by the inflow of foreign investment securing land concessions for large scale agricultural enterprises. The increasing demand for products from neighbouring Thailand and Vietnam are proving to be much greater determinants of change. Whilst there are many concerns in relation to these drivers, they also represent opportunities and if channelled appropriately and harmonised with climate adaptation needs, can prove to be an effective mechanism to achieve adaptation. This would require some investment into policy research, which currently does not seem to be undertaken, in order to provide recommendations on how best to mainstream the climate adaptation agenda into the broader development policies of Cambodia

While climate adaptation under the umbrella of the NCCC has yet to be mainstreamed into central government planning and policy formulation, there are more promising prospects of mainstreaming climate adaptation into local and provincial planning processes. This can be through the Provincial Rural Development Committees which comprise representatives for a range of provincial departments (e.g. Provincial Department of Agriculture - PDA, Provincial Dept. of Rural Development, Provincial Dept. of Water Resources).

Alternatively, several stakeholders suggested that climate adaptation measures should be linked to disaster management arrangements under the umbrella of the National and Provincial Disaster Management Committees. The advantage of this channel is that it would be possible to build on an already existing hierarchy of national, provincial, district and commune level information dissemination channels that have proven themselves reasonably effective in communicating flood alerts to rural communities. Moreover, there is a bi-annual process of reviewing and updating action plans, which could present itself as a dissemination channel for climate adaptation recommendations in addition to the more conventional agricultural extension procedures.

The link between climate adaptation (which is proactive) and disaster mitigation (which tends to be reactive) is the identification and implementation of disaster risk reduction measures. These are designed to protect livelihoods and the assets of communities and individuals from the impact of hazards such as flooding and drought by:

- Mitigation: reducing the frequency, scale, intensity and impact of hazards
- Preparedness: strengthening the capacity of communities to withstand, respond to and recover from hazards, and of government, implementing NGO partners to establish speedy and appropriate interventions when the communities’ capacities are overwhelmed

- Advocacy: favourably influencing the social, political, economic and environmental issues that contribute to the causes and magnitude (scale) of impact of hazards

Disaster risk reduction is often a complementary or integral part of other programmes such as food security, promoting agricultural diversity, or capacity building and sits comfortably within the rural livelihoods frameworks.

5.2 Lao PDR

The Lao PDR's long-term national development goal is to be achieved through sustained equitable economic growth and social development, while safeguarding the country's social, cultural, economic and political identity. The foundations for reaching this goal have been laid during the past 28 years of peace and development in the country by:

- Moving consistently towards a market-oriented economy.
- Building-up the needed infrastructure throughout the country; and
- Improving the well-being of the people through greater food security, extension of social services and environment conservation, while enhancing the spiritual and cultural life of the Lao multi-ethnic population.

The National Growth and Poverty Eradication Strategy (NGPES) was announced in 2004 (GoL, 2004) and is the Lao PDR Government's operational response to this over-arching goal. It builds on the medium-term strategic approach to poverty eradication, making it part of an overall "growth with equity" framework. The National Growth and Poverty Eradication Strategy (NGPES) is central to the national development agenda. However, in its entirety, it makes no reference to climate change.

Climate change has only in recent years become a higher priority policy issue in Lao PDR. The Department of Environment (DoE) within the Water Resources and Environment Administration (WREA) has been appointed as the national focal point for climate change actions and initiatives. In 2008 the National Steering Committee on Climate Change (NSCCC) was established, chaired by the Deputy Prime Minister and with the Director General of DoE as the secretary and with members from all concerned sectors. An overview of the institutional arrangements' in Lao PDR concerning climate change is presented in Fig. 5.2.

One of the first assignments of the NSCCC has been to initiate the formation of seven Technical Working Groups with representatives from various line agencies as follows:

- Food and livelihoods security and agricultural productivity led by the Ministry of Agriculture and Forestry.
- Forest and land management to reduce emissions from deforestation and degraded landscapes led jointly by the Ministry of Agriculture and Forestry and the National Land Management Authority.
- Energy Management including export of electricity to neighbouring countries led by the Ministry of Energy and Mines.
- Hydrology assessments to predict variability and vulnerability to water resources led by Water Resources and Environment Administration.
- City infrastructure resilience and efficient building design led by the Ministry of Public Works and Transport.
- Economic management to ascertain the implications of climate change impacts on growth targets poverty reduction goals and attaining the country's 2020 vision led by the Ministry of Planning and Investment.

- Financing instruments economic incentives and benefit sharing arrangements under the clean development mechanism or successor arrangements.

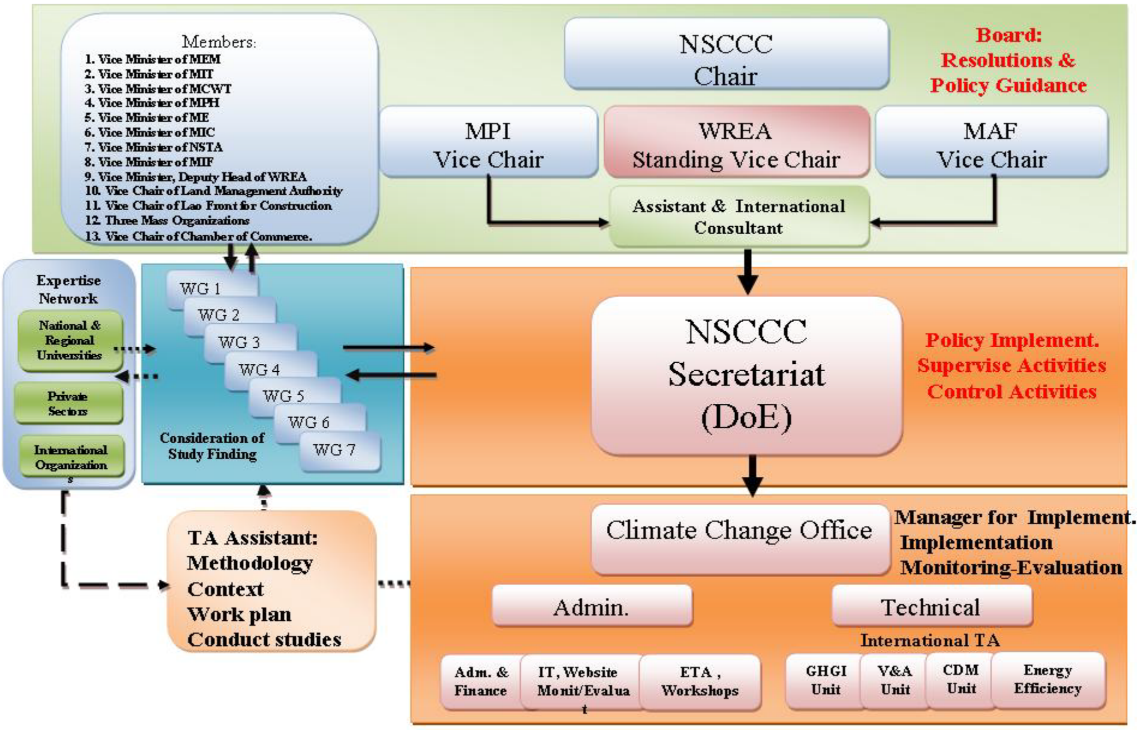

Figure 5.2: Lao PDR institutional arrangements for climate change (Source: MRC, 2009a)

The main task of the Technical Working Groups is to study and assess the impacts of climate change on the issues under their respective responsibility for the period 2009 to 2020. The DoE, which acts as the secretariat to the NSCCC, facilitates and coordinates the work of the Technical Working Groups. Based on future climate change impact studies, the DoE in cooperation with the Technical Working Groups will be responsible for drafting the following strategy and action plans:

- The National Climate Change Strategy for 2020
- The Interim Action Plan for 2009-2011
- The First National Action Plan for 2011-2016 in alignment with the 7th National Socio-Economic Development Plan

In addition, the Ministry of Labour and Social Welfare has responsibility for natural disaster management, particularly for flooding. In 1999, the Government created the National Disaster Management Committee to take the lead role in disaster management; the National Disaster Management Office was set up to act as its secretariat to assist the committee in carrying out its duties.

In 2005/2006, the GoL initiated its NAPA process, supported by the GEF/UNDP. A final report was submitted to the UNFCCC in 2009 (WREA, 2009). It states that the GoL has to some degree already been addressing climate adaptation issues in the past, through a number of activities, including building embankments for flood protection of nearly 30 km in length in Vientiane Capital and in Pakse and Champassak provinces and providing for enhanced drainage management structures. Comprehensive public irrigation systems have also been developed in six northern provinces to combat drought and provide permanent livelihoods for the local people. These activities all facilitate adaptation to climate change. At the same time, flood and drought prevention/response projects have been undertaken in cooperation with international organizations and non-governmental organizations.

The NAPA identifies four critical sectors for adaptation: agriculture, forestry, water and health (WREA, 2009). Across all four sectors, a total of 45 number activities were identified, of which 12 were 1st order and 33 were 2nd order priority activities/projects, respectively. Those relevant to agriculture and water are listed below:

Agriculture – 1st priority

1. Strengthen the capacity of the National Disaster Management Committees
2. Promote secondary professions in order to improve the livelihoods of farmers affected by natural disasters induced by climate change

Agriculture – 2nd priority

3. Land use planning in hazard prone and affected areas
4. Promotion of short-duration paddy and other cash crops in natural hazard prone areas
5. Technical capacities of local agricultural officers in natural hazard prone areas strengthened
6. Improve and develop crop varieties and animal species that are better adapted to natural hazard prone areas
7. Improve and construct crop and animal disease laboratories at central and local levels and build related capacity of technical staff
8. Train farmers on the processing and storing of human and animal food stuffs
9. Establishment and strengthening of farmers groups in natural hazard prone areas
10. Promote soil improvement using locally available organic fertilizer and existing agricultural waste
11. Develop appropriate bank erosion protection systems for agricultural land in flood prone areas
12. Promote integrated pest management (IPM) and use of herbal medicines in pest management and livestock treatment
13. Develop the capacity of technical staff in organic fertilizer research

Water – 1st priority

14. Awareness raising on water and water resource management
15. Mapping of flood-prone areas
16. Establish an early warning system for floodprone areas, and improve and expand meteorology and hydrology networks and weather monitoring systems
17. Strengthen institutional and human resource capacities related to water and water resource management
18. Survey underground water sources in drought prone areas
19. Study, design and build multi-use reservoirs in drought prone areas

Water – 2nd priority

20. Conservation and development of major watersheds.
21. Build and improve flood protection barriers to protect existing irrigation systems.
22. Improve and protect navigation channels and navigation signs.
23. Repair/rehabilitate infrastructure and utilities damaged by floods in agricultural areas.

Interestingly, many of the above priorities do not seem to directly align with one of the main climate change impacts anticipated, i.e. the need to develop irrigation infrastructure in response to increased drought, although some measures like No. 18 and 19 will partially address drought. Conversely, more activities will address the anticipated higher incidence of flooding. To date, no explicit donor funded projects have commenced tackling any of the listed priorities, with the exception of No. 15, where an ADB funded pilot study is due to assess the impact of flooding on Central and Southern Laos.

What is also lacking in the NAPA is a clearer indication of how the NAPA actions relate to the broader development priorities in Lao PDR. Perhaps this is because agricultural development does not play the same central role in the overall development of Laos as it does for instance in Cambodia. The main drivers for economic growth are seen by the GoL as the hydropower, mining, ecotourism sectors and possibly CDM/REDD for forest conservation. There is no concerted push to intensify agriculture and turn agriculture into a mainstream driver of economic growth, as in the view of key stakeholders Lao PDR does not have a comparative advantage in agriculture compared to Vietnam and Thailand.

However, this stands in contrast to reality in some parts of Lao PDR. Sovereign investment funds from Arab states, as well as private sector interests mainly from Thailand, Malaysia, China and Vietnam are seeking access to land to set up agro-enterprises in Cambodia and Laos to secure long term food and commodity supplies (e.g. rubber, cassava for bioethanol). Provinces particularly affected are the central and southern provinces, where labour shortages are also occurring as a result of migration to off-farm employment across the border into Thailand (as well as within Laos). Again, as in the case of Cambodia, the influx of foreign investment capital is arguably a greater driver of change in the immediate future than climate change or future government policies in relation to climate change.

Within the agricultural sector, developing irrigation infrastructure is seen as a primary strategy to both increase agricultural production and to buffer against climate variability. Again, as in Cambodia, this offers an opportunity of aligning development goals with adaptation goals, the development of irrigation serving the dual purpose of improving livelihoods (in itself a means of increasing adaptive capacity) and adaptation to a possible increase in the incidence of droughts. According to the Department of Irrigation in MAF, overall there are >21000 irrigation schemes in Laos, of which 18000 are <100 ha, ~3000 are 100-500 ha and <100 are >500 ha. Total actual irrigated area is only about 117,000 ha, of which 95,000 ha is for rice. All of the mountainous schemes rely on gravity fed water from weirs or small reservoirs, are small and many only operate during wet season flows, providing supplementary irrigation during the wet season. The schemes in the floodplains are mainly supplied through pump headworks supplying river water. Electricity costs of pumps are 30-50% subsidised. These schemes allow for some dry season cropping. More irrigation development is taking place. The long term target for irrigation scheme development is 400,000 - 440,000 ha to be irrigated by 2020. However, so far there are no programs to consolidate land and increase plot sizes. There is also no laser levelling being carried out, and there is a general lack of integrated drainage planning. As in the case of Cambodia, similar technical and institutional constraints to optimising irrigation will need to be addressed.

Stakeholders in MAF and the Dept of Irrigation, and the DG of the National Agriculture and Forestry Research Institute (NAFRI) clearly indicated that the ACIAR adaptation research should be targeted to the main rice producing areas in the 7 major floodplain areas, in particularly in Savannakhet. This is because these areas are more affected by drought and flooding, yet produce a major proportion of Lao PDR’s rice crop and therefore are critical to maintaining national food security.

Another priority relevant to climate adaptation that the Ministry of Agriculture has been pursuing through the NAFRI is the establishment of an agro-meteorological service to provide seasonal climate forecasts to assist in forecasting agricultural production and in disaster management. While this is within the mandate of NAFRI, to date there have not been enough resources and knowhow for NAFRI to implement this. ACIAR’s support for climate adaptation research in Lao PDR was seen by NAFRI as a catalyst to support the setting up of such a service in collaboration with the Department of Meteorology and Hydrology.

In addition to irrigation development, several stakeholders in Lao PDR also suggested that a greater emphasis needed to be placed on livestock intensification, as sale of livestock is seen as a key adaptation strategy to mitigate short term climate shocks, particularly after complete crop losses following severe drought or prolonged flooding. Some stakeholders also suggested that climate adaptation needed to be more closely linked to the National Disaster Management Committee. In terms of geographic focus, there was a general view that past and ongoing donor supporter has been directed primarily towards the northern uplands and that there was a need to redirect research emphasis towards the southern uplands, as well as climate proofing the main rice-growing areas in the 7 major floodplains along the Mekong valley, in particular those affected both by flooding and drought.

5.3 Bangladesh

In October 2005, the Government of Bangladesh (GoB) launched its 'Unlocking the Potential - National Strategy for Accelerated Poverty Reduction' (GoB, 2005). It is strongly predicated on the pursuit of eight specific avenues to achieve accelerated poverty reduction: supportive macroeconomics; choice of critical sectors to maximise pro-poor benefits with special emphasis on rural, agricultural, informal and SME sectors; safety net measures to protect the poor; human development through education, health and sanitation; participation and empowerment; promotion of good governance, improved service delivery and finally, caring for environment. Despite this being a comprehensive blueprint for development, the strategy, while briefly referring to the risk of climate change, does not mention any explicit policy measures to address climate change and even any considerations as to how to mainstream adaptation to climate change.

However, shortly after publishing the above strategy, the GoB produced its NAPA plan in November 2005 (MoEF, 2005; it was one of the first of the LDC countries to do so). This plan, produced in partnership with other stakeholders, highlights the main adverse effects of climate change and identifies adaptation needs. The future adaptation strategies suggested in the NAPA are:

1. Reduction of climate change hazards through coastal reforestation with community participation.
2. Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise.
3. Capacity building for integrating climate change in planning, designing of infrastructure, conflict management and land/water zoning for water management institutions.
4. Climate change and adaptation information dissemination to vulnerable community for emergency preparedness measures and awareness raising on enhanced climatic disasters.
5. Construction of flood shelter, and information and assistance centres to cope with enhanced recurrent floods in major floodplains.
6. Mainstreaming adaptation to climate change into policies and programmes in different sectors (focusing on disaster management, water, agriculture, health and industry).
7. Inclusion of climate change issues in curriculum at secondary and tertiary educational institution.
8. Enhancing resilience of urban infrastructure and industries to impacts of climate change.
9. Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change.
10. Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future.
11. Promoting adaptation to coastal crop agriculture to combat increased salinity.
12. Adaptation to agriculture systems in areas prone to enhanced flash flooding in North East and Central Region.
13. Adaptation to fisheries in areas prone to enhanced flooding in North East and Central Region through adaptive and diversified fish culture practices.

14. Promoting adaptation to coastal fisheries through culture of salt tolerant fish species in coastal areas of Bangladesh.
15. Exploring options for insurance and other emergency preparedness measures to cope with enhanced climatic disasters.

Research targeted at addressing adaptation is explicitly referred to in strategy No. 10, and is implicit in strategies 11 and 12.

The GoB went further and published the Bangladesh Climate Change Strategy and Action Plan (BCCSAP; MoEF, 2008). The BCCSAP is a 10-year programme (2009-2018) to build the capacity and resilience of the country to meet the challenge of climate change. The needs of the poor and vulnerable, including women and children, will be mainstreamed in all activities under the Action Plan. In the first five year period (2009-13), the programme will comprise six pillars:

1. Food security, social protection and health

1.1 Increase the resilience of vulnerable groups, including women and children, through development of community-level adaptation, livelihood diversification, better access to basic services and social protection (e.g. safety nets, insurance) and scaling up

1.2 Develop climate change resilient cropping systems (e.g. agricultural research to develop crop varieties, which are tolerant of flooding, drought and salinity, and based on indigenous and other varieties suited to the needs of resource poor farmers), fisheries and livestock systems to ensure local and national food security

1.3 Implement surveillance systems for existing and new disease risks and ensure health systems are geared up to meet future demands

1.4 Implement drinking water and sanitation programmes in areas at risk from climate change (e.g. coastal areas, flood-and drought-prone areas)

2. Comprehensive Disaster Management

2.1 Strengthen the government's capacity and that of civil society partners and communities to manage natural disasters, and ensure that appropriate policies, laws and regulations are in place

2.2 Strengthen community-based adaptation programmes and establish them in each of the disaster prone parts of the country

2.3 Strengthen cyclone, storm surge and flood early warning systems to enable more accurate short, medium and long-term forecasts

3. Infrastructure

3.1 Repair and rehabilitate existing infrastructure (e.g., coastal embankments, river embankments and drainage systems, urban drainage systems) and ensure effective operation and maintenance systems

3.2 Plan, design and construct urgently needed new infrastructure (e.g. cyclone shelters, coastal and river embankments and water management systems; urban drainage systems, river erosion control works, flood shelters) to meet the changing conditions expected with climate change

3.3 Undertake strategic planning of future infrastructure needs, taking into account the likely (a) future patterns of urbanisation and socio-economic development; and (b) the changing hydrology of the country, because of climate change

4. Research and knowledge management

4.1 Model climate change scenarios for Bangladesh by applying global climate change models and methodologies at regional and national levels

4.2 Model the likely hydrological impacts of climate change on the Ganges-Brahmaputra-Meghna system to assess likely future system discharges and river levels in order to derive design criteria for flood protection embankments

4.3 Monitor and research the impacts of climate change on ecosystems and biodiversity

4.4 Research the likely impacts of climate change on the macro-economy of

Bangladesh (a Bangladesh 'Stern Report') and key sectors (e.g. livelihoods and food security) and contribute to developing a climate-proof national development plan

4.5 Research the linkages between (a) climate change, poverty and vulnerability and (b) climate change, poverty and health (disease incidence, nutrition, water, sanitation) in order to identify possible interventions to increase the resilience of poor and vulnerable households to climate change

4.6 Establish a Centre for Research and Knowledge Management on Climate Change (or a network of centres) to ensure Bangladesh has access to the latest ideas and technologies from around the world, and ensure that data is widely and freely available to researchers

5. Mitigation and low carbon development

5.1 Develop a strategic energy plan and investment portfolio to ensure national energy security and lower greenhouse gas emissions

5.2 Expand the social forestry programme on government and community lands throughout the country

5.3 Expand the 'greenbelt' coastal afforestation programme with mangrove planting along the shoreline

5.4 Seek the transfer of state-of the art technologies from developed countries to ensure that we follow a low-carbon growth path (e.g., 'clean coal' and other technologies)

5.5 Review energy and technology policies and incentives and revise these, where necessary, to promote efficient production, consumption, distribution and use of energy

6. Capacity building and institutional strengthening

6.1 Review and revise, where appropriate, all government policies (sector by sector) to ensure that they take full account of climate change and its impacts

6.2 Mainstream climate change in national, sectoral and spatial development planning (in government ministries and agencies, local government, the private sector, civil society and communities) and ensure that impacts on vulnerable groups and women are prioritised in plans

6.3 Build the capacity of key government ministries and agencies to take forward climate change adaptation (e.g., Ministry of Food and Disaster Management, Bangladesh Water Development Board, Local Government Engineering Department; National Agricultural Research System, the health system, the Ministry of Women's and Children's Affairs)

6.4 Build the capacity of the government to undertake international and regional negotiations on climate change. Regional and international cooperation is essential in order to build necessary capacity and resilience

6.5 Build the capacity of the government, civil society and the private sector on carbon financing to access various global climate funds

Clear reference is made in the BCCSAP to research. In terms of agricultural research, sub-programmes 1.1, 1.2, 4.1, 4.2, and 4.5 are of particular relevance to future ACIAR funded climate adaptation research in Bangladesh.

Concurrent to the development of the BCCSAP and the Bali Conference in 2007, the GoB has also established new institutional arrangements to tackle climate change. The Ministry for Environment and Forests is the focal ministry for all work on climate change, including international negotiations. It provides the Secretariat for the recently-established National Environment Committee, which ensures a strategic overview of environmental issues and is chaired by the Chief Adviser. Immediately after the Bali Conference, the GoB formed the National Steering Committee on Climate Change. It is headed by the Adviser, Environment and Forests and comprises secretaries of all relevant ministries and civil society representatives. It is tasked with developing and overseeing implementation of the BCCSAP. Five technical working groups were also constituted on adaptation, mitigation, technology transfer, financing and public awareness. The Climate Change Cell in the Department of Environment, under the Ministry of Environment and Forests supports the mainstreaming of climate change into national development planning and has developed a network of 34 'focal points' in different government agencies, research and other organisations.

Another important institution linked to the GoB's response to climate change is the National Disaster Management Council (NDMC) headed by the Chief Adviser/Prime Minister. It is the highest-level forum for the formulation and review of disaster management policies. The Inter-Ministerial Disaster Management Coordination Committee is in charge of implementing disaster management policies and the decisions of the NDMC, assisted by the National Disaster Management Advisory Committee. The Ministry of Food and Disaster Management is the focal ministry for disaster management. Its Disaster Management Bureau is the apex organisation responsible for coordinating national disaster management interventions across all agencies. It is a technical arm of the Ministry of Food and Disaster Management. It has technical and scientific partnership with Space Research and Remote Sensing Organization (SPARSO), Geological Survey of Bangladesh, Centre for Environmental and Geological Information System (CEGIS), Water Resources Planning Organization (WARPO), Institute of Water Modeling (IWM), Bangladesh University of Engineering and Technology (BUET). It oversees and coordinates all activities related to disaster management at national and local levels. In 2000, the Government published Standing Orders on Disaster, which provide a detailed institutional framework for disaster risk reduction and emergency management and which define the roles and responsibilities of different actors. At the field level, the Office of the Deputy Commissioner at the district level, the Office of the Upazila Nirbahi Officer at the Sub-district level and the Union Parishad at the lowest level of the administration play crucial roles in disaster management.

Of all four countries investigated in this scoping study, Bangladesh is the most advanced in terms of formulating a response to climate adaptation, and in implementing on-ground activities (see section 6.3). Clear priorities have been identified, targeted at addressing the impact of sea water intrusion in coastal zones of SW and Southern Bangladesh, drought mitigation in the NW of the country and adapting to increased incidence of flooding in many parts of Bangladesh, but particularly in the Meghna floodplains. Also, farm level adaptation is widely recognised as having to take a livelihoods approach rather than being sectorally driven or relying solely on technical solutions. This is underpinned by a strong conviction, particularly in the NGO sector, that the best approaches to adaptation are development interventions that increase incomes and generally improve livelihoods, as this in turn by definition increases the community's capacity to withstand climate impacts and recover more rapidly from disasters.

5.4 India (Andhra Pradesh)

The broad development policy parameters at a national level for India are set by the Central Planning Commission through its five year plans. The 11th Five Year Plan for 2007-2012 recognises that substantial adverse change in climate appears unavoidable even with the optimal mitigation responses and outlines required responses (Planning Commission, 2007). It raises adaptation to climate change as a priority over mitigation in India's response to climate change. The Plan states that the most important adaptation measure is development itself. A stronger economy is more able to adapt both in terms of the cost of adaptation and technological capability. Achieving rapid economic growth as targeted in the Eleventh Plan is therefore a key element in adaptation. As a first step the 11th Five Year Plan requires for the compilation of a National Action Plan on Climate Change (NAPCC). The NAPCC would require (i) action in the area of agricultural research to evolve varieties that can cope with likely climate changes, (ii) action to cope with likely increases in water stress, (iii) action to be able to cope with a greater frequency in natural disasters. With respect to agricultural research, the11th Five Year Plan identifies improvement of productivity potential and water use efficiency of agricultural crops, specifically in regimes of water shortage and extreme variations of temperature, as priority areas of research. It also postulates that the adaptation response needs to be incorporated in the relevant government programmes, including those relating to watershed management, coastal zone planning and regulation, forestry management, agricultural technologies and practices, and health.

Recognizing the importance of climate change issues, the Indian Prime Minister established a Council on Climate Change under his chairmanship in June 2007 to co-ordinate national action for assessment, adaptation, and mitigation of climate change. This was followed in June 2008 by the release of India’s National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation (GoI, 2008). The plan identifies eight core “national missions” running through to 2017 and directs ministries to submit detailed implementation plans to the Prime Minister’s Council on Climate Change by December 2008:

1. National Solar Mission
The NAPCC aims to promote the development and use of solar energy for power generation and other uses with the ultimate objective of making solar competitive with fossil-based energy options.

2. National Mission for Enhanced Energy Efficiency

3. National Mission on Sustainable Habitat
To promote energy efficiency as a core component of urban planning

4. National Water Mission
With water scarcity projected to worsen as a result of climate change, the plan sets a goal of a 20% improvement in water use efficiency through pricing and other measures.

5. National Mission for Sustaining the Himalayan Ecosystem
The plan aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region, where glaciers that are a major source of India’s water supply are projected to recede as a result of global warming.

6. National Mission for a “Green India”
Goals include the afforestation of 6 million hectares of degraded forest lands and expanding forest cover from 23% to 33% of India’s territory.

7. National Mission for Sustainable Agriculture
The plan aims to support climate adaptation in agriculture through the development of climate-resilient crops, expansion of weather insurance mechanisms, and agricultural practices.

8. National Mission on Strategic Knowledge for Climate Change
To gain a better understanding of climate science, impacts and challenges, the plan envisions a new Climate Science Research Fund, improved climate modeling, and increased international collaboration.

At the national level, the Department of Agriculture and Cooperation within the Ministry of Agriculture has been charged with leading the Mission No.7 to implement climate adaptation polices in agriculture, which it will do by mainstreaming adaptation through its watershed development (WSD) programs. The National Rainfed Area Authority (NRAA) is one of the constituents of the Ministry of Agriculture involved in the Mission. At this stage, a planning document for the *National Mission for Sustainable Agriculture* has yet to be finalised and made public. According to the NAPCC, this mission will focus on four areas crucial to agriculture adapting to climate change:

Dryland agriculture

- Development of drought- and pest-resistant crop varieties
- Improving methods to conserve soil and water

- Stakeholder consultations, training workshops and demonstration exercises for farming communities, for agro-climatic information sharing and dissemination
- Financial support to enable farmers to invest in and adopt relevant technologies to overcome climate related stresses

Risk management

- Strengthening of current agricultural and weather insurance mechanisms
- Development and validation of weather derivative models (by insurance providers ensuring their access to archival and current weather data)
- Creation of web-enabled, regional language based services for facilitation of weather-based insurance
- Development of GIS and remote-sensing methodologies for detailed soil resource mapping and land use planning at the level of a watershed or a river basin
- Mapping vulnerable eco-regions and pest and disease hotspots
- Developing and implementing region-specific contingency plans based on vulnerability and risk scenarios

Access to information

- Development of regional databases of soil, weather, genotypes, land-use patterns and water resources.
- Monitoring of glacier and ice-mass, impacts on water resources, soil erosion, and associated impacts on agricultural production in mountainous regions
- Providing information on off-season crops, aromatic and medicinal plants, greenhouse crops, pasture development, agro-forestry, livestock and agro-processing.
- Collation and dissemination of block-level data on agro-climatic variables, land-use, and socio-economic features and preparation of state-level agro-climatic atlases

Use of biotechnology

- Use of genetic engineering to convert C-3 crops to the more carbon responsive C-4 crops to achieve greater photosynthetic efficiency for obtaining increased productivity at higher levels of carbon dioxide in the atmosphere or to sustain thermal stresses
- Development of crops with better water and nitrogen use efficiency which may result in reduced emissions of greenhouse gases or greater tolerance to drought or submergence or salinity
- Development of nutritional strategies for managing heat stress in dairy animals to prevent nutrient deficiencies leading to low milk yield and productivity

Although climate adaptation has now moved higher in priority following the recent Indian government elections, the delay in the finalisation of the Plan for the Sustainable Agriculture Mission has meant that the mainstreaming of climate adaptation into agriculture has not yet occurred at central and state government levels. However, a range of stakeholders in the central government and the Andhra Pradesh government anticipate that a probable avenue to mainstream climate adaptation in rainfed areas in India will be through the longstanding central and state government supported watershed development (WSD) policies and institutions. Watershed development has received very substantial government and donor support over the past three decades. One of the central facets of WSD is to increase the level of water harvesting and ground water use, in order to help mitigate the effects of droughts and to extend the cropping seasons from *kharif* into *rabi*. In recent years WSD has taken a more holistic approach and is now strongly embedded in a broader livelihoods based approach to rural development. Andhra Pradesh through its Department of Rural Development (AP DRD) has been at the forefront of reforming WSD and extending its scope from the traditional soil conservation and water harvesting focus to a broader based livelihoods approach.

As in Bangladesh, there is a strongly held view that increasing incomes and improving livelihoods constitutes a key pathway to achieving a greater level of adaptive capacity to climate change. Similar to the other countries investigated in this study, the development of water resources to provide supplementary irrigation is seen as a critical strategy to meet the dual objectives of increasing agricultural productivity and generating greater resilience to climate change.

An additional opportunity to link government programmes to adaptation measures is the National Rural Employment Guarantee Act (NREGA). Implemented by the Ministry of Rural Development in 2005, the NREGA is the flagship programme of the GoI that directly touches lives of the poor and promotes inclusive growth. The NREGA aims at enhancing livelihood security of households in rural areas of the country by providing at least one hundred days of guaranteed wage employment in a financial year to every household whose adult members volunteer to do unskilled manual work in scheduled districts. The NREGA achieves the twin objectives of rural development and employment. It stipulates that works must be targeted towards a set of specific rural development activities such as: water conservation and harvesting, afforestation, rural connectivity, flood control and protection such as construction and repair of embankments. Digging of new tanks/ponds, percolation tanks and construction of small check dams are also carried out under this scheme, as well as micro irrigation work such as construction of small canals. Andhra Pradesh through its Department of Rural Development administers the NREGA in AP, and has already taken the lead nationally in harmonising the NREGA with its WSD programs. Discussions with the AP DRD confirmed that the above linkage between WSD related works performed under the NREGA magnifies the benefits of the WSD programme and could be a potential additional avenue to achieve climate adaptation outcomes.

6 Donor funded programs to support climate change adaptation

The level of donor funding for adaptation measures has been far less than what might be expected. Perhaps this is not surprising given the only relatively short period during which adaptation has become a higher order priority in the study countries. Moreover, most governments are still grappling with the concept of adaptation at the same time that their very limited capacity for responding to climate change and adaptation has been diluted by an initial focus on mitigation (CDM), National Communications and NAPAs and a greater focus on disaster reduction and recovery planning. This view is shared with Resurreccion *et al.* (2008) in their assessment of climate adaptation work in South East Asia.

Donor activities and government programmes can be broadly categorised into three groups:

- Technical and single sector interventions prior to NAPA, mainly targeted at disaster alleviation and prevention
- Support for the NAPA process
- Post-NAPA projects, many of which still in a planning or pipeline stage, but with a greater emphasis on alignment with priorities emerging from the adaptation action plans and on mainstreaming climate change into the broader development agenda

An apparent hiatus between formulation of NAPA priorities and donor project responses can be attributed to at least three issues. Firstly many donor organisations are themselves in the process of developing or refining their strategies for adaptation, e.g. World Bank in its South Asia Climate Change Strategy (WB, 2009), USAID in its Roadmap for the USAID Regional Development Mission for Asia (USAID, 2008) or DFID in its Research Strategy 2008 – 2013 (DFID, 2008). Secondly, a quicker roll-out of adaptation programmes is hampered by the generally low institutional capacity in the countries studied. For example in Cambodia, Lao PDR and Bangladesh, whilst the level of expertise in the climate change offices is sufficient, the climate change offices are severely understaffed, with less than 8 technical staff operating in each office at the time of compilation of this report. This is further exacerbated by the almost complete lack of provincial or district level capacity to mainstream adaptation into routine planning and implementation of projects. Thirdly, stakeholder organisations in Bangladesh and Cambodia also raised the issue of uncertainty about how best to address local level adaptation in a more strategic way. Lack of robust programme design principles was mentioned as a key gap. This uncertainty is possibly a reflection of the disconnection between the many high level climate impact and vulnerability assessments, starting from the IPCC and ending with the NAPAs or Climate Change Action Plans on the one hand, and the poor understanding of how climate change will express itself locally and hence, what would constitute the most sensible local level adaptation interventions on the other hand.

Resurreccion *et al.* (2008) conducted a detailed gap analysis of adaptation activities in SE Asia. They summarised the shortcomings of adaptation interventions to date around three main sets of issues, which are corroborated by observations made as part of this study:

- Focus on adaptation as a technical means (rather than including a social dimension built around adaptive capacity) and concentration on sectoral responses in a few areas only (usually agriculture, water, health, and infrastructure)
- Disregard of autonomous practices and adaptation strategies (farmers adapt to changing circumstances all the time)

- Focus on natural systems (failing to recognise that rural livelihoods are not just agriculture based)

To identify donor and government adaptation projects relevant to farm level adaptation in the four study countries, a systematic search of the project databases of major donors was undertaken (World Bank, Asian Development Bank, FAO/IFAD, UNDP/GEF, DFID, USAID, GTZ, AFD, SIDA, CIDA and AusAID). This desktop search and analysis was complemented by interviews and information gathering carried out in discussions with key informants and stakeholders during the in-country missions. The following sections list and briefly describe mainly those projects that are directly relevant to this study, i.e. have an explicit farm level adaptation context. Many donor projects can also be seen as enabling climate adaptation, such as projects aimed at poverty reduction, food security or more general livelihoods strengthening, as well infrastructure development (e.g. market access, roads, irrigation schemes, rural electrification). Some projects in the former category have been selected in those cases where there are perceived opportunities for linkages with farm level adaptation. Projects with a stronger infrastructure emphasis have been excluded in our analysis. While mainly ongoing projects or projects close to implementation have been listed, a few concluded projects have also been included if they had a significant research component. Below some of the regional projects have been listed, while bilateral projects are listed under the respective country headings.

AusAID Mekong regional projects

MRC Climate Change Adaptation Initiative (AusAID/MRC)

A concept note was prepared early in 2008 by the MRC which set out various initial climate change adaptation activities, including the development of a long-term MRC Climate Change and Adaptation Initiative (CCAI) based on an extensive in-country and regional consultation process to identify the current status of climate change and adaptation, the gaps and the Lower Mekong Basin country priorities. This initial work was supported by AusAID with the intention that it lead to a broad multi-donor collaboration on this initiative.

During 2009, a CCAI framework document was forged on the basis of a series of consultative steps involving member countries (Thailand, Cambodia, Lao PDR, Vietnam), development partners and other international organizations and the preparation of national review reports and a regional synthesis report including:

- Establishment of National Expert Teams in each of the LMB countries which prepared the national reports identifying needs, gaps and priorities and supported the MRCS in developing the guiding principles for the design of the CCAI Framework
- Three rounds of national consultations and round table discussions involving National Mekong Commissions, line agencies and the National Expert Teams
- The Regional Climate Change and Adaptation Forum, which was held 2-3 February 2009, in Bangkok, with more than 200 participants including country delegations, regional organizations, development partners, universities, research organizations, NGOs and interested individuals
- Round table and other discussions with potential partners including e.g. development partners and research organizations

Within the MRCS, the Environment Division has taken the lead in developing the CCAI. It is an initiative that will involve all the relevant programmes and sectors for which MRC has a mandate, and be focused on the planning and implementation of climate change adaptation in the Lower Mekong Basin. It is intended to foster close partner relations with other technical organizations working on climate change issues within the Basin, including ACIAR. The CCAI is planned to extend for at least 3 five year phases and to be integrated with the MRC Strategic Planning cycles.

The CCAI framework document outlines the processes, features and implementation arrangements for the CCAI (MRC, 2009b). As a multi-phase initiative, the first phase running over seven years is described in some detail, with the following two five year phases to be developed based on implementation experience.

The CCAI intends addressing four overarching objectives:

Objective 1: Adaptation planning and implementation is piloted and demonstrated throughout the region drawing on lessons learned from existing practices and demonstration with feed back into improving performance and influencing strategies and plans

Objective 2: Improved capacity to manage and adapt at different levels in the Mekong including use of tools for different adaptation planning stages and methods

Objective 3: Strategies and plans for adaptation at various levels are in place and/or regularly updated and integrated with appropriate development plans, with implementation monitored and reported on a regular basis.

Objective 4: The CCAI is effective, financed, managed and implemented for at least three five-year phases, with a developed longer-term sustainability strategy

Complementing the longer term policy development process to be facilitated in the CCAI will be a number of shorter term demonstrations or case studies of adaptation, currently under design. In Cambodia the focus will be on fisheries, in Laos on hydro-power and in Vietnam on coastal management. The MRC team leading the project expressed a strong interest in an ongoing association with the ACIAR adaptation initiative. Opportunities for linkages are evident in the policy domain, and a key gap the ACIAR climate adaptation initiative could assist with addressing is the linkage between policy and on-ground adaptation strategies.

Research for Development Alliance (AusAID and CSIRO)

The CSIRO – AusAID Alliance is a strategic partnership that aims to improve the impact of aid, providing an opportunity to introduce approaches to international aid delivery that better respond to the relationship between poverty and the environment. Climate adaptation is one of four core themes of the Alliance.

Alliance projects are being delivered in two phases:

- Phase 1: Eight small phase 1 projects were designed in June 2008 and were completed in the course of 2009. Of these, the study conducted by Eastham et al. (2008) on ‘Mekong River Basin water resources assessment: Impacts of climate change’ is directly relevant to the future ACIAR work, and results have been presented in Sections 4.1 and 4.2. Details of the Phase 1 projects can be found under: http://www.rfdalliance.com.au/site/projects.php
- Phase 2: In this phase larger scale multi-sectoral projects are being designed through a participatory process with CSIRO, AusAID and international stakeholders. With respect to the Mekong, a project is being implemented in late 2009 on ‘Exploring Mekong Region Futures’. This 2 ½ year project aims at investigating possible future trajectories in the energy, water, food and climate nexus in the Greater Mekong Region using modelling approaches. It will feed into the CCAI as well as informing policy making through a number of additional policy forums.

In addition to the above projects funded through the Alliance, AusAID is also funding a study on ‘Reducing vulnerability of water resources, people and the environment in the Mekong Basin to climate change impacts’. This is a 2–year project being carried out by CSIRO‘s Water for Healthy Country Flagship, and is a collaborative venture with the MRC and IMWI. It will provide very useful baseline information and there are several opportunities for linkages with the ACIAR adaptation initiative in the crop impact modelling domain and using the regional analysis of this project as a basis for extrapolating the more detailed adaptation scenarios being developed as part of the anticipated ACIAR adaptation project.

6.1 Cambodia

The UNDP has been supporting Cambodia in climate change related work since 1995, when it provided support through GEF for the 1st Communication (to IPCC) and the NAPA. Currently UNDP are supporting the Climate Change Office (CCO) to prepare the 2nd Communication, due for Copenhagen in 2009. As part of the UNDP's ongoing support for capacity building and institutional strengthening a monthly donor forum on climate change has been established, with the aim of helping coordinate donor activities in relation to climate change.

The WB has announced a USD 50 M climate change fund, but is still in the process of designing its interventions and is aligning its climate change support to the strategic priorities of the RGoC, i.e. infrastructure (water supply, irrigation) and agricultural development. Policy development forms part of the latter, in particular to support response to disasters by strengthening livelihoods. In terms of other donors, DANIDA and SIDA are expressing interest in supporting the European Union in its selection of Cambodia as a pilot under the Global Climate Alliance Program. The French Development Agency (AFD) has traditionally been very active in supporting irrigation infrastructure rehabilitation and the establishment of Water User Groups, as well as promoting conservation agriculture in rainfed upland areas. AFD's support for climate change is primarily targeting interventions in REDD.

Due to the increasing availability of donor funds for climate change, the National Climate Change Committee is starting to become more active, and through ministries such as the Ministry of Economy and Finance, there is an increasing realisation that there are opportunities for development in climate change, and accordingly, this is becoming a driver for the RGoC to strengthen its institutions and policies in relation to climate change in order to be able to 'capture' this new donor market.

As noted previously, the Government of Cambodia has struggled to source international financing for activities identified in the NAPA. To date, only one activity arising from the NAPA has been financed and implemented.

Promoting Climate Resilient Water Management and Agricultural Practices in Rural Cambodia (UNDP/GEF)

The project responds to the government's National Strategic Development Plan (NSDP) to increase agricultural productivity by providing more irrigation systems to farming areas. Its target is to increase the provision of irrigation systems by 25 percent in 2010. This project builds on the NAPA. It will focus on institutional capacity building, demonstration of integrated water resource management (irrigation) and consolidation of best practice crop management to help famers adapt to climate change. It is in the process of being implemented by MAFF/MOWRAM and will initially focus on Siem Reap and Battambang provinces. However, it is planned to link it to a similar IFAD project under design that would expand the concept to other provinces (Kratie, Preah Vihear, Ratanakiri). There is potential for linkages with ACIAR's climate adaptation initiative by provision of adaptation strategies aimed at optimisation of crop, nutrient and water management to be mainstreamed under this project.

Other UNDP climate change related projects in the pipeline include a sustainable forestry management project, aimed at indentifying drivers for sustainable forestry management (links to REDD) and to explore ways of reducing demand for wood.

Other climate adaptation projects and donor projects of relevance to farm level adaptation are:

Micro-franchising Scheme for the Provision of Agricultural Extension Services (CIDA/WB/DFID)

This 2-year project carried out by the NGO IDE is training 35 Farm Business Advisors (FBAs), of whom about 7 are women. FBAs are village-based entrepreneurs who are being trained in a variety of skills relevant to crop production, harvesting and marketing. Provision of technical information to farmers is embedded as a service in the sale of inputs (improved seeds, irrigation equipment, fertilisers, and pesticides) and marketing services. IDE's scheme is linked to a partner organisation providing micro-finance to farmers for the purchase of inputs and services, although FBAs may also provide financing by way of payment at harvest. The logical link between the planned ACIAR adaptation project and the FBA scheme is that the ACIAR project could provide training modules to FBAs on managing climate variability and optimising crop and water management. Each FBA services about 100 farmers once fully operational, so that through this pathway it is feasible to reach out to about 3500 farmers, if the 35 FBAs are intensively exposed to project results. The FBA concept is also obtaining strong support from the Provincial Dept. of Agriculture in Svay Rieng.

Rural Integrated Development Program in Prey Veng and Svay Rieng (AusAID)

The NGO CARE is about 3 years into a 5 year, AusAID funded rural integrated development program in Prey Veng and Svay Rieng. The rationale for the program is to help prepare and mitigate for disaster by building community resilience and providing coping mechanisms for flood events. Under this program, CARE is expanding access to irrigation water to help farmer diversify and broaden their crop-based livelihood basis. Amongst other things, CARE have installed 500 farmer group managed tube wells (about 5 farmers per tube well; each tube well services around 1 ha), working in about 200 villages. This is complemented by crop improvement work (better inputs and fertilisers, training, post harvest treatment). The central theme is that broadening the livelihood base is the best perceived way of helping farmers prepare for flood or drought events, by enabling them to buffer shocks. As a part of the work CARE are also training farmers to record rainfall and are trying to relate the objective rainfall data to indigenous seasonal climate forecasting methods, in an attempt to better forecast when flood or drought events might be expected. There are opportunities for the planned ACIAR adaptation project to collaborate with CARE in selecting and testing farmer adaptation options with an emphasis on crop and irrigation optimisation.

Rural Poverty Reduction Project in Prey Veng and Svay Rieng (IFAD)

This project works primarily through provincial implementation agencies, under the umbrella of MAFF. It targets rural poor with capacity building and diversification measures. It has no research components. Scope for linkage is limited as this project is in its final stages, but there will be scope to extract learnings that will help guide future ACIAR adaptation activities in Cambodia.

Cambodia Agriculture Value Chain Program (CAVAC; AusAID)

CAVAC is a central part of AusAID's new program of support to the Cambodian agricultural sector. The overall purpose of the program is to deliver practical benefits including improved food security, increased income and reducing the vulnerability of poor farmers engaged in rice-based farming systems. This will be undertaken by promoting market-oriented agricultural development and product diversification, with an initial focus on the rice and vegetable/fruit value chains. This goal will be achieved through four components:

1: Agribusiness Development

2: Water Management

3: Research and Extension

4: Business Enabling Environment

The program will initially focus on three target provinces: Kampong Thom, Takeo and Kampot. The program is in the process of final design and implementation. Linkages between CAVAC and the ACIAR adaptation research will need to be further explored as CAVAC is ramped up and the ACIAR adaptation research project gets under way (see also section 8.1).

Smallholder Agriculture and Social Protection Support Operation (WB, AusAID)
This is a recently initiated intervention planned for 5 years. AusAID is contributing with about USD 2.5 M in technical assistance over 2 years, while the WB's contribution of USD 13 M is primarily for direct budget support to the RGoC. This project targets poor farmers in the most vulnerable provinces and was set up in response to the recent food price crisis and the economic crisis. It is piloting cash for work, conducting labour /migration studies (alternative livelihoods). The AusAID component will review the effectiveness of farmer associations, will target subsidies for seeds and fertilisers and will also pilot cash guarantees.

Pilot Program on Climate Change (WB with other donors)
A design mission is also currently exploring two new projects to come out of the USD 50 M climate change program that the WB has announced for Cambodia:

- Agriculture productivity development in poor provinces, focussing on Vietnam border provinces in the NE, probably 5 provinces
- Pilot Program for Climate Resilience. This will look at vulnerable sectors with a focus on agriculture, water resource development and rural infrastructure.

6.2 Lao PDR

The level of climate change related donor investments in Lao PDR is very low. An analysis of the UN's donor and development partner profiles report (UN, 2008) and a search of the directory of NGO activities in Lao PDR (http://www.directoryofngos.org/pub/index.php) yielded few projects. Key donors supporting agriculture, rural development and natural resource management in Lao PDR are ADB, WB, FAO, GTZ, AFD, SDC, JICA and KOICA. Traditionally, their support has tended to focus on poverty alleviation and food security, mainly in the upland and northern regions of Lao PDR. AFD has also supported the rehabilitation of irrigation schemes and the establishment of WUG. These interventions are relevant to climate proofing the targeted irrigation communities. The ADB is in the process of developing a major new initiative in southern Laos, but this will have a stronger emphasis on poverty alleviation and food security than climate adaptation. Nonetheless, ACIAR climate adaptation research in Lao PDR might well offer opportunities for linkages as this initiative unfolds.

In the past, the only explicit support for climate adaptation has come through the UNDP's support of the Lao PDR NAPA process. Emerging donor support for climate change seems to be biased towards mitigation (REDD, CDM capacity building). Nonetheless, there are some ongoing projects of relevance to climate change adaptation:

Watershed Management Project (GTZ/MRC)
This project has focussed on mainstreaming integrated watershed management and development into planning by building watershed committees comprising district administrators, community leaders, private sector and NGOs. It has tested this approach in 4 pilot watersheds (one in each member country). Prospects for linkages are limited, as the GTZ project is due to end in 2011. However, it has gathered some useful community level vulnerability assessments on climate change impacts.

Climate Impact and Adaptation Sectoral Strategy for Rural Infrastructure in Laos PDR (ADB)
This is a 9-month pilot study under the ADB's Small Grant Facility of the 'Promoting Climate Change Adaptation in Asia and the Pacific' programme. The project will

investigate the impact of climate change on irrigation infrastructure and other agricultural infrastructure, and ensuing policy implications (flood risk assessment). It is initially restricted to the provinces of Savannakhet, Saravane, Sekong, Attapeu and Champassak. Resolution of the risk assessment modelling will be at district and sub-basin scales. If successful the project is seen as a precursor to a larger regional initiative. This study will provide higher level impact projections that are likely to be useful input to future ACIAR climate adaptation research, while research output from the envisaged adaptation options modelling proposed in ACIAR's planned adaptation project could flow into the follow-on projects under this program.

Rice Productivity Improvement Project (WB)
The primary objective of this USD 3.5 M project being implemented by the National Agriculture and Forestry Research Institute (NAFRI) is to increase rice productivity and overall rice volume production among smallholders in lowland rice environments. While the project will focus on the central and southern provinces (Savannakhet and Champassak), some activities will also take place in Vientiane Province. The project has two main components, comprising the development of rice seed systems and support for farmer seed groups and on-farm demonstrations.

6.3 Bangladesh

Donor support for adaptation to climate change adaptation in Bangladesh in the last five years has been more substantive than for Cambodia and Lao PDR, and can broadly be categorised as:

- UNDP/GEF funding to support capacity building and the development of the NAPA and the NCCSAP
- Projects aimed at assisting Bangladesh develop an effective disaster response capability at the national policy and administration level as well as at the community level

In the first case the support has enabled Bangladesh to become a forerunner in preparing a more strategic blueprint for the country's response to climate change in the form of the NCCSAP. The process has culminated in the establishment of a Climate Change Fund in 2008, with an initial GoB allocation of USD 45 M. DFID has led the donor community by pledging a significant contribution to bolster this fund and ultimately the GoB hopes to attract additional donor support to take the fund to USD 5 B over the next years. However, apart from funding a range of research studies (see section 8.3) and further impact assessments, to date no significant projects have yet drawn on this fund. Some of the constraints inhibiting a more rapid deployment of funds stated by GoB stakeholders included bottlenecks in project identification and design due to lack of sufficient personnel, competing interests with respect to which priorities to tackle first and a certain degree of uncertainty on how to best design effective adaptation programmes for on-ground adaptation measures.

In relation to the second category listed above, the Comprehensive Disaster Management Program (CDMP) is the signature initiative, initiated in 2003 with the support of a donor consortium comprising UNDP, the European Union and DFID. The CDMP was approved by the GoB as a key strategy to advance whole-of-government and agency risk reduction efforts in the country. Its first phase is due to conclude in 2009 and a second phase of the programme is presently under design. The CDMP is a strategic institutional and programming approach that is designed to optimise the reduction of long-term risk and to strengthen the operational capacities for responding to emergencies and disaster situations including actions to improve recovery from these events. To achieve this, the CDMP seeks to reduce the level of community vulnerability and enhance sustainable development initiatives through a range of integrated strategies containing five strategic focus areas and twelve components (see Tab. 6.1). Implementation agencies are drawn from government and non-government sources with overall coordination provided by the Policy, Program and Partnership Development Unit within the Ministry for Food and Disaster Management. Since August 2006, an EU contribution extends the CDMP focus to the community level and provides resources for pilot implementation of CDMP initiatives, with early opportunities to experiment and learn lessons at that level which will enhance the effectiveness and probability of success of national implementation.

Under the umbrella of the CDMP, the FAO and the Asian Disaster Preparedness Centre are guiding a 'Livelihood Adaptation to Climate Change (LACC) Project' project to assess livelihood adaptation to climate variability and change in the drought- prone areas of Northwest Bangladesh. This project, carried out by the Department of Agricultural Extension, specifically looks at: characterization of livelihood systems; profiling of vulnerable groups; assessment of past and current climate impacts; and understanding of local perceptions of climate impacts, local coping capacities and existing adaptation strategies. It also is developing a good practice adaptation option menu, evaluating and field testing locally selected options, and introducing long-lead climate forecasting, capacity building and training of Department of Agricultural Extension staff and community representatives, drawing on input from BARI, BRRI and a range of NGOs. The initial focus on NW Bangladesh was later extended to include case study sites in the SW (Khulna and Pirojpur Districts), to address salinity management and flooding. The results of the research component of this project are discussed in section 8.3. The initial two phases of this project (LACC I, 2005-2007; LACCII, 2008-2009) have been concluded and a third phase is under design as an integral component of the second phase of the CDPM. Any future ACIAR climate adaptation research should seek linkages to this next phase.

Table 6.1: Programme structure of the CDMP (source: CDMP, http://www.cdmp.org.bd/)

Strategic Focus	Corresponding Components
1. Professionalising the disaster management system	1a Policy, Program and Partnership Development Unit (PPPDU) 1b Professional Development
2. Mainstreaming of risk management programming (partnership development)	2a Advocacy and Awareness 2b Capacity Building
3. Strengthening of community institutional mechanisms (community empowerment)	3a Program Gap Analysis 3b Risk Reduction Planning 3c Local Disaster Risk Reduction Fund 3d Support for Livelihood Security – Hazard Awareness
4. Expanding risk reduction programming across a broader range of hazards	4a Earthquake and Tsunami Preparedness 4b Climate Change and Research
5. Strengthening emergency response systems (operationalising response)	5a Disaster Management Information Centre 5b Support for a Disaster Management Information Network

Other projects of potential relevance to ACIAR supported adaptation research in Bangladesh are listed below.

Community-Based Adaptation to Climate Change through Coastal Afforestation in Bangladesh (UNDP)
This USD 5.4 M project is the first field-level project in Bangladesh that directly targets vulnerable people living in communities in coastal areas. The project intends to enhance the resilience of both coastal communities, and protective ecosystems through community-led adaptation interventions that focuses on coastal afforestation and livelihood diversification, which is a top priority intervention area as identified by the NAPA. The project also aims to further enhance the national, sub-national and local capacities of government authorities and sectoral planners to understand climate risk dynamics in coastal areas and to implement appropriate risk reduction measures. The five coastal districts in which the project will be operated are Barguna, Patuakhali, Bhola, Noakhali and Chittagong.
http://www.undp.org.bd/info/events.php?d=7&newsid=409&t=In%20News

Adaptation through the Chars Livelihoods Programme (DFID)
DFID is providing ~USD 82.6 M over eight years to help 50,000 extremely poor Chars households with a complementary ‘whole community’ approach covering a total of one million people. The programme assists by raising homesteads above the 1998 flood level, transferring income generating assets (such as cattle, goats, poultry, chickens and other agricultural inputs), training in animal rearing and crop diversification, providing access to irrigation and drinking water through the installation of tube wells, cash stipends and providing opportunities for daily labour through infrastructure works. Activities take place mainly during the annual *monga* (seasonal hunger) crisis periods.
http://www.dfid.gov.uk/Documents/publications/departmental-report/2008/Chapter9.pdf

Assistance to local communities on climate change adaptation and disaster risk reduction in Bangladesh (DANIDA)
This project is piloting adaptation options to deal with flooding and sea level rise in the SW of Bangladesh, as well as developing capacity in local planning, but due to end in 2009. On-ground implementation of the project is by Action Aid and there are good prospects of forming linkages with this NGO to share learnings between this and the planned ACIAR project.

Support to Agricultural Research for Climate Change Adaptation in Bangladesh (IFAD)
This 3-year project has commenced in July 2009 and will carry out participatory research to identify improved agricultural technologies to adapt to climate change in the Khulna District. However, this will be carried out in the absence of any long term assessment of future viability of technologies, for instance by using climate impact modeling, so that the planned ACIAR project could complement this project by providing modelling, while the IFAD project could carry out on-farm testing of adaptation options identified by the modeling. Linkages would be facilitated by IRRI being the lead organisation in the IFAD project and the primary collaborator on the planned ACIAR project in Bangladesh.

Cereal Systems Initiative for South Asia (CSISA; USAID and Bill & Melinda Gates Foundation)
CSISA was instigated in early 2009 and is being carried out by a consortium led by IRRI. Its aim is to bring together a range of public- and private-sector organizations to revitalise sustainable cereal production in India, Pakistan, Bangladesh and Nepal. The programme is built around 4 units of activity (‘hubs’) representing of the main agro-ecological regions within the Indo-Gangetic Plain. The Eastern Gangetic Plains encompass Bangladesh and India (but not Andhra Pradesh, the focus of the ACIAR climate change initiative). Programme activities include the packaging and dissemination of proven and available technologies developed in the precursor Rice-Wheat Consortium, breeding of new wheat, rice, and maize varieties more tolerant of adverse biotical and abiotic stresses, and the design and testing of improved cropping systems. While this programme does not explicitly address climate change, breeding of new varieties more tolerant of stresses

likely to increase as a result of climate change and their integration into more resource use efficient cropping system constitute a significant scientific underpinning to climate adaptation. As part of the cropping systems testing, a range of new long term controlled trials will be established in all four hubs, the Bangladesh hub being at Gazipur (the main BARI and BRRI experimental station). These trials will offer a unique opportunity to generate high quality datasets suitable for calibrating and validating the next generation of crop and farming systems simulation tools, such as those discussed in section 9. Conversely, the ACIAR funded work would offer an opportunity for CSISA to extrapolate and assess the long term suitability of the novel cropping systems being developed under future climate conditions.

6.4 India (Andhra Pradesh)

A number of major WB, FAO and DFID funded projects have either indirectly or directly addressed the impact of climate variability on farmers' livelihoods in rainfed areas of Andhra Pradesh. In general, the thrust of these activities has been to improve the livelihood base of poor farming households through harvesting of water and better utilisation for supplementary irrigation and the production of high value crops. Since the completion of a long suite of watershed development activities in Andhra Pradesh, DFID has now withdrawn from AP to other states (Orissa, Madhya Pradesh), and there are few if any new ongoing or planned projects in AP specifically targeting climate adaptation.

Some of the past and ongoing projects relevant to future ACIAR climate adaptation work in AP are listed below.

Participatory watershed management reduces rural poverty and helps people adapt to climate variability in India (DFID)
Participatory watershed management reduces rural poverty and helps people adapt to climate variability in India. DFID is supporting a livelihoods programme based on participatory planning in micro-watersheds with the State Government of Orissa, building on previous work in Andhra Pradesh. The programme will help poor people to manage their water, land and forest resources. It will provide people with skills and access to services, such as micro-credit, veterinary, business and agricultural advice. This combination of sustainable management of natural resources with diversification of activities, enables poor people to respond to current climate variability, and strengthens their ability to withstand the droughts and floods that may result from future climate change. Noting the crucial importance of water as a limiting factor in sustainable development, a water governance system has been pioneered in Andhra Pradesh to help allocate water in a fair way. An independent evaluation of the Andhra Pradesh programme estimated that more than one million people had been lifted above the poverty line over seven years of implementation. There have also been significant improvements in food security and reduction of distress migration.

Andhra Pradesh Drought Adaptation Initiative (AP DAI; World Bank)
The overall objective of the AP DAI is to enhance drought adaptation capacity of affected communities and reducing their vulnerability to drought in the long-term. The AP DAI pilot project was implemented in two phases due to different modes of financing. Phase I of the pilot program (June 2006–April 2007), financed by a World Bank-executed trust fund, initiated activities in 6 villages in three *mandals* of Mahbubnagar District. Phase II of the pilot implementation started in November 2007 and expanded the project into an additional 9 villages in Mahbubnagar and initiated activities in 10 new villages in Anantapur District. The implementation of the AP DAI Phase II was supported by the Japan Climate Change Initiative Grant (CCIG) and the World Bank. The pilot activities are implemented by the Society for Elimination of Rural Poverty in collaboration with district collectors in the pilot districts, and under oversight of the AP Department of Rural Development. The NGO WASSAN provided the technical support at the *mandal* level during the first phase and has been selected as the Lead Technical Agency for

implementation of AP DAI Phase 2 program. Although the project is close to termination, there would seem to be good prospects of the planned ACIAR climate adaptation project to build on the outcomes and learnings of the AP DAI and perhaps include WASSAN as a project partner in AP, amongst other things to use WASSAN's network of local NGOs and through this network channel outcomes of the planned ACIAR project to other Districts in Andhra Pradesh.

Andhra Pradesh Farmer Managed Groundwater Systems Project (APFAMGS; FAO)
This is a FAO funded project that was launched in 2003 and had had successive extensions until 2009. It was implemented and managed by the BIRDS, acting as an umbrella NGO for 9 other local NGOs operating in the target districts in Andhra Pradesh (rainfed districts in southern and western AP). Conceptually, the APFAMGS project is a partnership with farmers for implementing demand side groundwater management, based on a range of farmer capacity building approaches, including Farmer Field Schools (FFS) on water management. The unique aspect of the project is that it does not offer any incentives in the form of cash or subsidies to the farmers. What it offers is the means to increase their knowledge about the status of their groundwater resources by giving them the equipment and skills to collect and analyse rainfall and groundwater data. The project also facilitates access to information about water saving techniques, improving agricultural practices and ways to regulate and manage their own demand for water. The project is in the process of receiving further funding to incorporate adaptation to climate change and extend its FFS concept to Farmer Climate Field Schools, but details on project duration and scope were not finalised at the time this report was being finalised. In the event that the FAO funds a follow-on project aimed at pursuing the Farmer Climate Field School concept, it would be imperative to link the planned ACIAR project in AP to this project, as a means to channel project results to a broader range of farming communities, e.g. by providing the adaptation options to be tested by farmers and by providing curricular and training material for FFS modules on climate and climate variability.

Andhra Pradesh Community Based Tank Management Project (WB)
The objective of this 5-year project in Andhra Pradesh, which is funded by the WB and commenced in late 2007 is for selected tank based producers to improve agricultural productivity and water user associations to manage tank systems effectively. The project has the following technical components:

- Institutional strengthening which will focus on strengthening community-based institutions to enable them to assume greater responsibility for tank system improvement and management and enhancement of tank-based livelihoods;
- Minor Irrigation Systems Improvements which will enhance water use efficiency in tank areas selected under the project;
- Agricultural Livelihoods Support Services which will seek to enhance productivity, production and profitability of tank based agricultural activities. This component has five sub-components - 1) Agriculture and Horticulture, 2) Livestock 3) Fisheries, 4) Foreshore Plantation, and 5) Agri-Business and Marketing.

Similarly to the other projects discussed above, adaptation to climate change is achieved indirectly by assisting smallholders better manage climate risks through the use of supplementary irrigation.

Gender-sensitive strategies for adaptation to climate change: drawing on Indian farmers' experience (SIDA/FAO)
This is a 2-year project ending in 2009, that is studying how men and women farmers in drought-prone and flood-prone districts perceive and respond to inter-annual climatic variability and long term changes. The study is based on participatory focus group discussions and a quantitative survey. The project is being carried out by ANGRAU and the Samatha Gender Resource Centre.

National Agricultural Innovation Project (NAIP)

The World Bank and the GoI are jointly funding this 5 year USD 250 M project. It contributes to the sustainable transformation of Indian agricultural sector to more of a market orientation to relieve poverty and improve income. The specific aim is to accelerate collaboration among public research organizations, farmers, the private sector and stakeholders in using agricultural innovations. The project has four components:

- Component 1 strengthens the Indian Council of Agricultural Research (ICAR)
- Component 2 funds research on production-to-consumption systems
- Component 3 funds research on sustainable rural livelihood security.
- Component 4 supports basic and strategic research in the frontier areas of agricultural science.

Under the umbrella of the NAIP, there are several projects relevant to climate change, of which a few are also operating in Andhra Pradesh. These are reviewed in more detail in section 8.3.

7 Status of agricultural extension and agro-meteorological services

7.1 Cambodia

Responsibility for the delivery of agricultural extension services resides with the Department of Agricultural Extension (DoAE), which falls under the General Directorate of Agriculture in the Ministry of Agriculture, Forestry and Fisheries (MAFF). In general dissemination work and on-farm work is conducted through collaboration with Provincial Departments of Agriculture (PDA), mainly through field days and the production of Technology Implementation Packages. There are 24 PDAs (technical officers usually university trained), 180 District Depts. of Agriculture (DDA; extensionists with agricultural college or school diplomas) and presently about 4000 village based extension workers (out of 14000 villages; voluntary workers mainly recruited from villages). This network is complemented by a large array of NGO extension workers, linking mainly at the district, commune or village level. Further village level extension workers are still in the process of being appointed. PDA and DDA extensionists are responsible for training village level extension workers.

Through the previously AusAID supported Cambodia Australia Agricultural Extension Project, DoAE and PDA extensionists were trained in the Agro-Ecosystems Analysis (AEA) methodology, which in essence is a simplified form of the Sustainable Rural Livelihoods methodology (SRL; Scoones, 1998; Ellis, 2000). Thus the AEA is likely to provide a useful basis for assessing adaptive capacity in Cambodia, as there is a good convergence between the AEA and the SRL approach being suggested in section 10. However, mechanisms for systematic transfer of new technology from the various national and international research organisations seem weak. Mostly, technology transfer is predicated on the existence of specific projects and therefore is by nature time-bound and specific to the project areas. Overall older PDA staff have a reasonable capacity/skills level while the newer generation of PDA is staff not as well trained (Mak, *pers. comm.).*

Depending on the size of the province, the PDA is structured into a range of offices (agronomy, livestock, extension, administration, regulation, investment, agribusiness etc). In Svay Rieng for instance, the PDA has about 145 staff, including those stationed at the DDAs. Policy harmonisation at the provincial level occurs through the Provincial Rural Development Committee (PRDC) which comprises representatives from PDA, PDMOWRAM, PDRD, etc and which responds to the Provincial Executive Committee (ie provincial government). In fact, the PRDC could constitute an additional channel of engagement with communities on adaptation strategies. The PDRCs in collaboration with NGOs work with villages to set up the Village Development Committees (VDC). These were first established in the 1990’s, with about 8700 now up and running (~50 % of villages in Cambodia). After the VDC is elected, the PDRC provides training and capacity building with the aim of facilitating Village Action Plans, micro-project coordination and implementation etc. usually supported logistically by NGOs. The VDCs consist of elected members for a 3-year term, and they constitute a potential channel through which new agricultural technologies can be disseminated.

The public sector extension service is complemented by a range of national and international NGOs operating in many of Cambodia’s provinces. Some of these NGOs and their projects in so far as they relate to adaptation to climate change have been described in section 6.1.

Meteorological services in Cambodia are provided by the Department of Meteorology (DoM), which since 1998 sits under the Ministry of Water Resources and Meteorology (MOWRAM). Meteorological services in Cambodia were not properly established until after independence in 1954, although individual meteorological observations go back to 1894. Overall, the climate records are patchy and characterised by many gaps. Political instability and the rise to power of the Khmer Rouge regime led to abandonment and disruption of the entire meteorological network. The number of qualified staff was reduced from 300 to about 10. After 1979, a basic service was established with the assistance of the Soviet Union. From 1992 to 1995, the network was partially rehabilitated through a DANIDA-funded project, involving meteorologists from the Danish Meteorological Institute and the Australian Bureau of Meteorology. Further political instability from 1996 to 1997 again reduced the service to a very low operational level. A JICA-funded project established and upgraded some of the synoptic stations during 2001 to 2003, as well as providing some on-the-job training.

The DoM headquarters are located just opposite the Phnom Penh airport, in Ponchentong. However, as 19 of the 20 synoptic climate stations are based in the provinces, the DoM has to rely on provincial authorities for staffing and day-to day collection of climate data. DoM is primarily responsible for the cataloguing and dissemination of climate data, as well as maintaining equipment and training provincial meteorological observers. Transfer of climate data between provincial stations and DMH head office in Ponchentong is mainly through logbooks with manual entries.

Presently DoM manages 20 manual synoptic stations (one per province), supplemented by 9 automated stations, but only a few of these are functional. There are also 200 manual rainfall stations. Of the synoptic climate stations probably only 2 to 3 have a reasonably uninterrupted rainfall record of more than 50 years (Phnom Penh/ Ponchentong, Battambang, Kampong Cham). All other stations have had interruptions or have only been established more recently (2001). To date, no attempts have been made at patching data files through interpolation techniques.

While various donors have at various times provided some support, no comprehensive project on fully establishing the network and properly training the provincially based observers has yet been carried out. The Director of DoM expressed a strong interest in obtaining support to compile the existing data onto a common database and to carry out some missing data patching, as well as DoM staff receiving training in analysis of climate variability and in strengthening forecasting capabilities.

Forecasting is carried out by 5 trained forecasters (with formal degrees in meteorology obtained in Russia and Vietnam). Forecasting is done by manually creating ensembles out of a range of publically available satellite information sourced via internet from the Australian Bureau of Meteorology, the Japan Meteorology Agency, the Hong Kong and Thailand meteorological services and the Asian Disaster Preparedness Centre. Taking into account orographic influences in Cambodia the forecasters interpret that information in relation to Cambodia and issue daily public weather forecasts with a 3-day time horizon on a national level. No specific agro-meteorological forecasts or advisories are produced and disseminated to the wider public other than the daily weather forecasts.

The general lack of operational and forecasting capacity in DoM represents a major constraint to adaptation, as without a functional meteorological service and weak forecasting capabilities, it will be very challenging for Cambodia to streamline its adaptation responses.

7.2 Lao PDR

Until 2000, extension services for the different agriculture sectors came under their respective line ministries. In 2001, the Ministry of Agriculture (MAF) integrated all extension services into the National Agriculture and Forestry Extension Service (NAFES) with support from the SDC-funded LEAP project (now in its 4th and final phase). LEAP has two main thrusts: strengthening government extension systems and building village extension systems. Within the latter, there are three target groups: village authorities (e.g.

village development committees), production groups and the (voluntary) village extension workers (selected or champion farmers). This is being underpinned by strengthening the pool of extension trainers at provincial and district level. At present the system is being further decentralised down to village clusters of 5-8 villages. So far about 1200 clusters have been formed, covering ~10,000 villages. Two categories of farmers are identified, subsistence farmers, who receive the bulk of the extension support, and commodity or cash crop farmers.

Knowledge sourcing to train trainers is both top down, i.e. propagation of ‘certified’ or tested technologies from the central level down to provincial, district and cluster levels, as well as ’horizontal’ through media (from Thailand and Vietnam) and project based inputs from NGOs, being provided mainly at district and cluster level.

In 2008, the Provincial Agriculture and Forestry Service (PAFES) was integrated with other provincial level departments to come under the umbrella of the Provincial Agriculture and Forestry Offices (PAFO). NAFES continues to operate at the national level, with policy formulation and coordination roles. It also implements and runs a range of large donor funded activities. Conversely, the PAFO integrates agricultural administration, extension and research activities at a Provincial level. Usually, the PAFO is structured into sections covering irrigation, forestry, crops and livestock, in addition to extension. Within PAFO, the extension section has one head, a deputy head and 5-7 officers, reporting administratively to the Dep. Director of PAFO. In theory the PAFO structure should enable for subject matter specialists to be more be easily drawn upon from within PAFO out of the various sections. PAFO extensionists have MSc or BSc level qualifications. PAFES within PAFO determines provincial extension priorities, and would be the appropriate level for ACIAR projects to seek help to identify target districts and cluster villages.

Amongst other roles, PAFO provides project oversight, coordination and M&E for provincial level development projects. However, projects are mainly implemented at the district level through District Agriculture and Forestry Offices (DAFO), which are structured into a technical and an administration wing. Actual implementation and execution of projects and programmes is carried out at the district/cluster village level. Depending on size of districts, DAFO staff complements range from 30 - 50. Some of these are distributed in sub-district towns or cluster villages. At an administrative level, DAFO is mainly concerned with land entitlements, tax collection and collection of agricultural production statistics. Qualification levels in DAFO are at BSc or Diploma level (Technical Ag Colleges). DAFO offices usually do not have email, and not all have fax. Over the course of the next years, the plan is to successively roll out Technical Service Centres within each district alongside the DAFO, to be manned with about 15 staff that would then operate at cluster village level. A key role for these centres would be seed multiplication (currently also done at a national level by NAFES and PAFES). Likely capacity and capability constraints still exist at the cluster village level, and that is the level at which NAFES believes ACIAR projects could make a difference in training.

The degree to which effective extension is provided at a local level did not become clear during discussions, but there are indications that there are constraints both in capability and capacity, and that one of PAFO’s objectives is to improve the quality and local relevance of extension officers. Other problems with this model relate to district officers not having enough time or resources to transform extension messages from top down messages into locally relevant messages. Also, levels of motivation are low due to low pay. There is thinking in NAFES about moving to ‘shared benefit services’ where farmers pay some remuneration to extensionists (apparently one pilot in Bokeu Province underway), depending on whether their advice brought the farmer benefits.

Irrigation Water User Groups (WUG) are supported by the irrigation and extension units in DAFO. The latter provide technical input to crop production and irrigation scheduling, the former mainly providing channel design and maintenance support. WUGs collect water user fees; 15% of the fees go to the district administration, the remainder is used by the WUG for maintenance and/or use in the village development fund. Fees are paid in cash or paddy, at 200 kg paddy/hr/yr for gravity fed irrigation systems, 150 kg paddy/ha/yr for electric pump serviced systems and 100 kg paddy/ha/yr for diesel pump serviced schemes. The main issues faced by the WUGs are low farmer capacity and lack of skilled technical personnel in DAFO.

The Department of Meteorology and Hydrology (DMH) was part of MAF until July 2007, when it was included in the newly formed Water Resources and Environment Administration (WREA). Its mandate is to collect climatic and hydrologic data. Raw data coming from stations is compiled and analysed in Vientiane to produce advisories, mainly for other government departments. DMH is organised into three sections: technical, administrative and planning & cooperation. Within the technical section there are four divisions (all division heads report to the Director Technical):
- Climate division
- Weather forecasting and aeronautics division
- Meteorological and earthquake division
- Hydrological division.

DMH maintains a network of 17 synoptic weather stations, with one station in the capital of each Province. No radiation data are collected, but the synoptic stations record sunshine hours. There is one weather radar in Vientiane with 400 km range, used primarily for storm tracking and aeronautical purposes. There are only 3 stations with long term records starting in the 1950s (Vientiane, Luang Prabang and Seno near Savannakhet). Other stations were set up in the 1970s (e.g. Savannakhet) or only as recently as 1986. The data is recorded manually and sent to DMH Vientiane by modem with a SMS back-up. This is supplemented by a network of 139 weather stations (rainfall, temperature). Part of this network has been inherited from other agencies and incorporated into the DMH network. Presently DMH is reviewing the network for redundant stations and gaps. However, depending on DMH's budget allocation, in many years, no data is collected at some of the existing stations because of insufficient funds.

Apart from daily weather forecasts, which are broadcast and generally available through printed and TV/radio media, DMH also prepares weekly, monthly and 3-monthly weather forecasts. Spatial resolution is into 6 separate forecasts, for eastern (mountainous uplands) and western (Mekong valley) portions of northern, central and southern Laos, respectively. These forecasts are channelled to MAF, the Prime Minster's Office and the provincial Hydromet Services, but then are not further utilised. Data for seasonal climate forecasts is sourced from other meteorological services and the internet and are based on statistical approaches and expert interpretation. In DMH's assessment the forecast skill is around 60-70%. This comparatively high skill is due to the lower level of climatic variability in Laos compared to other countries (distance to sea, mountain barrier between Vietnam and Laos). However prediction skills are weak with respect to local variation due to thunderstorm activity.

DMH is also responsible for flood forecasting. The flood warning system operates under the auspices of the MRC, using a shared software system for Laos, Thailand, Vietnam and Cambodia. 17 gauging sites on the main Mekong and the synoptic weather stations in each country provide real-time data that is ultimately transferred to the Flood and Disaster Management Centre (FDMC) in Phnom Penh. In Laos, the forecasting is enhanced through the network of gauging sites on tributaries. In addition to the FDMC, forecasts are channelled to the Laos National Disaster Management Organisation, which sits under the Ministry of Labour. It receives daily DMH forecasts by 10 am. The forecasts are then transmitted by the Ministry of Labour through its network of provincial, district and cluster village nodes. At the cluster village level, dissemination to farmers is carried out by the head of village or lead farmers.

To date no analysis of the climate records with respect to determining trends in climate change has been undertaken by the DMH itself. However, at a national level some analysis might be being done by Institute for Water and Environmental Research in WREA, as well as through the work being carried out by Dr Thavone Inthavong of NAFRI.

DMH expressed a very strong interest in accessing Australian expertise in helping it improve its seasonal climate forecasting systems, both at a skill of forecast level, as well as identifying and trialling appropriate advisory delivery systems. The preferred modality of cooperation is training and joint data analysis in–country to improve DMH capacity.

7.3 Bangladesh

Bangladesh is endowed with a very extensive agricultural extension service. The Department of Agricultural Extension (DAE) within the Ministry of Agriculture is responsible for the service. The general structure of the systems is as follows:

- Regions (9 in all of Bangladesh): Headed by an Additional Director of Agricultural Extension (AE)
- District (24): Deputy Director AE (BSc or MSc level), covering 3-12 *upazilas* (sub-districts) and supported by:
  - 1 Crop production specialist (CPS)
  - 1 Plant protection specialist (PPS)
  - **1 Training officer (TO)**
- *Upazila* (439, formerly *thana* or sub-district): 3 extensionists, each covering 20 - 40 blocks:
  - 1 Upazilla agricultural officer (UAO, BSc)
  - 1 Additional agricultural officer (AAO, BSc)
  - **1 Agricultural extension officer (AEO, BSc)**
- Block level (blocks are a DAE specific subdivision, coming under the Union level administratively; each block reaches out to 800-1000 farmers):
  - 1 Sub-assistant agricultural officer (SAO, 3-year diploma in agriculture)

Highlighted positions are the critical target audiences for training and dissemination of project technologies. In the past, ACIAR and other donor projects have tended to rely on a combination of DAE staff to achieve out scaling, supported by NGOs providing training mainly to Block and *upazila* level extensionists. NGO technical staff often perform train-the-trainer roles, and generally there is a strong complementarity between the NGO sector and the considerable human resource that the Block level extensionists represent.

The Bangladesh Meteorological Department (BMD) comes under the Ministry of Defence in Bangladesh. It maintains a network of 35 meteorological observation stations, capturing a comprehensive range of data on a 3-hourly basis (rainfall, temperature, sunshine hours, solar radiation, evaporation, wind etc.). This is complemented by 12 agro-meteorological observatories. Five radar stations have also been established (Cox Bazaar, Barisal, Dhaka, Rajshahi, Sylhet), 3 of which are Doppler radars, mainly to help in cyclone and storm prediction. Access to data is generally not a problem but incurs a service fee. There are several long term climate records available, but they are not as comprehensive and complete as those in India.

The BMD does issue a range of forecast products. Daily weather forecasts are issued via media and on the BMD website. Ten day agro-meteorological forecasts are prepared using a mix of expert interpretation and forecasting products obtained from other meteorological services (NCMRWF in India, Japan Meteorological Agency - JMA, European Centre for Medium-Range Weather Forecasting - ECMRWF). More sophisticated numerical modelling based forecasting systems are not operational. The spatial resolution of the forecasts is to Division and occasionally District level. Currently these forecasts are not widely disseminated, although they are obtainable from BMD. A range of government organisations and NGOs obtain the forecasts through an email and fax based mailing list. The main channel to the agricultural sector is through the DAE, but from the discussions with BMD it remained unclear as to how the DAE further utilises these forecasts. Currently no agricultural advisories are being derived out of the forecasts and no systematic forecasting skills evaluation is being undertaken. The Storm Warning Centre within BMD also generates monthly and quarterly climatological forecasts. The former provides forecasts on rainfall, cyclones, number of rainy days, evaporation and soil temperature; the latter provides qualitative assessments of rainfall, cyclone activity and river discharges/flooding. These forecasts are not widely disseminated but can be accessed upon written request. They are mainly distributed to Ministry of Defence, Ministry of Agriculture (DAE), FAO, USAID, and the Prime Minister's Office. They are generated by expert opinion in a national committee comprising technical representatives from SPARSO, BMD, Flood Forecasting and Warning System (FFWC, Ministry of Water Resources) and DAE. Raw data underpinning these forecasts is obtained from ECMRWF and JMA, as well as products from NCMWRF. No systematic forecasting skills analysis has been undertaken, but it is estimated that during the monsoon, when there is generally less variability, forecasting skill level is at >80%, while during the higher variability Kharif I (pre-monsoon) it may be around 50%.

The BMD has recently been reviewed by the World Meteorological Organisation (WMO) which raised issues of understaffing and no dedicated personnel for agro-meteorological services, manual data transmission systems, lack of more rigorous cross-checking of data and the need to establish a dedicated maintenance and calibration unit. It also provides a range of recommendations relating to the establishment of a dedicated agro-meteorological service (similar to that in India). A 3-year capacity building project funded by JICA is due to commence in July 09. It plans to train and develop operational capacity at all levels within BMD. The WMO mission is due to return in August 2009 to assist in the development of a proposal being prepared for the GoB to support the establishment of an agro-meteorological service.

The Director General of BMD expressed a strong interest to collaborate with IRRI and Australian partners on testing the utility of 10 day seasonal forecasts with farmers. Another area the BMD explicitly requested support in was capacity building in assessing forecasting skill of current products.

7.4 India (Andhra Pradesh)

At the state level the agricultural extension service in Andhra Pradesh is a department within the Andhra Pradesh Department of Agriculture (AP DAE), structured into several levels down to the *mandal* level:

- Division level (3 districts): headed by a Joint Director, supported by 1 technical specialist
- District level (8-12 *mandals*[2]): headed by an Assistant Director (bureaucrat/administrator), supported by 1 agricultural specialist and 2 to 5 support officers for tactical/day-to-day services
- *Mandal* level: 1 agricultural officer (BSc or MSc level); this is the main delivery platform for new technologies to farmers.

This system is supported through a network of 12 Regional Agriculture Research Centres (RARS) belonging to the Acharya NG Reddy Agricultural University (ANGRAU). Each RARS represents a different eco-climatic zone in Andhra Pradesh. RARS conduct local testing of varieties, seed multiplication and training/backstopping for *mandal* level agriculture officers. The ICAR institutes (e.g. CRIDA) in turn provide more specialised training. In parallel to the RARS, the ICAR network of institutes also maintains a KVK centre in each district. These centres have a more strategic/long term/future oriented role, acting as 'demo and knowledge centres' for new technology and to train 'model farmers'.

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[2] *Corresponds to sub-district*

NGOs prefer to maintain close links with the AP DAE, partly to access seed, but also to capitalise on its role of disbursing Government funding to farmers (e.g. fertiliser subsidy programs). The benefit for AP DAE to partner with NGOs is access to 'trustworthy' farmers and to ensure fund disbursement is more efficient and better targeted.

In summary, in Andhra Pradesh there are a range of possible target extension channels for adaptation outputs, comprising:

- AP DAE – through *mandal* and district level offices
- KVKs
- NGOs (e.g. WASSAN, BIRDS, BAIF)
- District Water Management Agencies
- District Rural Development Agencies

Meteorological observations in India have a long tradition, dating back as far as 1636 when Halley, a British scientist, published his treatise on the Indian summer monsoon. India is fortunate to have some of the oldest meteorological observatories of the world. The British East India Company established several such stations, for example, those at Calcutta in 1785 and Madras (now Chennai) in 1796 for studying the weather and climate of India. In the first half of the 19th century, several observatories began functioning in India under the provincial governments. Today the India Meteorological Department (IMD) has its headquarters at New Delhi, supported by 6 regional meteorological centres at Mumbai, Chennai, New Delhi, Calcutta, Nagpur and Guwahati. IMD is structured into 11 technical divisions.

Research in meteorology is one of the basic functions of the department. The *Parameters and Power Regression Model* developed by IMD for the long-range forecasting of southwest monsoon rainfall over India has proven to be a good tool to provide reliable long-range forecasts of monsoon rainfall. The IMD maintains an extensive network of observatories, amongst others comprising:

- Surface observatories – 559
- Hydro-meteorological observatories – 701
- No-departmental rain gauge stations – 3540
- Agro-meteorological observatories – 219
- Evaporation stations – 222
- Evapotranspiration stations – 39

The India Meteorological Department renders an Agro-meteorological Advisory Service (AAS) through its 130 Agro-meteorological Field Units (AFMU), which are operated in collaboration with State Agriculture Universities and other ICAR Institutes. Under this service weather forecast-based agro-advisories are issued for different districts/agro-climatic zones of the country. At present bulletins are being issued from three levels as mentioned below:

National Agromet Advisory Bulletin
The bulletin is prepared for national level agricultural-planning and management and is being issued by National Agromet Advisory Service Centre, Agricultural Meteorology Division, India Meteorological Department. Prime users of this bulletin are Crop Weather Watch Group (CWWG), Ministry of Agriculture. The bulletin is also communicated to all the related Ministries, organisations and NGOs.

State Agromet Advisory Bulletin
This bulletin is prepared for State level agricultural planning and management. These bulletins are issued from 22 AAS units at different State capitals. Prime user of this

bulletin is the state CWWG. This is also meant for other users like the fertilizer and pesticide industry, the Irrigation Department, seed corporations, transport and other organizations which provide inputs in agriculture.

District Agromet Advisory Bulletin
This is prepared for the farmers of the districts. These bulletins are being issued from 30 AMFUs functioning at State Agricultural Universities. The district level bulletins contain advisories for all the weather sensitive agricultural operations from sowing to harvest. It also includes advisories for horticultural crops and livestock. These weather-based advisories are disseminated to the farmers through mass media dissemination, internet, as well as through district level intermediaries.

The AAS bulletins are issued in a bi-weekly model (mainly on every Monday and Thursday) through network of 23 AAS units distributed throughout India. The Agromet Advisory Service (AAS) Centres are functioning at the state capitals at Ahmedabad, Bangalore, Bhopal, Bhubaneswar, Kolkata, Gangtok, Guwahati, Hyderabad, Jaipur, Lucknow, Chennai, Patna, Srinagar, Dehradun, Raipur, Thiruvananthapuram, Simla for respective states and at Chandigarh for Punjab and Haryana, at New Delhi for Delhi State and at Pune for Maharashtra. The content of the bulletin includes:

- Weather information including past weather for 3 or 4 days (along with chief amount of rainfall, the highest maximum temperature, the lowest minimum temperature, heat/cold wave information, depending on season).
- Weather forecast for next 48 hours and outlook for subsequent two days
- Crop information for major standing crops, their growth stages and state (along with information regarding water stress, pests and diseases infestation etc.)
- Agro-meteorological/agricultural advisories

A comprehensive website providing details on the operations of the IMD as well as providing access to advisories is at http://www.imdagrimet.org/

ACIAR project LWR/2006/073 is presently piloting the dissemination and improved packaging of district level advisories in collaboration with ANGRAU, IMD and NCMRWF.

The generation of seasonal climate forecasts is shared between the IMD and the National Centre for Medium Range Weather Forecasting (NCMRWF) in Delhi. The NCMRWF was originally established with the mandate of supporting farmers through the provision of better seasonal climate forecasts. Subsequently however, the 127 agro-meteorological network sites established under NCMRWF were transferred to IMD. This is in addition to IMD’s traditional role of overseeing the network of 300 observational stations and acting as custodians of met data. Presently the NCMWRF is placed under the Ministry of Earth Science, and it is presently focussed on delivering the forecasts using dynamic modelling, as opposed to the statistical forecasting still carried out by IMD. In the near future it is planned to migrate the dynamic modeling capability out of NCMRWF to IMD, with NCMRWF over the next 5 years focussing on the development of enhanced models (numerical modelling products, initially atmosphere driven; later to be coupled land-ocean-atmosphere driven).

In contrast, the Indian Institute of Tropical Meteorology in Pune, which also comes under the Ministry of Earth Sciences, has a more generic research role, e.g. the role of the Indian Ocean dipole etc. Recently plans by the GoI have been announced to establish a Regional Climate Centre under guidance of the IMD and the WMO, also based in Pune, but responsible for coordinating research into the regional climate of South Asia.

8 Existing knowledge base and research linkages

8.1 Cambodia

No explicit research on farm level adaptation has been carried out to date in Cambodia, reflecting the generally weak research capacity. Some impact assessments have been carried out as part of the regional climate impact studies. These were discussed in section 4.1. In conjunction with the NAPA, some socio-economic surveys to assist in vulnerability studies of selected provinces (mainly Prey Veng) were carried out, but results are not yet published.

Nonetheless, there is a very useful body of knowledge available that will underpin many aspects of future farm level adaptation research. Within the Cambodian Agriculture Research Institute (CARDI), breeding of rice varieties with enhanced tolerance to submergence based on the introduction of the *sub1* gene isolated by IRRI and the breeding of shorter duration and more drought tolerant rice varieties can be considered as a significant contribution towards more climate resilient rice-based cropping systems, which still predominate in Cambodia. Ongoing collaboration with IRRI and the University of Queensland in backcrossing of the *sub1* gene into Cambodian varieties is continuing, with the release of new submergence tolerant rice varieties expected in the next 3 years.

As indicated in section 5.1, the expansion of irrigation is seen as a key adaptation strategy. Whilst surface water is available in many floodplain areas of Cambodia, the main constraint has been the development of more functional irrigation schemes, both from an infrastructure perspective (tertiary distribution systems), as well as with respect to institutional arrangements (effective water user groups). In the latter domain, donor supported research into understanding and improving the capacity of water user groups to function more efficiently is being carried out by the Cambodian Development Research Institute (CDRI), in collaboration with the University of Sydney. This work is located in the Tonle Sap region (Siem Reap). CDRI is an independent research organisation which has been operating for about 15 years. It has five programs, of which three may be relevant to future climate change adaptation research:

- Economy, trade and regional cooperation
- Poverty, agricultural and rural development
- Democratic governance and public sector reform
- Natural resources and environment
- Social development

In the absence of functional irrigation schemes, where ground water is available tube wells to access ground water are becoming increasingly widespread. There is information available on the distribution of ground water use and its availability (Roberts, 1998; Seng *et al.,* 2007; IDE, 2009), primarily for Prey Veng and Svay Rieng, where the predominant use is located. There is very little irrigation research and there are still major gaps in optimisation of irrigation, particularly with respect to the strategic use of supplementary irrigation to buffer drought, matching irrigation to crop choice and irrigation scheduling. There are also some concerns about over extraction of ground water (IDE, 2009) as well as poor quality of irrigation water (As and Fe contamination).

As part of its work in Prey Veng and Svay Rieng, IDE has also undertaken preliminary work on defining typologies of rice-based cropping with and without irrigation. This could provide a very useful base for future analysis of typologies in support of adaptive capacity assessment as proposed in section 10.3.6.

Over the past years, ACIAR and other organisations have primarily supported CARDI in agronomy and cropping systems research, building on earlier work carried out under the IRRI-Cambodia project. There is now a good understanding of the rice agronomy in rice cropping systems as well as some knowledge on performance and management of alternative crops, underpinned by a useful knowledge base on soil and nutrient management.

Linkages to ongoing or recently concluded ACIAR projects comprise the land suitability for rice diversification project (SMCN/2001/051) for access to climate and soils data, the cropping systems project being led by Prof Shu Fukai (CSE/2006/040) for some soil and crop data, and the horticulture project (HORT/2003/045) for vegetable crop parameters as input to APSIM. Livestock data to calibrate the IAT may be accessed through CIAT and the ongoing ACIAR livestock projects (AH/2003/008 and AH/2005/086). Under the CAVAC umbrella, two new projects will also provide opportunities for linkages. One project is on enhancing rice germplasm development for transforming production systems, while a second project is on improved rice establishment and productivity.

8.2 Lao PDR

Similar to the case in Cambodia, in general very little farm level climate adaptation work has been carried out in Lao PDR. Initial work focussed on impact and vulnerability assessments, facilitated by the Southeast Asia START Regional Centre (SEA-START), which is the regional research node of the Southeast Asia Regional Committee for START. Southeast Asia is one of the eight existing regions of the Global Change SysTem for Analysis, Research and Training network, jointly initiated by the International Geosphere-Biosphere Programme, International Human Dimension Programme, and World Climate Research Programme. START is a global network that supports multidisciplinary research on the interactions between humans and the environment. SEA START RC was established in 1996 between Chulalongkorn University, National Research Council of Thailand, and International START. The centre is located on Chulalongkorn Campus in Bangkok, Thailand. Some of this work has already been discussed in section 4.2 and is reported in Chinvanno *et al*., (2006), Snidvongs (2006) and Boulidam (2005).

Reflecting the bias of international donor support for the upland areas of Lao PDR, a strong focus of the National Agriculture and Forestry Research Institute’s (NAFRI) research programmes in the past has been the development of more sustainable land use systems to enable a transition out of shifting cultivation to more permanent forms of agriculture, including livestock intensification, plantation agriculture and forestry. Much of this work has been conducted in collaboration with international research organisations such as IRD, CIRAD, IWMI and CIAT. The latter organisation has also used the SRL framework in its work, but in an extended form that includes two additional dimensions – ‘appreciation enquiry’ and ‘visioning’. There is scope for the SRL approach suggested in section 10 to build upon this work in Lao PDR.

The above uplands research has been complemented by NAFRI’s rice programme. In terms of climate adaptation, current germplasm development is focussing on:

- Breeding for drought resistance in rice, targeting traits that affect vulnerability to drought in early season transplanting and flowering/panicle formation stages
- Adaptation of rice to low fertility soils (acidity, Fe toxicity; sandy soils)
- Diseases: rice leaf and stem blast in both wet and dry season rice

Prior work involving IRRI as well as NAFRI has enabled a good characterisation of rice cropping systems in Lao PDR, with the basic G x E interactions for key sites understood. ACIAR funded rice systems work conducted by the University of Queensland (UQ) has further expanded the knowledge base of rice cropping systems, so that this constitutes a good basis for developing adaptation options in rice based cropping systems. Schiller *et al.* (2006) provide a more recent synopsis of the current knowledge.

The most relevant work to date for farm level adaptation is the application of crop modelling and GIS techniques to more comprehensively characterise rainfed lowland rice based cropping systems in Lao PDR, conducted in collaboration between NAFRI and the UQ (Inthavong and Fukai, *pers. comm.*) under the auspices of ACIAR project CSE/2006/041- Increased productivity and profitability of rice-based lowland cropping systems in Lao PDR. This work, which was carried out by Inthavong as part of a PhD study is shortly to be published. He compiled a comprehensive climate dataset and has conducted water balance and crop modelling with particular reference to Savannakhet Province, which is the main lowland rice growing province and at the same time the most susceptible to drought and flooding impacts on lowland rice. All of this work constitutes an invaluable base by providing useful model calibration datasets for models such as APSIM to carry out further farming systems scenario modelling in Lao PDR aimed at determining crop and water based adaptation options.

Other linkages have already been touched upon in sections 6 and 6.2, i.e. the AusAID funded modelling work of CSIRO by Mainuddin, Kirby and Eastham to assess the impacts of climate change on water resources, which has selected Savannakhet as one of its more detailed case study sites, and the ADB funded work on modelling the impact of climate change on flood risk being carried out by RMSI (Satya Priya, *pers. comm.*).

Finally, significant complementarities exist between the climate adaptation and future ACIAR food security related activities in Laos and Cambodia. It will be important for the two initiatives to maintain ongoing liaison to facilitate a seamless connectivity to generate the desired synergies. The adaptation research proposed in this study for Lao PDR in section 11 can provide the tools and methodologies relevant to the food security projects (e.g. APSIM for rice-based systems; social research approaches; climate projections). Conversely, envisaged projects under the food security umbrella offer an opportunity to extend improved cropping, nutrient and water management options identified under this project to other provinces in Laos and Cambodia.

8.3 Bangladesh

Of all four countries studied here research on climate adaptation is the most advanced in Bangladesh and there is a considerable body of in-country research to consider, although a large part of this research has tended to focus on climate impact assessments (see 4.3 for a brief review there). For instance, below is a list of recent research commissioned by the Climate Cell in the MoEF (some reports not yet available):

- Climate change and transmission dynamics of cholera
- Climate change and health impacts
- Adapting crop agriculture in the Haor region
- Adaptive agriculture in the coastal zone
- Crop insurance as a risk mitigation strategy
- Climate change, gender and vulnerable groups
- Characterising long term changes in BGD climate
- Climate impact scenarios using PRECIS (spatial resolution at district level)
- Impact assessment of climate change and seal level rise and flooding
- Environmental costs of climate change

As reports for these studies become available, they will need to be evaluated in greater depth with respect to their relevance for farm level adaptation research. Several recent workshops have also compiled useful material that provides invaluable baseline information to ACIAR adaptation research in Bangladesh (Ahmed, 2008; BCAS, 2009; Rahman *et al*, 2009).

There are several high quality research organisations engaged in climate related research, many of them independently funded and all of them presently involved in the MoEF projects listed above:

Bangladesh Centre for Advanced Studies (BCAS)
This is an independent research organisation (think tank) established in the mid 90's. It has about 100 staff based in the Dhaka HQ, two regional sites and in ~7 co-locations with other organisations. BCAS has a high national and international profile in livelihoods, policy and climate change research. BCAS was closely involved in the NAPA process.

Bangladesh Institute of Development Science (BIDS)
This is a multi-disciplinary organisation that conducts policy research on development issues for Bangladesh. It is supported by the Government of Bangladesh and functions as a think tank, helping formulate socio-economic policies. The institute conducts research and promotes study and education in development economics, rural development, demographics and social sciences. It was also intimately involved in the production of the NAPA report and provided input into the BCCSAP.

Center for Environmental and Geographic Information Services (CEGIS)
CEGIS was established in 2002 under the Ministry of Water Resources and operates under an independent Board of Trustees. It has been carrying out integrated environmental analysis by using modern technologies such as geographic information system (GIS), remote sensing, databases and information technology. It provides solutions to issues and problems in various sectors like water, land, agriculture, fisheries, environment, engineering, power, energy and transportation and provided input into the BCCSAP.

Bangladesh University for Engineering and Technology (BUET)
The environmental engineering group within BUET has used DSSAT and EPIC to model the impact of climate change on crops. Other groups in BUET are linked to downscaling and climate modelling (Dr Nasrul Islam; Associate Prof, Dept of Physics). The Institute for Water and Flood Management Research within BUET focuses on water management with major emphases on water resources management in floodplain environment, river and coastal hydraulics, wetland hydrology, hazard management, urban water management, irrigation and water management, environmental impact of water development, water resources policy.

In contrast, the traditional ACIAR partners in the agricultural research domain such as BARC, BRRI and BARI have carried out less research specific to climate adaptation, perhaps with the exception of plant breeding.

The Bangladesh Agriculture Research Council (BARC) has been closely involved in the formulation of the first NAPA in 2005. It led the compilation of the agriculture/fisheries/ livestock subsector chapter, and has also been involved in drafting the BCCSAP. BARC raised a number of key research priorities:

- FACE and phytotron experimentation
- Crop, systems and climate impact modelling
- Socio-economic research
- Depletion of ground water (shallow tube wells during *rabi*)
- Arsenic contamination

Broader research issues in the context of global change raised by BARC relate mainly to transboundary problems of river diversions in countries neighbouring Bangladesh and the impact of changed flows on the agricultural sector and the emergence of rural labour shortage as more young people leave the land for urban employment.

The Bangladesh Rice Research Institute (BRRI) highlighted the need for a systems approach towards improving system productivity ('total agriculture') and also argued for more socio-economic research and in particular, the need to link livelihoods to the health sector. BRRI's current climate adaptation related work in plant breeding includes breeding rice for salinity tolerance (e.g. BR47, being tested with 500 farmers in the coastal salinity belt), introgression of the *sub1* gene in a range of varieties, cold tolerance (Haor region) and drought tolerance. A lot of the breeding work is supported through the Bill & Melinda Gates Foundation and the German aid programme.

Within BARI the On-farm Research Division is undertaking some experimental on-farm testing of farm level adaptation options ('no-regrets' solutions). This research is supported by FAO (LACC-II as part of the CDMP; see section 6.3). Initially this focussed on the drought prone NW and subsequently has been expanded to one site near Khulna in the SW to address the issue of salinity intrusion. Broader outcomes of the research carried out under the auspices of the CDMP have been published by Selvaraju *et al.* (2006) and Baas and Selvaraju (2008).

The other climate change adaptation related activities within BARI focus on development of new germplasm, in particular the development of salt tolerant mung beans, barley, sesame and soybean varieties. This is being complemented by screening of wheat varieties for heat and salinity tolerance. Generally underpinning adaptation options is the extensive work being carried out on conservation agriculture (Resource Conserving Technologies), initiated under the guidance of CIMMYT and IRRI through the Rice-Wheat Consortium.

Despite this substantial knowledge resource in Bangladesh, several major gaps remain. There is little evidence of a more comprehensive approach to assessing farm level adaptation based on systems analysis and taking into account projections of 'local' climate change. Although, some APSIM modelling has been carried out in ACIAR projects LWR/2005/001 and LWR/2005/146 that will serve as a useful starting point for such studies. In addition, the linkage between high level impact and vulnerability assessments and the extrapolation of meaningful on-ground adaptation options seems very weak and was voiced by some stakeholders as an impediment to the implementation of adaptation programmes as foreshadowed by the BCCSAP.

A number of ongoing and planned projects under IRRI leadership offer a unique opportunity to progress the development, testing and validation of new routines in APSIM-ORYZA (for details see section 9.2), as there are several high quality, long term and comprehensive datasets that could be readily accessed for this purpose. Some of these projects are donor funded and have been outlined in section 6.3.

Cereal Systems Initiative for South Asia (CSISA)
At each of the sites in India, Nepal and Bangladesh, 5 'scenarios' will be tested:

- Farmer practice
- Best management practice (yield optimisation of current farmer practices)
- Direct seeded rice using existing resource conserving technologies
- Future systems (cereals)
- Spare dummy to cater for future changes

In Bangladesh the long-term CSISA trial will be set up at the BRRI/BARI main experimental farm near Gazipur. Each treatment will have 3 replicates with an area of 0.2 ha each. A comprehensive set climate, crop and soil parameters will be determined, making this a fairly complete future model validation dataset.

IRRI-CGIAR Challenge Program CP10 Project

The experimental site of the IRRI-CGIAR Challenge Program CP10 project on managing salinity is located near Batiaghata, a sub-district about 30km SE of Khulna. Currently experimental work is still being carried out by BRRI. In essence, this project has been looking at opportunities to use a range of sources to provide supplementary or full irrigation to *boro* rice or other *rabi* season crops. Sources of water include on-farm ponds, shallow or deep ground water tubewells and freshwater stored in the canals and creeks by trapping water from tidal backflow with temporary earthen dykes before reduced discharge allows brackish water to reach further upstream. Usually the cut-off for freshwater still entering canals in this area is late February, but this date seems to be shifting to an earlier date, as discharge from India into the Ganges supplying the SW tributaries in BGD decreases and/or sea level rise pushes sea water further upstream. Not only has the project generated a series of well managed on-farm experiments testing irrigation options that constitute a good starting point for adaptation, but it has been designed to generate high quality datasets amenable for future use in modeling. This alone would constitute a good reason to focus some of the future ACIAR supported adaptation research in this region, as it would provide a unique opportunity to validate ASPIM-ORYZA in Bangladesh.

8.4 India (Andhra Pradesh)

As in Bangladesh, there is a good body of research on which to build in Andhra Pradesh, and, also as in Bangladesh, the majority of this work has been focussed on refining climate change projections and on climate impact modelling (for a more detailed review refer to section 4.4). One recent overview of the state of knowledge is provided by Prasada Rao *et al.* (2008).

India is endowed with a very diverse, well-resourced and capable research infrastructure, both within the public sector as well as with respect to independent research organisations. Within the Indian Council of Agricultural Research (ICAR), the National Climate Change and Adaptation Network has now recently been expanded to include 23 ICAR institutions with CRIDA as the nodal ICAR institute. Its role is mainly to coordinate and prioritise climate charge related research across ICAR’s mandate institutions. A new ICAR Centre for Abiotic Stress Management is being established in Maharashtra, the structure of which will be equivalent to IARI, with 4 Schools on drought stress, atmospheric stress, edaphic stress and a policy school.

An All-India Coordinated Program on Farming Systems is also being established, built around 3 key farming systems. The nodal institute for this initiative is the Directorate for Farming Systems located in Modipuram. Overall, the intent is to strengthen cropping and farming systems modelling capacity, and the strong farming systems modelling emphasis likely to arise out of ACIAR’s climate change research is seen as a good vehicle to help strengthen modelling capacity and modelling linkages to APSIM within India.

Under the NAIP umbrella (see section 6.4) 179 projects have now been sanctioned. Of those, only a few are directly relevant to climate adaptation research, and only the following subset of those has components in Andhra Pradesh:

- Modeling the performance of a few major cropping systems in eastern India in the light of projected climate change (CRIDA)
- Sustainable rural livelihoods through enhanced farming system productivity and efficient support systems in rainfed areas (consortium led by CRIDA)
- Soil organic carbon dynamics vis-à-vis anticipatory climatic changes and crop adaptation strategies (involves ANGRAU)
- Development of a set of alternative ICT models based on a study and analysis of the major ICT initiatives in agriculture in India to meet the information need of the Indian farmers (consortium)

- Re-designing the farmer-extension-agricultural research/education continuum in India with ICT-mediated knowledge management (ICRISAT)

There is a long history of livelihoods research in AP, much of it underpinning watershed development in rainfed areas. Earlier work was led by ICRISAT, and at present a large consortium led by CRIDA involving ICRISAT and NGOs is continuing this work under the NAIP umbrella (the second project listed above). While the CRIDA NAIP Livelihoods project does not have any explicit activities in relation to climate adaptation, its strong grounding in livelihoods analysis make it a logical starting point for the analysis of adaptive capacity in any future ACIAR supported adaptation research in AP. It is operating in 8 districts of AP, using a Participatory Action Research mode to generate livelihoods for cluster groups of farmers. Benchmarking is undertaken using the Sustainable Rural Livelihoods approach (see details on SRL in section 10.2 and 10.3). The survey schedule is very comprehensive, with each farmer interview taking about half a day. This information is shortly to be published in a report and would constitute a very useful resource for farming systems typology and analysis of farmer adaptive capacity.

In India there is consensus that seasonal climate forecasting offers an important entry point to work with farmers in improving their adaptive capacity towards climate change. As India is endowed with a very extensive and advanced agro-meteorological service (refer to section 7.4), it would appear that there is a good opportunity to build on this capability to test the applicability of seasonal climate forecasting in helping farmers adapt to climate change. An ongoing ACIAR project on assessing seasonal climate forecasting in farmer decision making (LWR/2006/073) is piloting the feasibility of using these enhanced advisories at a farming community level to help farmers make better tactical planting and crop management decisions. However, despite early encouraging results, there is still a need to improve the skill level of these advisories and more importantly, to develop longer range forecast products in order to enable a more strategic response (i.e. affecting cropping systems or diversification decisions). More research is also required to improve the packaging of the advisories based on a more extensive analysis of climate variability in relation to optimisation of crop, water and nutrient management.

Such longer range forecast products are presently being developed by a collaborative project on *Development and application of extended range forecasts system for climate risk management in agriculture (ERFS)* involving the IMD, NCMRWF, the Indian Institute of Technology-Delhi, and the International Research Institute on Climate and Society (IRI) as part of a is a recently commenced, 3-year GoI funded research project. Partners in IMD and NCMRWF expressed a strong interest in the ACIAR adaptation research building on the earlier work in LWR/2006/073 by helping evaluate and field test the applicability of this new generation of forecast products in AP.

Other research relevant to climate adaptation in AP was carried out under donor funded projects discussed briefly in section 6.4 and includes the FAO funded APFAMGS project. It used a simple spreadsheet based approach to generate water budgets using hydrological data collected by farmers. This was used farmer field schools to match cropping and irrigation decisions to predicted availability of water (accumulated rainfall stored in the soils and if available, supplementary irrigation). The approach has set a benchmark in fostering farmer management of ground water resources in a way that over extraction of ground water is being significantly reduced. At the time of compilation of this report, a follow-on project extending this approach to incorporate climate adaptation using a new Farmer Climate Field School concept was under consideration by the FAO and the GEF.

Also relevant is the World Bank funded work on climate change impacts in drought and flood affected areas of AP, which generated downscaled climate projections for SW districts of AP and conducted crop scenario modelling to assess the impact of climate change on future productivity and farmer livelihoods (WB, 2008). This work was mainly carried out by RMSI, which is one of the leading global providers of geospatial data and software services and is a wholly Indian owned subsidiary of RMS in the US. RMSI's resource base comprises over 600 software, data and technology specialists, out of a employee force of >1000. A key market strength is in risk assessment for insurance and reinsurance companies and RMSI's success hinges on its unparalleled domain expertise, specifically in natural disaster and climate change risk modeling, and its unique application of geospatial technologies. Amongst other sectors, RMSI delivers high end geospatial, remote sensing, and modeling services to governments, multilateral funding agencies, and private enterprises that are actively involved in agriculture, forestry, geology, and geo-technical applications.

The Tata Energy and Resources Institute (TERI) is one of India’s foremost independent research organisations. It recently set up a Climate Change division, but climate change research at TERI has been going on since 1989. Initial activities focused upon awareness generation and capacity building for different stakeholders, viz., governments, industries and civil society organizations. Through its research, TERI has made significant contributions to the international climate debate, and in bringing out a developing country perspective. TERI researchers have also contributed to the IPCC process in various ways. Different focus areas of climate change research include impacts and vulnerability assessment, adaptation strategies, exploring GHG mitigation options and issues therein, climate change policies and climate modeling activities.

As part of its subprogram 2 in the India program, ACIAR has established an integrated cluster of water projects based out of AP. The cluster is built around the issue of increasing the efficacy of watershed development with the aim of achieving a more equitable and productive use of water in rainfed areas of AP and the Deccan Plateau of India more generally. Climate adaptation research envisaged by ACIAR in AP needs to be linked to the ongoing projects, e.g. through shared study sites. Outputs generated by the planned project on the application of seasonal climate forecasting will constitute a key input to the two recently commenced WSD projects LWR/2006/072 and LWR/2006/158. Conversely, the analysis of institutional arrangements at local levels and the livelihoods analysis being undertaken in these projects will be highly relevant input to the planned climate adaptation work. Linkages should also be sought to the pipeline project LWR/2007/113 - *Impacts of climate change and watershed development on whole-of-basin agricultural water security in the Krishna Basin, India* where it is anticipated that adaptation strategies developed at the local level will be relevant input to the whole of basin modelling in the above project. The planned adaptation work based on the use of seasonal climate forecasting as an entry point to climate adaptation is a direct follow-on to the ACIAR Small Research Activity project LWR/2006/073 - *Assessing the feasibility of farmers managing climate related crop production risk in Andhra Pradesh*, India.

9 Enhancing the modeling of rice-based farming systems

9.1 Overview and use of farming systems models in participatory action research

The discussion in the previous sections highlighted the central role farming systems models will be required to play in helping bridge the gap between empirical testing of improved farm level adaptation management options and more systematically assessing their efficacy in dealing with present day climate variability, as well as evaluating whether these measures will still be viable for some time into the future and for a range of projected climate change scenarios. Given the predominance of rice-based farming systems in the four study countries, this implies that cropping and farming systems models must be able to simulate rice crops within rotations. As will be explained in more detail below, until recently two of Australia's most commonly used modeling tools (APSIM and IAT) were not able to adequately represent rice-base cropping systems. Whilst some work has been done to overcome this limitation, there are still a few critical gaps to be addressed. In line with objective 2 of this study, in this section APSIM and IAT are assessed with regard to the steps required to extend their utility as scenario analysis tools to determine adaptation options based on alternative crop, nutrient and water management techniques. In doing so, APSIM and IAT are also briefly benchmarked against similar models used by other overseas research groups.

Section 4 highlights that most of the climate change related modeling carried out to date has focussed on assessing likely impacts of increases in temperature and elevated CO_2 regimes on crop productivity (e.g. Aggarwal, 2003; Mall *et al.,* 2006 for India; Faisal and Parveen, 2004; Basak *et al*., 2006 for Bangladesh). However, in all of these modelling studies, generic farming practices were assumed and models typically configured to reflect 'average' practices, or perhaps a range of 'improved' or 'recommended' practices. Whilst this is legitimate when the primary modelling purpose is to assess process trends or general system responses, it is not useful to derive specific adaptation options. Lack of location and farm specific context of modelling will significantly reduce the relevance of modelling to individual farmers, greatly diminishing the likelihood of modelling results influencing them to adopt new farming techniques. The problem of lack of locational specificity goes hand in hand with the problem of lack of farmer acceptance of modelling results.

To overcome both, it is important to take a participatory approach to modelling. This allows for a more realistic representation of farming practices by soliciting farmers' input into characterisation of the farming system in the model. At the same time, adhering to joint scientist-farmer validation processes will enhance the acceptance of modelling outputs (Carberry *et al.,* 2002), preparing a better base for farmer adoption of changes to practices. This places particular demands on models. Not only do they need to reliably capture the underlying crop-soil-livestock processes of the **production systems**, but they also need to realistically reflect the **management systems**, i.e. the decisions and actions farmers take in the course of a particular cropping season (Keating and McCown, 2001). In order to calibrate models to local conditions they need to incorporate the many possible permutations of farmers' choices and decision points, in dependence of markets, climate and resource availability. This poses a significant challenge to model design, as there is a trade-off between enabling the desired flexibility to reflect farm management diversity on the one hand and model computational efficiency and user friendliness on the other.

An additional dimension to the ability of models to represent not just the production systems, but also the management systems is the question of what and in which formats do the models generate useful outputs that relate to farmer decision making. Early generation models tended to focus on outputs describing the production system responses, e.g. yields or biomass, and environmental indicators such as N and water use efficiency or soil loss due to erosion. More relevant to famer decision making are the implications of changed practices on risk, labour and costs of other farm inputs and income benefits. The detail with which these can be generated is predicated on how well farm financial and other socio-economic aspects of the management system have been integrated into the model.

A review of farming systems models reveals that very few are in fact true farming systems models. Rather, they are cropping systems models. Some of the internationally more widely used cropping systems models are briefly described below.

CropSyst

This is a user-friendly, conceptually simple but sound multi-year, multi-crop, daily time step simulation model. The model has been developed to serve as an analytic tool to study the effect of cropping systems management on productivity and the environment. The model simulates the soil water budget, soil-plant nitrogen budget, crop canopy and root growth, dry matter production, yield, residue production and decomposition, and erosion. Management options include: cultivar selection, crop rotation (including fallow years), irrigation, nitrogen fertilization, tillage operations (over 80 options), and residue management. The model is currently written in C++. Its modular structure allows it to be used as a submodel within other models (e.g. Olympe). For details refer to Stöckle *et al.* (2003) or http://www.bsyse.wsu.edu/cropsyst/.

EPIC

The Erosion-Productivity Impact Calculator (EPIC) is a comprehensive model originally developed to determine the relationship between soil erosion and soil productivity through the USA (Williams *et al*., 1989). The model continuously simulates erosion processes using a daily time step and readily available inputs over hundreds of years. Physical components of EPIC include hydrology, weather simulation, erosion sedimentation, nutrient flows and cycling, plant growth, plant environmental control, and tillage. Beyond the conventional use of EPIC to predict soil erosion and productivity change, as well as its use as a decision-support tool to determine the impact of different management strategies, the model has been utilised the model to specifically describe, compare and interpret functional changes of agro-ecosystems.

DSSAT

The Decision Support System for Agrotechnology Transfer (DSSAT) is a software package integrating the effects of soil, crop phenotype, weather and management options that allows users to ask "what if" questions and simulate results by conducting, in minutes on a desktop computer, experiments which would consume a significant part of an agronomist's career. It has been in use for more than 15 years by researchers in over 100 countries. DSSAT combines crop, soil and weather data bases into standard formats for access by crop models and application programs. The user can then simulate multi-year outcomes of crop management strategies for different crops at any location in the world. DSSAT v4 includes improved application programs for seasonal and sequence analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer and nutrient management, climate change, soil carbon sequestration, climate variability and precision management. For details refer to Jones *et al*. (2003) or http://www.icasa.net/dssat/

APSIM

The Agricultural Production Systems Simulator (APSIM) is a modelling platform developed in Australia to simulate biophysical processes in farming systems, particularly as they relate to the economic and ecological outcomes of management practices in the face of climate risk. APSIM is structured around plant, soil and management modules. These modules include a diverse range of crops, pastures and trees, soil processes including water balance, N and P transformations, soil pH, erosion and a full range of management controls. APSIM resulted from a need for tools that provided accurate predictions of crop production in relation to climate, genotype, soil and management factor while addressing the long-term resource management issues. For details refer to Keating *et al.* (2003) and http://www.apsim.info/apsim/releases/Apsim.asp.

Of the above models, two have been more widely used in assessing the impacts of climate variability and impact. In addition to its widespread use in the US, DSSAT has been used to study rice-based cropping systems in Asia, primarily in India and Bangladesh. Usually the CERES-Rice module has been used for these studies, although there is also an option to use IRRI's ORYZA 2000 model (Bouman and Van Laar, 2006). DSSAT's structure based on looking up predetermined crop, soil and weather data bases makes it a computationally efficient model, with comparatively less data input requirements. At the same time, this advantage constrains its use in participatory action mode, as the configuration of the model to represent a given farmer situation is limited by the options included in the management module. The model has had widespread use in impact assessment and process studies, including climate impact studies, but has been less frequently used in participatory mode.

APSIM has been widely used in Australia as well in a number of African (Kenya, Malawi, Zimbabwe, South Africa) and Asian cases studies (India, Bangladesh, Indonesia). Despite having some ability to incorporate livestock (forage) production, in the past APSIM has mainly been used as a cropping systems model, and the full farming systems functionality is still under development. Nonetheless, even when used as a cropping systems model, APSIM has proven its versatility in participatory farming systems research in Australia (e.g. FARMSCAPE, Carberry *et al.,* 2002; YieldProphet, Hochman *et al*., 2009), as well as in a range of mainly ACIAR-funded projects in Africa (e.g. SMCN/2000/173) and Asia (e.g. LWR/2006/073). The main strength it has is its versatility in programming farmer decision making through the use of a unique programming language in its management module. The main weakness is its only partial functionality of modelling rice-based cropping systems.

A review of literature reveals that there are also several farming systems models available.

IMPACT

The Integrated Modelling Platform for Mixed Animal Crop Systems (IMPACT) is a modelling platform developed by ILRI. It provides a protocol for collecting essential data to characterize a farming system. This data collection protocol is organised in such way that it describes the flow of resources through all the farming activities and their interactions. Information within IMPACT is organised in eight groups: climate, family structure, land management, livestock management, labour allocation, family's dietary pattern, farm's sales and expenses, soil nutrient flow. In addition, IMPACT processes these data to provide a base-line analysis of the system's performance. This base-line analysis includes: monthly financial balances, the family's monthly nutritional status and an annual soil nutrient balance. Household economics is assessed by calculating both farm expenses and income. Net revenue is calculated in three categories: crops, livestock and other. There is no information on whether IMPACT is capable of simulating livestock in rice-based cropping systems and a search did not yield many applications of this model in recent times. A User Manual is available at http://www.ilri.org/research/ContentDetail.asp?SID=9&CID=361&CCID=11.

Olympe

This is a decision support tool developed by a French consortium (CIRAD, Agronomy Montpellier, IRD) that allows simulation of possible evolution pathways of farms according to their choices of activities and their allocation of production factors over a ten years period or more. Olympe provides forecasts on economic results, cash flows, and manpower requirements. It can thus be used to assess the sustainability of production and farming systems. Olympe also permits the user to test robustness of systems against variability of climate or macro-economic conditions (prices, markets). For example, Olympe has been applied to organic and traditional cocoa farming systems in Togo, assessing their sensitivity to prices and the impact of climate changes on their productivity. It has been used to analyse the evolution of irrigation systems in Tunisia under the liberalization of agricultural markets and introduction of new water pricing system. Olympe is not an optimization model insofar as it does not calculate the optimal combination of activities for a farm or a scheme, but it allows the evaluation of impacts of scenarios imagined by farmers with the help of the researchers. If relevant, Olympe can be associated with an optimization model (data stored in the Olympe database can be used as inputs in the optimization model and the optimal solution can be introduced in Olympe as a scenario). Olympe can also be integrated with other kinds of models: geographic information system, agronomic model, multi-agent modelling. Olympe is composed of a database on farming systems and a simulation tool. The database, which allows the storage of data collected through surveys and secondary data, is structured into several modules based on general concepts of farming systems. More details can be found in Attonaty *et al.* (2005) and http://www.olympe-project.net/olympe_en/home

IAT

The Integrated Assessment Tool (IAT) incorporates key economic and biophysical processes, and their interactions in smallholder farming systems. It accommodates a diversity of current and potential farming systems (i.e. management, soil and climate), as well as variation in commodity prices and seasonal climate. It is easy to operate by research or extension professionals in an interactive way with farmers as it is a spreadsheet based tool, enabling rapid assessment of the potential production and economic impacts of changes in a farming system (i.e. management, crops, forages, prices, costs). However, whilst this also allows it to be readily updated for application to new regions, changes in farming practices etc., the spreadsheet based architecture limits modular extensions to farming systems differing significantly from the original small-holder based systems of Indonesia for which it was originally designed.

Of the farming systems models briefly portrayed above, only Olympe and IAT seem to have been used more widely and lend themselves to effective use in participatory scenario analysis, together with ASPIM. However, Olympe has not been used widely in Asia outside Indonesia, and there is no expertise in Australia in its use. Conversely, there is extensive experience in the use of APSIM and IAT by several Australian research groups and a track record of successful application of these models in the Asian and African smallholder context. Thus, extending the capability of APSIM (and hence IAT) to represent rice-based farming systems seems a feasible approach, particularly as this would leverage substantial earlier investments in model development supported by ACIAR.

9.2 APSIM

9.2.1 Development history

APSIM was developed by the Agricultural Production Systems Research Unit (APSRU), based in Toowoomba, Queensland. APSRU was a collaborative organisation with researchers from CSIRO, the University of Queensland and the Queensland State Government. APSRU was established in 1990 by the Queensland State Government and CSIRO. The formation of APSRU brought together expertise in the computer simulation of farming systems with the aim of facilitating research that would impact on how agricultural production systems are managed. The APSIM model has been the result of this collaboration.

In 2009, the APSRU group decided that future development of the APSIM model was best handled under the auspices of an “APSIM Unincorporated Joint Venture” (APSIM UJV), to encourage collaboration amongst diverse agricultural systems modelling and development groups both within and outside Australia. The aim is to enable model developments to be captured more rapidly and effectively within the APSIM infrastructure, regardless of APSRU membership. The aim of the APSIM UJV is to support the ongoing development and maintenance of a world class computer modelling framework for the testing and simulating of agricultural systems. Specifically the objectives of the new APSIM UJV are:

- To create a joint venture of research bodies that wish to lead and contribute to the ongoing development and use of APSIM;
- To co-develop and manage APSIM as a high quality world class research tool in its field and;
- To ensure that APSIM is developed by the facilitation of broadly based collaborative science.

Since the APSRU consortium has evolved into the APSIM UJV, a number of international research institutions have expressed their interest in joining the UVJ. These include the IRRI, University of Wageningen and CIRAD. In anticipation of a more formal participation in the APSIM UJV, IRRI and CSIRO have already commenced an informal collaboration on integrating IRRI’s ORYZA2000 rice model into APSIM and working together to overcome some of the constraints to more widely applying APSIM in the modelling of rice-base cropping systems (see 9.2.5).

9.2.2 APSIM model overview

APSIM was developed to simulate biophysical processes in cropping systems, particularly as it relates to the economic and ecological outcomes of management practices in the face of climate risk. APSIM is structured around plant, soil and management modules (Figure 9.1). These modules include a diverse range of crops, pastures and trees, soil processes including water balance, N and P transformations, soil pH, erosion and a full range of management controls. APSIM resulted from a need for tools that provided accurate predictions of crop production in relation to climate, genotype, soil and management factors while addressing the long-term sustainability of natural resource management.

The APSIM modelling framework is made up of the following components:

- A set of biophysical modules that simulate biological and physical processes in farming systems.
- A set of management modules that allow the user to specify the intended management rules that characterise the scenario being simulated and that control the simulation.
- Various modules to facilitate data input and output to and from the simulation.
- A simulation engine that drives the simulation process and facilitates communication between the independent modules.

The management module can either be set up using defaults, or it can also be customised to reflect a particular farm reality by the writing of detailed manager code, using simple *if-then-else* logic to capture the farmer’s thought processes and their interaction with other system variables (crop, environmental, or climatic).

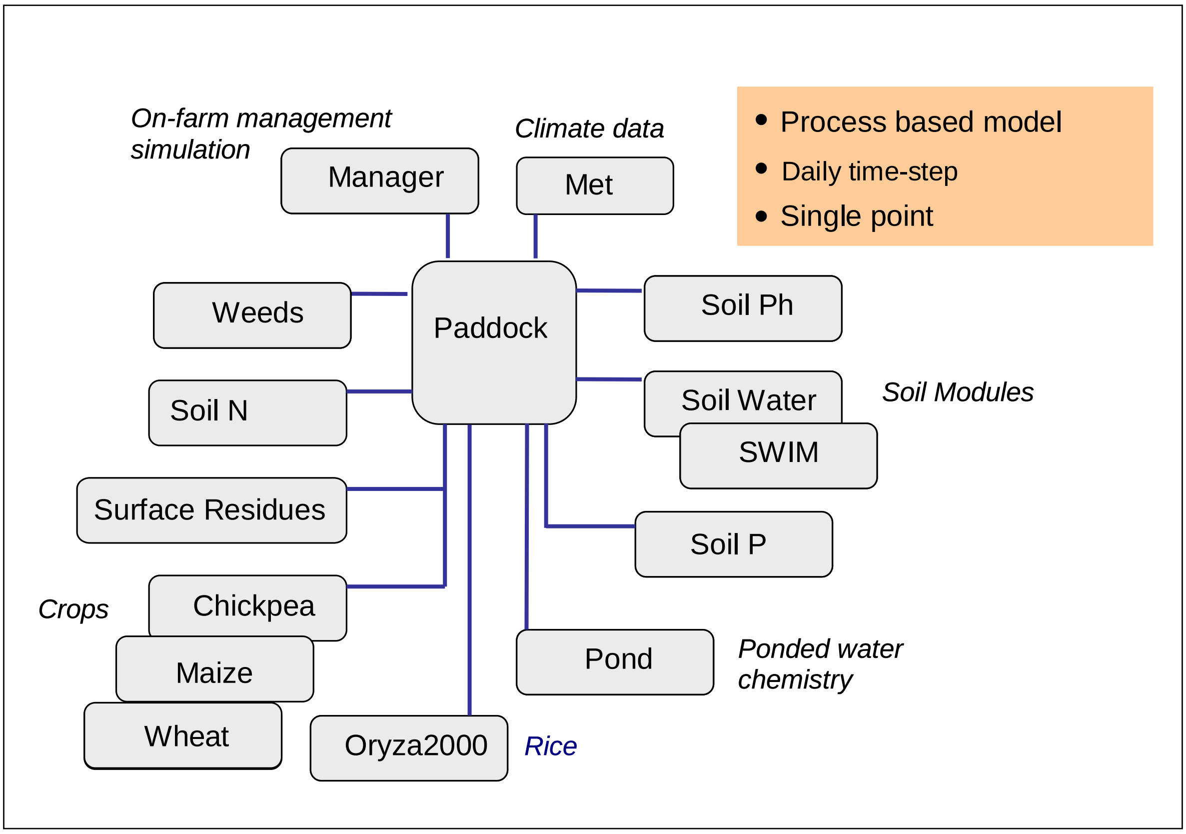

Figure 9.1: Structure of APSIM

In addition to the science and infrastructure elements of the APSIM simulator, the framework also includes:

- Various user interfaces for model construction, testing and application
- Various interfaces and association database tools for visualisation and further analysis of output.
- Various model development, testing and documentation tools.
- A web based user and developer support facility that provides documentation, distribution and defect/change request tracking.

One of the main benefits of APSIM is the ability to integrate models derived in fragmented research efforts. This enables research from one discipline or domain to be transported to the benefit of some other discipline or domain. It also facilitates comparison of models or sub-models on a common platform. More detailed information on the APSIM model is available in Keating *et al.* (2003).

9.2.3 Current capabilities and APSIM extensions

APSIM is used in a broad spectrum of research applications from cropping systems to agro-forestry and ecology, and also in education and under licence, in commercial situations by both farmers and agricultural consultants. Additionally, a range of APSIM *extensions* have also been developed to utilise point-scale APSIM functionality in broader applications. Examples of some of these current capabilities and uses are listed below.

Farming systems research

- Production and resource management including cereal–based systems (Meinke *et al*., 1998, Asseng *et al.,*1998), rotations and legume systems (Probert *et al.,*1998), intercropping (Carberry *et al*., 1996), sugarcane systems (Keating *et al.,*1999), and agroforestry (Huth *et al.,* 2002; Paydar *et al.,* 2005)
- Investigation of climate change impacts and adaptations (eg Howden *et al.,* 2007, Crimp *et al.,* 2009)
- Environmental issues such as leaching, drainage, effluent (Snow *et al.,* 1998), carbon and nitrogen dynamics, residue management (Thorburn *et al*., 2001; Probert *et al*., 2004)
- Investigating impact of rat and mouse population dynamics on grain production (Brown *et al*., 2007)
- Horticulture (Huth *et al*., 2009)
- Irrigated Systems (Paydar *et al.,* 2009; Gaydon *et al.,* 2006)

Ecological research

- Agricultural and ecological tradeoffs (Huth and Possingham, 2007)

Catchment scale research

- The FLUSH framework allowed the linking of APSIM points in a catchment modelling environment (Paydar and Gallant, 2007)
- Investigation of changes in land use and subsequent impacts on catchment water balance (Wang *et al.*, 2007)

Whole Farm Research

- A new phase of APSIM application has developed through whole-farm simulation extensions such as APSFarm (Rodriguez *et al.,* 2007, Power *et al*., 2008), which use APSIM point simulations to represent paddocks in a whole-farm enterprise, but bring a range of potential whole-farm constraints into the simulation such as irrigation water, labour, machinery etc.

Commercial

- Yield Prophet® is an on-line crop production model designed to provide grain growers (and/or their consultants) with real-time information about the crop during growth. To assist in management decisions, growers enter inputs at any time during the season to generate reports of projected yield outcomes and risk, showing the impact of crop type and variety, sowing time, nitrogen fertiliser and irrigation. This on-line decision-support tool uses APSIM together with paddock specific soil, crop and climate data to generate information about the likely outcomes of farming decisions. http://www.yieldprophet.com.au

9.2.4 Data requirements

Basic data

A considerable amount of biophysical data and farming system operational information is required to parameterise APSIM for simulation of interactions between crop, environment, climate, and management options. This includes climate, soil, crop and management data.

Required soil data fall into two categories, water-related parameters and chemical parameters. Soil parameterisation in APSIM is required on a layered basis, the depth and number of layers being arbitrary. The majority of required APSIM soil parameters are commonly measured characteristics of soils which are readily available, such as bulk density, field capacity, organic carbon, pH, CEC etc. Other parameters need to be estimated, but can be inferred if relevant data is available. It is usual practice for these values to be subsequently calibrated through an iterative process, successively optimising the simulated outputs against known or estimated variables are available (e.g. crop yields, crop irrigation water usage, etc).

APSIM has numerous crop and pasture modules available for simulation, together with subsets of varieties which can be chosen. Quite often, however, particularly in international applications, the local varieties have not been parameterised internally within the standard APSIM release and new varieties must be created. This is achieved by starting with one of the existing APSIM crop varieties and executing several years of a cropping simulation using real temperature and radiation data. The simulated phenology dates for that variety are then manually compared with the known/measured phenology dates for the new variety desired. By an iterative process of changing the input values for different growth-stage-related phenology parameters and then re-running the simulation, the user eventually creates a new APSIM *variety* for that crop which can then be used in future simulations. This is a standard practice for seasoned APSIM users, but information on local crop phenology is required (time to panicle initiation, flowering, maturity etc).

One of the most sensitive APSIM parameters (in water-limited) environments is the maximum crop rooting depth, as this effectively determines how much water the crop will have access to at any given time. This characteristic is defined via three soil layer-based parameters *xf* (the root exploration factor), *kl* (the soil water utilisation factor*),* and the crop lower-limit (*cll*). The *xf* is set to zero in soil layers which the roots are not allowed to reach. This may be due to a known physical or chemical impediment. *Kl* and *cll* together are utilised to determine how much water the crop can extract from a given soil layer on a given day. The crop lower limit for each layer can often being measured by assuming that the crop has dried the soil down to the maximum extent at the end of a cropping season, and then taking soil samples for oven-dried moisture testing. The *kl* is a more empirical parameter, which needs to be inferred rather than measured. The standard assumption is that *kl* decreases with depth down the profile, reflecting the decreasing density of crop roots with depth. More than 20 years experience in estimating this parameter for various soil type and crop combinations has allowed seasoned APSIM users to make sensible estimates for this parameter. These are available for all users in the APSRU Soils Database supplied with the APSIM release. Although almost of the included soils at this time are from Australia, a similar type of soil to the target soil can be selected and the protocols for specifying *kl* can be followed.

The APSIM Manager module captures the farmer’s logic in changing between crops, deciding when to sow or harvest, when to fertilise or irrigate, when to conduct a field operation such as spraying, cultivation, or grazing. Detailed information on sowing dates/windows/rules for each crop or pasture in the simulation are required, as are any fertiliser and irrigation schedules or *rules of thumb,* and details of residue management practices.

This information is specified using one of two options:

- A series of internal APSIM *templates* which allow specification of detailed management practices through provision of key dates, amounts etc.
- Writing of detailed manager code, using simple *if-then-else* logic to capture the farmer’s thought processes and their interaction with other system variables (crop, environmental, or climatic). For example, **IF** there is no crop in the ground AND the next crop due in the rotation is wheat **AND** >15mm of rain has just fallen over the

last 3 days **AND** there is now more than 60mm of stored soil moisture in the top 40 cm of soil, **THEN** sow a wheat crop, variety = hartog, plants/m^2 = 150, etc.

For non-experienced APSIM users, a large variety of scenarios can be explored using the template management options within APSIM, without resorting to writing their own code. This allows a user to specify farming systems actions via simply supplying dates or conditions for actions via a series of user-friendly boxes. These templates are then automatically converted into APSIM manager code ‘behind the scenes’, for the execution of simulations. If no template options are available for the particular scenarios which the user is envisaging (this is unusual, as the list of template options is large), then it will be necessary to write some specific code. As mentioned above, the APSIM manager code follows a simple *if-then-else* construct, and can be easily learnt from supplied examples, or else learnt during the two-day APSIM introductory training course.

Benchmarking/surveying

A *benchmarking* process is the first step in gaining confidence that APSIM has been parameterised adequately. This involves running the APSIM model with historical weather data, local management practices and crop/soil information, then comparing the simulated output (for example, yields and phenology) over a number of years with experimentally measured data or farmer/regional records. At least ten years data is preferable for testing the model’s capacity to simulate system response to climatic variability. If longer-term data is available, then that is even better. In the absence of specific records, the best available information might be regional “ball park” yields and measures of variability which are often freely available from local consultants, farmers or grain merchants. Local estimates for key phenological dates are also vital (panicle initiation, flowering, and physiological maturity). In overseas applications, these estimates are typically obtained by monitoring farmers’ fields or on-farm plots.

Data on soil water and nutrient dynamics associated with local practice are much rarer, but extremely valuable if available as they provide another perspective to validate model performance, much like the method of *triangulation* in navigation. In most cases, initial comparison between APSIM simulation and available records indicates discrepancy, which must then be addressed by modification of crop and/or environmental model parameters. For a given location, once APSIM is able to capture the historical mean yields and variability associated with a range of crops in rotation, the end of the benchmarking phase has generally been reached and confidence gained that the subsequent *what if* scenario questions relating to changed management or climatic conditions will be realistically handled by the model.

While the above benchmarking process has proven itself in applications of APSIM in Australia, where there are good datasets originating from controlled experiments or well monitored on-farm experiments, the reality in smallholder environments of Asia and Africa is that these data are sometimes lacking, so that falling back on regional datasets or inferring from one site to another to help in benchmarking introduces additional variation as a result of increasing spatial heterogeneity as one scales up. For similar reasons of spatial heterogeneity with increasing scale, participatory or bottom-up processes, even if grounded in good datasets and robust benchmarking at the local scale also do not easily lend themselves to scaling-up to provincial or national scales. One way to reduce this dilemma is by placing more emphasis on embedding the farm scale benchmarking into a more systematic typology of farming systems, i.e. selecting the local scale sites to represent ‘generic’ farming systems.

Scenario data

For using the APSIM model in scenario analyses subsequent to the benchmarking process, the required data depends on the scenario under investigation. These could include modified weather files to represent a changed future climate, a modified irrigation water supply, new rotational logic or crops/varieties, changed stubble management practices, new fertiliser regime etc. In participatory applications, the relevant scenario characteristics are generated through process such as focus group discussions and/or farmer interviews. The flexibility of the Manger Module to capture the many farmer decision options is a critical capability of ASPIM.

9.2.5 Improvements required for APSIM to model rice-based cropping systems

Adapting rice-based farming systems to reduced availability of irrigation water is an emerging research issue in irrigated districts worldwide. Water shortages in parts of the rice-growing world have prompted research into a range of alternate agricultural practices, including expansion of rice as a component in diverse farming systems, in rotation with dryland and aerobically irrigated crops and pastures, utilising a range of modified tillage and residue management practices. Evaluation of potential future adaptation strategies can be assisted by well-tested farming systems models that capture interactions between soil water and nutrient dynamics, crop growth, climate and management inputs/practices. APSIM represents such a model, however due to its ‘dryland heritage’ APSIM has been unequipped to describe the soil water, carbon and nitrogen dynamics as soil environments progress from aerobic to anaerobic and back again, such as occurs in crop rotations involving ponded rice and other non-ponded crops (wheat, maize, legumes, pastures etc.). Various relevant chemical and biological processes that occur in long-term ponded water were also unaccounted for in APSIM. Also, no previous farming systems modeling framework has addressed the issue of switching between aerobic and anaerobic environments during a simulation, which is particularly important if the focus of the modeling exercise is evaluating new farming system practices that include ponded rice in rotation with non-flooded crops.

The ORYZA2000 rice crop model (Bouman and Van Laar, 2006) has been incorporated into the APSIM framework and validated in a range of environments (Zhang 2007; Gaydon *et al.,* 2006). The soil water routines within the original ORYZA2000 were stripped out and replaced by APSIM’s soil water balance modules. In each of these studies, however, N was either assumed to be non-limiting, or calculated for a rice monoculture using a simple N accounting component within ORYZA2000. Up until recently (with new developments in APSIM), it has been impossible to simulate the complete C and N dynamics in complex farming systems, which involve rice in rotation with other crops and pastures.

Recent collaborative work between CSIRO, IRRI and Wageningen University (Gaydon e*t al.,* 2009) has begun addressing some of these shortcomings within APSIM. The structure and science required has been incorporated into the APSIM framework to allow simulation of C and N dynamics in rice-based systems, and preliminary testing has been promising. Continued testing in a variety of environments is still required to achieve the necessary confidence in performance. Also, several outstanding required improvements have been identified in key areas of the APSIM-ORYZA2000 framework before the model can be effectively utilised in climate change–related adaptation studies in rice-based farming systems. These fall into two categories: (i) APSIM ‘soil environment’ modelling enhancements required, and (ii) ORYZA2000 crop model enhancements required. These are discussed below.

APSIM ‘Soil Environment’ modelling enhancements required

The Ponded environment

Figure 9.2 illustrates the broad nutrient processes relevant to simulation of a ponded soil environment. All but one of these processes (denitrification) was originally absent from APSIM. The following is a brief description of the new system elements which have been incorporated into APSIM, but remain only partially tested:

- Pond C and N loss and gain mechanisms. Ponded water introduces a range of C and N loss and gain mechanisms not present in aerobic soil environments. These include significant volatilization of ammonia (NH_3) from the free water surface, and the growth of photosynthetic aquatic biomass (PAB - algae) which may be N-fixing.
- Fertiliser applied directly on standing water in ponded fields. In rice-based systems, fertiliser is often applied as urea directly into the pond. This fertiliser is then subject to hydrolysis, potential losses via ammonia volatilization, diffusion into the soil via mass flow and adsorption, and ultimately the main aim - uptake by the rice plant. Previously in APSIM, all applied fertilizer was conceptualized as being applied directly into the soil layers.
- Surface organic matter decomposition in pond. Surface organic matter decomposition was comprehensively modelled already in APSIM, however decomposition in water take place at slower rates than decomposition in air.
- Reduced rates of soil organic matter decomposition and cycling. In an anaerobic soil profile saturated for extended periods, reduced rates of organic matter decomposition and cycling are likely to be a significant factor in modeling system behaviour (Jing *et al*., 2007).

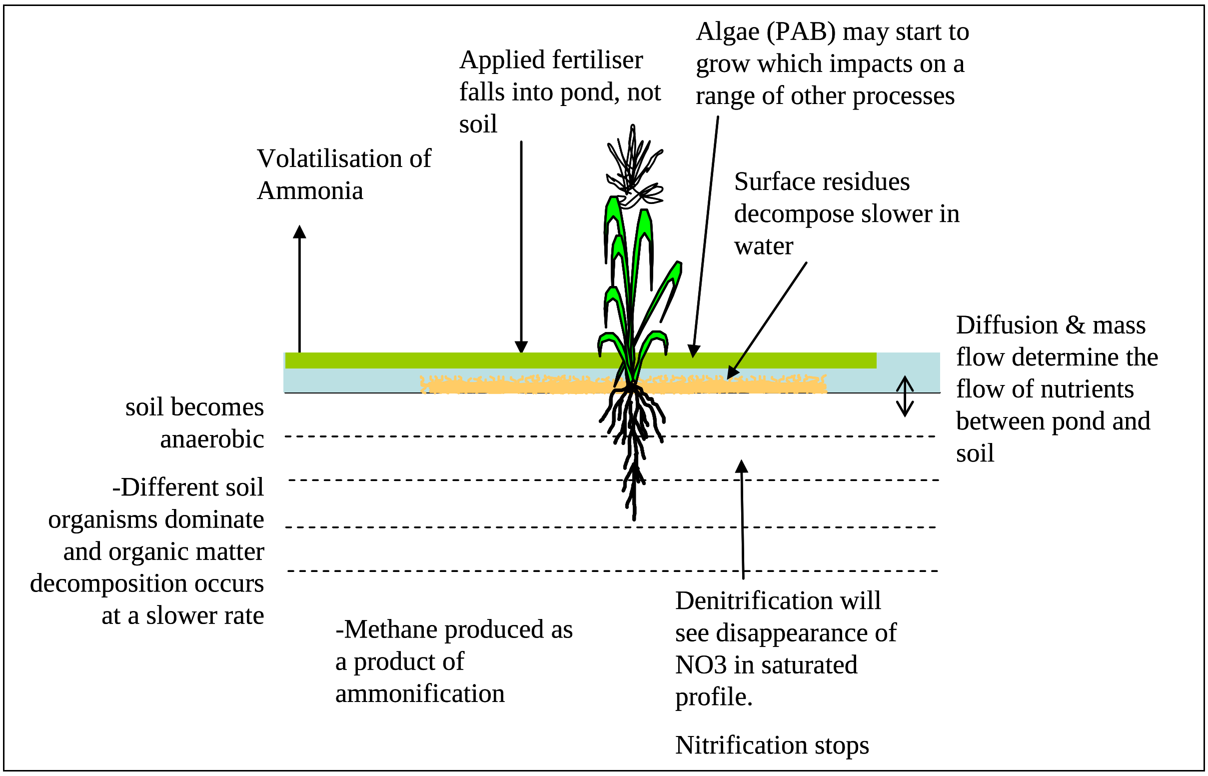

Figure 9.2: Key Processes for system simulation in a flooded rice environment

Transitional ability

Changing the aeration status of the soil can have significant consequences for nutrient dynamics, movement, and availability to plants. Nitrogen behaves very differently in flooded (anaerobic) soil environments compared with aerobic soil environments. In flooded conditions, ammonia volatilisation from the pond is a major source of N loss, hence movement of urea, ammonium and nitrate between the pond and the soil becomes an important process for simulation. Ammonium (NH_4), the major source of mineral N for rice crops, is rapidly nitrified to nitrate (NO_3) when the soil is drained. Nitrate is the major form in which mineral N exists in aerobic soil environments and is utilised by non-flooded crops such as wheat. When aerobic soil is re-flooded, the nitrate present in the system is lost by denitrification to the atmosphere. These cycles of nitrification and denitrification, together with ammonia volatilisation during the flood phase, are major loss mechanisms for N loss in farming systems which include flooded rice phases.

The key challenge for incorporating any new process descriptions into APSIM has been to establish smooth transition within a simulation between modelling of flooded and non-flooded soil environments. It was a design criterion that this transition be contingent on continuous hydraulically-modelled variables, rather than an arbitrary ‘switch’ when one phase has finished and the next begun. This functionality has been incorporated, yet requires further testing.

Puddling, hard-pan disruption and affects of soil structure dynamics on water movement

Changes in soil structure and physical properties which occur when a soil is ‘puddled’ in the presence of ponded water are not currently described in APSIM. In south-east Asian rice-based farming systems puddling is widely practiced, as is subsequent tillage following the rice phase which again alters soil properties. Cracking of puddled soils during the dry-down phase in ‘alternate wet-and-dry’ rice water cultivation represents a significant avenue for unproductive water loss in these systems when ponded water is initially re-introduced. The ability of ASPIM to simulate these soil changes in the context of assessing adaptation scenarios will be essential. Implementation and testing of this functionality is a major agreed priority between CSIRO and IRRI in future model development work.

ORYZA2000 crop model enhancements required

Phenology modelling

Currently, rice crop varieties within ORYZA2000 are parameterised in a way which ties the specific calibration to a location. There is a confounding mix of genetic and locational characteristics in the way different cultivars are conceptualised within the ORYZA2000 model. Simulation of a successfully calibrated ‘variety’ for one location, at a different geographical location, will result in incorrect phenological simulation, and requires re-calibration. APSIM crops are not conceptualised in this fashion – there is no ‘locational’ component to the parameterisation, and varieties of wheat (for example) may be simulated to grow in Western Australia, Victoria, and in Queensland with the resultant changes in phenological development due to climate and location successfully simulated. Work is required on the varietal specification and phenological modelling routines within ORYZA200 to enable this same APSIM-type functionality for transferability of varieties. This will be necessary in future climate-change studies, where use of varieties from warmer regions could be an adaptation option under consideration

CO_2 response

In any modelling study of climate change adaptation strategies, it is essential that the modelling tool has a well-tested capacity to simulate changes in crop-response to increased levels of atmospheric CO_2. The ORYZA2000 rice model within APSIM already has a functionality to simulate CO_2 response of crops, but this requires further testing and validation.

Extremes of temperature response

Like CO_2, increased levels of climate variability and greater temperature extremes are projected by the majority of GCM climate models. The ORYZA2000 rice model, like the APSIM crop models, already has the capacity to simulate crop response to both high and low temperatures, but the reliability of the simulated response requires further testing given that algorithms used generally have not been validated under the extremes of temperature likely in future climates.

Interactions between CO_2 and temperature

Several studies have shown that high air temperatures can reduce rice grain yield even under CO_2 enrichment (Baker and Allen 1993; Ziska *et al.,* 1997). There is also evidence to indicate that the relative enhancement of rice yields due to CO_2 fertilisation could be limited by increases in air temperatures (Matsui *et al.,* 1997), as the critical temperature threshold for spikelet sterility is reduced. The central nature of these interactions to climate change adaptation studies necessitates the continued testing and validation of all APSIM crop models (including ORYZA2000) as experimental data becomes available.

Drought tolerance

IRRI have identified simulation of the crop response to periods of drought in the ORYZA2000 model as an area requiring enhanced testing and validation, and potential improvements. Regions traditionally growing lowland rice could experience greater periods of drought stress if in-crop rainfall decreases. Similarly upland and aerobic rice varieties could experience more extreme levels of drought stress. The ability of a farming systems model to simulate the crop response to drought will be essential in adaptation scenario analyses. This is also an agreed high priority for further collaborative effort between CSIRO and IRRI.

Water-logging and submergence response

In some regions of SE Asia, in-crop rainfall and river flows are projected to increase or experience changes in timing. This may result in greater periods of water-logging in upland rice cultivation or more crop submergence in some lowland environments. The capacity of ORYZA2000 to reliably simulate crop behaviour under these situations has also been identified as requiring further testing, validation and enhancement.

Salinity response

Similarly, encroaching seawater represents an environmental consequence of climate change from sea level rise and this may impact significantly in some rice growing regions (for example, Bangladesh). The ability of the ORYZA2000 model to simulate crop response to changes in salinity level will be important in these situations, and IRRI has identified this as a current weakness in the ORYZA2000 model. Hence it will be important to enhance this capacity of the model for future application in regions likely to be subject to salinity stress.

Whilst the ongoing collaboration between CSIRO and IRRI on integration of ORYZA2000 into the APSIM framework has already lead to a substantially increased ability of APSIM to model rice-based cropping systems, the above list of gaps illustrates that there is still some way to go in attaining a level of functionality that would make APSIM a more versatile tool to explore climate adaptation options in rice-based cropping systems. However, further investment in this venture is likely to yield significant benefits, as expanding the capability of APSIM to successfully simulate rice-based cropping systems will have a major impact on Australian research aimed at improving the productivity and sustainability of these systems, particularly given that these systems constitute the mainstay of staple production in all the major Asian floodplain environments (e.g. Red River, Mekong Delta, Irrawaddy, Indo-Gangetic Plains). This scope has been recognised by IRRI, which is one of the reasons it is seeking to formalise the alliance with the APSIM Joint Venture to make APSIM the main modelling platform for future rice-based cropping systems research. Other partners likely to join this endeavour are the University of Wageningen and CIRAD.

9.3 Integrated Analysis Tool (IAT)

9.3.1 Rationale and applications history of the IAT

Analysing trade-offs between different farming activities (e.g. cropping vs. livestock production) and assessing the benefits of different allocations of inputs and resources in the context of small-holder subsistence or market-oriented enterprises are core to designing more efficient farming systems (Herrero *et al.,* 2002; Castelan-Ortega *et al*., 2003a, 2003b), minimising negative impacts on natural resources and identifying options to improve smallholder households' income and livelihoods. The complexity of a typical smallholder farm-household production system is presented schematically in Figure 9.3, using an example from Eastern Indonesia. While the overall performance of this system might be judged in terms of monetary outcomes (e.g. total gross margin, annual net profit), production and consumption pathways are typically indirect and not always well defined. A key aim of biophysical and economic modelling components of smallholder systems is to better understand how these pathways might operate in order to provide new options that may generate an improved level of farming system performance and positive welfare outcomes for the smallholder communities.

In 2000, ACIAR approached CSIRO to develop and carry out a suite of projects aimed at resolving these kinds of trade-offs in the context of Indonesian small-holder crop-livestock farming systems. Despite the apparent availability of a range of simulation models (including APSIM) to support this task, these models were typically either focussed on crops or livestock, and none were directly capable of analysing the tradeoffs between cropping and livestock production, particularly when there are intermediate activities involved and competing or complementary interrelationships exist between the various

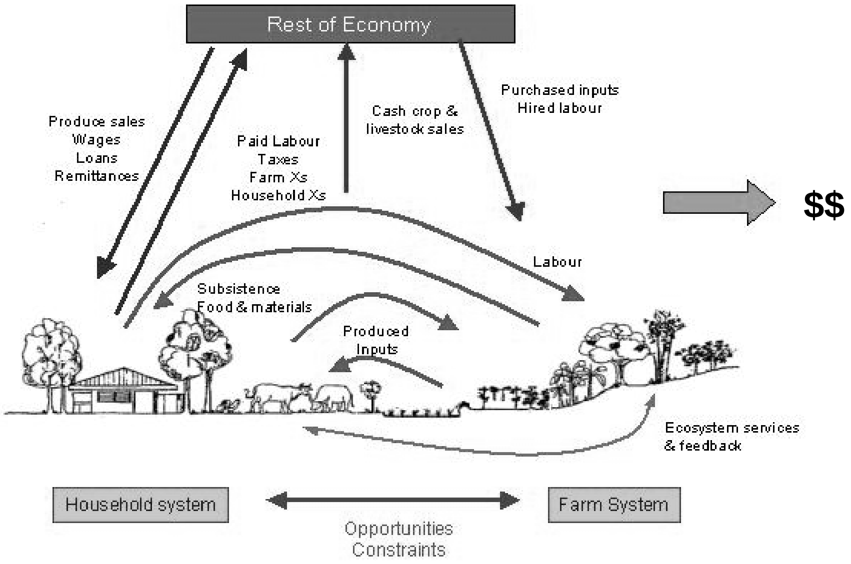

Figure 9.3: Schematic representation of the complexity of smallholder systems, based on an example from Eastern Indonesia.

activities. This lack of integration made it hard to undertake detailed systems analysis of such mixed farming systems. In the absence of any viable modeling tools at the time to perform these trade-off analyses, the Integrated Analysis Tool (IAT) was specifically developed to explore the biophysical, social and economic impacts of adjustments to smallholder farming systems in eastern Indonesia, primarily through changes to existing cropping practices, the adoption of novel forages and different livestock management practices (Lisson *et al*. submitted).

To meet the foregoing requirements for addressing farming system relationships, the IAT was developed as a core component of a suite of ACIAR projects[3], principally to explore options for integrating improved forages and livestock management practices into traditional smallholder farming systems – in that case the farming systems common to much of eastern Indonesia. The livestock component is dominated by the husbandry of Bali cattle which have strong prospects for increasing the economic welfare of resource-poor smallholder households. These systems include both irrigated and dry land cash and subsistence cropping activities with a heavy reliance on rice. The main areas in which prototyping task was undertaken were Barru Regency, South Sulawesi and Dompu Regency, Central Sumbawa. This component of the development represented a ‘proof of concept’ phase to demonstrate that the performance of smallholder household farming systems could be analysed using farming systems principles and successfully mimicked through simulation modelling. The phase also addressed the issue of determining whether such an approach was deemed useful by both smallholder households and the agencies servicing their agricultural needs.

A second ‘proof of application’ phase was undertaken under a subsequent ACIAR project[4] in which the model played a central role in the planning and implementation of a series of on-farm trials of an array of crop, forage and cattle management options. These trials were successfully conducted in 4 communities in Barru Regency, South Sulawesi, 2 communities in Gowa Regency, South Sulawesi, and 5 communities in Central Lombok and Dompu Regencies, Nusa Tenggara Barat (MacLeod *et al.* 2008).

9.3.2 Description of the component models

Structure of the IAT

The IAT integrates data and output from 3 separate simulation models (described below): a pre-existing cropping system model (APSIM), and 2 new models for predicting cattle growth and mimicking the economic performance of a typical smallholder farm-household enterprise (Figure 9.4). The IAT specifically operates at the scale of the smallholder household and enables a whole-of-enterprise analysis of alternative crop, forage and livestock management options. A simple (user-friendly) interface forms the ‘hub’ of the IAT with links to other input forms. Different regions/climatic zones or soil types can be selected to align with the smallholder community being analysed. User forms allow entry of farm-specific details (i.e. model inputs) relating to farm area and design, household structure, labour allocations for household members, cattle herd structure and management, and keeping of other livestock types (e.g. goats, poultry), cropping sequence and management. Sub-forms allow for the addition of more detailed information on crop input costs, non-farm income, labour etc. This information parameterises the cattle and economic models and directs the selection of input from a database of crop model output.

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[3] *AS2/2000/124 – Prospects for improved integration of high quality forages in the crop-livestock systems of Sulawesi, Indonesia and AS2/2000/125 - Optimising crop-livestock systems in West Nusa Tenggara Province, Indonesia,*

[4] *LPS/2004/005 - Improving smallholder crop-livestock systems in eastern Indonesia.*

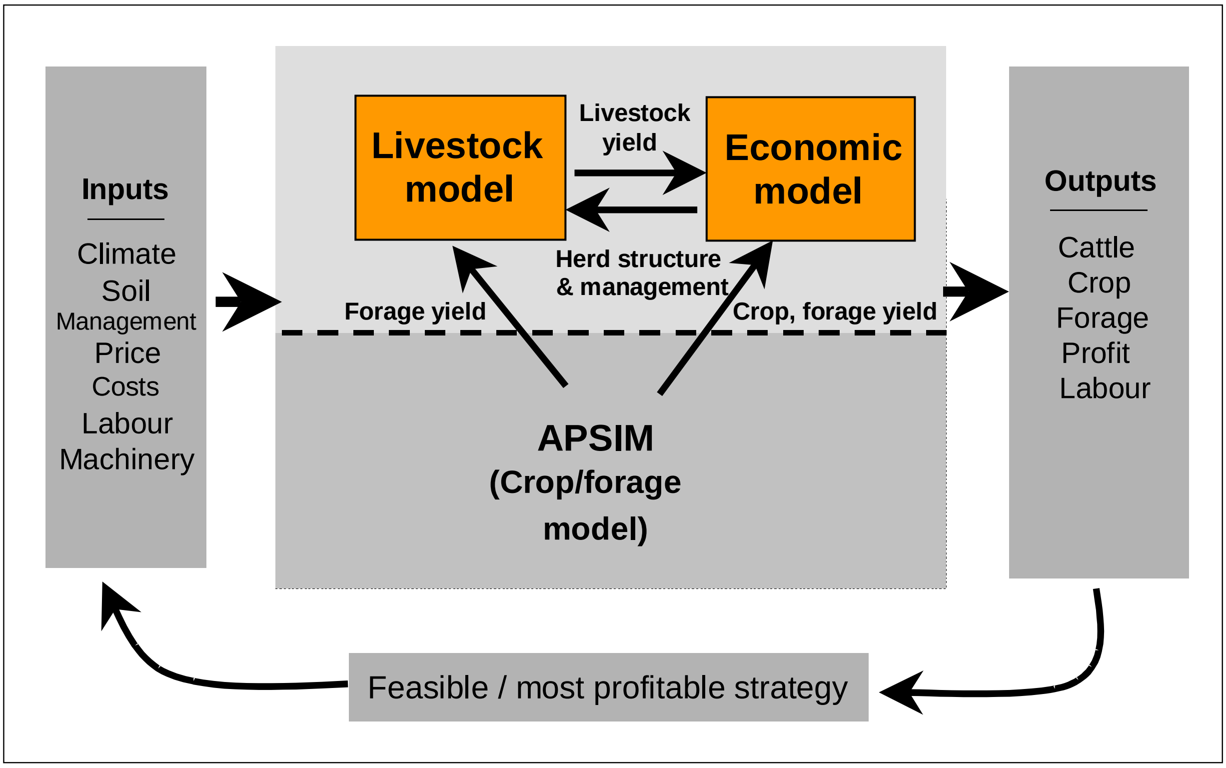

Figure 9.4: Structure of the Integrated Analysis Tool (IAT)

In the current configuration of the IAT, the crop database is generated using APSIM. Cropping systems scenarios are pre-run and key parameter output from these scenarios is then incorporated into IAT as look-up tables. In this way, IAT is computationally efficient and allows for real time modelling in discussions with farmers or extensionists. While APSIM has been used in all versions of IAT to date, in theory, simulation output can be generated by any other crop simulation model that provides the parameters that are presently required by IAT. The 'real-time' cattle and economic models are then run over a variable period (typically 10 years) with the exchange of relevant output. Final output from the model is presented in graph or tabular form describing: (a) biophysical characteristics of the system (i.e. crop and forage yield/biomass and animal liveweight gain); (b) labour details and; (c) economic performance (cash balance and gross margins are presented, but a wider range of profit metrics can also be generated).

By conscious design, the IAT does not employ an automated optimization strategy, but rather uses a 'creep budgeting' approach to explore the impacts of various options. Optimisation analyses typically require the problem setting to be heavily simplified and the process of actually finding a solution is rarely transparent to anyone other than experienced users. It was deemed desirable to be able to explore potential options and the complexity of the farm-household linkages in a transparent manner. The creep budgeting approach involves re-specifying various input and output variables in a systematic manner to iteratively explore the system response to these changes (Makeham and Malcolm, 1981). That is, the decision-maker 'creeps' around the various response surfaces in a systematic fashion to examine whether there is a shift towards or away from a more satisfactory position than some present baseline or starting position. In this way, the use of 'what-if' questions is able to provide smallholders, researchers and extension specialists with many insights into how the welfare of the farm-household system will respond to different activities, input and output levels and their respective prices. By including all of the activities that are available to, or necessary for, the household to meet its needs and objectives, the model is able to provide an accurate guide as to whether exploiting different crop and forage options will actually make it better or worse off. This insight is not restricted to financial gains and losses alone, as the output also includes information on labour requirements (including gender), food yield, and surplus resources which might be usefully employed within or outside the farming enterprise.

Output from each simulation run can be saved for comparison with other simulations. The parameter settings used to generate the particular output are saved with the output and can be reloaded at a later date.

APSIM crop model in IAT

Depending on the farming system being studied, relevant crop modules (e.g. for rice, peanut, mucuna, cowpea, maize, soybean and mungbean) are combined with a soil water module, a soil nitrogen and carbon module and a residue module. These crop modules are parameterised using management, soil and climate data collected from surveys of smallholder households and biophysical monitoring activities of the farming activities.

APSIM simulations are configured for a range of species x soil type x climatic zone combinations, with the resulting model output relating to forage and crop yield and quality incorporated into a database within the IAT. The IAT user selects the APSIM configuration that best matches the conditions of the smallholder enterprise under consideration. Additional regional databases can be added to the IAT database as the application of the model is extended to new areas.

While APSIM captures the key processes influencing crop and forage production, it does not handle all yield-limiting constraints, such as weed competition, insect damage, water logging and effects of severe weather on growth and yields. Therefore, simulated yields and resource demands can often exceed field results, especially in low input smallholder production systems. In the absence of comprehensive field trials, ‘validation’ of the model is necessarily based on a comparison of model output (e.g. predicted yield) with village records and individual household records.

Animal growth model

A critical requirement for integrating a livestock model into the IAT framework was that it be both simple and sufficiently precise to predict livestock production outcomes under local field conditions. The key determinant of animal growth, reproduction and mortality rates is animal nutrition. Forage quality, measured by digestibility and protein availability, commonly limits production, but smallholders have an array of different feed sources of varying quality available at intermittent intervals; e.g. native and introduced grasses and legumes, field crop residues, plantation residues (leaf, stem, fruit), tree leaves etc. In the initial configuration of IAT, the livestock model is in effect a cattle model, but as discussed below, IAT can be expanded to include other livestock components.

The cattle model is spreadsheet-based and combines published data and field data relating to animal liveweight, liveweight gain, milk production, age at first calf and calving interval, as well as the quality, composition and quantity of the various sources of feed. The model is largely based on published energy functions (SCA, 1990) with coefficients adjusted for local cattle breeds (e.g. Bali cattle in Indonesia), with additional intake restrictions based on estimated crude protein (CP) requirements (Poppi and McLennan, 1995). Although energy coefficients for different breeds are included, currently, calving and mortality rates are specific to Bali cattle and to the feeds and husbandry practices of Eastern Indonesia. The model is sufficiently robust to capture responses to both grazing and cut and carry systems, cope with distinct wet and dry season conditions, and the feeding of crop residues.

Data input is restricted to the quantity and quality of available forage, with annual pasture, sown forage and crop residue biomass, nitrogen content and date of harvest sourced from the APSIM output database.

Animal growth is determined by the quantity and quality of animal intake. Potential intake is determined from the age and current or previous highest weight of the animal. This growth rate is adjusted for the effects of available forage (for grazing), forage quality, and whether the animal is lactating. Protein requirements are calculated on the basis of the adjusted intake, which, if insufficient, is reduced linearly in relation to CP required and CP supply. The digestibility and calculated intake determines the digestible and metabolisable energy intake which is partitioned into energy for maintenance and for growth. Calving interval, age at first calf and calf mortality rates are related to the condition of cows, based on published survey data and field observations. Applications of IAT in new areas (particularly outside Indonesia) with different cattle breeds would have to obtain similar data specific to the breed in question.

Labour requirements for cut and carry of forages are varied according to forage availability, or lack thereof, if none is available on farm. The greater the shortage of forage, the greater the labour requirement as smallholders need to collect forage from greater distances or spend time herding animals on common land. The model runs on a weekly basis with information on calving, animal liveweight, sales, and labour requirements passed to the economic model as aggregated annual input data.

Smallholder enterprise economic model

The central features of the household enterprise model are the interlinking of a wide array of activities that may be undertaken by the household. These include plantation trees, crops, forages, livestock, off-farm and non-farm activities that are linked systemically through 4 resource ‘pools’ on which they can either draw or contribute. Off-farm activities (e.g. contract ploughing, planting, weeding and harvesting etc) are those which are still farm-based in orientation and may draw on the same resources as on-farm activities. Non-farm activities (e.g. operating a kiosk, seasonal construction labour) also potentially contribute to, or draw on, the resources that are available to the family for production, consumption (e.g. education, consumer goods) or wealth accumulation (including increased cattle herd sizes.

The core of the household model is the constraining and enabling potentials of the 4 resource pools. These include (a) labour, including both household members and access to additional casual labour - by functional category and season, (b) land by type and quality, (c) forage by type and seasonal availability, including crop and plantation residues, and (d) cash reserves and credit - i.e. working capital to support production and consumption activities. The starting size of the different pools is set according to assumptions on the resource endowment associated with the particular smallholder enterprises that are under review. Crop and livestock activities also provide input for home consumption. As different activities are specified, their net demands and contributions to the 4 resource pools are evaluated and a series of ‘flags’ is created on the IAT user interface screen that will confirm whether or not the particular activity mix and level is feasible given the resources available to the household. The model specifically identifies which pools are acting as constraints on the particular activity mix that is being explored, and the extent to which other resources might be free to provide opportunities for other activities within or outside the farming system.

Inputs to the household model are drawn from several sources. Yield data for crop, forage and livestock activities are sourced directly from the APSIM database and the livestock model. Price and cost data, production input levels (e.g. fertiliser, seed, materials), and home consumption needs of different products and family expenses are usually derived from a baseline survey of households located in the target communities, although secondary data such as survey reports or informed person interviews might also be usefully employed.

The economic measures that are produced by the household model include: (a) total gross margin - including value of home consumed produce, (b) disposable income after household consumption, (c) net cash balances, and (d) the level of accumulated household capital and any outstanding debt balances. The advantage of the gross margin budgeting approach lies in its simplicity and transparency for potential users of the model. It also has the capacity to run simple sensitivity and risk analyses by varying the main parameter values in the underlying gross margin budgets.

9.3.3 Data requirements

Benchmarking/surveying

Although the IAT is relatively simple to use to explore new scenarios, a considerable amount of data is required to initially calibrate the model for a particular region. Much of this data will come from benchmark surveying of individual farmers and local extension personnel to ascertain the types and areas of crops and forages that are grown, what animals are kept and how they are fed, commodity prices, labour demands, etc. Information can also be obtained from literature, local government records etc, and modelling can be used to broaden the scope of available data.

Care needs to be taken in surveying smallholder households. Many smallholders do not keep records and hence are usually relying on recent memory. As such, the response given will often be what has been grown or what has happened the previous year or in the last couple of years. This needs to be clarified by the interviewer correlating answers with each other. Good results are obtained when 2 people visit a household and while one cultivates an on-going dialogue with the respondent (rather than a question and answer session), the other records key pieces of information.

Labour requirements for specific activities can also be difficult to ascertain. Many smallholder households help each other to sow or harvest their crops. So, while it may take only 3 days to harvest a particular crop, they may have had many people helping them, and then spent many days helping other households to harvest their crops. Similarly with animal numbers – sometimes households keep cattle for other households or traders, so the same animals can be counted twice, or not counted at all.

Data structure

The IAT selects and processes data based on 3 broad categories – climate zone, soil type, and season. For grain/food crops, there is an additional factor of irrigation. There are different amounts data required depending on what is being grown. For grain/food crops and forages details of yield etc over 10 years is required, while for plantation and fruit trees, vegetables and spice crops, only a single value is needed for each attribute and the crop will have the same value each year.

Climate zone – to specify a new country or a new region within a country that has a different climate, each can be given a zone number. For example, currently, the dry areas of Indonesia are climate zone 1, the wet areas are zone 3, areas with the wet season commencing in June rather than December are zone 5.

Soil type – five different soil types are presently allowed: sand, silt, loam, clay, and heavy clay, but more can be added

Seasons – each year is divided into the main cropping seasons. Crops can be grown in any of these seasons, and labour availability is specified according to season. For example in Indonesia, normally the first season is the rainy season (R), followed by the early dry season (D1) and the late dry season (D2).

10 year period – the IAT is currently limited to run over a 10 year period. However, this is not a limit due to design, but a limit imposed by the typical availability of reliable climate data. The time period of a simulation run could be extended simply by including the extra data in the database, and adjusting the reference cells of the output graphs.

In addition to the above three categories of data, the IAT needs information on a range of farm activities:

- Grain/food crop information
    - Harvest quantity and quality data, and harvest dates
    - Fixed input costs and labour demands
- Forage information
    - Harvest quantity and quality data, and harvest dates
    - Fixed input costs and labour demands
- Plantation and fruit tree information (numbers and yield)
- Vegetable, spice and other crops (area and yield)
- Animal information
    - General animal information (feeding system and labour demands)
    - Cattle/buffalo information
    - Goats, chicken and other animal information
- General farm information (area, land types)
- Labour availability and permitted activities

9.3.4 Applicability of IAT to other smallholder systems and to climate adaptation science

Extension of IAT to other farming systems

The current structure of the IAT is suitable for analysing most rice and cattle based smallholder systems in south-east Asia. So long as estimates of crop and forage production and quality can be provided, along with commodity prices, labour demands and availability, representative analyses of farming systems should achievable. While it could be easily modified to do so, the IAT is not currently well-suited to modelling various crop farming options in the absence of cattle.

Following the development and application of IAT in the ACIAR projects in Indonesia, the IAT is currently being modified for application to dairy production systems in Pakistan and is being proposed for application to smallholder crop-livestock production systems in Central Vietnam, East Timor and in ACIAR’s farming systems project in Gansu, China.

A number of additions have been made to the IAT since the original structure was developed for application in Indonesia. These include provision for animals other than cattle, supplementary feeding of specific animal classes (i.e. calves or weaners), a milk production routine, manure output, allowance for different breeds. While some of these (e.g. supplementary feeding and manure output) add little additional complexity to the IAT, others will require more validation and parameterisation before they can be used widely.

Other animals – currently this is represented in a simplistic and static manner with little connectivity to some of the household ‘resource pools’. Reproductive rate is a fixed parameter entered by the user, as are the labour demands and feed costs. It is assumed that all feed is purchased for these extra animal types and there is no demand placed on farm feed resources.

Milk production – this routine has been added for a dairy-based project in Pakistan and is yet to be validated for Pakistani cattle, or any other breed. Current parameter settings for the various breeds are based on the literature.

Different breeds of cattle - while suitable growing and intake parameters are included for various breeds, many other parameters regarding calving interval, age at first calf, mortality rate, etc have yet to be parameterised. Currently this is a major shortcoming of this aspect of the IAT and is why the current version has not been made available for wider circulation.

While different crop and forage types can be added if suitable yield and quality data is available, there is a limit to the number that can be grown in any one year. For crops the maximum is 6, and for forages 5. This has not been a limitation for applications to date, but could be elsewhere, particularly if there is access to irrigation and crops can be grown in all 3 seasons of the year. Increasing the capacity of the spreadsheet economic model to include extra crops or forages, while possible, would require major revision of much of the cell formulation and a thorough cross-check of the VBA code in the animal model.

As well as the limitation in the economic model, the number of harvests per year in the forage inputs is currently set to 6, irrespective of whether there are 6 harvests or not. Again, while this has not been a limitation in Indonesia it may be elsewhere. Similarly, off-farm and non-farm activities are limited to 2 activities for any one family member.

In other regions, many farmers do not own or share cattle. It would be desirable to be able to explore different crop and forage options of these farms, without including any cattle. In many regions of south-east Asia (e.g. Vietnam) farmers keep pigs rather than cattle, in other regions farmers have shrimp in ponds which are fed, at least partly, with animal manure. It would extend the versatility and regional applicability of the IAT to be able to select combinations of these various activities and determine opportunities and constraints.

If further development of the IAT were to be undertaken to address the above limitations, then it would be an opportune time to restructure the model to enable any future additions to be more readily accomplished. Such additions could include aquaculture, goat and pig breeding, cattle trading, green house gas emissions, etc. A revision such as this would require disassembling the key elements of the IAT and, under the guidance of software engineers, re-assembling it with a more flexible structure, possibly using a different platform (i.e. software other than Excel).

Strengths and weaknesses of IAT

The major strengths of the IAT for analysing smallholder farming systems include:

- ability to integrate complex biophysical (crops, forages, animals), resource endowment (land, labour, money) and social (cultural practices, attitude to risk) elements
- greater use can be made of the vast amount of existing knowledge
- production, feed supply, labour and cash flows can be explored and any constraints identified
- potential options to alleviate resource constraints can be explored without the need for multiple on-farm trials
- production and risk from existing farming systems and potential interventions can be demonstrated to researchers, extension personnel and smallholders
- smallholders can actively participate in selecting options suitable to their resources, their objectives, and their attitude to risk
- use of sophisticated crop/forage model to generate data for the tool allows new climate zones, soil types, etc to be added easily

Major weaknesses of the IAT include:

- it is limited to the crops and forages available in the database
- the animal model is limited to 1 breed of cattle at a time
- only cattle are modelled dynamically, other animals types (e.g. goats, chickens) are included in a simplistic static manner only
- the rigid structure of the spreadsheet component of the tool limits the number of crops, forages, etc that can be specified for any one scenario
- additional activities such as milking, aquaculture, etc cannot be added easily

- there is no feed back between the IAT and the crop/forage model e.g. if manure or fertilizer are used on crop fields this has to be modelled separately and entered in the database
- because of the low animal numbers, calving rates etc can only be represented as fractions of an animal

A role for IAT in climate adaptation research?

Based on the above assessment, it would appear that IAT is an effective tool and offers significant opportunities in systems analysis directly relevant to exploring farm level options for climate adaptation. However, this versatility comes at the expense of several limitations. From a software perspective, the current versions of IAT are limited by the programming and spreadsheet configurations inherent in Excel. To make IAT more user friendly and to efficiently add future modifications or application extensions (e.g. a module for fish farming, modules for off-farm income generation), consideration needs to be given to a complete redesign of the tool and a transition to a model software structure more akin to APSIM. This would represent a major investment that seems outside of the scope of the immediate climate adaptation project under design, but may be a worthwhile investment in the broader context of food security research, especially to underpin future research in rainfed, rice-based farming systems of S Asia and SE Asia that have a significant livestock component.

Other limitations revolve around the ability to provide suitable crop and forage data, which in turn is limited by the availability of local climate data, information on the phenology of the particular crop(s) to be added, and suitable routines with applicable parameters in the crop/forage model (e.g. APSIM) that can be adjusted to simulate the growth and production of the particular crop/forage system.

Irrespective of the medium term case to redevelop IAT into a more streamlined software product, IAT can be readily utilized as a tool to generate adaptation options in an on-farm participatory modeling approach once the basic calibration to local conditions has been achieved. A major attraction of IAT is that, because it assesses implications of changes to farming practices across a range of socio-economic parameters (labour, cash flows, off-farm employment), it lends itself more easily to integration with information generated by the SRL analysis in terms of adaptive capacity and farmers' endowment with the five capitals.

Given the data requirements, particularly for the livestock component of IAT, the immediate transferability and applicability of IAT seems to be restricted to Cambodia and Laos. This is because in these countries a substantial body of information on local livestock systems has been built through a number of previous and ongoing ACIAR projects with CIAT and other Australian research organizations. From this existing knowledge base it should be possible to obtain the required parameters in a comparatively cost-effective way. Also, there are good existing research relationships between livestock and forage scientists in the region with CIAT and CSIRO that would facilitate a compilation of data for local calibration. Conversely, given that less (Andhra Pradesh) or no (Bangladesh) ACIAR funded research on livestock production systems has been carried out, setting up IAT for these countries would require a more significant investment. This would be compounded by the absence of existing relationships between Australian and partner country livestock scientists.

10 Frameworks to assess adaptive capacity and impacts of climate change

10.1 Overview of approaches used in vulnerability and livelihood assessment

Resilience and vulnerability are terms increasingly used in a wide range of applications, but rarely defined or converted into practical information to support policy development. The concepts of vulnerability and resilience[5] have their origins in the ecology of natural systems (Holling, 1973), and the transfer of these concepts to broader socio-ecological systems (Walker and Salt, 2006). The vulnerability of land managers to the negative impacts of change depends on their exposure and sensitivity to the drivers of change, as well as their capacity to adapt to different drivers of change.

The concepts of vulnerability, resilience and adaptive capacity are intimately linked, particularly in a social context and specifically in relation to livelihoods (Adger and Vincent, 2005; Gallopín, 2006; Smit and Wandel, 2006; D. Nelson *et al*., 2007). Vulnerability and livelihood assessment has also been of academic interest and an active research domain in social sciences and anthropology, particularly aimed at understanding causes underlying poverty (Adger, 2006). However, vulnerability assessments often focus on potential threats (exposures, hazards, stresses etc) that affect livelihoods and well-being (reviewed in Kofinas and Chapin, 2009) rather than in considering what people can do to improve their livelihoods. Conversely, assessments of adaptive capacity are better positioned to consider the constraining and enabling factors for individuals, households or communities to cope with various types of change. Adaptive capacity is defined as "*the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements*" (D. Nelson *et al*., 2007).

Much of this work has focussed on the potential negative impacts of exposure and sensitivity to specific drivers of change such as declining terms of trade, land degradation and rising temperatures. This tends to be disempowering for individuals, households and communities unable to directly influence these change drivers. A focus on impacts is also disempowering because it overlooks the intrinsic adaptive capacity and demonstrated ability of land managers to adjust positively to significant change. Furthermore, delivering impact or vulnerability measures as an end in itself is unhelpful, and delivering such measures as a means to assist adaptation often requires the impacts and vulnerability to be understood and expressed in different terms.

There have been calls to specifically link climate change adaptation and mitigation to sustainable development of communities to enhance their adaptive capacity (Laukkonen *et al*., 2009). Kofinas and Chapin (2009) argue that participatory place-based approaches are required to improve well-being and to enable for planning for change. There are few published examples where climate change, adaptive capacity and participatory approaches have been successfully conducted. Furthermore, there is a recognised need to develop adaptation assessment frameworks that are relevant, robust, and easily operated (Howden *et al*., 2007).

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*[5] **Vulnerability** is defined as the susceptibility of a system to disturbances determined by exposure to perturbations, sensitivity to perturbations, and the capacity to adapt. **Resilience** is defined as the amount of change a system can undergo and still retain the same function and structure while maintaining options to develop (Nelson, Adger and Brown, 2007).*

Depending on the needs (i.e. development or research), a wide range of methods to assess livelihoods and adaptive capacity have been developed. These can be broadly categorised into four categories, described below.

Top-down national-level indicators and indices assessments using measures such as Gross Domestic Product (GDP) and other high level indices (Brooks *et al*., 2005; Vincent, 2007; also used by Yusuf and Fransisco, 2009) – these aggregate indicators can be used to guide international decision making to prioritise investments in adaptation, particularly in response to climate change. Most attempts to measure adaptive capacity at this level use secondary data from national accounts to compare nations, but initially overlook important regional differences and local drivers of adaptive capacity. Most of these attempts to measure adaptive capacity either lack a conceptual understanding of adaptive capacity altogether, or lose sight of it as data limitations redirect the original objectives of the research. Also the selection of indicators can sometimes be controversial. For example, it is recognised that after serious disasters some indicators such as GDP often increase because of recovery efforts, despite widespread hardship or losses.

Bottom-up participatory rural appraisal techniques (using social-ecological resilience) (Berkes and Jolly, 2001) – this approach is based on participatory approaches and provides enormous insight within the communities to which they are applied and provide opportunities for community empowerment, but lack policy application since they are not readily transferable to other regions. They can also be used to explore the linkages between communities, regional institutions and government agencies necessary to facilitate collective adaptation.

Detailed cross-sectional household surveys of farmers (*sensu* Deressa *et al*., 2009) – these are often very reductionist (top-down and data intensive through thousands of surveys) which are analysed by discrete choice models, with the objective of identifying barriers. However, they do not identify what farmers see as important.

Participatory vulnerability analysis (reviewed by Smit and Wandel, 2006; Kofinas and Chapin, 2009) – this is a holistic but relatively complex approach which assesses (1) exposure and sensitivities to determine risks, (2) historic strategies and constraints for coping with risks, (3) identification of possible future risks, (4) developing plans for mitigating or adapting to future risks. This approach needs multiple sources of knowledge, (local and traditional knowledge, modelling techniques, science-based analysis and remote sensing imagery), but which can be applied at multiple scales. However, there are few if any published studies demonstrating the success of this approach.

In general, the shortcomings of these approaches are:

- They cannot easily be implemented at a small-scale (scale too large);
- They are expensive and time-consuming to run or require complicated modelling;
- The indicators or frameworks cannot be nested; and
- Farmers lack the opportunity to select indicators that are relevant for themselves and have little opportunity to consider what could be done to improve them.

In the context of the climate change debate and the emergence of an adaptation research agenda the inclusion of social and institutional research in technologically driven adaptation options has regained new prominence (Howden *et al*., 2007; Resurreccion *et al*., 2008; Meinke *et al*., 2009). This has also revived interest in vulnerability and livelihoods analysis, as it is increasingly being recognised that effective adaptation is as much a socially driven process as it is one reliant on technological solutions. Furthermore, it is important to understand how and why people adapt to climate change and which adaptation options are most feasible to them.

This has also led to a reassessment of vulnerability and impact assessments in their own right as falling short of informing effective adaptation strategies, as either they are too location and context specific and do not lend themselves to up-scaling to other areas, or they are conducted at a too generic level and therefore fall short of providing meaningful options applicable and acceptable at a farming household level. This is compounded by the difficulty in comparing the different approaches used as well as integrating them into biophysical research required to identify and test viable adaptation measures.

CSIRO Sustainable Ecosystems has in recent years significantly expanded its research agenda into the integration of social research into mainstream biophysical research. A range of research teams within the Social and Economic Sciences Program, the Climate Adaptation Flagship, and other research teams, are applying the theory and methods of the social and economic sciences in research that integrate the human and biophysical dimensions of natural resource management. One area of focus has been the application of livelihoods theory to rural development and sustainable use of natural resources. This has led to the extension of the Sustainable Rural Livelihoods framework (SRL) (Ellis, 2000) to novel applications in the area of improving the livelihoods of indigenous Australians (Davies *et al*., 2008), the assessment of adaptive capacity to environmental change in rural Australia (Brown *et al*., 2009) and to global climate change more generally (Nelson *et al*., In Press *a* and *b*), as well as applying the SRL as a research tool in some of its overseas sustainability projects in Indonesia and the Pacific (Park *et al*., 2009).

The concept of Sustainable Rural Livelihoods (SRL) has been central to the assessments of rural development, poverty reduction and environmental management (Scoones, 1998). The SRL approach is used widely among international development agencies, particularly those active in Asia and Africa for planning, reviewing, and evaluating projects, as well as researching, analysing and developing policy. It has a background in research on poverty reduction, sustainability, and livelihood strategies (Ellis, 2003). It is used extensively by DFID, UNDP, Oxfam and CARE. The rationale for using SRL in these contexts is to identify key target groups, poverty and vulnerability hotspots for priority donor project interventions.

Some of the features that have led to the choice of the SRL above other methods of vulnerability and livelihoods assessment are:

- The underlying principles of the rural livelihoods are scale invariant, so that the SRL potentially lends itself to assessing livelihoods at a range of scales, and can be used to link bottom-up and top-down approaches in a nested manner;
- It provides a systematic and rigorous framework that is relatively cheap and easy to conduct, is reasonably rapid, and can be easily repeated; and
- It can be used both as a community engagement process and as an analytical framework; this leads to a high potential degree of ownership of results obtained using the SRL. This approach also adheres to many of the philosophies of rapid rural appraisals which are well grounded in social development research.

On this basis, the feasibility of utilising the SRL as a key tool to assess adaptive capacity of farming households was further investigated in the targeted countries of this scoping study. This was conducted on the basis of two pilot studies conducted in India (Andhra Pradesh) and Bangladesh. The following sections report on the outcomes of these pilot studies.

10.2 Overview of the Sustainable Rural Livelihoods Framework

10.2.1 Rural livelihoods analysis and adaptive capacity

Rural livelihoods analysis can empower rural communities and policy advisers by identifying the attributes of adaptive capacity that can be enhanced through individual and policy measures. Adaptive capacity is an emergent property that depends on the diversity of assets and activities from which rural livelihoods are derived, and the flexibility to substitute between them in response to external pressures (Ellis, 2000). This includes the continual process of inventing, adapting and adopting more sustainable farming practices to anticipate and respond to change.

Adaptive capacity transcends changes in farm management to include the broader livelihood strategies that farm families pursue through off-farm and non-farm employment. Farming households with a greater diversity of assets and livelihood options are likely to be more resilient because of a greater capacity to substitute between alternative livelihood strategies in times of stress. This is particularly the case when alternative livelihood options differ in their exposure to specific external pressures. Diversification at a household or enterprise level often complements economic specialisation within a household, and economic specialisation in any one set of activities can facilitate investment in other forms of capital from which future livelihoods can be derived (Ellis, 2000). This approach complements more dynamic concepts of resilience for which specific understanding of causal relationships and local thresholds or “tipping points” is required (Holling, 1978, Walker and Salt, 2006). It also forms the base from which many NGO-led projects have developed their interventions, particularly in Bangladesh.

The ability to diversify between the assets and activities that comprise livelihood strategies depends on the human and social capital that underpins individual and community ingenuity and persistence in the face of difficulty. Strategic investment in learning, the motivation to innovate and intelligent risk management arise at least partially from good health, education and willingness to cooperate with others.

The rural livelihoods analysis can also be used as a lens to measure the impact of the project through the self-assessment approaches described below.

10.2.2 Conceptual framework and general methods

Conceptual framework

The sustainable rural livelihoods framework (SRL) developed initially by Scoones (1998) and later refined and expanded by Ellis (2000) views livelihood strategies as comprised of activities that are continuously invented, adapted and adopted in response to changing access to five broadly defined types of capital including:

- **Human capital** – the skills, health and education of individuals that contribute to the productivity of labour and capacity to manage land;
- **Social capital** – reciprocal claims on others by virtue of social relationships, the close social bonds that facilitate cooperative action and the social bridging, and linking via which ideas and resources are accessed;
- **Natural capital** – the productivity of land, and actions to sustain productivity, as well as the water and biological resources from which rural livelihoods are derived;
- **Physical capital** – capital items produced by economic activity from other types of capital that can include infrastructure, equipment and improvements in genetic resources (crops, livestock); and
- **Financial capital** – the level, variability and diversity of income sources, and access to other financial resources (credit and savings) that together contribute to wealth.

The conceptual framework provided by Ellis (2000) recognises that rural livelihoods are generated and sustained in a complex operating environment in which multiple trends and shocks interact and coalesce (Figure 10.1). The framework also recognises that the ability of households to access alternative forms of capital to generate livelihoods is influenced by social and institutional factors that can be uncertain and largely beyond individual control. The position of individuals within society determined by class, gender, ethnicity, age and religion can significantly influence access to resources, as can both formal and informal institutions such as laws and local systems of resource governance (Ostrom, 1999).

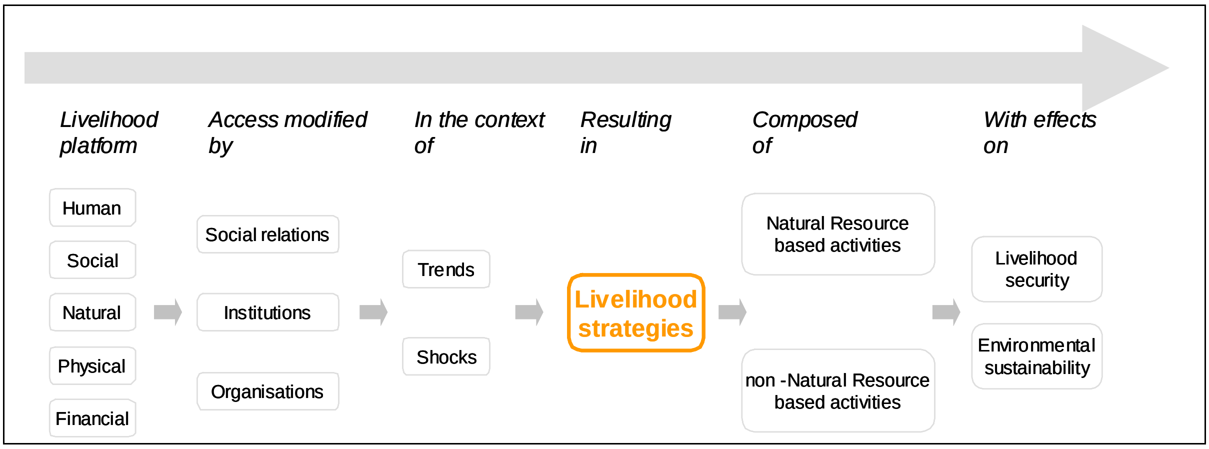

Figure 10.1: A framework for the analysis of rural livelihoods (after Ellis, 2000)

Government policies and programs comprise only one category of many organisational and institutional influences on access to resources, along with community and industry-oriented non-government organisations. Nelson *et al*. (2006) drew on the ideas of Woolcock (1998) to expand the definition of social capital used in rural livelihoods analysis to include the internal and external forms of social capital through which ideas and resources are accessed.

From the perspective of rural livelihoods analysis, the balance between the five capitals is equally if not more important to the adaptive capacity of farming households as the amount of any one type of capital considered in isolation (Carney, 1998; Ellis, 2000) (Figure 10.2). This is because the five capitals often complement each other in the process of generating livelihoods. For example, minimum levels of human and social capital are necessary to effectively make use of natural, physical and financial capital. Viewing adaptive capacity as a balance between the capitals is also useful for capturing the transformative nature of the capitals (Ellis, 2000).

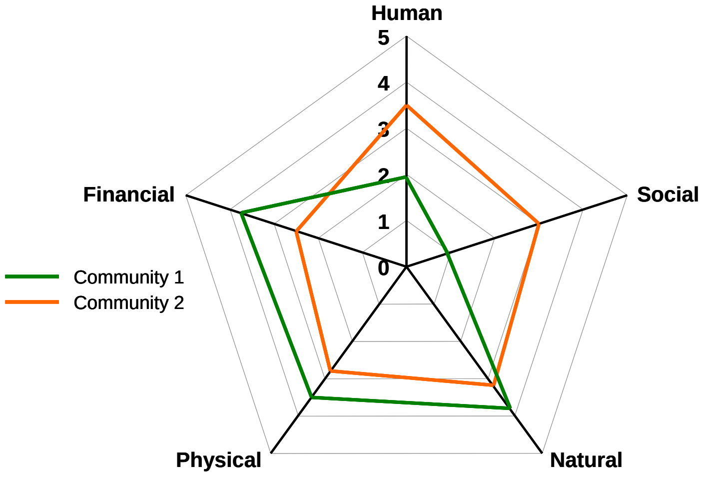

Figure 10.2. Adaptive capacity depends on the balance between the five capitals from which rural livelihoods are derived (after Carney 1998). This example could represent the relative adaptive capacity of two households, regions, industries or even nations. In the example provided Community 2, despite a lesser endowment with natural and financial resources, is likely to be more resilient given its greater level of human and social capital and more even balance between the capitals.

An important strategy for generating both current and future livelihoods is transforming one form of capital into another. Natural capital, for example, can be transformed into physical and financial capital via economic activity, while financial, social and physical capital can be transformed into human capital by increasing access to education. As discussed by Ellis (2000: p. 34), financial assets are not productive forms of capital in their own right, but contribute to current and future adaptive capacity through their convertibility into consumption or other assets.

Methods and scale of livelihoods and adaptive capacity analysis

The ability of the SRL to be applied across a range of scales, starting from the individual household through to the community, village, district and ultimately national levels constitutes one of the major elements of attractiveness of the framework. This is because the basic framework built around the five capitals and the use of indicators to rank or score the endowment with assets underpinning each capital is scale invariant. What is scale dependant is the technique of obtaining data to derive values for the indicators.

At the household or community level, a range of techniques are commonly employed:

- **Participatory Rural Appraisals** (PRA) – these are extensively used in the development area and are particularly useful in identifying underlying issues and problems faced by communities. They are useful in contextualising the local setting and provide guidance on how to frame question around livelihood options. PRA were formerly known as Rapid Rural Appraisals (RRA).
- **Structured interviews** – this is a process of gathering detailed information from key informants (sometimes referred to as key informant interviews). The surveys are structured around a particular topic and the questions might be open-ended or closed-ended, but the interviewer needs to be well trained to elucidate the correct information. Data needs to be coded and analysed appropriately.
- **Focus groups discussions** (FGD) – these can be operated at a few different scales (small groups of 4-5, medium groups of 10-12, or larger groups). These discussions follow a pre-determined topic, but as discussions can easily be side-tracked, it is important for facilitators to keep the topic of discussion on track. Many FGD can be completely side-tracked because participants have alternative agendas they wish to pursue.
- **In-depth interviews** – these can be conducted through open discussion or by a few lead questions, but can be used to add value to other types of data, for example, FGDs. These need to have a specific purpose.

At the provincial[6] or national level, these techniques are not feasible and have to be replaced by other data sources. The approach at this level is designed to gather secondary data at a provincial or national scale to identify a set of relevant indicators to determine the adaptive capacity of provincial or national levels. Typically these are obtained from existing national or provincial level census data or recurrent statistics. Often data also has to be sourced from national collections or from universities on socio-economic issues from household censuses/surveys and cross sectional data. Other sources of data should also be considered, such as grey literature (reports, documents, records, theses etc), which include context specific information. There is much international-level data available, but much is not useful because it is not directly relevant to what rural households consider is important to them in the context of climate change.

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[6] *'Provincial' is used here to delineate an approximate sub-national geographic extent. In Laos and Cambodia in coincides with actual Provinces, whilst in Bangladesh and Andhra Pradesh it is closer to Districts*

10.3 Pilot studies in India and Bangladesh to test the utility of the SRL framework to assess adaptive capacity

10.3.1 General approach and methodology used in the pilot studies

Two case study villages were selected in Andhra Pradesh and in Bangladesh respectively, in collaboration with partners in both countries to assess the utility of the SRL in assessing adaptive capacity. In Andhra Pradesh, the pilot study was carried out by Dr Ratna Reddy and his team[7] from the Livelihoods and Natural Resource Management Institute (LNRMI), an independent research organisation in Hyderabad associated with another ACIAR project (LWR/2006/072) and with a strong history in livelihoods analysis. To create additional synergies, the two villages selected in Andhra Pradesh were the same villages being studied by the ACIAR project on ‘Assessing the feasibility of farmers managing climate related crop production risk in Andhra Pradesh, India’ (LWR/2006/073), and the project leader of this project Dr Raji Reddy and his ANGRAU[8] team facilitated access to the villages and participated in the pilot study.

In Bangladesh, the SRL team consisted of Dr Iqbal Khan, Ms Sharmin Afroz and Ms Himu Bain, currently SRL consultants collaborating with the ACIAR project on wheat expansion in Southern Bangladesh (LWR/2006/146). Villages in this case were selected on the island of Bhola, one of the three main intervention areas of this ACIAR project.

The methodology for both India and Bangladesh was to run an exposure training session with the respective team leaders and the key field staff (enumerators), to field test the survey techniques in one or two villages with a range of stakeholders (farmers), and to reflect on the process and plan the main field component for the pilot study as part of this scoping study. The pilots commenced in March 2009 with the main field survey component occurring through May and June 2009 and concluding in August 2009. Reports on both pilots are provided in appendices 5 and 6, sections 13.5 and 13.6.

10.3.2 Household/community level analysis

Two types of household/community level survey techniques were selected that can work together and which were complementary:

- Self assessment through Focus Group Discussions
- Short case studies (in-depth interviews)

Outputs from the self-assessments were used to help identify individuals for use in the short case study (in-depth interviews) assessments to provide richer context information and improve our understanding of the situations. These approaches are complementary ways of capturing the livelihood outcomes.

Self-assessments

The self-assessment methodology was designed to induce rural households to self-assess their own levels of adaptive capacity. It explicitly assesses the adaptive capacity of rural households to climate change, but is modified from a process developed and used by Brown *et al*. (in press). Data to inform this were collected via workshops with key informants that represented important categories of farming households. It was important to develop an appropriate framework and to consider whose adaptive capacity and adaptation to what? Where possible existing farmer networks or groups were drawn upon. The aim was to run one or more workshops each with a particular type of farmer group that had been previously identified.

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[7] *Dr T Chiranjeevi and Mr B Madhusudhan*

[8] *Dr G Sreenivas, Dr Prabhu Prasadini, Dr Vijaya Lakshmi and Ms Madhavi Lata*

Resource map of village

At the beginning of the workshops, a short exercise was conducted to encourage participants to draw a resource map of the village. This was best done using large pieces of paper with pens or drawn into the dirt on the ground. The participants were asked to draw their village and identify particular physical and social features that enhanced or enabled their ability to grow their crops. This process helped to frame the discussion later when particular indicators and collective actions to improve their adaptive capacity were discussed.

Self-assessment of adaptive capacity

Through facilitated small groups, the farming household reference groups were asked to select their own locally relevant indicators for each of the five capitals in relation to how they manage their rice-based farming system for increased climate variability. Each group was asked to select a minimal set of the most important 3-5 indicators for each capital. The facilitators encouraged an evaluation of each indicator against the conceptual understanding of the components of adaptive capacity provided by rural livelihoods analysis. The common set of indicators was then populated for each farming household category using the expert judgement of the focus group members.

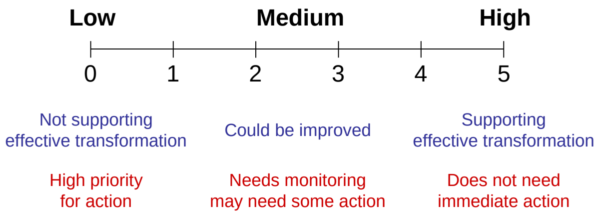
The representatives from each stakeholder type were then asked to work together as a group to derive an adaptive capacity index for the type of stakeholder type and/or community/area/village that they represented. They were asked to discuss and provide a rationale for the indicators chosen to represent each asset capital around the following three sets of questions:

1. What was the rationale for choosing this indicator?
2. Why was this indicator low or high in each community/area/village? What were the most important differences between community/area/village?
3. What were the highest priority actions for improving this? Who needs to do what?

Each indicator was scored (self-assessed) on the basis of its current adequacy for adaptation to climate change (asset transformation) in each situation (group/region). In other terms, the scoring of an indicator can be taken to represent a measure of the ability of a household to transform their farming based livelihood to adapt to climate change through asset transformation. This was expressed as the priority that should be accorded to enhance the dimension of adaptive capacity represented by each indicator rather than as an estimate of its stock (Figure 10.3). Hence a score of “5” would not imply an abundance or high level of a particular component of adaptive capacity, but rather that it would be effectively supporting adequate asset transformation to adapt to climate change. Conversely, a score of “0” would not imply a complete absence of a component, but rather that the indicator was currently not effectively supporting adequate asset transformation to adapt to climate change and therefore represents a high priority for action. Care was taken to ensure that workshop participants understood the rating system so that they scored the indicators consistently. This type of subjective scoring has limitations in terms of precision, and can run into legitimacy issues if some of the more passive participants in larger groups acquiesce to scores that they ultimately disagree with (as outlined in Nelson *et al.*, 2007). It was used in this exercise to facilitate a deliberative discussion leading to agreement over priorities for collective action to build adaptive capacity.

Data was recorded in two formats drawing on PRA tradition. Firstly, large pieces of paper were used to record the discussions in local language in rural villages in Bangladesh and India so that participants could see what is discussed; secondly, detailed notes were taken using a pen and notebook. Using a laptop computer was not considered appropriate in many of the villages.

Figure 10.3. Each component of adaptive capacity was scored on the extent to which it would be effectively supporting adequate asset transformation to adapt to climate change, and the priority for action to enhance it. A low value (a score of “0” or “1”) would mean that a component of adaptive capacity was currently not effectively supporting adequate asset transformation to adapt to climate change and therefore received a high priority for action. An indicator would be judged as effectively supporting adequate asset transformation to adapt to climate change (a score of “4” or “5”) if no immediate action to enhance it was required.



Moderation and identifying common priorities for action

The final session of the workshop was designed to moderate the ranking of adaptive capacity across the whole area. Common priorities for building adaptive capacity were then explored in order to agree on recommended collective action between the different stakeholders.

The self-assessments were designed to identify particular indicators within the five capitals that were considered important by the stakeholders in terms of adapting to climate change. Through the workshop process practical ideas for action were identified to improve the participant’s capacity to adapt to climate change.

Short cases (in-depth interviews)

The self-assessment process described above provided a collective view of the relative importance of indicators and overall asset endowment for each farmer category group. The purpose of the in-depth interviews was to understand how individual farmers adapted to climate change and how they transformed their assets/stocks to make decisions about household livelihoods. In particular, it was important to understand the motivations for asset transformation and how farmers were able to cope using a range of different strategies (eg diversification or intensification). The emphasis was on how farmers had tried to cope with changes that they had observed over the last 10-15 years. The in-depth interview approach was designed to reveal how empowerment could be improved.

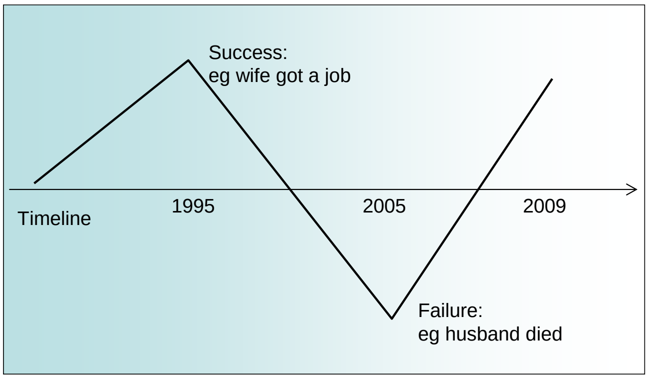
The in-depth interview essentially used a key informant interview process, but was designed to collect a range of information to provide further depth about asset base and potential usage. The interviews were conducted according to three case study types, with the aim for at least two people (key informants) from each case type. The participants for the in-depth interviews were selected from participants from the self-assessment for each farming household category.

The three case types were:

1. Successful adaptation (likely to have a balanced set of assets);
2. Coping adaptation (unbalanced, but able to transform assets, e.g. through intensification); and
3. Not coping adaptation (not well balanced, and assets declining/failing).

There were two steps in the in-depth interview (timeline analysis and narrative). The first step was designed to collect information about the timeline of the stakeholder in terms of climate change adaptation (develop a timeline to highlight “golden times” or success and failures and find out why this happened in terms of their life, perhaps identify the year). An example is shown in Figure 10.4.

Figure 10.4. Example of a timeline showing some important events during the lifetime of the key informant. These important events may constrain or enable the ability of the informant to manage their farm when considering adaptation with climate change.



The second step was designed to involve a series of questions about their ability for asset transformation to develop a narrative of their own story. The questions were based around:

- What is the reason for their success?
- What is the reason behind them coping?
- What is the reason why they are not coping?

The idea was to pick up information about the driving forces that enabled the stakeholders to cope or not, and to try to understand their ability. What are the opportunities and constraints that enable them to transform? Some of the key driving forces may include health, training and education. Data/information was collected by writing down notes (detailed if possible) to form the bases of a story (not more than 1½ pages in length).

10.3.3 Secondary data at a national level (top-down approach)

In addition to the household level assessments the type, extent, and ease of access of data available to help inform a provincial or national measure of adaptive capacity was also determined. This was conducted along the lines of R. Nelson *et al*. (2007) who assessed the potential utility of Australian Bureau of Statistics (ABS) data to map the adaptive capacity of Australian land managers for natural resource management (NRM) policy. The approach used by Nelson *et al*. (2007) was to identify nationally consistent data collections conducted by the ABS that were relevant to rural land managers, and assess whether those collections provided indicators of the five capitals from which rural livelihoods are derived (human, social, natural, physical and financial capitals). A key challenge was to select data that were consistent with the conceptual framework used to define adaptive capacity, and that included landholders in their target population. The aim was to identify data that was currently available with minimum expense and effort, had been collected consistently in the past, and that data contributed intuitively to the definition of adaptive capacity using rural livelihoods analysis.

In their Australian based study, Nelson *et al*. (2007) identified a range of indicators for each of the five capitals. For each potential indicator, they described what the variable was, the rationale for including such a variable, the scale at which the data were collected, and the source of the data. They went on to consider data issues relating to the nature of the indicator, the target level of the data, availability of the data, and whether it had previously been collected (Table 10.1). It was considered appropriate to use this general approach in conducting an initial assessment of the potential indicators available to construct a national-level adaptive capacity index for India and Bangladesh. Part of this assessment was to consider access, availability, and cost associated with obtaining the data.

Table 10.1: Example of a template to collate metadata characterising data to inform measures of adaptive capacity of rural households at national or provincial levels.

Indicator	Variable	Scale	Source of data	Nature of indicator	Target level of data	Availability	Last collected

It was not always possible to find adequate and appropriate data for all capitals. Some data were not available. Further discussion of this is provided in the results section below. An important consideration was the scale at which the data was available. It was more appropriate to obtain provincially-specific data rather than national-level data, but this was not always available.

10.3.4 Key results from the pilot studies

The key findings and results from the pilot application of the methodology to assess the adaptive capacity of farming households to increased climate variability are presented here. Full reports from the pilot studies in India and Bangladesh are provided in appendices 5 and 6, sections 13.5 and 13.6.

There were some slight differences in approaches used in each of the countries. For example, because of the different mixes of land holder types and social categories (castes), the structure of the workshops in the two countries was slightly different. This did not affect the overall outcomes and findings from the self-assessment workshops, but care is needed to interpret any differences in response between the different groups. Also, an additional household survey was conducted in India. The findings from that survey are not summarised here, but will be made available in a forthcoming, separate volume of this study.

Overview of villages and stakeholders

The population size, number of households, population/household, geographic area and net sown area were all larger in Bangladesh than in India (Table 10.2). The average farm size was smallest in Diderullah in Bangladesh, followed by Bairanpalli in India and Sachia in Bangladesh, with the largest average farm size in Srirangapur in India. Rice (rainfed and irrigated) were important crops in all villages, but other crops were grown also.

A range of landholder types and social categories (castes) were represented at the eight self-assessment workshops that were held in India in the two villages (Table 10.3). The representation was proportional to the social categories profiles for each village. There were few OC (Other Caste; see footnote in Table 10.3) large farmers present at their workshop, but there are very few of them in the village anyway.

In Bangladesh, there was also a good representation of the different classes of landowners.

Table 10.2: Basic village profiles for each of the four villages where the self-assessment workshops were conducted in Bangladesh (Sachia and Diderullah villages), and Andrah Pradesh India (Bairanpalli and Srirangapur villages).

Category	India		Bangladesh	
	Bairanpalli	Srirangapur	Sachia	Diderullah
Union			Alinagar	Charkhalifa
Upazila/Mandal	Hasanparthy	Kondurg	Bhola Sadar	Daulatkhan
District	Warangal	Mahbubnagar	Bhola	Bhola
No. of households	587	187	880	1068
Total population	2400	923	6040	7747
Male	1250	473	3040	3931
Female	1150	450	3000	3816
Population/household	4.09	4.94	6.86	7.25
Total geographical area (ha)	283.3 (700 ac)	197.9 (484 ac)	458	336.5
Net Sown Area (ha)	242.8 (600 ac)	150.5 (372 ac)	324	300
Average farm size (ha/HH)	0.48 (1.19 ac)	1.05 (2.59 ac)	0.52	0.32
Major crops grown in Kharif -1	Maize, cotton, paddy	Maize, cotton, paddy, castor, millet sunflower	D-Aus[A], vegetable	Aus, jute, vegetable, green fertilizer
Major crops grown in Kharif -2			T-Aman[B], vegetable	T-Aman, vegetable
Major crops grown in Rabi	Vegetables, paddy	Vegetables, paddy	Pulse, wheat, chilli, sweet potato, ground nut, vegetable, spices	Pulse, vegetable, wheat, potato mastered, spices

[A] *D-Aus is early wet season rice (Kharif I)*

[B] *T-Aman is monsoon wet season rice (Kharif II)*

Table 10.3. Summary of number of participants for each self-assessment workshop by landholder type for workshops conducted in India.

Country	Village	Landholder type [C]	Number participants
India	Bairanpalli	SC Small Farmers	4
		BC Small Farmers	15
		OC Small Farmers	8
		BC + OC Medium Farmers	9
India	Srirangapur	SC Small Farmers	10
		BC Small Farmers	14
		BC Medium Farmers	4
		OC Medium Farmers	2

[C] ***SC = Scheduled caste****. These communities are at the lowest rung of the social ladder and have constitutional provision of reservations in educational institutions and public sector jobs (15 percent).*

BC = Backward castes. *These communities are at the middle of the social ladder. These communities have reservation in educational institutions and public sector jobs. However, the extent of reservation varies from state to state depending on the proportion of the community in the state population.*

OC = Other Castes*. These are at the highest rung of the social ladder.*

Key livelihood indicators

The indicators that were selected by participants in both India and Bangladesh fitted the Ellis (2000) rural livelihood framework suggesting the overall self-assessment process worked well in each of the countries (Table 10.4). Some of the indicators chosen by participants were broadly similar between the two countries, while other indicators were country-specific. Common elements across both countries for Human capital were health and experience, for Social capital these included farmer cooperatives and social cohesiveness/connections with neighbouring farmers, for Natural capital were soil/land quality/fertility and water resources, for Physical capital were farm machinery/water pumps, and for Financial capital were savings. The country-specific indicators included migration, cyclone shelters and incentives for eco-friendly farming.

Table 10.4. Summary of indicators used to assess the adaptive capacity of farmers derived during self-assessment workshops in India and Bangladesh.

Capital	India	Bangladesh
Human	Age/health Training Climate change awareness Farming experience	Health Education Experience
Social	Connections in administration Farmer cooperative group (Raithu Mitra Sangham) Self-help groups (SHGs) Connections with neighbouring farmers Political connections Migration	Access to information Cooperative Social cohesiveness Membership of formal group
Natural	Soil/land quality Ground water High intensity agricultural practice	Water bodies Trees Livestock Soil fertility
Physical	Open wells / bore wells Canal Water pumping motor	Extension services Road Farm machinery Cyclone shelter
Financial	Agricultural investment Agriculture income Incentives for eco-friendly farming Savings Debt	Low cost of agricultural input Government aid Loan Savings Alternative income sources

Comparisons of villages and countries

An effective way to depict the scoring results is the use of spider webs or pentagons, as shown in Figure 10.5. The overall self-assessment of capital assets was generally lower in Bangladesh than it was for India (Figure 10.5). The overall variation in self-assessed scores for capital assets was greater at the two pilot villages in India, but very similar for the two pilot villages in Bangladesh.

All levels of self-assessed capital assets at the two pilot study villages in Bangladesh were rated as low/moderate. It is therefore likely that farmers in both of these villages were constrained in their ability to manage for increased climate variability across all assets. Natural capital and Human capital scored marginally better than the other capitals. However, the ability of farmers to transform capital assets might be constrained by the relatively low scores for Social, Physical and Financial capitals. Farmers in Bangladesh apparently have few options for transforming capital assets to improve their adaptive capacity to better manage for increased climate variability. A critical issue faced by farmers in these two villages were the severe climatic events that shape their livelihoods, such as the cyclones that destroy their crops, but these events also damage their houses and can cause injury to people. This in turn impacts immediately on their food resources and they often have to take loans which they struggle to repay, especially when they have no immediate income from their farming activities, which can draw them into a poverty trap.

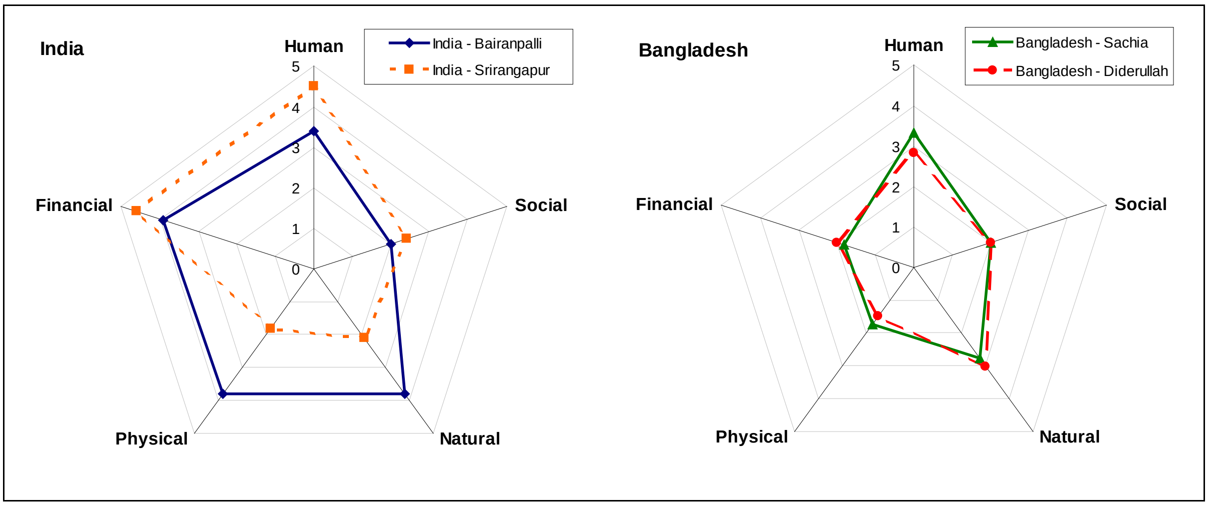


Figure 10.5: Summary of comparison of elements of adaptive capacity from self-assessment workshops for pilot study villages in India (Bairanpalli and Srirangapur) and Bangladesh (Sachia and Diderullah).

There were marked differences in the capital assets of the two villages in India. Bairanpalli scored higher for Natural and Physical capitals, whereas Srirangapur scored higher for Human, Financial and marginally higher for Social capital. The self-assessed capital assets for Bairanpalli village were all scored moderate to high except for Social capital. In this village, it is likely that the farmer’s ability to manage for increased climate variability would be constrained by the relatively low levels of social capital in the village, despite the relatively moderate to high scores for the other assets. Social capital is an important attribute in successful farming in highly variable environments which are prone to droughts. Farmers need to have good access to information and support from other farmers in difficult times. Conversely, in Srirangapur village, the self-assessed capital assets were scored high for Human and Financial capitals, but scored low to moderate for Social, Natural and Physical capitals. In this village, the ability of farmers to manage for increased climate variability would be constrained by the lack of Social, Natural and Physical resources available to the farmers.

The differences observed in the self-assessed capital assets between the two countries highlight the different farming systems and social systems as well as overall levels of adaptive capacity. This was reflected in the selection of indicators to represent the capitals.

Collective actions to improve adaptive capacity

As part of the self-assessment of capital assets, participants at the workshops were asked what could be done to improve the particular levels of each indicator. This was expressed as collective actions designed to increase their ability to manage for increased climate variability. Practical actions were identified at the self-assessment workshops in Bangladesh (Table 10.5).

Several suggestions were raised to enhance the adaptive capacity of farmers, many of which the community could not do on their own. This means that multi-faceted cross-sectoral partnerships of government, NGO and community are needed. However, the more important observation in relation to Table 10.5 is that the respondents did not list changes to cropping systems and water management as an action to assist in adapting to climate variability (and change). In hindsight, it would have been more informative if a similar table had been constructed to capture the adaptation options identified by individuals, in addition to those identified by the collective.

Table 10.5: Collective actions identified by workshop participants to enhance the adaptive capacity of farmers in Bangladesh.

Capital	Collective actions required to enhance capital
Human	• Promote sharing with other farmers. Share the experiences with others when someone is successful in some farming activities • Training on what is expected in the near future and how they can efficiently face that. The DAE and NGO people can provide the training. • Improve regional education services. Establish government primary and secondary school within the village. Increase number of skilled teachers according to students to ensure quality education. • Minimise the cost of education so it is available to poor people. • Design the education curriculum so that it is sensitive and inclusive of local problems and should include adaptation strategies across personal, family and to social levels. • Provide health facilities in low cost up to remote area.
Social	• Improve community trust and respect through improvement of education. • Improve management of conflicts. • Increase the participation in community activities. • Increase the involvement of villagers in formal and informal organizations. • Avoid political issues when considering social issues and problems/conflicts. • Establish the community base organization.
Natural	• Provide additional training and exposure for appropriate use of organic fertilizer. • Training on maintaining and improving soil condition by the DAE and NGO. • Improve in infrastructure (veterinary hospital, doctor and medicine) up to village level. • Train the villagers so they can identify the diseases of livestock and can take the initial steps. • Provide low interest loans so that the poor farmers can afford to rear more cattle. • Increase awareness training about the usefulness of trees and the government and NGO can supply free sapling. • Encourage the use of road side and Khas land for plantations. The villagers have to be given ownership of a certain proportion of trees. The participatory approach will lead to better management of trees. • Dredge the rivers and canals to improve water flow and reduce flood incidence.
Physical	• Establish cyclone centre within the village. • Reduce the high price of farm machines through the farmer cooperative. Cooperative will own the machines. The member of the cooperative will use the machineries at a low price. • Provide training on using the modern equipments. • Improve roads networks up to village level. • Improve education and infrastructure for getting access to information.
Financial	• Provide the facilities of the formal financial institution up to village level. • Rethink the Government financial institution policies to enable support for all categories of people. • Inspire the cooperative system as the farmers can resolve their problem by their own. • Reduce rate of interest by NGO by cutting their operational costs. • Provide agricultural input at subsidised cost especially after natural disasters.

Short cases (in-depth interviews)

The main objective of the in-depth interviews was to gather information that would provide wider context to help analyse and improve the understanding of how farmers manage for climate change. In the in-depth interviews, the first step was to collect information about the timeline of the interviewee in terms of how they have made changes over the past 10-15 year in response to various problems that they faced, including how they adapted to climate change. The second step was to ask a series of questions about their ability to adapt, that is, how they were able transform their assets in response to a problem and to maintain a livelihood. This information was gathered to develop a narrative of their own story.

The experience from India and Bangladesh was that the narrative was sometimes lost during the course of the interview. In a “narratives” approach, the researcher’s responsibility is to be a good listener and the interviewee is a storyteller rather than a respondent. To tell something means to relate an ordered sequence of events to listeners, the narrator selects certain events and arranges them as to from a whole; with beginning, middle and an ending. Any natural calamity constitutes a disruption, a discontinuance of an ongoing life and changes the very foundation of the livelihoods. Narratives provided a context that encompasses both climate variability events and surrounding life events and recreates a state of inter-relatedness. The interview may sometimes become too complex and too deep, and so it then becomes difficult to easily summarise. Further practical experience for field staff is required to refine their in-depth interviewing skills.

Despite some of these issues, the short case studies extracted a useful level of information from the respondents. It was very helpful when other members of the family were also present to give their inputs. However, a more structured questionnaire, containing details of the questions to be asked in sequential order could have been much better in gathering further information. It was also suggested that these studies be re-named “in-depth interviews”.

Overall assessment of adaptive capacity at the local level

Overall the results of this pilot study show that farmers in the surveyed villages in both India and Bangladesh are constrained in their ability to manage for increased climate variability, with much variation in the levels of capital assets associated with how farmers consider themselves to be coping, but also the balance of capital assets between the five capitals. There are a few indicators as selected by the workshop participants that tend to indicate how farmers to cope with increased climate variability, but these seem to be confounded by a range of other issues identified. An overriding factor, particularly in Bangladesh, was the impact of severe weather events such as cyclones. However, the process did yield a range of collective actions farmers felt they could undertake as a community with outside support from government and non-government organisations (Table 10.5).

In India, there was no set pattern in terms of levels of capital assets. Traditionally farmers owning more land are treated as better off, but as our analysis has revealed even the socioeconomically backward groups may possess higher levels of a particular capital, which enhances their potential to deal with climate variability. This holds good even across the villages with differential resource endowments.

In Bangladesh, the site level data disclosed farmers’ level of adaptive capacity to climate change in terms of five capitals of livelihoods. The human capital depends not only upon the amount of labour available to a social group, but also the quality, capacity, education and health of individuals. Improvements in health and education in remote communities are essential to building human capital and hence are relevant to building adaptive capacity. Physical capital is a key factor in promoting better livelihoods for remote communities, but is variable in quality and reliability. The lack of affordable transport, and energy, secure shelter, adequate water and sanitation and access to information are core dimensions of poverty. Inadequate road links and transport prevent access to markets which again have an influence on the level of adaptive capacity to climate change. Financial capital, whether savings or income, is versatile in that it can be applied in different ways and to serve a range of objectives. Building financial capital in remote communities is constrained by limited access to financial services. The diversification of income sources appears as a survival strategy in rural areas which are constrained through the low endowment of other capitals. Rural communities are often characterised by informal networks of social obligation. People are frequently able to draw upon reciprocal ties relating to family, kinship friends and neighbours which provide them with a higher level of social capital, which offers the potential for people to improve sharing of knowledge and resources and to do this in a way which is efficient since it reduces the costs of transactions.

Secondary-level data

In Bangladesh, the Bangladesh Bureau of Statistics (BBS) collects a broad range of data that could potentially be used in constructing a top-down adaptive capacity index (Table 10.6). Potential indicators were found for each capital except for social data, where there is little available in the BBS collection. There is no information on norms, trust, and reciprocal relationships. The only social data BBS collects via the statistical year book is whether the person surveyed is a member of a cooperative.

Table 10.6: Summary of National-level data on potential indicators and variables for an index of adaptive capacity from data collected by the Bangladesh Bureau of Statistics. The data represented here are specifically related to the Bhola District of Bangladesh, where the two pilot study villages were located.

Capital	Indicator	Variable	Value
Human	Education	Adult literacy rate	37%
		Highest level of education	Primary = 55% Secondary = 29% Higher secondary = 13% Degree + = 3%
	Health	Age	48% in productive age
		Hospital facility	1. Hospital = 1 (100 bed) 2. Thana health complex = 7 3. Union sub centre = 7
	Size of household and livelihood option	Average number of family members	5.24
		Sector wise occupation	1. Agriculture work = 21% 2. Non farm activities = 16% 3. HH activities = 33% 4. Not in workforce = 30%
Social	Bridging	Membership of cooperative	6%
Natural	Land productivity	Crop intensity	211%
		Crop yield (kg/ha)	Kharif - 1(Aus): Local = 1230, HYV= 1568 Kharif - 2(Aman): Local = 1529, HYV= 2070 Rabi season: pulse = 534
		Water sources for agriculture production	Pond, canal
	Livestock	Number of households with livestock	48%
	Forestry	Area of forest	13%
Physical	Household facilities	Safe drinking water	47%
		Sanitation	27%
		Electricity connection	9%
	Road networks	Condition of road	Paved road = 7%
	Irrigation facilities	Area of land under irrigation	18%
Financial	Income and capacity to save	Savings	55%
		Average monthly income (Tk)	0-4000 = 45% 4001-8000 = 31% 8000+ = 24%
		Income source	Agriculture = 63% Non-agriculture = 37%
	Loan	Access to commercial bank	30%

Further work is required to develop a comparative adaptive capacity index at this level. The data available can be extracted at the district level (Bhola district) and it is not possible to obtain finer resolution of the data. It would be possible to compare the Bhola district to other districts or to Bangladesh as a whole to obtain a comparative assessment of adaptive capacity. One weakness of the BBS data is that there is little social capital data, so alternative data sources would need to be explored. Furthermore, a range of issues also need to be resolved regarding the scale/target level of data (e.g., individual, household, community etc.) and how these data could be aggregated.

Table 10.7: Summary of National-level and community data on potential indicators and variables for an index of adaptive capacity from data collected by the Census Department, Government of AP and from local village information. The data represented here are specifically related to each of the villages (Bairanpalli and Srirangapur) in Andhra Pradesh, India.

Capital	Indicator	Variable	Value (Bairanpalli & Srirangapur)
Human	Literacy rate	Literacy rate	39.4% & 33.3% (State average = 60%)
	Size of household and livelihood option	Number of households	587 & 187
		Number of persons	2400 & 923
		Sector wise occupation	Agriculture = 37.2% & 49.7% Agriculture labour = 35.9% & 29.1% Other services (artisans) = 26.9% & 18.8%
	Infrastructure	School	Yes & yes
		Health centre	No & no
		Safe drinking water	Yes & no
Social	Social networking	NGOs	0 & 0
		Farmer associations (RMS)	22 & 0
		Self help groups (SHG)	32 & 8
		Village federations	0 & 1
		Youth association/groups	0 & 1
	Social category	Scheduled Caste (SC)	13.6% & 29.9%
		Scheduled Tribe (ST)	0.2% & 0%
		Backward Caste/Class (BC)	69.2% & 59.5%
		Other / Forward Caste (O/FC)	17.0% & 10.6%
	Infrastructure	Community hall	No & no
		Agriculture Information Centre (Agro-Met)	Yes & yes
		Community hall	No & no
Natural	Agricultural production	Net area sown	85.7% & 76.8%
		Average farm size (ac/HH)	1.19 & 2.59
		Area irrigated	70% & 20%
Physical	Irrigation facilities	Tanks	3 & 6
		Open wells	100 & 14
		Bore-wells	0 & 64
		Canal	1 & 0
	Infrastructure	Communication (telephone/ mobile/ TV/ newspaper)	Yes & yes
		Grocery and daily needs shop	Yes & yes
		Markets	No & no
		Transportation	Yes & yes
		Bank	No & No
		Electricity (domestic and agricultural)	Yes & yes
Financial	Income from agriculture	Farmers solely dependent on agricultural income and animal husbandry	30% & 17%
	Non-farm activities	Farmers who undertake non-farm activities to supplement agriculture income	70% & 83%

A different approach was used in India. A range of sources of data were explored to obtain information against each of the capitals (e.g. census collections), but some information was gathered from the communities themselves. The information presented in Table 10.7 has been reorganised from that presented in the pilot study reports. Nevertheless, there appears to be some relatively useful information available, but further exploration of data, particularly from the national or state level would enhance this information. It would then be possible to do a comparison of Andhra Pradesh against India as a whole, and also potentially to compare the adaptive capacity indexes between India and Bangladesh.

Gaps and overlaps

At this stage it is not appropriate to analyse these secondary data any further. To do so would require additional national level data for Bangladesh and further refinement of secondary data is required for India. An analysis of the adaptive capacity of farmers conducted at a district or state level using data in comparison against national figures would reveal the overall adaptive capacity and particular indicators that might enable or constrain the ability of farmers to manage for increased climate variability. Results from such an analysis could then be used to compare and contrast the findings from the self-assessment of capital assets by the farmers to determine gaps and overlaps between the two approaches. This approach would allow a higher level analysis of some of the drivers behind how farmers might be able to cope with increased climate variability or climate change. For policy purposes it is important to understand these differences and formulate implementation strategies accordingly.

10.3.5 Assessment of the SRL as a process

The pilot studies were conducted to explore the utility of the SRL to assess adaptive capacity in the context of primarily subsistence farming households. The approach was specifically designed around methods to assess the baseline adaptive capacity of samples of farming households in India and Bangladesh and their ability to adapt to present climate variability and future climate change. Some of the key issues in relation to the SRL as a process were identified during the pilot studies and are discussed below. An evaluation from a methodological perspective and suggestions on methodological improvements in the use of SRL to determine adaptive capacity are covered in the section 10.3.6.

Overall, the approach used in both pilot studies confirmed that the self-assessment based SRL methodology proposed is a useful means to engage with farming households on the topic of adaptation to climate variability and change. However, while much of the process worked very well, there are some modifications required to fine-tune the interview, survey and facilitation techniques in response to issues that arose during the pilot testing of the work in both India and Bangladesh.

General comment from Indian perspective

As far as the adaptability of SRL framework in the context of climate variability is concerned, there is a need for local tailoring of the method. The tools for data generation (FGD, self-assessment workshop, in-depth interviews) need to be designed specifically to suit the local situations. The pilot study, though located in the villages where climate stations have been set up and run by the local communities under ACIAR project LWR/2006/073, took effort to find entry points that are clearly understood by the communities and that led to meaningful participation. This is a learning process. Once these tools are designed and tested the outcomes would be effective and insightful. However, the self assessment approach may not be effective in some communities that are less exposed or articulate. There is a need for some mix of self assessment elements with more directed facilitation following a prescribed structure and set of researcher-identified indicators. Also, in India the timing of the pilot study had an impact on the availability of farmers because the sessions clashed with the beginning of the monsoon season when farmers were more focussed on farm activities.

Bangladesh experience

The learnings and issues encountered in Bangladesh are typical of similar participatory processes and are probably not unique to the SRL approach. With sufficient time and preparation, these issues can be resolved reasonably well through experienced facilitators.

Courtesy bias

Some participants could not express themselves adequately. If one person was hesitant, or did not explain or illustrate fully, others might take over in drawing conclusions, or even to encourage exaggeration depending on the topic of experience and the position of the participants in the village. Participants who could not express their own experiences in a group situation were quite different when talked to individually, particularly when they were interviewed for short cases. In a heterogeneous session (comprising farmers from different socio-economic categories like owners, owner-tenants, tenants, and landless labourers), people that are related to each other through patron-client arrangements often did not express their opinions or raise their voices (e.g. landless vs. land owners). This follows the broader custom that subordinates should show deference by keeping silent in the presence of those on whom they depend.

Audience effects

The organized focus group discussions (FGD) were continuously interrupted either by the new participants or by curious audiences which affected the behaviour of participants throughout the whole exercise. The participants became hesitant to speak up or share their own experiences about climatic hazards in the presence of the diverse audience. It was also observed that the cultural composition of the group affected the session. This affected most the group exercise with women. No men were accepted in these sessions, and only women facilitators ran them. However, they were then surrounded by curious men and women making the situation rather inhibitory for open discussion. Moreover, during women FGDs, the women brought in their children, which caused some commotion and hence distracted the focus of participants. A certain percentage of the participants, in both male and female FGDs remained passive, while only a few took the dominant role.

Time effects

The FGD sessions were organized during the day which is working time both for men and women group. Focus group discussions comprising men were heterogeneous (depending on whether farmers were owners, owner-tenants, tenants, and landless labourers), whereas women FGDs are rather homogeneous in terms of household work (cooking and caring children). Long sessions are not feasible for effective participation. It was found that in most cases participants could not continue their participation till the end of the session. Some of the participants who were involved in the session did their work at the same time. This was not very effective in terms of gathering information or for understanding the dynamics and complexity of how farmers addressed vulnerability and the coping mechanisms they applied.

While the FGD process has limitations, it proved useful in that it identified actors and issues which were later followed up through short case interviews. Thus, along with particular information gathering and analysing, the exercise helped identify different categories of households reflecting different livelihood contexts. Experiences such as this taught the survey team to devise different strategies and techniques for undertaking the FGD exercise.

Comments on the short case process

The short case studies could be renamed as ‘in-depth interviews’ so that they have a better scope of collecting information and its narratives. A pre-prepared semi-structured questionnaire could be used to collect wider information about the asset-base, livelihood options, climatic hazards faced, losses incurred and the adaptation strategies used by the respondents. The participants for this exercise should be selected with care so that it is possible to cover people at different coping stages, rather than randomly selecting people who are easy to access.

10.3.6 Evaluation of the SRL as a methodology to determine adaptive capacity

Although the scoping study was only able to allocate comparatively limited resources and the pilot studies operated under time constraints, the methodology piloted in India and Bangladesh as part of this scoping study confirmed the general utility of the SRL framework to obtain information on community and farming household level adaptive capacity. As the preceding sections and the more detailed information contained in the pilot study reports show, the combination of FGD and in-depth interviews yielded much detailed and useful information, both of contextual nature as well as specific to the five capitals and indicators to assess the endowment with these capitals. The assessments in both countries clearly indicated that adaptation to climate variability and climate change will have to be undertaken in a livelihoods context rather than focussing on individual sets of technologies, as many of the responses demonstrated.

Despite the possibility of using secondary data to assess adaptive capacity across larger geographic entities, the pilot studies were not resourced to go beyond assessing what statistical and census data is easily accessible, which could be used to derive meaningful indicators of the five capitals and then lend itself to a more quantitative scoring. In general it appears that sufficient data probably exist, but there will be a number of problems relating to different variables being differently dated or collected at varying scales (and therefore raising questions of comparability) as well as perhaps some critical data gaps (for instance measures to assess social capital).

The comparison of the village level assessments between the two countries as well as some of the concerns of comparability of differently dated data mentioned above expose one potential major shortcoming of the methodology. Particularly in the self-assessment mode primarily used in the pilot studies, communities invariably generated indicators relevant to their particular conditions and that were meaningful to them. This empowers and increases the relevance of the approach at the local level and it generates detailed insights. However, since there was a strong focus on using the Sustainable Rural Livelihoods (SRL) framework and taking care in categorising the indicators into the five capitals (human, social, natural, physical and financial), many of the comparisons between capitals still remains valid. There still remains a potential problem when comparing secondary data of both countries, making a divergence of indicators underlying the higher level assessments even more likely. The strength of using the SRL approach is that such comparisons between villages, regions and countries can be made without losing rigour because comparisons are made at the capital level, not at an indicator level. This points to the potential utility of the SRL to allow nesting of indicators and to support a multi-scaled approach.

There was some degree of subjectivity in the scoring process. Even if the same indicators were used in different villages in different countries, their scoring might vary not because there are real differences in the endowment with capitals, but because there is no easy way of ‘normalising’ the scoring between different groups surveyed by different enumerators. An option to overcome this issue is to conduct more preliminary training and trialling of the SRL methodology with facilitators and enumerators prior to its deployment.

Further work into refining the SRL into a method capable of more consistently assessing adaptive capacity seems warranted. A possible future activity would be to consider harmonising the choice of indicators as well as finding more quantitative approaches to scoring the indicators. Ideally, one might attempt to monetarise indicators or relate them to units of effort or productive output. This however is likely to take some time, if achievable at all. In the short term and in relation to the SRL framework being used as a tool in future

ACIAR funded climate adaptation research, an additional complementary activity would be to develop a more prescriptive approach, where indicators and scoring criteria are predetermined by researchers and injected into the FGD or interview processes. This appears achievable, and would constitute a researchable issue in its own right as a critical component of any adaptation research.

An additional issue is the question of representativeness of such assessments, and the degree to which it is possible to extrapolate detailed survey results from one village or district to another. One might argue that this is more a question of sample size and stratification of sampling. However, taking a statistical approach to achieving representativeness is constrained by the comparative resource intensity such surveys demand. For instance, in the pilot studies three enumerators were required for each FGD, each FGD took 2-3 hours, and a few days were required to synthesise and write up the results. The in-depth interviews took 1-2 hours and also required time to write-up. So, approximately 0.5 to 1 week was required per village. In the lead up to the survey, there was also a need for some intensive training and prior testing of surveys.

A key mechanism to manage the shortcomings identified above will be the use of typologies. A robust evaluation of typologies will enable a more stream-lined assessment of rural livelihoods in response to climate change. The typologies approach will reduce the amount of surveys and will be a key mechanism to facilitate integration across spatial scales, as well as integration of the SRL with the farming systems components. Typologies will enable a characterisation of the different types of farmers/stakeholders/ actors in each project area and will allow an identification of potential gaps and overlaps in land manager types to determine the extent to which they are represented more broadly.

Recommended process for assessing the adaptive capacity of farmers

Based on the above considerations, the following modified process to determine adaptive capacity of farming households is proposed.

Step 1: Determination of typology

As a first step, case study sites should be selected according to a typology developed to reflect the diversity of rice-based smallholder systems in Asia. In each community, types of smallholder systems should be identified in order to determine how the particular community fits into the variety of types. Typologies should support the process of scaling-up and determining representativeness of cases in the wider national and inter-regional context and should be based on both social as well as biophysical/agronomic indicators and will represent the diversity of smallholder systems observed in the target countries. Information to develop the typologies could come from desktop reviews and expert knowledge from key stakeholders. It is also recommended that, if feasible, the types should be constructed in a way to reflect cross-country communalities, which paves the way for a general typology of Asian rice-framing systems. The novelty of such an approach consists of the fact that typologies thus far have been disciplinary, while the one envisioned here describes smallholder rice-farming systems from an integrated perspective, i.e. using social, cultural, economic, and biophysical indicators.

Step 2: Selection of groups to involve (ethnic, gender, land ownership, type etc.)

Based on the analysis of typologies, relevant groups could be selected. Participants could be selected previously through informal village visits (PRA tools like transact walk). This would be followed up with some key informant interviews to check the appropriateness of the groupings and to subsequently check for locations, venues, timings, etc, to hold small focus groups.

Step 3: Guided small focus group discussions with each of the groups (5-6 participants)

These small focus groups could be run with relatively few participants to overcome some of the problems identified during the course of the pilot studies. The focus group discussions should be held in locations where the farmers would feel comfortable and should occur at a time when they are not busy in their fields. There should be an initial open discussion about some of the constraints the farmers face in terms of increased climate variability. After a short break, an informal session would run to get an understanding of what the farmers see as their relative levels of capital assets for a range of potential indicators. As outlined above, whilst it will be desirable to retain a level of self-assessment, determination of indicators will have to be more prescriptive and guided. In effect a two-tiered approach might be taken, where a stage of formal scoring of predetermined indicators could be complemented by a stage where participants are given the opportunity to select and score what they felt were important indicators, or to suggest other indicators altogether in addition to the ones predetermined. In a similar manner, scoring should be more tightly based on predetermined criteria. As part of the discussion, the participants should be asked what they thought should be done to try and improve the overall endowment with capital assets, and consequently their adaptive capacity.

Step 4: Run in-depth interviews

Leading on from the small focus group discussions, a series of in-depth interviews could be held. Participants for this would be stratified across different land manager types and social classes. A pre-prepared semi-structured questionnaire would be used to collect greater information about the asset-base, livelihood options, climatic hazards faced, losses incurred and the adaptation strategies used by the respondents.

Step 5: Hold one community workshop to draw all together (open for all)

In order to obtain wider community feedback from a range of stakeholders, an open community workshop could be held. This workshop could be designed to expose the wider community to the results of the discussions arising from the small focus groups and the in-depth interviews. It could also seek general feedback on the indicators and scoring criteria used, to ‘ground-truth’ overall levels of capital assets and to identify possible collective actions to improve them in a manner conducive to increasing adaptive capacity to climate variability and climate change. This process would also serve as an opportunity to re-cast the discussion around how farmers have been coping with increased climate variability in recent years (say the last 10-15 years).

As the SRL is being more widely used within CSIRO’s Climate Adaptation Flagship and the newly established Sustainable Agriculture Flagship, it is planned to conduct methodology development workshops in the coming months across the various groups in CSIRO using the SRL in order to refine the methodology along the lines outlined above, in preparation for possible application in future ACIAR -funded adaptation and food security work.

11 Conclusions and recommendations

Recommendations to ACIAR in relation to future investment into farm level adaptation research were extracted from the review of the above sections, covering:

- Existing knowledge with respect to projected climate change and its likely impacts
- Key priorities and policies relevant to adaptation to climate change
- Current donor funded activities,
- Extension and agro-meteorological services in each country
- The current knowledge base with respect to farm level adaptation:

These recommendations were clustered into seven domains that are generally applicable to all four countries, followed by a set of country specific considerations. Some of the recommendations are already being addressed by ACIAR through its planned farm level adaption project in Cambodia, Lao PDR, Bangladesh and India.

11.1 Projected climate change and climate science research priorities

The review of recent studies on future climate projections indicates that there is a reasonable body of work, with a greater knowledge base existing for India and Bangladesh than for Cambodia and Lao PDR. As part of regional assessments in the Mekong Basin, there are also a number of studies conducted covering Cambodia and Lao PDR. Effectively, there are now regional climate change projections available for all four countries that take the resolution of the IPCC projections to a finer spatial resolution and allow for more geographically differentiated conclusions to be drawn within each of the four study countries.

Notwithstanding some degree of geographical variation, particularly with respect to projected changes in rainfall regimes, the general trend is for a rise in temperature, wetter monsoons and decreased dry season rainfall in most areas of the four countries studied. Higher rainfall is more often associated with higher rainfall intensities and fewer rainy days. Compounding the generally still very coarse level spatial resolution of the projections is the very high degree of uncertainty with respect to magnitude and even direction of climate change. Whilst it is generally stated that rainfall variability will also increase (more flooding, more droughts), there is less data available backing these statements. Few examples were found where projected variability is clearly differentiated from existing background variability, so that it would appear that statements concerning increases in drought incidence are also very uncertain.

Despite continuing international and national research efforts aimed at refining climate projections, unavoidably these will continue to retain a high degree of inherent uncertainty. Moreover, when considering farm level adaptation, climate projections 10 or 20 years out are well beyond the day-to-day decision making horizon of smallholder farmers in Asia, even if they were to become more reliable. Accordingly, it is recommended that:

1. Better understanding and managing for current climate variability at local scales should be considered as a more important entry point for farm level climate adaptation for ACIAR than allocating effort to refining national climate projections.

The above conclusions emanating from the climate projection work are reasonably well corroborated by observed changes in temperature and rainfall regimes in the case of India (and Andhra Pradesh) and Bangladesh, where there are good long-term climate datasets for analysis of past and present trends. An analysis of historical datasets has generally not been undertaken in Cambodia and Lao PDR due to fewer long term and generally more patchy datasets. Results of analyses of historical climate data in India and Bangladesh are generally consistent with projections, although rainfall trends probably still fall within current variability bounds. However, these analyses have tended to be rather simplistic and there is scope for a more refined analysis. Hence:

2. A more sophisticated statistical analysis of historical climate datasets should be undertaken to determine characteristics of climate variability (all four countries) and to determine/confirm trends in climate change (Cambodia, Lao PDR).

To make climate information relevant to farmer decision making not only requires more certainty in terms of temporal projections, but more importantly requires that climate projections reflect local conditions. This is challenging, but without a 'localisation' of climate variability and climate change information, there is little scope for climate projections to be used in driving farm level adaptation and farmer decision making. Statistical downscaling tools are available that may achieve a higher degree of 'localisation' than other methods (e.g. dynamical downscaling using regional climate models). However, there will still be a high degree of uncertainty associated with downscaling, as these methods ultimately inherit the uncertainty from the GCMs. Despite this limitation, it is recommended to:

3. Explore the utility of statistical downscaling methods to 'localise' climate change projections and apply these methods in regions or locations of interest and where more detailed farm level adaptation research is envisaged.

In addition to better information on local climate projections, helping stakeholders address climate adaptation will also require better communication of climate uncertainty and variability. Traditional, science based methods of determining and expressing uncertainty are mostly complex and abstract, and do not easily lend themselves to effective communication. This often leads to stakeholders disregarding uncertainty and interpreting projections as if they were predictions, thereby risking suboptimal decision making. It is therefore important to back the above recommendations with the:

4. Development of innovative ways of communicating climate uncertainty and variability, tailored to the different communication skills and needs of policy makers, government and non-government extensionists and smallholder farmers.

Most smallholder and subsistence farmers in Asia are less concerned about future projections of climate change 10 or 20 years from now than they are concerned about the short term prospect of a cropping season experiencing drought or flooding. Many decisions are made based on assumptions about how a given season will progress. This further strengthens the case for recommendation 1, although it needs to be recognised that the expectations of the likely outcome of a particular cropping season are only one of the many parameter sets farmers will consider when making decisions about farm resource allocations. Nonetheless, the provision of more reliable and timely seasonal climate forecasts would go a long way in helping farmers manage climatic risk.

In essence, using better seasonal climate forecast information would constitute an adaptation measure in its own right, irrespective of having to convince farmers about the merits of taking a longer term view on climate adaptation. In fact training in the interpretation and use of seasonal forecast information would enhance the capacity of farming households to adapt to changing climatic conditions as they arise, rather than being too concerned about what may or may not happen in the longer term.

The provision of reliable and timely seasonal climate forecasts is predicated on a robust and effective climate forecasting capability. The results presented in section 7 show that the meteorological services in all four countries generate a range of forecast products, with India having the most advanced system, and the two Mekong countries the least developed systems. While in India there is a strong capability in assessing the reliability of forecast products and continuously improving their temporal horizon to generate new forecast products with longer lead times, the reliability and hence merit of expanding the use of forecasts in the other countries is less clear cut. Before effort is expended in establishing more formal agro-meteorological advisory services in Cambodia, Lao PDR and Bangladesh, there is a need to assess the current forecasting skills. If insufficient, prospects should be assessed for improving the forecasting skills to levels where farmers are likely to place enough confidence in the forecasts to use them in their decision making. Accordingly, it is recommended that ACIAR consider supporting the:

5. Evaluation of seasonal climate forecasts currently generated in Cambodia, Lao PDR and Bangladesh with respect to their current forecasting skill and with respect to options for improving their reliability and extending their lead times.

11.2 Improving the assessment of climate change impacts on rice based farming systems

Quite extensive crop modelling has been carried out to assess the impact of climate change on major staple crops of India and Bangladesh. However, most of the modelling has tended to focus on individual process variables (e.g. temperature only with all other variables constant) or on single–crop models, not easily applied to simulating crop rotations within a farming system and for multiple, interacting variables (CO_2, temperature, water, N). Hence, the interactions between crops and the trade-offs involved are often not well captured, if at all. In most cases, the model parameterisation has also been conducted by using researcher based assumptions of average farmer practices or based on calibration data derived from controlled research station trials rather than true calibrations of farmer field practices.

While the assumption of ’average’ farmer practices and the simplification of climate scenarios in model calibrations are legitimate for generalised impact assessments and the delineation of broad response trends, there is a risk that such broad generalizations of crop responses to climate change will be misleading. They do not take account of location-specific baseline climate and soil conditions, nor do they cater for the far more subtle manipulations the farmers are likely to carry out in response to climate variations.

There is a case for refining impact modeling, but, to be more useful, this needs to be based on the analysis of farming systems rather than individual crops and it also needs to better account for the realities of farmers’ practices. Ideally, such modeling would also be able to draw on more ‘localised’ representations of climate variability and change as suggested in recommendation 3. It is therefore recommended that to generate more meaningful impact assessment information:

6. Future impact assessments need to better reflect local conditions of farming systems and to the extent possible take into account ‘local’ climate variability and climate change.

An additional shortcoming of the impact modelling carried out to date is that in most cases this has tended to focus on risks and potential negative impacts of climate change. Yet in a number of studies modelling results suggest that climate change may also lead to improved productivity. Given that in many areas climate change projections are pointing towards increased precipitation, it is quite plausible that in conjunction with increased levels of atmospheric CO_2, those crops less affected by temperature stress will in fact perform better. Hence, rather than focussing solely on risks:

7. More emphasis should be given on assessing opportunities and avenues to maximise positive impacts of climate change.

A major gap in the impact assessment modelling reviewed in section 4 of this study is the lack of data about impacts of climate change on productivity of livestock components of farming systems. Whilst it is conceivable that heat stress and changes to air humidity are likely to affect animal performance directly, little evidence was found for this. It seems there is a general lack of systematic, modelling based impact assessment of climate change effects on livestock productivity in the four countries studied.

Dairy animals in India and Bangladesh are likely to be the most sensitive to changes in temperature and humidity, but possibly the indirect flow on-effects from reduced feed production as a result of changes to crop productivity might be more severe than the direct impacts in some areas. In view of the fact that animals are a significant component of most of the rice based farming systems in many areas of all four countries and given that the rearing of animals is seen as one of the main adaptation options available to smallholders to buffer adverse short term climate impacts, this seems to be a major gap in knowledge. However, before recommending a more substantive research investment into climate change impacts on livestock performance and possible adaptation options, it is recommended that:

8. A scoping study should be considered by ACIAR to assess the direct and indirect impacts of climate change on livestock performance.

Both recommendations 6 and 8 require farming systems models capable of capturing not only the production components of farming systems, but also the management components, i.e. the decisions and actions farmers take in the course of a particular cropping season. The review of farming systems models in section 9 indicates that IAT is eminently capable of simulating integrated crop–livestock systems and therefore would be the model of choice to assess indirect effects on climate change on residue and fodder production. However, IAT is predicated on APSIM-generated crop outputs including rice yields (grain and straw). While APSIM was considered the most versatile model for use in a participatory mode to capture cropping systems as close as possible to reality, at present its ability to simulate rice crops is still somewhat limited.

Given the central role farming systems modelling has to play in extrapolating the impacts of climate change both temporally and spatially, there is a need to enhance APSIM's capability in simulating rice crops. Such a capability would not only underpin improved climate impact assessments, but would also provide a critical capability in the broader food security domain, where scenario modelling is also a key research tool. Therefore it is recommended that:

9. ACIAR should continue to invest in the further development of APSIM and in particular support its extension to fully capture rice crops in rice-based cropping systems.

The current versions of IAT are limited by the programming and spreadsheet configurations inherent in Excel. To make IAT more user friendly and to efficiently add future modifications or application extensions (e.g. a module for fish farming, more modules for off-farm income generation), consideration needs to be given to a complete redesign of the tool and a transition to a model software structure more akin to APSIM. This would represent a major investment that seems outside of the scope of the immediate climate adaptation project under design, but may be a worthwhile investment in the broader context of food security research, especially to underpin future research in rainfed, rice-based farming systems of S Asia and SE Asia that have a significant livestock component.

10. In the context of wider application in food security and livestock intensification research, ACIAR should consider supporting the redesign of IAT to achieve greater versatility and more user friendliness.

Such investments both in APSIM and IAT would further capitalise on previous investments by ACIAR, as well as further strengthening Australia's already strong research capability in simulation modelling.

11.3 Research to underpin government and donor supported adaptation programmes

Early donor support in Cambodia, Lao PDR and Bangladesh concentrated on developing the NAPAs. In India and Bangladesh several donor funded projects also addressed drought and disaster alleviation. The NAPA process has concluded in all three countries and national level institutional arrangements to mainstream climate change have been established in all countries, but only Bangladesh is at present implementing a more strategic climate change action plan.

The adaptation action priorities identified through the NAPA process are generally opportunistic in nature and of ‘no regrets’ character. Very few of the priority actions have been implemented because of lack of donor support. Generally, government led and donor supported adaptation interventions suffer from a focus on adaptation as a technical issue (rather than including a social dimension built around adaptive capacity) and concentration on sectoral responses in a few areas only (usually agriculture, water, health, and infrastructure). Other shortcomings are the low level of consideration of autonomous practices and adaptation strategies at the local level (farmers adapt to changing circumstances all the time) and the narrow focus on natural systems, i.e. the failure to recognise that rural livelihoods are not just agriculture based. Conversely, though they avoid some of the above problems of narrow scope and lack of participatory approaches, many ‘bottom up’ or local adaptation interventions led by NGOs are lacking systematic assessments as to their long-term appropriateness to address climate change, thereby risking future maladaptation. Often they are also too context specific to be able to be readily transferred to other areas outside the immediate intervention area.

In summary, it appears that there is a major disconnection between national scale climate change vulnerability and impact assessments carried out as part of the IPCC and NAPA assessments on the one hand, and adaptation interventions at the household and community level that are mainly being led by NGOs on the other hand. The former approach provides strategic insights into sectoral and regional vulnerabilities, but offers no advice on either the resilience or adaptive capacity of sectors or regions or a location-specific context to enable household or community level adaptation. Conversely, the latter approach is constrained by the difficulty in scaling household or community level information to higher levels (e.g. provincial).

In fact, there were clear indications by stakeholders canvassed during the scoping study, particularly in Cambodia and Bangladesh, that uncertainty about what climate change projections mean for farm level adaptation, the lack of location specificity and the general absence of information on impacts and vulnerabilities at local scales were perceived as reasons behind the apparent hiatus in donor support for adaptation projects. Figure 11.1 illustrates this disconnection between generalised and locally too specific approaches.

This gap constitutes a unique investment niche for ACIAR, allowing ACIAR’s investment to be clearly differentiated from other research and development initiatives in climate adaptation. This is reinforced by the demand from government and donor organisations canvassed during the scoping study for knowledge to support the design of future adaptation programs that are better aligned to local realities, but still retain enough validity for implementation across larger geographic or administrative entities. Similarly, there is a widely recognised need by adaptation practitioners (NGOs, agricultural research and extension services, farmers) for tested and robust farm level adaptation options that will outperform existing farming practices under current conditions of climate variability but can also be adapted to future climate conditions. Accordingly, it is recommended that:

11. ACIAR’s investment in climate adaptation research should consider targeting the gap between national scale climate change vulnerability and impact assessments, and the demonstration of adaptation interventions at the household and community level.

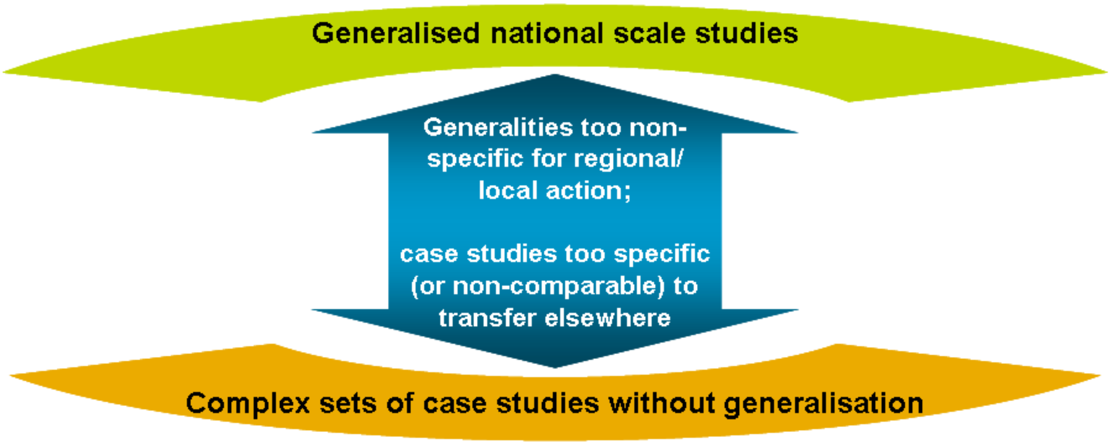


Figure 11.1: Tension between national level and local level adaptation studies (Howden et al., 2009)

To achieve this bridging will require a research strategy that uses a multi-scale approach to identify and test technically feasible adaptation options at the farming household or community level, before using these 'ground-truthed' options as the basis for generalisations and up-scaling to allow promising adaptation options to be transferred to spatially larger units. This approach is contrary to the prevalent impact modelling, which takes a top down approach and tries to extend generic solutions to local conditions. Progress in adaptation science is predicated on achieving this bridging across scales and in their recent paper providing the rationale for adaptation science, Meinke *et al.* (2009) have proposed an 'adaptation cycle' as a **multi-scale** conceptual framework on which to base a reflective analysis-action continuum that connects science with society at every step in the process. Following on from recommendation 11, it is also recommended:

12. The ACIAR emphasis on adaptation research should be to demonstrate the development of multi-scale adaptation strategies that enable policy makers to deliver more effective climate adaptation programs elsewhere.

Despite some of the above bridging problems, a range of donor funded climate change adaptation programs are currently underway or in the pipeline in all countries. Some offer major opportunities to outscale adaptation options identified as part of the future ACIAR funded work. Examples where there are possibilities for linkages to donor projects are provided in sections 6.1 to 6.4. Such linkages can vary depending on circumstances, ranging from communication of research outcomes through briefings and training workshops, to explicit sharing of data and case study sites. Hence, to maximise the impact of its research investment, it is recommended:

13. ACIAR should ensure its future adaptation research projects are explicitly linked to other donor funded adaptation projects where there are clear opportunities for outscaling of adaptation strategies and where there is a high likelihood of application of outputs generated by the ACIAR projects.

Another aspect of climate change adaptation that seems to have received little attention in the policy domain and in impact assessments to date is the need to more systematically assess the limitations to adaptation, i.e. in which locations and after what time spans incremental adaptation to climate change may no longer be sufficient and where more transformational shifts in farming systems will be required. Examples are low-lying floodplains in Cambodia and Bangladesh, where increased frequency and duration of flooding will overstep a threshold beyond which monsoonal, rainfed rice is no longer viable and has to be replaced by other livelihood activities, such as a combination of aquaculture and dry season irrigated rice. Accordingly:

14. As a key input to policy formulation and the design of adaptation programmes, ACIAR should consider supporting research that also determines the limitations to adaptation.

Following on from the above is the need to also capitalise on opportunities arising out of climate change. In fact transformational change may end up being more profitable, while changes in rainfall foreshadowed for some regions in the countries studied here might also offer opportunities for increased water harvesting and crop productivity to incrementally improve the productivity of existing farming systems.

11.4 Understanding adaptive capacity as the base for developing technical adaptation options

Vulnerability studies of varying depth and geographic extent have been conducted in all four countries, mostly in association with the NAPA process. However, few examples of comprehensive, national level vulnerability studies seem to be available. As s result, stakeholders in a number of cases suggested that further, more detailed vulnerability assessments be carried out as part of future research. There is no doubt that vulnerability assessments, particularly if they are spatially explicit (e.g. Yusuf and Francisco, 2009) are useful in identifying hotspots where climate change impacts can be expected to be more adverse than elsewhere, and in consequence allow a more targeted approach to allocating limited resources towards climate adaptation.

However, as discussed in section 10.1, a weakness of vulnerability assessments is that they often focus on potential threats (exposures, hazards, stresses etc.) that affect livelihoods and well-being rather than considering what people can do and already do to improve their livelihoods. The focus on potential negative impacts of exposure and sensitivity to rising temperatures and on extreme events (cyclones, floods) tends to be disempowering for individuals, households and communities unable to directly influence these change drivers. A focus on impacts is also disempowering because it overlooks the intrinsic adaptive capacity and demonstrated ability of land managers to adjust positively to significant change.

As argued in section 10.2, assessments of adaptive capacity are better positioned to consider the constraining and enabling factors for individuals, households or communities to cope with various types of change. This is because such assessments link possible responses back to actions that households or communities are able to initiate using resources at their disposal. Moreover, assessments of adaptive capacity lend themselves more readily to uncovering what actions farming households are already undertaking to adapt, as managing climatic risk is nothing intrinsically new to farmers, who are constantly adapting to drivers of change, be they climatic in nature, or due to other socio-economic, political or market drivers.

It is evident from the review conducted in the scoping study that there is a lack of research on adaptive capacity, although understanding how it relates to drivers of change is a prerequisite for selecting the most appropriate adaptation strategies. In other terms, the analysis of adaptive capacity ensures adaptation strategies are not merely technically feasible, but are also accepted by farmers as being more profitable and importantly, less risky and within their means to adopt easily. Based on these conclusions, it is recommended:

15. A high priority should be accorded to social research aimed at understanding adaptive capacity in conjunction with the evaluation of technical adaptation measures.

A significant component of this scoping study was directed at evaluating whether the Sustainable Rural Livelihoods (SRL) framework, which has a substantial application history in development practice particularly in South Asia, is suitable to be used as a tool to assess adaptive capacity in ways that are empowering at the local level, but also allow for higher level and more policy relevant assessments of adaptive capacity to be carried out. The conclusion of this evaluation (see section 10.3.6) is that, with some further refinement (e.g. basing the design of sampling and survey schemes on typologies of farming systems), the SRL framework at the local scale does appear to be a useful tool to analyse adaptive capacity in relation to climate change as well as other drivers of change. Additional research will be required to ensure whether the SRL is also a robust tool to assess adaptive capacity at provincial and national scales, or whether other approaches are better suited. In slightly more general terms, it is therefore recommended that:

16. A focus of social research should be the development of more rigorous tools and frameworks to assess adaptive capacity at a range of scales (household to national policy levels).

While the primary rationale for assessing the factors constituting adaptive capacity is the basis for designing more effective adaptation programmes at policy and local community levels, it is only when this understanding is used to guide the development and evaluation of technical adaptation options that the approach attains its maximum potential benefit. Indeed, integration of biophysical and social research has been recognised as one of the science frontiers in adaptation research (Howden *et al.,* 2007; Resurreccion *et al.,* 2008; Meinke *et al.*, 2009).

This integration can take place at two levels. At the farming household level, surveys conducted to carry out the analysis of adaptive capacity could be designed in a way that they also capture data relevant to defining cropping/water management practices to assist a more realistic configuring of adaptation options to be tested in modeling based scenario analysis (e.g. using APSIM or IAT). At the same time, the assessment of adaptive capacity will also help identify which future scenarios are worth investigating and which options, though technically feasible, are less likely to be selected and adopted by smallholder farmers. In effect IAT modeling outputs link the cropping and water management response options back to social attributes such as labour availability and access to other capitals assessed under the SRL framework. In this way computer-based scenario analysis can be made to be more relevant to smallholders by evolving farming systems modelling into participatory livelihoods analysis.

This scale can be complemented by an analysis of adaptive capacity at provincial scale using secondary (e.g. census) data, to match with the aggregation of crop and water management options at a more generic level. Integration of these two streams in a GIS modelling framework can then enable an analysis of transferability of adaptation options. A critical element in scaling will be the development of farming systems typologies. As farming systems encapsulate biophysical, economic and social system attributes the typologies in themselves represent an integration of the social and biophysical research. Summarising the above, it is recommended that:

17. Greater emphasis should be placed on supporting research into the integration of social and biophysical sciences by using the insights obtained from the adaptive capacity analysis to inform the choices of technical adaptation options requiring further evaluation.

In addition to the gaps highlighted in the preceding discussion, it also is apparent from the review of research conducted in section 8 that, in the four countries studied here, there is a general paucity of data quantifying the financial and economic costs and benefits of adaptation. This is a complex domain, and has also not been yet comprehensively covered elsewhere other than some higher level studies proposing methodologies to assess costs and benefits. Work conducted in Australia by Howden *et al*. (2009) suggests that there may be substantial payoffs for government and private sector support of adaptation in the agricultural sector. Related to this question is the need to identify and better quantify the financial and risk reduction incentives that would help influence farmer decision making towards adopting longer term adaptation strategies and to move beyond their more immediate focus on minimising the seasonal impacts of climate variability. Hence:

18. Adaptation research should be underpinned by the quantification of the financial and economic costs and benefits of adaptation and a determination of the incentives that will encourage smallholder farmers to adapt to longer term climate change.

11.5 The role of farming systems research in selecting and evaluating farm level adaptation options

Ultimately, farm level adaptation will revolve around helping farming households identify and implement appropriate changes to their farming systems, albeit in the context of their adaptive capacity and in recognition of their preferences and other factors influencing their decision making. A range of farm level adaptation options exist, and can be summarised into the following categories:

- Reducing risk of production through supplementary irrigation to minimize the impact of within wet season drought and to extend cropping seasons: supplementary irrigation can be sourced from water harvesting, establishing tube wells, or gaining access to irrigation canals
- Matching current crop varieties and cropping systems to likely shifts in rainfall and temperature regimes; this is predicated on a better understanding of climate variability and the access to reliable seasonal climate forecasts
- Diversifying cropping systems into higher value crops or improving crop productivity, particularly if supplementary irrigation becomes available
- Diversifying farming systems by integrating more intensive, forage-based livestock production (or fish farming in the case of Cambodia and Bangladesh)
- Development and dissemination of higher yielding crop varieties that are better adapted to inundation, drought, temperature stress and emerging pests and diseases and increasing CO_2
- Development of stronger farmer to market linkages, both with respect to commodities sold by farmers, as well as in relation to providing farmers with better access to inputs and new knowledge

However, in evaluating any one of these options, researchers are confronted with the challenge of having to test adaptation options under today’s climate for some future, uncertain expression of climate change. This means that, perhaps with the exception of very costly FACE experiments not easily replicated across a wide range of farmer practices and conditions, many of the above adaptation techniques are intrinsically untestable experimentally. As a consequence, testing of adaptation options will by necessity have to rely on systems modelling to extrapolate farm level adaptation options into future climate projections. This further strengthens the rationale in support of recommendation 9.

In addition to the use of farming systems models to determine the impact of climate change variability on whole-of-farm (crop and livestock) response, farming systems modelling has to be used to explore the trade-offs between cropping, livestock production and other sources of rural livelihoods to help inform farmers which options to choose. However, in accordance with the discussion in section 9.1 and the rationale in support of recommendation 16, in order for modelling based scenario analysis of alternative farming practices to be relevant to farmers, participatory approaches need to be used in capturing and parameterising farmer practices in the models; as well, farmers will need to be given the opportunity to define and select the scenarios to be tested. Therefore, it is recommended that:

19. Any evaluation of adaptive farm management practices (crop density and planting dates, choice of alternate crops or varieties, nutrient and water management, cultural practices, livestock nutrition and management, etc.) should be conducted using farming systems models that are capable of capturing farming practice realities and that are used in a participatory mode, soliciting farmer input to scenario definition and output assessment.

The selection and evaluation of modifications to farming systems deemed feasible based on the modeling then need to be tested under field conditions. Again, this should be done in an on-farm participatory mode and build on the community engagement processes conducted as part of the social research aimed at assessing adaptive capacity (recommendation 14). Ultimately, the preferred adaptation options should be those that offer farmers immediate benefits in terms of increased productivity and/or reduced risk of production under current climatic variability, while at the same time being likely to also continue to perform into the future under changing climatic conditions.

Despite many stakeholders in all countries repeatedly affirming that climate resilient farming systems constitute one of the key farm level adaptation strategies, very little systematic analysis of adaptability of current farming systems and the potential of modified farming systems to withstand climate change impacts is being carried out using modelling as a tool. Partly this is due to an underdeveloped capacity in the use of crop and farming systems modelling to inform choices of options and help design experimental protocols to test selected options. In India and Bangladesh it was noted that there is now a renewed interest in strengthening modeling capabilities, drawing on the Australian experience of participatory farming systems modelling. There is now also more institutional support in leading agricultural research organisations (e.g. ICAR institutions like IARI and CRIDA in India; BARC, BRRI, BARI and BUET in Bangladesh) to establish and maintain crop and farming systems modelling units. Based on the above it is recommended that:

20. Capacity building in participatory farming systems modelling and in depth training of appropriately selected and institutionally supported researchers should be undertaken in conjunction with farming systems modeling to evaluate farm level adaptation options.

While farming systems research directed at delineating farm level adaptation options is perceived to be a major research gap, considerably more work is taking place in all four countries studied in relation to breeding more climate resilient crops. In many cases this is not necessarily an explicit response to adaptation needs, but reflects traditional breeding priorities to improve crop tolerance towards a range of important biotic stresses, including heat, drought, salinity, waterlogging and inundation tolerance. It just happens that these traits are well matched to the traits required to withstand climate change impacts. Given that Australian research organisations do not have much comparative advantage in rice breeding and that there are other organisations like IRRI and CIMMYT assisting NARS with their breeding programs, and in view of ACIAR’s emphasis on achieving short term impacts through its climate adaptation initiative, it does not seem warranted that ACIAR place a major emphasis on breeding in its adaptation research programme. Continued support for breeding research should, however, be provided through its traditional avenues of research programme support and through ACIAR’s new food security initiative. Irrespective, choice of alternate crop varieties is one of the most frequent adaptation decisions farmers make, and the implications of choosing different varieties needs to be reflected in the trade-offs assessed by the farming systems modelling.

Moreover, crop simulation modeling has an increasing role to play in helping target desirable traits for more efficient breeding. This is still a comparatively new field, but it holds promise not just of helping to streamline breeding programmes, but also to evaluate *a priori* the relative benefits of choosing more climatically adapted varieties *vis-à-vis* other adaptation options available. This sort of modelling can be very helpful in prioritising breeding needs in partner countries and can assist in more efficiently allocating breeding resources. Hence:

21. Crop and farming systems scenario modelling should be carried out to inform the prioritisation of breeding programs developing the next generation of climate-resilient crop varieties.

A final consideration in relation to farming systems research is the need to evaluate farm level adaptation options in relation to their likelihood of exacerbating GHG emissions. Indeed, building adaptive capacity of farming households in general is predicated on overall improvement in their livelihoods base. This in turn more often than not requires an increase in the productivity of farming systems. Higher crop yields and large numbers of livestock will by necessity draw on increased levels of inputs as farm intensification is increased. This will increase GHG emissions in absolute terms, even if, as part of improved input efficiency, the rate of GHG emissions per unit of output might be decreased. To minimise this risk of maladaptation, it is recommended:

22. The evaluation of farm level adaptation options should also take into account their efficiency in terms of unit use of input factors (e.g. water productivity, nitrogen use efficiency, fuel/energy use per unit biomass produced) to ensure that adaptation does not inadvertently lead to future maladaptation.

11.6 Research into improved water management as a key to buffering climate impacts

Water management will play a central role in climate adaptation. This is because climate projections discussed in section 4 indicate that projected changes to rainfall regimes will lead to increased rainfall and flooding during the monsoon periods, while in other areas there is the prospect of decreases in rainfall, leading to more variable rainfall with more frequent within season drought spells. Against the backdrop of increasing demand for water as a result of population growth and development, in drier areas a reduction of rainfall will further exacerbate water scarcity. The prospect of increased flooding and drought incidence has placed water management into the forefront of adaptation in all four countries.

Floods impact on all livelihood facets, not just crops. While there are some options that farmers can employ to mitigate against moderate flooding (e.g. raised bed cropping, selection of submergence tolerant rice varieties, raising of homesteads and livestock pens), the prevention of floods is largely beyond the means of individual farming households. The erection of levee banks and flood management structures is more in the domain of government agencies.

In Bangladesh the construction of flood gates and levee banks is part of the government's mainstream response to flood mitigation. In Cambodia and Lao PDR flood mitigation works and integrated drainage management schemes that could benefit larger areas do not yet seem to be seen as a major adaptation response to flooding. Yet in more developed countries, integrated drainage management and the establishment of drainage networks is a critical element of quickly dissipating the impact of floods once they have occurred. An example of this is the Australian sugar industry, which would not be able to economically produce sugar cane in many of the low-lying floodplains of northern Queensland without putting integrated drainage networks in place. Information on the feasibility of drainage management appears to be a gap, particularly in Cambodia and Lao PDR, and it is recommended that:

23. ACIAR should commission a scoping study to assess the technical, economic and environmental feasibility of government and donor supported implementation of integrated drainage networks to mitigate the impacts of flooding.

Whereas flooding is anticipated to be one of the main impacts, increased incidence of drought and drier dry seasons is also being anticipated in some areas of the four countries studied. In these areas, particularly in rainfed parts of Andhra Pradesh and in central and southern India more generally, there has been a long tradition of drought mitigation through water harvesting and watershed development. Moreover, development of irrigation resources to provide water for supplementary irrigation, especially to extend cropping into the dry season and to buffer within season droughts during the monsoon is a clear priority in all four countries. Structures and techniques to maximise the retention and storage of runoff on-farm and at a community level are reasonably well understood, but there is still some scope for additional research into improved water harvesting and storage structures, the optimisation of the use of limited water these strategies provide, as well as designing more functional community-based institutions to manage shared storages.

The use of ground water to provide additional water is the alternative strategy to mitigate against drought, with shallow tube-well development widespread in India and in a majority of areas of Bangladesh. Tube wells are also rapidly increasing in number in parts of Cambodia, but there is virtually no use of groundwater for irrigation purposes in Lao PDR. A common problem to all areas with ground water use is the issue of sustainable extraction underpinned by a sound knowledge of the size and recharge rate of the resource. However, evidence suggests that ground water tables are depleting in many areas of India, Bangladesh and even Cambodia. Against the backdrop of increasing water demand not just for irrigation, this poses a significant threat to the use of ground water as a key adaptation strategy to buffer against climate variability. While there is an extensive knowledge base on farm level water saving techniques in India and Bangladesh there is still a need for more research into the assessment and sustainable management of ground water resources in Cambodia and Lao PDR. There is also anecdotal evidence and some data pointing to water quality problems in Cambodia and Lao PDR (arsenic contamination, salinity). Therefore, it is recommended that:

24. A more systematic assessment of ground water resources in terms of quantity and quality, and their sustainable use for supplementary irrigation should be carried out primarily in Cambodia and Lao PDR.

In addition to flooding and drought, another major anticipated impact of climate change is the intrusion of seawater in low-lying coastal zones. In the context of this study, this impact is mainly an issue in Bangladesh. A reasonable body of knowledge exists in Bangladesh on the underlying dynamics of salinity pulses towards the end of the *rabi* season, the factors determining the spatial and extent of salinity, and a suite of crop and water management options that can help farmers manage the effect of salinity on their crops, primarily *boro* rice. However, what appears to be less well understood is how climate change is likely to affect salt fluxes and balances and how temporal and spatial shifts in salt fluxes will interact with irrigation, flood gate and drainage management, and what the implications of these dynamics might be for short term and long term adaptation responses. There is already clear evidence of transformational changes taking place in farming systems in the most affected areas of SW Bangladesh (Khulna Division), with farmers abandoning traditional *T. aman* rice in favour of brackish water shrimp farming; many intermediary stages of this transformation are observable as one progressively leaves the more salt affected areas and moves to less salt affected areas further north. This offers a unique opportunity to investigate the relationships between adaptive capacity and climate induced drivers of change. Therefore, it is recommended that:

25. A focus of the climate adaptation research in Bangladesh should be the determination of spatial and temporal dynamics of salinity intrusion as a result of

climate change and the implications of these changed dynamics for the adaptation of crop and water management.

11.7 Strengthening the capacity of information delivery systems

With the exception of the regional arm of the Dept. of Agricultural Extension operating in the drought affected NW of Bangladesh, in the course of the study no evidence was found of government extension services providing any explicit climate adaptation related advice to farmers. This is not surprising, given little research is taking place with respect to identifying and evaluating farm level adaptation techniques. It is also likely that the disconnection between the high level vulnerability and impact assessments conducted as part of the NAPA processes and what they mean for local level adaptation is contributing to a general lack of advice to farmers by extension services. Particularly in Cambodia and Lao PDR, there is a need to conduct training and awareness raising workshops targeting district and commune or cluster village level extensionists. A two-tiered training approach is likely to be required. Initially, general training in concepts of climate variability and climate change should be carried out, followed at a later stage by training in farm level adaptation techniques as these become available through on-farm research. The training will need to be underpinned by the production of tailored training materials and modules.

Many NGOs in Bangladesh and India are already involved effectively in climate adaptation work within a livelihoods context and experimenting with innovative concepts such as Farmer Climate Field Schools. Much can be learned from their experience on how to communicate concepts of climate variability and, more generally, how to demystify science results and communicate new information in more farmer friendly ways and how to extract and build on indigenous knowledge. Whilst NGOs have real strengths in communication and engagement with farming households, often the adaptation options they offer to farmers have not been sufficiently tested and evaluated with respect to their adaptability and appropriateness for future climate conditions. Exposing NGOs to a more formal evaluation process using scenario modelling to evaluate farm level adaptation options will increase the technical rigour of the adaptation options recommended to farmers. As a consequence:

26. All farm level adaptation research activities should be designed with a significant capacity building component to enhance the skills of government and NGO extension workers in the provision of advice to farmers on farm level adaptation options.

In all four countries it was found that medium range and long range seasonal climate forecasts (of unspecified reliability) are being produced. Assessing the reliability and skill of forecast is one important component of utilising this information resource, as articulated in recommendation 5. The other, perhaps more important, aspect is the implementation of effective dissemination procedures that are able to channel locally relevant forecast information to farmers in a timely manner. In addition, currently the information contained in the forecasts is not useful to farmers and would require packaging to convert the forecasts into more practical recommendations for actions farmers should take. This process is being trialled by ANGRAU and CSIRO in an ACIAR Small Research Activity in Andhra Pradesh (LWR/2006/073), with strong support from IMD and NCMRWF, who are responsible for generating the forecast products and have a strong interest in improving the utility and relevance of their forecasts for farmer decision making. In addition to India, where there is already a network in place for the rapid dissemination of state and district level advisories, Bangladesh and Lao PDR also offer opportunities to explore the feasibility of establishing an agro-meteorological advisory system. However, the level of investment in the establishment of agro-meteorological advisory services in these two countries should depend on the forecast skill to be established following recommendation 5. Accordingly, contingent on the forecast reliability, it is recommended that:

27. The design of effective dissemination pathways and the packaging of seasonal forecast information into farmer friendly advisories should be piloted in Bangladesh and Lao PDR.

In Bangladesh, and to a lesser extent in the other countries, flood/cyclone warning systems and disaster risk and recovery services are now quite effective and capable of transmitting weather warnings from capitals to villages and communes quite rapidly. In several cases stakeholders suggested that the feasibility of using existing networks being maintained by the various disaster management and flood warning services should be to investigated before embarking on the implementation of new, dedicated agro-meteorological advisory dissemination systems. Indeed, there seems to be merit in exploring more broadly how climate adaptation might be mainstreamed into these existing structures.

11.8 Country specific considerations

The recommendations in the preceding sections generally are applicable to all four countries. In the cases where a particular country emphasis seems warranted, this has been indicated (i.e. recommendations 2, 5, 24, 25 and 27). In this section an attempt is made to condense the preceding recommendations into a suite of slightly more geographically and thematically delineated project ideas. In doing so, regard is given to the research priorities expressed by country partners in sections 5.1 to 5.4 and 8.1 to 8.4, as well as taking into account opportunities for linkages to ongoing or planned ACIAR projects in Cambodia, Lao PDR , Bangladesh and Andhra Pradesh. To further narrow down the range of possible projects, ACIAR’s country priorities as published in the ACIAR Annual Operational Plan 09/10 are also taken into account, thus disregarding possible project ideas that lie outside of ACIAR’s priorities.

11.8.1 Cambodia

The analysis of country priorities in section 5.1 clearly indicates that further expansion and optimisation of irrigation is seen as one of the key adaptation strategies in Cambodia, which at the same time is also well aligned with the overall goal of alleviating poverty and improving rural livelihoods. Given that at this stage many if not most irrigation schemes using surface water are not yet fully functional, in the immediate future a more promising avenue is to focus irrigation research on provinces that already have a high degree of groundwater usage. These are Prey Veng and Svay Rieng, and to a lesser degree Takeo and Kampong Cham.

Of these preference is given to Prey Veng and Svay Rieng, for a number of reasons:

- There is a good database on ground water depths, distribution and recharge dynamics
- Both provinces are seen as amongst the most vulnerable provinces, experiencing both high incidences of drought and flooding
- Poverty levels are higher than the Cambodian average, particularly in Prey Veng
- There are good prospects for adoption, as market signals from neighbouring Vietnam are providing incentives for change
- The prospects for adoption and short term impact are further enhanced by the potential to link to a number of very complementary NGO projects being carried out by CARE and IDE in both provinces
- There was strong provincial level support for a project on climate adaptation in Svay Rieng, and at the same time there is reasonable provincial capacity for collaboration within Svay Rieng

Thematically, the focus should be on assessing adaptive capacity to inform local level choice and testing of crop and water (irrigation) based adaptation techniques as the basis for the development of more general adaptation strategies to underpin national and provincial planning and policy making. Despite the geographic focus being restricted to Svay Rieng and Prey Veng, opportunities for linkages to CAVAC and UNDP/IFAD projects should be explored further as these projects are implemented.

Depending on the outcome of recommendation 23, in the mid term there may also be opportunities to develop projects around integrated drainage and flood management.

Project options in the non-irrigated upland areas of Cambodia seem of a lower priority, as they are likely to experience a lower exposure to climate change. However, building on ACIAR’s livestock portfolio in Cambodia, in some cases it may be warranted to explore how livestock intensification could be aligned with climate adaptation objectives.

11.8.2 Lao PDR

Similarly to Cambodia, the analysis of country priorities in section 5.2 indicates that further expansion and optimisation of irrigation is also seen as one of the key adaptation strategies in Lao PDR. Again, this aligns well with the overall goal of alleviating poverty and improving rural livelihoods. However, here the focus needs to be on surface water supplied irrigation schemes, as presently ground water is not being used for supplementary irrigation in Lao PDR.

Stakeholders in Lao PDR made a strong case for adaptation research to focus on crop and water management in irrigated areas of the main lowland rice areas of Lao PDR, with a clear preference stated for Savannakhet. The rationale for selecting Savannakhet above other provinces is:

- Savannakhet produces the highest proportion of the rice crop in Lao PDR and therefore climate related disruptions to production have a more significant impact on national food security
- Savannakhet has the highest incidence of drought and flood impacts
- Generally adaptive capacity is higher in lowland rice areas than in upland areas, and, combined with market signals emanating from Thailand, there is a higher likelihood of impact
- Savannakhet is one of three provinces with long term climate records; there is also good data available from recent crop modelling that will facilitate APSIM based scenario analysis

Lack of data in other regions, a generally lower adaptive capacity (but combined with a lower anticipated exposure to climate change impacts) and the past emphasis of donor funded research on upland areas over lowland areas are other reasons for recommending Savannakhet as target area.

In addition to the above priority on adaptation research revolving around crop and water management options in lowland rice based farming systems, there was also strong stakeholder support for piloting the dissemination of seasonal climate forecasts.

Accordingly, in Lao PDR the primary thematic focus should be on assessing adaptive capacity to inform local level choice and testing of crop and water (irrigation) based adaptation techniques, supported by the piloting of seasonal climate forecasting in assisting farmer decision making, as the basis for the development of more general adaptation strategies to underpin national and provincial planning and policy making. Despite the geographic focus being restricted to Savannakhet, opportunities for linkages to ACIAR’s food security projects in southern Lao PDR should be considered as these projects are implemented.

Again, as for Cambodia, depending on the outcome of recommendation 23, in the mid term there may also be opportunities to develop projects around integrated drainage and flood management. In addition, there is scope for ground water use in the future, requiring a more systematic assessment of ground water resource availability (recommendation 24).

In non-irrigated areas, there is also a case for more research on enhancing the role of livestock in mitigating climatic disasters. This will require a stronger emphasis on crop-livestock integration and transition of livestock from extensive, grazing based to more intensive, fodder-based system. Again, given the greater capacity for change hypothesised in lowland areas and given the greater exposure to market drivers, it is recommended that this research be located in lowland, rainfed rice based farming areas.

11.8.3 Bangladesh

In Bangladesh there are several options for focus. Foremost, of all four countries, Bangladesh offers the best prospects for the further refining, testing and validating of an extended APSIM-ORYZA model as stipulated in recommendations 9 and 19. This is because it is possible to draw on several high quality datasets not available elsewhere, making it unnecessary to invest in new costly controlled experiments. Also, Bangladesh is the most appropriate country for collaboration with IRRI on farming systems modelling given its expertise, partnerships and past research history in Bangladesh. Hence, the further development of APSIM-ORYZA is seen as the highest priority for ACIAR's climate adaptation portfolio in Bangladesh.

In addition, there are at least two other project options revolving more around the development of multi-scale adaptation strategies that bridge local and policy levels – the central theme proposed in recommendation 11 as the main thrust of ACIAR's adaptation research.

One such project could target the salinity intrusion and flooding hotspot in the SW of Bangladesh (Khulna district), thereby building on previous IRRI and BRRI work, linking with NGOs in ongoing donor projects in that area and further capitalising on ACIAR's investment in LWR/2005/0146. Such a project could focus on the following issues:

- Determine salt balances and fluxes for the different land uses where brackish/salt water shrimp farming is emerging
- Develop water harvesting, irrigation and drainage management options to enable *rabi* season cropping
- Assess the long-term sustainability of combined rice - shrimp farming and determine threshold points of no return, after which it becomes unfeasible to revert to *T. aman* rice
- Develop salinity management and drainage strategies that allow for rice - shrimp farming with fresh or brackish water, but 'buy time' before such thresholds are overstepped
- Investigate at the long-term viability of *T. aman* rice cropping and livestock production faced with increasing salinisation of the landscape
- Implications of the above for adaptation policy and planning

The second project option relates to another of the climate impact hotspots, namely addressing the drought prone NW of Bangladesh. Here the optimisation of water for supplementary irrigation is seen as the primary adaptation strategy, complemented by the development of alternative livelihood options where there is insufficient availability of water for broad acre irrigation. Such a project would build on the CDMP project, previous ACIAR work (LWR/2005/001) and a large body of underpinning work on resource conserving technologies generated under the umbrella of the Rice-Wheat Consortium (raised bed farming, zero-tillage, crop diversification). Novel aspects of an ACIAR project could include:

- Assessment of long term ground water availability and depletion trends
- Piloting of seasonal climate forecasts to minimise climatic (drought) risks
- Role of niche crops in areas with less irrigation water
- Optimisation of water harvesting and on-farm storage
- Integration and intensification of livestock production

Finally, depending on the level of donor support for the establishment of an agro-meteorological service in Bangladesh, there could be future scope to support research into the application of seasonal climate forecasting in Bangladesh.

11.8.4 India (Andhra Pradesh)

Given the tighter focus of ACIAR’s country program in India and the specific emphasis in subprogram 2 on increasing the water productivity to enhance livelihoods in rainfed areas of Andhra Pradesh, and taking into account the existing cluster of integrated water productivity projects, the resultant thematic focus of the ACIAR adaptation research is much more constrained than in other countries.

Based on stakeholder feedback at national (Indian Meteorological Department, National Rainfed Area Authority) and state level (Andhra Pradesh Department of Rural Development), a clear preference is given to building on the earlier work carried out under LWR/2006/073 and to further refining the use of seasonal climate forecasting in farmer decision making. This will now be underpinned by a better understanding of adaptive capacity and a stronger level of engagement with policy stakeholders at central and state government levels.

Geographically the work should target those rainfed districts of Andhra Pradesh which offer the greatest level of linkage to the other ACIAR projects in AP by sharing study sites where possible with LWR/2006/072 and LWR/2006/158, as well as depending on operational considerations and the availability of relevant climate, soil and crop data to parameterise APSIM.

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December 2008 – Cambodia and Lao PDR (Roth)
February 2009 – India (Roth)
March 2009 – Cambodia, Lao PDR, Bangladesh (Roth)
May 2009 – Bangladesh and India (Roth, Hochman and Brown)
June 2009 – Lao PDR (Roth, Brown)
July 2009 – Cambodia (Roth, Grunbuhel)

14 List of acronyms and abbreviations used

AAS	Agro-meteorological Advisory Service (India)
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AEA	Agro-Ecosystems Analysis
AFMU	Agro-meteorological Field Units (India)
AFP	Agence Française de Développement
ANGRAU	Acharya NG Reddy Agricultural University
AP	Andhra Pradesh
AP DRD	Andhra Pradesh Department of Rural Development
APSIM	Agricultural Production Systems Simulator
APSRU	Agricultural Production Systems Research Unit
AusAID	Australian Agency for International Development
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BIDS	Bangladesh Institute for Development Studies
BMD	Bangladesh Meteorological Department
BRRI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
CCAI	Climate Change Adaptation Initiative (MRC)
CCCO	Cambodian Climate Change Office
CDM	Clean Development Mechanism
CDMP	Comprehensive Disaster Management Programme (Bangladesh)
CEGIS	Center for Environmental and Geographic Information Services (Bangladesh)
CIDA	Canadian International Development Agency
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CIRAD	Centre de Cooperation International en Recherche Agronomique pour le Développement (France)
CP	crude protein
CRIDA	Central Research Institute for Dryland Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSISA	Cereal Systems Initiative for South Asia
CSU	Charles Sturt University
CWWG	Crop Weather Watch Group (India)
DAE	Department of Agricultural Extension (Bangladesh)
DAFO	District Agriculture and Forestry Services (Lao PDR)
DDA	District Department of Agriculture (Cambodia)
DFID	Department for International Development (UK)
DMH	Department of Meteorology and Hydrology (Lao PDR)
DNA	Designated National Authority
DoAE	Department of Agricultural Extension (Cambodia)
DoM	Department of Meteorology (Cambodia)
DRR	disaster risk reduction
DSSAT	Decision Support System for Agrotechnology Transfer
ECMRWF	European Centre for Medium Range Weather Forecasts
EPIC	Erosion-Productivity Impact Calculator
EU	European Union
FACE	free-air CO2 enrichment experiment

FAO	Food and Agriculture Organisation
FBA	Farmer Business Advisor (Cambodia)
FDMC	Flood and Disaster Management Centre (Lao PDR)
GCM	Global Circulation Model
GEF	Global Environment Facility
GIS	geographic information systems
GoB	Government of the People's Republic of Bangladesh
GTZ	German Agency for Technical Cooperation
IARI	Indian Agricultural Research Institute
IAT	Integrated Assessment Tool
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITM	Indian Institute of Tropical Meteorology
IMD	Indian Meteorology Department
IPCC	International Panel on Climate Change
IRD	Institut de Recherche pour le Développement (France)
IRRI	International Rice Research Institute
IVM	Institute of Environmental Studies (Netherlands)
IWMI	International Water Management Institute M million
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
KOICA	Korea International Cooperation Agency
KVK	Krishi Vigyan Kendras (India)
LDC	Least Developed Countries
LMB	Lower Mekong Basin
MAF	Ministry of Agriculture (Lao PDR)
MAFF	Ministry of Agriculture, Forestry and Fisheries (Cambodia)
MoE	Ministry of Environment (Cambodia)
MoEF	Ministry of Environment and Forests (Bangladesh)
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MRD	Ministry of Rural Development (Cambodia)
NAFES	National Agriculture and Forestry Extension Service (Lao PDR)
NAFRI	National Agriculture and Forestry Research Institute (Lao PDR)
NAPA	National Adaptation Programme of Action
NAPCC	National Action Plan on Climate Change (India)
NARS	National Agricultural Research System
NCCARF	National Climate Change Adaptation Research Facility (Australia).
NCCC	National Climate Change Committee (Cambodia)
NCMRWF	National Centre for Medium Range Weather Forecasting (India)
NDMC	National Disaster Management Council (Bangladesh)
NGO	Non-government organisation
NREGA	National Rural Employment Guarantee Act (India)
NSDP	National Strategic Development Plan (Cambodia)
PAFES	Provincial Agriculture and Forestry Services (Lao PDR)
PAFO	Provincial Agriculture and Forestry Office (Lao PDR)
PDA	Provincial Department of Agriculture (Cambodia)
PRDC	Provincial Rural Development Committee (Cambodia)
PTD	Participatory Technology Development
RARS	Regional Agriculture Research Centres (Andhra Pradesh)
REDD	Reducing Emissions from Deforestation and Forest Degradation (UNDP)
RGoC	Royal Government of Cambodia
SDC	Swiss Agency for Development and Cooperation
SIDA	Swedish International Development Agency
SPARSO	Space Research and Remote Sensing Organization (Bangladesh)

SRES	Special Report on Emissions Scenarios
START	Global System for Analysis, Research and Training
UJV	Unincorporated Joint Venture
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development
USD	US Dollar
UWS	University of Western Sydney
VDC	Village Development Committee (Cambodia, Lao PDR)
WB	World Bank
WMO	World Meteorological Organisation
WREA	Water Resources and Environment Administration (Lao PDR)
WSD	watershed development
WUG	water user groups (Cambodia, Lao PDR)