Climate Change and Farming Communities in Deltas: Coping with Climate Variability while Adapting to Change

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Abstract

The study addresses the variation in adaptive capacity of farmers located in Asian deltas due to different forms of resource availability and institutional governance as well as physical location.

The data presented in this paper suggests that adaptive capacity is highly volatile and depends on a vast number of factors and influences even in a general area considered 'vulnerable'.

The analysis shows that the specific set of resources available to communities differentiate potentials for adaptation. Institutions govern the availability of resources and thereby determine the level of adaptive capacity of a community or household. The analysis concludes that any future strengthening of adaptive capacity needs to take current adaptation into account in order to create ownership among beneficiaries and become effective.

Finally, a framework for policy interventions is introduced that targets four main areas influencing institutional adaptive capacity (a) households, (b) government, (c) community and (d) markets.

Key words: climate adaptation; adaptive capacity; deltas; smallholders; Bangladesh; Cambodia; climate change.

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Terms and Acronyms

Aman	A varity of rice, mainly cultivated in Kharif-II season
Ashin	Name of a Bengali month (mid September –mid October) according to Bangla calendar
Bepari	Beparies are professional traders who purchases agricultural product from farmers.
Bhadro	Name of a Bengali month (mid august -mid September) according to Bangla calendar
Bigha	Local unit of land in Bangladesh, 1 Acre = 100 Decimals, 1 Bigha = 33 Decimals.
Boro	A variety of rice, mainly cultivated in Rabi season.
BRAC	Bangladesh Rural Advancement Commitee, acronyms of one of the biggest NGOs of Bangladesh.
Brinjal *(baygoon)*	Also known as eggplant and aubergine, one of the most popular vegetables in Bangladesh.
CARDI	Cambodia Agricultural Research and Development Institute.
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia (http://www.csiro.org).
cf.	(lat. confer) "compare to".
Gher	An area which comes under shrimp farming called Gher. ghers (areas impounded by dykes).
Gonogher	A vast area under shrimp farming where farmers were collectively participate, the process of doing gher together is known as gonogher.
Hilsha fish	One kind of saline water fish.
IDE	IDE Cambodia; an international, non-profit NGO working on market-based approaches of overcoming poverty (see http://www.ide-cambodia.org/).
Karthik	Name of a Bengali month (mid October - mid November) according to Bangla calendar.
Kathas	See *Nakhshikatha.*
Kharif	There are three cropping seasons (Rabi, Kharif-I or Pre-Kharif, and Kharif-II) in Bangladesh.
Machas	A higher place where people can store/preserve their food and fuel.
Maunds	Local unit of weight in Bangladesh, 1 *maund* = 37.5kg.
Nakshikatha	Embroidered quilts, bedspreads, wall hangings, and pillow shams made by artists in rural Bangladesh. Nakshikatha is a folk art that has been passed down through generations of Bangladeshi families. It takes tatters, cotton and needles to weave a Nakshikatha. Women weave it with their creative skills.
Owner-tenant	Land owner who also cultivates others' land through sharecropping.
Polder	This is a Dutch word refers to embankment to protect an area from saline water and tidal surge.
Rabi	There are three cropping seasons (Rabi, Kharif-I or Pre-Kharif, and Kharif-II) in Bangladesh.
SERDI	Socio-economic Research and Development Initiative
WAPDA	*Water and Power Development Authority* (*WAPDA*) is a government-owned public utility maintaining power and water.

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Executive Summary

As most Asian economies largely depend on agriculture, in terms of share of GDP as well as absorbing the labour force, they are likely to be more heavily affected by climatic perturbations than industrialised countries. According to the IPCC, deltas, particularly so-called "megadeltas" are vulnerable to climate change due to increased susceptibility to sea-level rise, storm surges, saltwater intrusion and floods. The Ganges-Brahmaputra Delta and the Mekong Delta are the largest in South and Southeast Asia, respectively, incorporating large amounts of people across international borders. Bangladesh and Cambodia, both delta countries, are among the most vulnerable countries in Asia. Both depend on rice-based cropping systems to provide the mainstay of food security and both are exposed to a number of water-related hazards. With an anticipated increase in rainfall variability, rain-fed farming households are confronted with the challenge of not just maintaining productivity in an environment of global change, but of increasing rice production to match growing food and cash demands. The question, thus, is whether the most disadvantaged households being impacted by climate change will be able to sufficiently adapt to these pressures while being able to improve livelihoods. Within vulnerable areas, however, livelihoods are by no means homogenously difficult. Depending on livelihood strategies, resources and differential opportunities households have varying levels of adaptive capacity to cope with changes. Thus, rather than taking a purely geographic approach we need to take a closer look at delta areas and identify differential types of households, their respective resource availability and consequent adaptive capacity. This case study attempts to use local data to look into types of livelihoods, which provide us with a richer picture on what households do – and what they could do – to adapt to climate change in the region. Given the points above, the case of Khulna, Bangladesh, and Svay Rieng, Cambodia, is not only meant to provide an example for specific adaptation. In fact, the case tries to open up the black box of "vulnerability" and map out differential adaptation strategies according to varying levels of resource access, livelihood strategies, and perception of risk. The aim is to incorporate self-assessments of farmers with scientific descriptions of exposure to hazards and available resources to cope. The idea behind these new approaches is to match experts' assessments of adaptive capacity with a self-evaluation of the target populations on what can actually be done to adapt to ongoing processes (in addition to the continuing effort to improve livelihoods).

For determining the household typology a number of indicators were selected namely: ownership of assets, access to public goods or resources, household ability to transform assets, individual status and capacity for following alternative livelihoods options. The study revealed how household typologies can be used in assessing adaptive capacity and climatic vulnerability. The communities selected for this study represent a range of delta-specific communities and may be considered as representative for different levels of vulnerability. Rather than recommending 'one-size-fits-all' solutions, this study addresses the variation in adaptive capacity found due to different forms of resource availability and institutional governance as well as physical locations.

In all communities a series of adaptation techniques are used to cope with hazards and minimize economic and social loss. Though households and communities have historically adapted to climate variability through many different strategies, their capacity to adapt is significantly affected by the ways local institutions regulate and structure their interactions: both amongst themselves and with external actors. As a result, practicing of such strategies eventually increases household and community level adaptive capacity that in turn reduces

climatic vulnerabilities. Successful adaptation practices depend on specific formal or informal institutional arrangements, i.e., adaptation never occurs in an institutional vacuum but is guided and managed by existing structure. Institutions are the channels through which external interventions reinforce or undermine existing adaptation practices such as agricultural techniques, water management techniques, diversification, common property resource management, etc. The analysis shows that not only do the varying characteristics of what "climate change" means to different communities determine the ability and capacity to adapt. It is also the specific set of resources available to and their respective access by the communities that differentiate potentials for adaptation. In addition to geomorphological factors, the institutional setting plays a rather important role as to which resources are available in a particular community and how they can be accessed. In fact, institutions govern the availability of resources, which, in turn, determine the level of adaptive capacity of a community or household. Additional factors affecting adaptive capacity include: (a) remoteness; (b) economic structure; (c) community action; and (d) social structure

Any future strengthening of adaptive capacity needs to take current adaptation into account for three reasons: (a) adaptation strategies, especially technical adaptation strategies, are inefficient if they are imposed upon farming households already struggling to make ends meet. Transaction costs are high and ownership is low. Only the most desperate will engage with the level of risk involved; (b) current adaptation strategies are, by definition, adaptations to an ongoing process of change. By having adapted, it shows that farming households have capacity to do so, even if adaptations have not proven successful; and (c) screening the suitability of current adaptation strategies seems more cost-efficient than introducing new practices. In addition, even when introducing new technologies, it seems reasonable to look for locally acceptable entry points rather than forcing resource-disadvantaged populations into high-risk transitions. For effective interventions, understanding of existing livelihoods is necessary.

The data presented in this paper suggests that adaptive capacity is highly volatile and depends on a vast number of factors and influences even in a general area considered 'vulnerable'. Megadeltas are in itself vulnerable areas, but adaptive capacity, in the cases presented above, depends on geography, economic dependency, community action, and social structure. It follows that large-scale programs devised into vulnerable areas are unlikely to increase adaptive capacity as they cannot take local specifics into account. Rather, policy should be able to allow for local variation within vulnerable areas and thereby create the space needed by communities to become active in their adaptation processes. Thus policy recommendations targeted at improving adaptive capacity towards climate change can be divided into four fields covering the social reality of resource use by smallholding and landless households: (a) The households themselves - The household level is the locus of specific measures of adaptation. As added benefits, households are less dependent on monopolistic traders for their product but can make use of trader competition or even choose to sell locally; (b) Government - Government must assume the responsibility to maintain *protective infrastructure*, such as Polders, irrigation canals and stormwater drainage. No single community can afford to maintain infrastructure on this scale and it is crucial for adaptive capacity to be able to adequately access the critical resources land and water; (c) The community - This study shows that community action and community structure can make the difference between high and low potential adaptive capacities. Hence, there needs to be a focus on functioning and integrated communities to provide opportunities for adaptation strategies; and (d) Markets - Markets play a crucial role in providing opportunities to farming

households. Provided markets allow fair pricing and equitable access to rural households they can act as a major catalyst to improving adaptive capacity.

This study covers communities situated at the top (Mekong) and the very bottom (Sundarban) of a delta. While all are highly vulnerable, the analysis of adaptive capacity has shown that communities with higher adaptive capacity show a higher diversity of resource use portfolios, horizontally integrated social structure, mature economic structure and the vicinity to market hubs. Therefore, this community is more likely to withstand shocks as well as adapt to slow-onset effects of climate change. The recommendations presented here, however, do not imply that communities with lower adaptive capacity should strive to become like the ones identified to have higher adaptive capacity. Such a goal would be highly unrealistic because of different levels of exposure as well as particular characteristic specific to each community. We can, however draw some lessons through the comparison and extract policy goals that could be achieved and improved in both communities.

Climate Change and Farming Communities in Deltas: Coping with Climate Variability while Adapting to Change

1. Introduction

While climate change may seem as lying in a remote future, it is already a reality in many parts of Asia, with evidence of increasing temperatures (Lal 2003; Cruz *et al.* 2007); projections of an increase in monsoonal rainfall in some countries (Kumar *et al*. 2006); a higher frequency of extreme weather events; and accelerating rates of glacier and snow melt (Cruz *et al*. 2007). As most Asian economies largely depend on agriculture, in terms of share of GDP as well as absorbing the labour force, they are likely to be more heavily affected by climatic perturbations than industrialised countries. The most disadvantaged[1] farm households in delta areas bear the brunt of climate change because they typically live in areas more exposed to extreme climate effects or otherwise marginal locations[2].

According to the IPCC (2007) deltas, particularly so-called "megadeltas" are vulnerable to climate change in due to susceptibility to sea-level rise, storm surges, saltwater intrusion and floods. In Asia, deltas tend to attract high population densities, many of which base their livelihoods on the deltas' natural capital[3]. There is broad consent over the fact that policies and programs need to provide for integrated and co-ordinated development of deltas, balancing the needs of the populations living in them with the ecosystem services provided by deltas as well as mitigating further erosion of natural capital in these highly fertile areas (ibid.).

The Ganges-Brahmaputra Delta and the Mekong Delta are the largest in South- and Southeast Asia, respectively, incorporating large amounts of people across international borders. Bangladesh and Cambodia, both delta countries, 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, i.e. low institutional and community capacity to adapt, and a high exposure to climate risks, (i.e. flooding in delta areas as well as increased drought and extreme weather events). While other Asian countries are also vulnerable, these two countries, with their high percentage of agricultural population and dominating waterways, warrant particular focus.

Both Bangladesh and Cambodia depend on rice-based cropping systems to provide the mainstay of food security and both are exposed to water-related hazards from the sea as well as freshwater arteries. Situated in deltas, both countries attempt to harvest the immense freshwater discharge for irrigation. Most farming systems apply at least basic forms of

[1] "Disadvantaged", in this paper, is used to designate households with poor or lacking access to resources compared to fellow co-residents in the community. The authors are reluctant to use the term "poor" as, by all international definitions, all households covered in this report would be classified poor in terms of their absolute resource base, income levels and social stratification. However, among those households there are those that are able to access the scare resources and use them for their own benefit and there are those that cannot.

[2] In fact, the IPCC (2007) identifies two particularly vulnerable populations, those residing in *Megadeltas* and those in *Megacities*. Levels of exposures specific to these areas apply in addition to the fact that both areas are attractors to large numbers of people.

[3] Ganges-Brahmaputra: 1300cap/km^2; Mekong: 250cap/km^2 (calculated from data in IPCC 2007).

irrigation while large investments into irrigation technology (e.g. water pipelines) are not needed due to the abundant availability of water. Rice is the main staple crop, with annual rice production in Bangladesh of 47 Million tons (285t/cap) and Cambodia of 7.2 Million tons 478t/cap in 2008 (FAOSTAT 2010). With an anticipated increase in rainfall variability, rain-fed farming households are confronted with the challenge of not just maintaining productivity in an environment of global change, but of increasing rice production to match growing food and cash demands. The questions, thus is whether the most disadvantaged households being impacted by climate change will be able to sufficiently adapt to these pressures while being able to improve livelihoods.

The vicinity of low-lying areas to large quantities of water often spells a formula for disaster. Technology can play a role to mitigate potential threats but the rising uncertainties attached to climate change means that technological solutions of today may lead to structural lock-ins and less flexibility to adapt in the future, e.g. by transforming agriculture into a high-input system under resource-constrained circumstances. Bangladesh, in itself a Delta country, is a case in point. Large numbers of people live very close to coastal and delta areas, which are characterised by tidal surges, seasonal fluctuations, the balance of fresh and saltwater and the increase of extreme weather phenomena. Hence, it becomes progressively difficult for populations in those areas to maintain livelihoods, let alone improve them. Extreme events, especially, seem to destroy any progress that is made over years in the blink of an eye. Within one and a half decades six devastating cyclones and tidal surges hit the coastal areas of Bangladesh (in 1994, 1997, 1999, 2007 and 2009).

In the context of the climate change debate and the emergence of an adaptation research agenda, the inclusion of social and institutional research in technology 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. As such, social capital remains one of the key elements in assessing the capacity of people to adapt, particularly to climate change (Prasad *et al.* 2009).

Within vulnerable areas, however, livelihoods are by no means homogenously difficult. Depending on livelihood strategies, resources and differential opportunities households have varying levels of adaptive capacity to cope with changes. Thus, rather than taking a purely geographic approach we need to have a closer look at delta areas and identify differential types of households, their respective resource availability and consequent adaptive capacity. This case study attempts to use local data to look into types of livelihoods, which provide us with a richer picture on what households do – and what they could do – to adapt to climate change in the region.

Selecting a case-based approach highlights several issues inherent to much climate change related research today:

- Many donor-funded Climate Change Adaptation (CCA) programs are underway in Asia. Several of these do not regard the particular context within which adaptation occurs.
- Many Government and Non-Government programs are ‘top down’, technology or sector-driven and lack household and village level assessments of adaptive capacity.

- In some instances, uncertainty about appropriate adaptation strategies and lack of proven design principles is constraining donor and government funding.
- CCA research has been primarily focussed on impact and vulnerability assessments to underpin policy and investment prioritisation, as well as on breeding new climate resilient varieties. There are very few cases where research has been undertaken to optimise practical approaches to farm level adaptation.

Adaptation to climate change is as much a research domain as it is also increasingly becoming an advocacy domain, where the distinction between both domains becomes blurry. While there is a predominance of portraying the potential risk and negative impacts of climate change on development, less emphasis has been given to exploring the opportunities those changes to climate might entail (e.g., carbon fertilisation effects in some parts of South and Southeast Asia, which could give rise to opportunities, such increased productivity (Rosegrant 2008)[4]. There is a need to assess not just the risk, but also demonstrate how to capitalise on opportunities arising out of climate change (Howden *et al.* 2009).

As Bangladesh and Cambodia continue to ramp up their policy response to implement climate change adaptation programmes, there is recognition that this process will take several years to consolidate and become evidence-based. However, there is broad consensus within leading agricultural research institutions and the non-governmental organization (NGO) sector of these countries, that enhancing adaptive capacity in rural communities is predicated on broadening livelihood opportunities of smallholder households through a range of technical and socio-economic and institutional approaches. Some of the key elements comprise:

- Developing adaptation options at various scales, i.e. policy development, capacity building, as well as local technical interventions into farming systems.
- Extensive consultations with relevant government stakeholders which confirmed the proposed approach and focus on demonstrating how adaptive capacity can be fostered at the community level.
- Adapted interventions, i.e., interventions developed in a participatory way that ensure ownership by the community and fit into the local institutional arrangements to be easily absorbed into existing structure rather than building parallel structures.
- Capitalize on ongoing adaptation. Assuming that farming household constantly need to adapt to external pressures, try to identify these processes of adaptation and screen them as to their adaptability to climate change.

Given the points above, the case of Khulna district, Bangladesh, and Svay Rieng province, Cambodia, is not only meant to provide an example for specific adaptation. Instead the case tries to open up the black box of "vulnerability" and map out differential adaptation strategies according to varying levels of resource access, livelihood strategies, and perception of risk. Vulnerability assessments are undoubtedly useful in identifying hotspots where climate change impacts can be expected to be more adverse than elsewhere, particularly if they are spatially explicit, and in consequence allow a more targeted approach to allocating limited resources towards climate adaptation (see Yusuf and Francisco 2009).

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

[4] It must be stated, however that carbon fertilization effects are still being debated (*cf.* Rosegrant *et al.* 2008).

considering what people can do to improve their livelihoods. Much of the work on vulnerability assessment 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 because they can overlook intrinsic adaptive capacity and the ability of land managers to adjust to change. It is important to specifically link climate change adaptation and mitigation to sustainable development of communities to enhance adaptive capacity (Laukkonen *et al*. 2009). Kofinas and Chapin (2009) argue that participatory location specific 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). Although there are several adaptation assessment frameworks, methodology and tools available for assessing community vulnerability and assessing adaptation options including technologies for adaptation at local level, their relevance and robustness is often questionable owing to their contradictory nature of being either too context-specific or being too generic. 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 (cf. Klein 2009). 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.

The focus on potential negative impacts of exposure and sensitivity to rising temperatures and other extreme events (cyclones, floods) tends to be disempowering for individuals, households and communities who are unable to directly influence these events. A focus on impacts is also disempowering because it overlooks the intrinsic adaptive capacity and historically demonstrated ability of affected populations to adjust positively to significant change under conditions of limited options and limited access to livelihood resources.

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 because they typically link possible responses back to actions and behavioural change that households or communities are able to initiate using the resources at their disposal and taking environmental constraints into account (Gallopín 2006). Moreover, such assessments more readily lend themselves to uncovering actions that farming households are already undertaking to adapt, as managing climatic risk is nothing intrinsically new to people who are constantly adapting to drivers of change, be they climatic, socio-economic, political or market in nature (Crehan 1992).

As the applicability of the vulnerability concept, especially in the context of climate change adaptation, is being debated, current research is developing frameworks that integrate investigations into the adaptive capacity of populations exposed to climate risks with more biophysical and quantitative research (cf. Roth *et al.* 2010). The aim is to incorporate self-assessments of farmers with scientific descriptions of exposure to hazards and available resources to cope. The idea behind these new approaches is to match experts' assessments of adaptive capacity with a self-evaluation of the target populations on what can actually be

done to adapt to ongoing processes (in addition to the continuing effort to improve livelihoods).

2. Two communities in South-West Bangladesh

Within Khulna District, located in the South-West of Bangladesh, two distinct communities are considered (see Table 1). The purposively selected communities give us an overall understanding of the situation in south-west coastal region of Bangladesh, and an indication of different levels of vulnerability. The community of *Kapalfuli*[5] is a subsistence-oriented agricultural community, which focuses on growing rice as the staple. Rice is grown for consumption while any surplus is sold off to earn additional cash income. Moreover, other agricultural activities are followed during the dry season, e.g. livestock holding, fish breeding, or dry season cropping (e.g., mungbean, okra). However, the availability of fresh water constrains agricultural production and precludes developing an entire second crop in the dry season. Hence, the focus is on subsistence while farmers constantly search for opportunities to make additional cash income to pay for agricultural inputs, maintenance of tools and machinery, commodities, and any repayments of debts from investments made. Rice is farmed intensively, i.e. at a high labour cost, and many farmers hire labour from local landless people to keep up with production.

Table 1: Community population and structure - Bangladesh

	Kapalfuli	*Labonkhola*
Total number of households	312	428
Average household size	4.5	5
Male/female ratio	49 : 51	50 : 50
Number of female headed households	10	15

Source: Data collected in 2011 by SERDI staff on location.

On the other hand, *Labonkhola* has until recently been dominated by the shrimp industry. As Khulna lies in the main shrimp-producing area in Bangladesh, the country itself being one of the major shrimp producers globally, this community has experienced a surge in conversion of formerly fertile rice fields into shrimp ponds over the last two decades (cf. Islam 2007; Ahmed *et al*. 2010). In recent years, however, it became obvious that shrimp cultivation exacerbates already existing issues of salinity in the area. Shrimp production, which uses saline or brackish water in ponds, has increased soil salinity in agricultural fields to a point where it becomes unfeasible to grow rice any longer, thus creating major problems of food security (Haque 2006). Shrimp cultivation has been branded as having major positive livelihood and income benefits (Ahmed *et al*. 2010). It seems, however, that farmers are now turning their back on this particular option as it endangers their livelihood portfolios and, most importantly, their subsistence base (Azad *et al*. 2009; Muralidhar *et al*. 2010). Issues of disease in shrimp farms – as in most monocultures – are virulent (Tuong and Hoanh 2009). Rather than being an adaptation to the limited availability of freshwater resources due to sea level rise, storm surges, saltwater intrusion, and changing water regimes in deltas, shrimp farming actually worsened the already dire situation of farming on Bangladesh's South West coast (Azad *et al*. 2009) (Box 1). Not only were households losing their staple, rice, which was the foundation of every other livelihood activity, but the shrimp production system, being

[5] All Bangladeshi names of communities and individuals have been altered to provide anonymity and protection of privacy.

built on a foundation of credit and debt hinged on every other aspect of farmer households' lives (Islam 2007).[6]

Box 1: The social and ecological implications of shrimp/prawn cultivation

The social and ecological impacts of both, marine shrimp and freshwater prawn cultivation first became known in the late 1980s and early 1990s with the "blue revolution" gradually taking over vast stretches of coastal areas in South and Southeast Asia. Previously, the demand for these products had been met by wild catch providing local fishermen and – women with an additional source of income. However, there were ecological issues around the rapid depletion of wild stock as well as large quantities of by-catch, which was dumped back into the sea. The plight of the sea turtle, which was often ensnared in shrimp trawler nets, caught the attention of the environmental movement in the West and international pressure to end wild shrimp harvesting and shrimp cultivation was widely seen as the solution to the problem (Martinez-Alier 2001).

It became apparent shortly after, however, that shrimp and prawn cultivation comes with its own ecological issues and, on top of that, threatens local farming households whose traditional livelihood sources are depleted. Globally, the bulk of shrimp ponds are usually converted from coastal mangrove areas, which leads to ecological decline, such as deforestation, coastal erosion and loss of biodiversity. In addition, mangroves are usually a source of food and income for coastal dwelling populations. In the case of South Asia, much of the shrimp cultivation area had been converted from rice paddies, which leads to soil and water salinity as well as decrease in local food security and dependency on global market demand as well as shrimp traders and processors (Martinez-Alier 2001; Ahmed *et al*. 2010; Islam 2007; Azad *et al*. 2009).

The case of converting agricultural land to shrimp ponds, especially, has implied drastic changes to local livelihoods. Whereas the depletion of wild catch and mangrove stocks have largely been identified as an ecological issues by comparatively more powerful environmental NGOs in the West, the deterioration of local livelihoods has gone virtually unnoticed in the public eye of industrialised countries. Thus, as global demand for crustaceans is rising the high likelihood of more paddies being converted to shrimp production due to pressure exerted by the powerful shrimp industry in the country (Martinez-Alier 2001; Azad *et al*. 2009; Ahmed *et al*. 2010). In order to mitigate increasing salinity levels, the Government of Bangladesh has devised policies to promote prawn cultivation instead of shrimp and is developing the formation of hatcheries to alleviate the pressure on wild stocks (Ahmed *et al*. 2008).

3. Two communities in Southeast Cambodia

In order to compare to a wholly different situation, albeit equally in a delta area, two communities in Cambodia are also considered. The aim of the comparison is to use the different observations as a correcting lens when listing policy principles towards the end of this paper. Policies on supporting the adaptive capacity of delta populations must be developed for large numbers of people and, hence, a large diversity of livelihoods. The bias of inferring recommendations from a non-representative sample of case studies seems

[6] The top 10% of farmers benefitted from this process, however only in the short term. Interviews in the field suggested that once a disease that caused widespread damage to shrimp larvae came through the area more advantaged farmers were basically left with worthless land and virtually no production. It may be suggested that those farmers were hit even harder because of their absolute dependency on marketed product while more disadvantaged farmers were able to resort to traditional methods of mitigating food security (fishing, backyard gardens, etc.).

inevitable. The two cases from Cambodia shall provide a glimpse into the range of livelihood types in delta areas.

Svay Rieng Province is located on the south-eastern tip of Cambodia with Viet Nam bordering the province on three sides. The province is part of the greater Mekong Delta, which includes most of eastern and South-Eastern Cambodia and well as the Southern tip of Viet Nam. The Mekong delta system includes the hydrological anomaly of the Tonle Sap Lake and river, which acts as a giant reservoir for the Mekong river's immense discharge during the wet season. As the lake's water table waxes and wanes the river changes the direction of its flow twice per year. Virtually all tributaries in Cambodia (with the exception of the far West) are connected to this system and are thus subject to flooding, depending on the amount of water in the main artery.

Such is the case in the community of *Chey Ressey*, whose agricultural land is flooded during large parts of the wet season and therefore unusable. Even though the community focuses on rice production, wet season rice cannot be planted. Instead, most households plant "recession rice" twice every year, before the rains come into full force as well as towards the end of the wet seasons, when floodwaters recede. Large parts of Cambodia follow this system of rice cultivation. Along virtually every major waterway recession rice is the standard production method, i.e., around the Tonle Sap Lake and river, the Mekong River, as well as its tributaries.

In comparison, the community of *Koul*, which lies further inland, practices rain-fed wet season rice. In fact this is virtually the only major agricultural activity conducted in the community. In addition, a few households grow vegetables for home consumption and a few keep cattle or pigs for emergency savings. Although there is a canal built through the community area of *Koul*, it appears that a secondary crop is not feasible to its residents in spite of water availability in the canal throughout most of the year.

Table 2: Community population and structure – Cambodia

	Chey Ressey	*Koul*
Total number of households	467	202
Average household size	5.7	5.1
Male/female ratio	56 : 44	46 : 54
Number of female headed households	51	43

Source: NCDD 2009.

Basic demographic statistics (Table 2) reveal distinct differences between the two case communities. Besides the differential community size, both male/female ratio and the percentage of female-headed households stand out. Both communities show relatively large household sizes, which is nothing unusual in rural Cambodia[7], and a high proportion of female-headed households , which is explained by decades of war and the Khmer Rouge regime The differential male-female is likely to be multi-causal, i.e., cannot be attributed to migration of males only. In *Chey Ressey*, many women are attracted to work in garment factories at the South-Eastern outskirts of Phnom Phenh. The relatively larger number of female-headed households in *Koul* contributes to the relative majority of females. While

[7] The overall – rural and urban – household size for Svay Rieng Province is 4.7; cf. NCDD 2009.

Koul's male-female ratio is less pronounced, most of *Chey Ressey*'s imbalance can be attributed to a drain in female labour from the village. With a number of off-farm income opportunities within reach of the community (Phnom Phenh is approximately 200km away), especially for females, many previously agricultural communities in Svay Rieng are losing their rural labour.

4. Living with and around water

4.1 Bangladesh

Both communities are based on mainly rain-fed agriculture. The first community, *Kapalfuli* on Polder 30[8], mostly cultivates rice during monsoon and several *rabi* – dry season - crops in winter using fresh water collecting from a canal under the polder. The second community, *Labonkhola*, on Polder 31 mostly depends on shrimp cultivation along with rain-fed rice.

General Features

While *Labonkhola* produces a single harvest in the agricultural season *Kapalfuli* is able to supplement the main rice harvest with secondary crops, such as mungbean, or ancillary production, such as cattle. In a general sense, variation of cropping patterns between villages may be understood as an outcome of geography. The single crop community is situated close to sea and dominated by characteristics of remote villages, such as disadvantaged access to markets or services. This paper shows how climatic change may create different opportunities and/or constraints depending on different social conditions. In this section we provide a brief overview of the study communities so the reader can build an understanding of the communities whose stories are told in this paper.

Labonkhola is characterized by poor road and communication networks, an absence of Polder maintenance activities, disadvantaged market facilities and, above all, a negligible presence of service providing agencies. Though government institutions have offices in *Labonkhola*, officials often remain absent. On the other hand, *Kapalfuli* is more accessible to the outsider and well connected to Khulna district town.

As shown in Table 1 the demographic features of both communities are not significantly different. The average household size of Labonkhola (5) is slightly larger than Kapalfuli (4.5). It has been observed that the population growth rate in hazard prone areas is comparatively higher since family planning service providers are reluctant to stay in those areas (Khan *et al*. 2010). This absence of service provision affects the supply of family planning facilities.

[8] *Polders* are areas surrounded by dykes or levees to protect that area against seawater intrusion. Often areas of reclaimed land, the embankments are man-made and allow regulating water within the area. They are a common in deltas around the world and the alluvial soil they are built around, together with the control over water usually making them exceptionally fertile.

Household types

To understand the farmer communities, within the given population composition and socio-economic conditions, focus group discussions were held in both villages to explore what different types of farming households are present, with the aim of understanding how different households perceive or apply different adaptation strategies. Facilitators explained the aims of the discussion and a participatory wealth ranking was used to explore and select indicators and characteristics of the different groups. Farmers considered:

- Ownership of assets;
- Access to public goods or resources;
- Household ability to transform assets;
- Individual status;
- Capacity for following alternative livelihoods options.

No single indicator is able to determine the typology of households. Thus, a combination of indicators is considered. For example a household with a small farm could be considered advantaged if they have access to reliable alternative income source(s). In contrast, a large landholding household, which has poor soil that does not have appropriate education and training to farm efficiently or is unable to join the non-agricultural labour market could be considered as a medium or disadvantaged household. Both communities defined four different types of farming households present in their community (***Table 3***).

The presence or absence of landless labourers is a significant difference between the villages (Table 3). In *Kapalfuli* 30% of households were identified as landless. In addition 20% were classified as disadvantaged households[9]. This means that the community is divided into 50% disadvantaged and 50% non-disadvantaged households[10], indicating that *Kapalfuli* is a polarized farming community, similar to other Bangladeshi village communities (cf. Arnes and Beurden 1977; Jansen 1987). In contrast, there are no landless households in *Labonkhola*, but it shows a higher percentage of disadvantaged households (60%) which provides a sense of less polarized community.

[9] During the self-assessment workshops the categories used across the two communities were *advantaged, medium, disadvantaged* and *landless*. Being a self-assessment, the categorization depended on the perception of the workshop participants. Our assumption is, however, that the categorization comes close to the results of a hypothetical wealth ranking (if one had been carried out) with land ownership being the main determining criterion.

[10] This classification refers to the farmers' self assessment. According to international definitions a much larger percentage, if not the entire community, would be classified as poor. Because this classification does not refer to absolute poverty the groups cannot be compared across communities. For example, a "medium farmer" in *Labonkhola* might be a "poor" farmer in *Kapalfuli*.

Table 3: Household types and land holding in two Khulna communities				
	Percentages of types identified in the two communities (%)		*Average land holding for household types (bigha)*	
	Kapalfuli	*Labonkhola*	*Kapalfuli*	*Labonkhola*
HH type 1. "advantaged"	10	10	5-10	>10
HH type 2. "medium"	40	30	1-4	5-10
HH type 3. "disadvantaged"	20	60	<1	<5
HH type 4. "landless"	30	-	-	-

Note: 1 bigha = 0.1338 hectare
Source: Data collected in 2011 by SERDI staff on location.

Does land size matter?

In both the communities, the top 10% of households were considered more advantaged farmers by the focus groups. They consistently have larger land holdings than the other types. Farmers in *Labonkhola* on average had bigger parcels of land than *Kapalfuli* farmers (Table 3). However, we must also acknowledge community differences in land productivity and land use. For the time being, however, it is noteworthy that *Labonkhola* tends towards larger land parcels.

Land productivity is determined by the quality of soil and water and the level of salinity. *Labonkhola* households achieve poor yields regardless of capital-intensive equipment and inputs compared to *Kapalfuli*. The reason behind such lower productivity is the location of croplands and level of salinity protection. *Labonkhola*, situated in Polder 31, is poorly protected from saltwater intrusion, while *Kapalfuli*, situated in Polder 30, is better protected. Weak protection from saltwater forces the *Labonkhola* farmer community into producing a single monsoonal crop (*Kharif*). The low productivity due to saline soil and water results in huge economic losses for the farmers regardless of land size or social differentiation. In this sense, land size is less relevant than the quality of the land and subsequent crop production.

In *Kapalfuli* the community is able to produce a monsoonal crop with higher yields per acreage as well as engaging into secondary agricultural activities in the dry (*Rabi*) season without an irrigation system in place. Advantaged farmers are able to invest in technology such as tractors to increase yields and diversify as well as intensify their cropping patterns. The medium farmers who are mostly *owner-tenants* cultivate their own and rented land to maximize production. In this case the size of land determines the wealth ranking. However, the level of yield per land unit depends on the farmer's economic position and their ability to invest in higher agricultural inputs. Yield differences are most visible in the case of the top 10% advantaged households.

Box 2: The impact of shrimp cultivation on *Labonkhola*

Labonkhola had different circumstances prior to the introduction of shrimp cultivation around 10 years ago. In the past, farmers were able to double crop in a diversified way. The introduction of shrimp forced the community into single cropping and resulted in lower rice yields. This forced a shift away from farming crops in favour of shrimp - from food to cash crops. Although there is less social differentiation in this community, the intensification of cash-oriented farming demands larger land size in order to maximize profit. Regardless of their economic status, farmers are drawn into competition to increase their farm size. This may affect the household's economic position and ability to explore off-farm options.

Additional income sources

Along with land size, the additional source of earning is a decisive indicator. Due to increasing level of salinity the productivity of land decreases constantly. As a result different types of households in *Kapalfuli* and *Labonkhola* community are now seeking more sources of alternative income.

In *Kapalfuli*, advantaged and medium households have well established alternative income activities. Advantaged farmer households are financially solvent with additional income sources such as poultry farming, livestock rearing or permanent employment like teaching and working for NGOs. In some instances, advantaged households store their rice and purchase food for consumption from the market, only to sell the stored products at peak market times at higher prices. They have the savings and facilities to be involved in this business where other household types cannot.

Medium farmer households are involved in petty businesses (e.g., tea stalls), poultry farming, and small formal and informal wage jobs such as teaching. As farmers with a higher degree of mechanization, many of them lease out agricultural equipment on a regular basis.

In *Labonkhola* all households involved in shrimp farming (see Box 2), regardless the status, are ridden with debt. With limited or no cropping option, farmers seek alternative earnings. Advantaged households are in a better position as they have access to local credit markets and products and links with local political institutions and service provider agencies. They get involved with small scale poultry farming, shop keeping and regular paid jobs.

However, in both communities, farmers of all household types develop additional sources of earning such as fresh water fishing, fruit tree plantation and small and medium poultry farming. These serve two purposes depending on the type - cost savings or income. For instance, for advantaged households, the productivity of pond fishing or small scale poultry is used for household consumption; while the medium household type use the product as a source additional income.

Landless households living in *Kapalfuli* are migrants from neighbouring areas. Due to its well-maintained Polder and income opportunities, the community attracts people to take up residence. These people often arrive from areas where livelihoods have become untenable due to, e.g., cyclone damage. They come to *Kapalfuli* to work for the more advantaged households and the few small businesses in the area. However, in the dry season, almost 100% of male members of the disadvantaged and landless type, and around 50% of the male members of the medium type migrate seasonally after harvesting the rice.

To bolster food supply most households use the area around their homesteads to cultivate food plants. Women of advantaged and medium household types of both villages grow seasonal vegetables and fruits such as *brijals*, potato, tomato, and banana around the house. In comparison, women of land disadvantaged households are involved in handicraft production such as making mats and sewing *Nakhshikathas* which is common in *Kapalfuli.*

4.2 Cambodia

General Features

Almost all residents of both, *Chey Ressey* and *Koul*, are landholders with a focus on rice production, however, with marked differences. As evident in Error! Reference source not found., average landholding in *Chey Ressey* is larger than in *Koul*[11]. The larger emphasis on rice production becomes more pronounced considering the fact that the former community harvests twice per year, while *Koul* only invests in one crop per season. Consequently, *Chey Ressey* manages to produce an average of 2.8 tons per hectare while *Koul* yields 1.7t/ha.

Table 4: Land area and harvested area in Svay Rieng, Cambodia		
	Chey Ressey [ha]	*Koul [ha]*
Total land area	472	264
Wet season	62	220
Dry season	395	44

Source: NCDD 2009.

Household types

The household classification follows similar categories as in the Bangladesh case[12]. Essentially, Error! Reference source not found. visualises social differentiation at the community level. Both communities tend to concentrate around the "medium" category, although *Koul* is more differentiated.

Table 5: Household types in Svay Rieng, Cambodia		
	Chey Ressey (%)	*Koul (%)*
Advantaged	-	16
Medium	77	50
Disadvantaged	14	30
Marginal	10	5

Source: Agroecosystems Analysis (AEA) of Chey Ressey and Koul villages (Department of Agricultural Extension, Ministry of Agriculture, Forestry and Fisheries, Cambodia)

[11] Around 1ha per household in *Chey Ressey* versus 0.8ha/hh in *Koul*.

[12] Note, however, that the categories are not comparable between Cambodia and Bangladesh as they reflect local circumstances and are context-specific. Refer also to Footnote 2. Effectively, the Cambodian types were assessed using household land size and income levels.

In *Koul*, while around two-thirds of farming households focus on rice farming and ancillary agricultural activities, the remainder grows rice for satisfying household demand, i.e., rice for self-consumption, and satisfy their cash needs through off-farm income sources. ***Table 6*** shows that over a third of the total population migrate seasonally to generate cash income[13]. Many villagers specified that they worked at garment factories, which is one of the booming industries in the country.

Table 6: Seasonal labour migration in Cambodian case communities		
	Chey Ressey	*Koul*
Factory	9%	31%
Construction	2%	3%
Total	11%	34%

Note: "Factory" refers to the growing industrial areas at the fringes of Cambodia's capital city, Phnom Penh.
Source: NCDD 2009.

Chey Ressey, on the other hand due to its higher yields and advantaged water availability is able to draw income from farming. In addition to satisfying local demand, farmers can produce an additional harvest with the recession rice system, which they market for export through traders. The rice planted for home consumption is a local variety, which is preferred by the villagers for its qualities in taste and appearance to modern improved varieties. To add to the local staple, vegetables and forages are grown along the banks of the canals and floodplains. Hence, there is less need to seasonally migrate in order to maintain a livelihood (***Table 6***).

Household dependency

In an analogy to the Bangladesh case of *Labonkhola*, however, *Chey Ressey* had put itself in the dependency of Vietnamese rice traders. All rice planted for export is of the Vietnamese VN504 variety[14]. This variety is somewhat controversial as it is not listed as one of the 10 official varieties eligible for export under Cambodia's new foreign trade laws of late 2010. Nonetheless, 100% of the cash crop rice harvested in the community is sent to Viet Nam through a network of Vietnamese traders. Cambodia has disregarded VN504 for various reasons: the state has no control over the quality of seeds and crop; the variety is susceptible to the Brown Plant Hopper (*Nilaparvata lugens)*, one of the most widespread pests in the country; the variety is prone to seed rot and blight; planting VN504 requires a higher amount of chemical inputs as the official varieties. Instead, Cambodia aspires to replace VN504 with the local *Chulasa* variety, which has similar qualities but avoids some of the negative characteristics.

[13] Seasonal migration has been identified as a growing trend albeit numbers are difficult to produce as seasonal and temporary migrants are not reflected in national statistics. Seasonal and temporary migration can be seen as a precursor to permanent urban migration but may actually remain a distinct livelihood strategy for some time in the future (Deshingkar 2006). The explicit link between seasonal migration and climate change has yet to be investigated.

[14] The information regarding the production and marketing system of VN504 originates from an interview with Mr Ngin Chhay, Department of Rice Crops, Ministry of Agriculture, Forestry and Fisheries, Cambodia (Ngin Chhay, pers comm.).

The farming households of *Chey Ressey*, however, continue farming VN504. Similar to the dependency created in the case of shrimp farming, VN504 creates a dependency on a specific supply chain, out of which farmers have difficulties liberating themselves. The seeds for VN504 are sold with a package of inputs (fertiliser, pesticides), whereby the buyer must purchase the entire package. In return, the crop is bought back at a guaranteed price after the harvest. The farmer does not have to worry about storage, seed loss, seed quality, chemical inputs or marketing of produce as everything is taken care of when entering into the agreement with the Vietnamese trader. Even loans or early payments for anticipated yield can be accessed (at a lower price) through the trader. The well-established system creates a dependency on a crop that leaves little flexibility to respond to changing requirements.

5. Current Adaptation Strategies

There are a series of adaptation techniques used in the villages to cope with hazards and minimize economic and social loss. Though households and communities have historically adapted to climate variability through many different strategies, their capacity to adapt is significantly affected by the ways local institutions regulate and structure their interactions: both amongst themselves and with external actors. *Survival strategies* drawn onto in times of crisis could be defined as adaptations to climate variability (see, e.g., Crehan 1992). As a result, practicing of such strategies eventually increases household and community level adaptive capacity that in turn reduces climatic vulnerabilities.

In general, successful adaptation practices depend on specific formal or informal institutional arrangements, i.e., adaptation never occurs in an institutional vacuum but is guided and managed by existing structure. Institutions are the channels through which external interventions reinforce or undermine existing adaptation practices such as agricultural techniques, water management techniques, diversification, common property resource management, etc.

Agricultural technology

In *Bangladesh*, in order to cope with dwindling yields and demands for increasing production, both villages have adopted saline tolerant crop varieties in addition to rice production. This diversified cropping pattern is prescribed by official agriculture extension departments as well as local NGOs due to the farmers' lack of adequate knowledge about innovative technological adaptation strategies. For instance, from 1972 farmers of *Kapalfuli* have harvested sesame at a small scale during the dry season. This saline tolerant crop enables villagers to grow a secondary crop in addition to their rice, albeit not at the same extent.

In some instances infrastructure investments by government or non-government programmes support diversification of cropping patterns. For example, the construction of Polders with sluice gates by the government has enabled the cultivation of sesame, pulses, jute and other seasonal fruit and vegetables. Ten years ago farmers kept agricultural land fallow during the dry season; today, crop diversification in this region is maintaining food security as well as economic gain for those with sufficient resources of land and labour. Medium farmers are most often able to take advantage of this option, but disadvantaged farmers are unable to do so due to lack of capital, inadequate access to local institutions and disadvantaged networking within the community.

In *Labonkhola***,** farmers are dependent on local rice varieties of wet season rice, such as *Borhan, Patnai, Rajasail,* suggested by government and non-government institutions. To adapt to the changed situation of increased soil and water salinity they are now trying to cultivate high-yielding varieties such as BR-47 or BR-23, which have been tested for their suitability to withstand salinity by agriculture departments. BRAC[15] is supporting this type of adaptation by providing seeds, training, and other technical support.

In terms of advantaged household types in both villages, crop diversification is relatively feasible due to better access to local government and non-government institutions. Such networking with relevant institutions enables them to adopt practices of reducing salinity in the soil. In addition, better access to other formal or informal private institutions, such as local banks or NGOs, also helps them to access loans for adopting such capital-intensive practices. Their communication with formal cooperatives, informal community-based organizations or even neighbour and kin networks also result in receiving more information and resources such as agricultural loans, training, and agricultural inputs.

In *Kapalfuli,* the slow and irregular onset of the monsoon season has destroyed huge amounts of seed in the past. In order to cope with loss of seeds and minimize the cost of purchasing seeds after initial planting has failed, the Bangladesh Agricultural Development Corporation has suggested developing emergency seed stores, which mitigate risk, should the first seeding suffer from rains are slow to arrive in the season (ODI, 1996). Emergency seed stores allow farmers, who typically store sufficient seed for a single seeding, to re-seed if first sowing is unsuccessful. This option is usually only feasible for advantaged households but medium and disadvantaged households can actually benefit from these as it becomes possible to borrow emergency seed from their advantaged co-residents

In *Cambodia,* agricultural adaptations can be made in three areas: (a) rice crops; (b) secondary crops; and (c) cropping patterns. In terms of rice, adaptations can be made by switching to other varieties, such as drought/flood tolerant varieties and/or improved (high-yielding) varieties. Also the production and storage of seed can be improved to prevent loss and increase germination efficiency.

In terms of secondary crops, the emphasis for adaptation is on plant legumes that regenerate soils after the rice harvest and provide for an additional income source. Currently, CARDI (Cambodia Agricultural Research and Development Institute) as well as some NGOs are experimenting with mungbean and maize as well as forage legumes. The objective is to rely on supplementary irrigation systems, such as ground water wells, or to make use of residual moisture in the soil following the wet season.

The third area of adaptation is essentially a combination of the former two. If, for example, households switched to short maturation rice varieties and started earlier in the season (using supplementary irrigation) they could easily plant a second crop and then even let their livestock graze on the stubble in the dry season when water becomes too scarce to plant. This is the type of integrated farming system the Provincial Department of Agriculture in Svay Rieng is promoting for poor and marginal households (Thach Rattana, pers comm.).

[15] BRAC = Bangladesh Rural Advancement Committee, one of the largest NGOs in Bangladesh and an important influencing factor in national rural development policy.

Water management techniques

In Bangladesh, before the arrival of commercial shrimp cultivation in *Labonkhola* during the early 1990s, the *gher* system – traditional fish farming – kept most canals fully functioning. Today, the villagers see better water management as the foremost requirement to return to their previous status of crop production. Organising the community to ensure canal maintenance is, however, increasingly difficult as shrimp production expands and interests on what type of works are needed diverge.

According to respondents, Polder 31 needs to be repaired as it does not sufficiently protect against saltwater intrusion. This task cannot be carried out by community labour without the support of public works. Political support for these infrastructure investments, however, seems lacking.

In the coastal region it is crucial to maintain an adequate supply of fresh water and prevent incursion of saline water through the management of sluice gates. In order to prevent *water salinity*, control of sluice gates is critical. Sluice gates are managed by relevant local extension departments to allow fresh water into the crop area during the wet season and prevent saline water to incur during the dry season. A committee of elected members, informal community-based organizations and cooperatives monitor water levels. All villagers have the same level of access to the provision of fresh water from rivers and canals; however, participants claim that the Water and Power Development Authority (WAPDA[16]) prioritize the concerns and needs of large landholders in considering control of the sluice gates.

The two communities in *Cambodia* face different issues. While the "recession rice" community is well adapted to the rise and ebb of the natural water cycle, managing two crops before and after the floods, they remain at risk should the water cycle change as in, e.g., an extreme weather event. Extreme flooding puts their livelihoods at risk as they could potentially lose an entire crop.

On the other hand, in *Koul* the issue is rather one of access to water. Even though there is a canal running through community territory this canal does not hold water year-round. It is only sufficient for supplementary irrigation during the wet season. Similarly, those households not adjacent to the canal do not benefit from stored water, since there is no system of distributary canals in place. Some get by with supplementary ground water wells if they are able to afford them (advantaged and medium households only). During the dry season agricultural water remains a highly sought commodity, to the extent that it may become unfeasible. Currently, all villagers have given up on dry season agriculture as the last two seasons have proven to provide insufficient water for a full dry season crop. Historically, that has not been the case and dry season crops (various kinds) were grown in the village. Today, residents prefer to find work in or around the growing urban centre of Phnom Penh.

[16] This authority has since split into two separate units: the Bangladesh Water Development Board (BWDB) and the Bangladesh Power Development Board (BPDB).

Market interventions

In *Kapalfuli*, due to better infrastructure and road communication farmers have better access to local markets and are able to exchange goods at the district town. Such access has enabled them to develop a more diversified economy. In *Labonkhola*, due to its inaccessibility and poor access to agricultural inputs the shrimp industry is monopolizing land use, and most farmers have little control or information on pricing and often incur losses as a result.

Involvement in small business or paid labour ultimately diversifies the livelihood portfolio of rural agricultural societies. Due to extreme salinity levels and other hazards, households in these villages are no longer fully dependent on agriculture. The need for cash forces households to apply a diversified income strategy. However, while off-farm income is mostly brought to *Labonkhola* through seasonal migration to construction sites, *Kapalfuli* is able to diversify both in-village production, such as cash crops and small businesses as well as external income through a larger range of opportunities in urban centres. In *Labonkhola* NGOs such as *Prodipon* provide loans to farmers to start non-farm income activities. Advantaged and the medium households mostly run grocery shops, while the disadvantaged are mostly involved in petty business.

As natural hazards increase (increasing frequency of cyclones, increasing levels of salinity) along with the decline in agricultural productivity, villagers stated they are trying to adopt other means of securing livelihoods (Box 3). Through the creation of markets farmers are now reverting to poultry, fisheries, homestead gardening, tree plantation, petty business, rickshaw-van pulling, etc., to gain extra income. In *Labonkhola*, more than 80% of the villagers engage in rickshaw pulling as an alternative income source. A local NGO, *Prodipon* supports this activity by providing free rickshaws to villagers.

Box 3: Household adaptation in Bangladesh

One villager named Syed Jalal has been given a rickshaw-van by BRAC, which helped him significantly to increase his income as he did not have the capability to purchase the vehicle. Through this small business he earns some money (150-200Tk or approx. USD 2-3 per day), which helps him finance his son's education and buy basic necessities for his household.

Sahajahan is a poor farmer living in *Kapalfuli*. He has two dairy cows. For every three litres the cows produce, he uses 1l to meet the nutritional needs of his family and sells the remaining 2l in his grocery shop. His wife usually takes care of the shop and earns 150Tk (USD 2) per day. They were able to start the shop about 5 years ago after receiving a loan from *Propidon*, an NGO. They repaid the loan of Tk 8,000 (USD 107) within 3 years.

Shudir is a poor farmer who owns 3 *bighas* of arable land in *Labonkhola*. During *rabi* season, he cultivates vegetables (watermelon and okra). He has also bought three mango-tree seedlings (5 Tk each) and has planted them in his homestead garden. He expects to get good quality mangoes in 3-4 years.

Bogoban is a farmer living in *Labonkhola*. He sold one of his six cows for Tk 16,000 (USD 214) and bought 2 chicks and 24 ducklings. He has started selling eggs and gets an annual income of Tk. 20,000 (USD 267). He also received training in livestock rearing from the Department of Agricultural Extension to make him more capable in rearing cattle.

Source: Household interviews conducted by SERDI staff in 2011.

In both communities, local informal institutions inspired the emergence of poultry farming among all types of households. This has increased their ability to cope with adverse situations. Local markets provide access to inputs for poultry as well as an avenue for sale of animals. In *Kapalfuli*, some households are entering in joint, profit-sharing poultry ventures with other households. In *Labonkhola*, poultry is carried out by the advantaged and medium farmers. In addition, by taking experiences from them, medium and disadvantaged are inspired to venture into poultry farming as well.

In the two *Cambodian* communities the international NGO International Development Enterprises (IDE) is working through "Farmer Business Advisors" – essentially, model farmers – to promote agricultural production for sale at local markets. Rather than seeking income outside of the community, the program is designed to create business opportunities in the village by, e.g., promoting a secondary crop that can be marketed (maize, mungbean) or planting vegetables during the dry season using small-scale irrigation facilities (groundwater wells, small reservoirs).

Household capabilities

Farmers in the Bangladesh study areas seasonally migrate to neighbouring, more advantaged areas. This usually occurs, when the croplands remain fallow or crops do not reach maturity to harvest. Advantaged households do not need to migrate; on the contrary, they are usually recipients of seasonal migrants for farm labour. In *Kapalfuli*, around 25% of the population (medium and disadvantaged) migrate from the village to spread risks should crops fail or yields falter. In *Labonkhola*, before the introduction of shrimp farming in the 1990s, seasonal or temporary migration was rare as labour was needed year-round (rice cultivation during wet season and secondary crops during the dry season). Under conditions of shrimp cultivation, almost 100% of the disadvantaged and 50% of the medium farmers migrate after harvesting rice as shrimp cultivation does not require the amount of labour available in the village.

Local NGOs have supported rural women to get involved in homestead gardening and grow cabbage, cauliflower, *brinjals*, pumpkins, ladies finger, gourd, kidney beans and other vegetables. Over the last 5 years, farmers are more inclined to cultivate homestead trees in their courtyard. Trees that bear fruit and those that can be sold for wood production are favoured to meet subsistence needs and provide income to the household.

In rural parts of Bangladesh, women of medium and disadvantaged classes are mostly supported in handicrafts by local institutions and the influence of kin and neighbour networks. As a result, rural women are able to contribute in household income. In *Labonkhola*, through a joint venture of *Heed Bangladesh* and *Father Rudi* women are sewing *Nakshikatha.* Gradually a cottage industry is developing within the village, helping the women to become self-sufficient. Women sew the *kathas* in their leisure time, receiving 500tk (approx. USD 7.00) for one item.

Throughout the coastal area in Bangladesh stocking foods and medicines is now common practice in order to cope with adverse climate events, especially cyclones. Households prepare by storing dry foods, emergency seeds, and medicines. In the example of *Kapalfuli* mentioned earlier, the community maintains a communal emergency seed store in order to safeguard against the loss of seedlings due to salinity or extreme events. These measures have

become standard due to increasing number of cyclone experiences and represent household coping strategies for natural climate hazards.

In *Cambodia*, while the IDE program promotes crops additional to rice for business purposes, many households in both communities plant vegetables for home consumption. This saves them from spending on food items and keeps those individuals busy who opt to stay behind during the dry season. In 2010, forty hectares of vegetables have been planted throughout the village of *Koul*, which has been made possible since the installation of the canal that retains rainwater during much of the dry season. In addition, they use techniques adopted by IDE, such as composting, and apply them to their homestead vegetable plots.[17]

The main adaptive strategy for *Koul*, however, seems to be migration. According to residents, an increasing number of seasonal migrants choose not to return during the wet season to plant rice. Rather, they find it more lucrative to work in the garment factories and constructions sites. Residents claim that most migrants eventually return to establish a household and revert to farming rice. The fact is, however, that the *Koul* community is losing inhabitants and, thus, farm labour. As early as 2008 close to a third of rural households in Svay Rieng District has at least one member working in the private sector (NCDD 2009). In *Koul*, over 30% of the population have found work in factories, which represents a strong pull factor should these jobs become permanent (Table 6). Already, 15% of the population commute beyond the district borders (most likely with the destination Phnom Phenh) to find work.

6. Adaptive capacity in Khulna District, Bangladesh

At a broad level Khulna District could be classified as vulnerable to the effects of climate change. However, looking at our two case communities, the picture becomes somewhat differentiated. Geomorphological, geographic, infrastructural, social and institutional factors determine the adaptive capacity of communities and households to deal with the primary effects of climate change in South West Bangladesh. Thus, different communities in Khulna district deal with very different types of climate change effects due to varying levels of adaptive capacity. Thus, interventions and practices introduced affect each community differently. For example while structural interventions like improved polders may be suitable for communities experiencing intermittent salinity intrusion from storm surges, they often exacerbate the problem in communities already suffering from intense salinity intrusion. The most prominent climatic hazards in Khulna are (a) salinity; (b) increased frequency of cyclones; and (c) changing monsoonal patterns. Each of these phenomena can be further disaggregated:

- Water salinity; soil salinity
- Wind, storm surge, and flood hazards associated with cyclones
- Quantity and seasonality/temporality of precipitation.

Each of these phenomena requires different types of adaptation. Hence, adaptation is not a matter of changing a few activities, e.g. applying more fertilizer to maintain production, but

[17] These activities were part of the implementation of the project *Developing multi-scale climate change adaptation strategies for farming communities in Cambodia, Lao PDR, Bangladesh and India*. IDE is a partner in this project and much of the Cambodian data in this report stems from observations made from either CSIRO or IDE staff.

requires a process of transformation of approach(es) that takes into account ramifications of adaptation for the entire production-consumption system of the community.

Equally, it is difficult to speak of adaptation as such, as each of these phenomena is characteristically different. For example, salinity is an ongoing, slow-onset threat to livelihoods but does not necessarily endanger lives directly. On the other hand, cyclones are (increasingly frequent) events that often lead to major loss of life but sometimes livelihoods can be rebuilt in a relatively short time span following their occurrence.

Not only do the varying characteristics of what "climate change" means to different communities determine the ability and capacity to adapt. It is also the specific set of resources available to and their respective access by the communities that differentiate potentials for adaptation. Three aspects can be identified here:

a Kind/type of resources available
b Amount/quantity of resources
c Range/distribution of varying resources

In addition to geomorphological factors, the institutional setting plays a rather important role as to which resources are available in a particular community and how they can be accessed. In fact, institutions govern the availability of resources, which, in turn, determine the level of adaptive capacity of a community or household.

Even though the two case communities, *Kapalfuli* and *Labonkhola*, are located in the same general area (same political district, same geographic area along the Sundarban Delta) they are characteristically quite different in terms of resource use and institutional governance. While *Kapalfuli* benefits from full access to government institutions, services and markets, *Labonkhola* suffers from its remoteness and its reliance on the supply chain. This section analyses some of the key differences that hinge upon adaptive capacity of the communities. Before going into this analysis, however, the key *physical* difference needs to be pointed out, which strongly affect the differences in the scale of exposure to climate change effects. Both areas are bounded by coastal embankment; equally, both communities are in close proximity to the sea and are situated in the same risk zone. However, the exposure to storm surges, flooding, and salinity is higher the further downstream a community is located. Storm surges affect those communities within closer reach to the open sea. Due to the frequency of these events, Polders tend to become dysfunctional earlier, i.e. more and more frequent maintenance work is required. This issue is evidenced by the devastation of Polder 32 following cyclone *Aila* in September 2009. The Polder wall was destroyed intruding water destroyed houses and agricultural fields. The population now still lives in temporary shelters on the Polder wall. There is no agricultural activity. Men are off working as labourers in other areas and the women and children remain at home without occupation. They are supplied with small amounts of rice from the government, but nowhere near enough to satisfy daily needs. Thus, regardless of resource management and institutional arrangements, *Labonkhola* will always be struggling with greater external pressures and constraints than *Kapalfuli* due to its physical location.

Remoteness

In part due to the location further downstream or closer to the sea, as well as the nature of the landscape, which is ridden by rivers, canals, streams, and other waterways, *Labonkhola* is far

more difficult to reach by vehicle than *Kapalfuli*, which is more easily accessible via main roads and geographically closer to the district centre. Most major road arteries in Bangladesh are built along an East-West axis, i.e. perpendicular to the major water arteries. Communities lying in the extreme South of the country often are not well connected to the road network, which gives them a disadvantage in terms of transport connectivity. Such is the case of *Dacope* sub-district, where *Labonkhola* is located.

Closely linked with the lack of road connectivity is another type of remoteness – lack of full institutional integration into the Government's administrative system. When accessibility is limited, local power structures tend to become more important than those imposed by the Government. The emergence of local *big men*, i.e. local leaders with power or wealth, becomes more evident and parallel structure of leadership replace the Government's bureaucratic arrangements (Devine 2000; Sarker 2006).

In *Labonkhola* two types of informal power figures are discernible: (a) traditional (Hindu) leaders with a community-sanctioned power base; and (b) modern (Muslim) middlemen connected to the shrimp industry who act as link between shrimp producers and the shrimp value chain (Islam 2007). While the latter have risen in influence in this previously Hindu-dominated community, the former remain important because government institutions have been slow in establishing their authority over community matters. *Kapalfuli*, on the other hand is more "mainstreamed" as the formal institutions (local authorities, formal political parties) have gained a foothold and there is no single institution dominating the community.

Economic structure

Due to the over-reliance on shrimp cultivation - a "cash crop" - in *Labonkhola*, the shrimp industry has been dominating the community's economic structure. Islam (2007) describes how this fertile region has come under the control of the industry, with local middlemen controlling all economic activities, including access to loans and provision of agricultural inputs. The farmers are disadvantaged in this process. The quasi-monopolised structure is supported by the central government policy on promoting the shrimp industry in Bangladesh, which is the second-most valuable industry in the country[18]. Thus, even if farmers intend to move away from shrimp farming they cannot easily do so as other options are not easily accessible (for alternatives, see Box 6). In addition, shrimp farming exacerbates salinity levels and, to a certain degree, encourages the intrusion of salt water on agricultural land. Consequently, other agricultural options are minimised, even if they are actively sought.

On the other hand, *Kapalfuli* displays a more diversified economic structure. While prawn cultivation is practiced by some farmers it has not taken dominance over other activities. Rice cropping is still the universal activity in the community. However, while rice is primarily produced as a subsistence crop, surplus is sold off to local agricultural markets, as are other crops produced during the dry season or around the homestead as well as any additional livestock. Regional markets are freely accessible and prices may be negotiated or, at least, follow the national standard rather than being set by a monopolised industry. Whereas in

[18] Relevant Government policies are the "Shrimp Mohal Management Policy (1992)" which identified and declared shrimp areas; the "National Land Use Policy (2001)", which allocated land for shrimp culture through zoning; and the "Export policy (1997-2002)" which promoted export and consequently shrimp cultivation.

Labonkhola, farmers are in the hands of industry middlemen, *Kapalfuli* farmers are "self-employed" and may chose to sell their produce at their own quantity and timing.

Community action

The history of land claiming in Bangladesh involves large-scale public works and major government investments into infrastructure, drainage, water management and, most importantly the construction of massive Polders. These dykes protect the land from the incursion of brackish water from the delta. A system of *sluice gates* allows regulating water levels.

Initially, the Government took on managing the sluice gates (opening/shutting, maintenance, cleaning) itself. Community members were trained and given a salary and a permanent house to perform duties as sluice gate masters. Due to budget cuts, these positions eventually got slashed and communities were left to manage the sluice gates by themselves. This has turned out to work better in some communities than in others. Comparing the two case communities, sluice gate management seems to work better in *Kapalfuli* whereas in *Labonkhola* sluice gates are clogged with debris and apparently dysfunctional, exacerbating the intrusion of saline river water during the dry season.

Kapalfuli, due to its higher levels of social integration as well as the lack of internal conflict over resources, has managed to establish a functioning management committee to regulate and maintain sluice gates. Smallholders in *Kapalfuli* follow a common objective, i.e. preserving available fresh water for irrigation while preventing incursion of saline water. They have the capacity to self-organise and assign responsibility to individuals to assure proper management of the sluice gates. While this still entails issues, such as whether the farmers of *Kapalfuli* have adequate information regarding seasonal water availability and how the decision is made to open or shut the gates, the system, based on community action, works well for the inhabitants. While the previous government-paid position of sluice gate master endowed an individual with an advantage and control over the village's water management the current system allows for greater ownership by the community and independent control over its assets[19].

On the other hand, in *Labonkhola* two issues prevent the proper management of sluice gates. Firstly, the lack of horizontal social networks (see section below) largely decreases the community's ability to install mechanisms of community action to address the management of its assets. Traditional institutions of arbitration and administration have virtually dissolved and have not been replaced by modern institutions of the state.

Secondly, there is actually no agreement over the objectives of sluice gate management. While shrimp cultivators encourage the incursion of saline water onto their land, rice farmers seek to prevent this. The result is that gates are opened and shut arbitrarily and, due to poor maintenance, tend to clog up and become unusable.

[19] This phenomenon is comparable to the debate in economics around common-pool resource management, which allows for the community taking responsibility in managing its resources without the need of government intervention. In this case, however, the resource is not a natural resource but infrastructure. We believe, however, the concept could be extended to common infrastructure as well (cf. Wade 1987; Bromley and Cernea 1989; Ostrom *et al.* 1999).

In *Labonkhola*, community based organizations, cooperatives and neighbour and kin networks are coming to terms with the long-term environmental and economic loss associated with shrimp farming. They are taking initiatives to phase out this activity against the vested interest of the shrimp industry. This insight was further enhanced by spells of disease in shrimp ponds that led to widespread loss and exposed the risks of their venture. While prawn farming is touted as a sustainable alternative to shrimp, its market value is lower and it also comes with environmental baggage (see Box 1, above). In the view of many villagers, reverting back to wet-season rice complemented by saline-tolerant cash crops and seasonal labour migration would better ensure long-term livelihoods (Rashid Bhuyan 2010).

Social structure

Kapalfuli could be characterised as a "traditional" village, based on subsistence agriculture with an objective of food security and additional surplus production being marketed for necessary cash income. While the more advantaged farmers – usually those with larger land parcels – are more market-integrated, the medium and disadvantaged farmers focus their efforts on subsistence production. The relatively large proportion of landless community members, however, necessarily needs to respond to market demands for labour. Interestingly, *Kapalfuli* seems to attract landless labour from elsewhere as those residing in the community have mostly migrated from other areas of Bangladesh's Southwest. The relatively high number of large landholdings demands agricultural labour. Workers enter in a traditional *patron-client* relationship with landowners and receive, in addition to financial reimbursement, food and the landowners' responsibility to look after their labourers in times of need (cf. Scott 1976 1985)[20]. This moral responsibility of those better-off towards people employed by them is embedded in the concept of community solidarity in Bangladeshi culture and transcends religious and ethnic boundaries. In times of strife this sort of relationship – albeit exploitative in nature – mitigates impacts through provision of basic needs.

Similarly, there are neighbourly responsibilities as well as those within the family, which, together with established work relations make up a "horizontal" social network (Datta 1991; Van Schendel 1986; Chen 1986) that boosts adaptive capacity of community members in villages like *Kapalfuli*. In contrast, *Labonkhola* is not characterised by such intense lateral networks within the community. Due to the hierarchical nature of the economic relations that come with shrimp farming, as well as the fact that the relations between individuals are purely transactional without traditional obligations involved, networks are "vertical", i.e. they follow the supply chain. This implies that the moral obligation for reciprocity in times of crisis is weaker. If a farmer cannot deliver produce the buyers may just turn to the next producer. As a consequence, community solidarity is weakened as traditional social relations become irrelevant and inter-community competition increases (Hartmann and James 1983). The farmer becomes dependent on the shrimp industry and options to draw resources from elsewhere become drastically limited.

The consequence of the contrasting social relationships in the two communities is that households in *Kapalfuli*, even if they may show indications of low adaptive capacity (low

[20] More recently, however, changes can be observed in traditional patron-client systems in rural Bangladesh. Landowners have been moving out of the rural areas into urban centres. As *absentee landlords*, they lease out land or employ a managers and labourers. In this case, landlords are usually concerned with the financial gain from the farm and, in case of a disaster, tend to omit support for their staff on-farm (cf. Scott 1972).

income levels, little or no landholdings, lack of economic assets) can cope with unforseen events due to stable and traditionally regulated social relationships. On the other hand, while *Labonkhola* farmers may earn income and economic assets are available, their brittle social networks tend to falter in times of crisis. The adaptive capacity of disadvantaged households in *Kapalfuli* depends on the moral responsibility of those with sufficient assets. In *Labonkhola* the adaptive capacity of all households is mediated by the shrimp industry, which does not need to abide to moral obligations.

7. Adaptive capacity in Svay Rieng Province, Cambodia

Whereas in the Bangladesh cases we have found one community likely to have a higher potential for adaptive capacity, the two cases in Cambodia, while economically and structurally different, seem to each have their own set of issues that tend to keep adaptive capacity low in both cases.

On one hand one could argue that *Chey Ressey* has successfully adapted to current economic demands and ecological limitations. Households have adapted their pattern of agricultural production to the hydrological cycle of the delta. They successfully do so by achieving two harvests of rice and have the potential to improve by adding secondary crops in the interim seasons. The cropping pattern keeps the labour in the community and there is little need to enter potentially exploitative labour relations with the industrial sector.

Economic structure

In terms of economic relations, however, the households of Chey Ressey have entered into agreements with Vietnamese traders that keep them dependent with little hope of exiting this relation quickly. They rely on the Vietnamese for seeds, agricultural inputs and loans, which is exactly the sort of vertical integration into the supply chain that *Labonkhola* has adopted in the case of shrimp farming. The traders naturally have more leverage in this quasi-monopolistic structure and, analogous to the shrimp case, it keeps the households of *Chey Ressey* poor. Poverty, in turn, keeps the potential for adaptation low.

Infrastructure

The other case of *Koul* suffers largely from the ecological limitations it is presented with. Even though it is situated in a delta, *Koul* is suffering from the lack of access to agricultural water during the dry season. With not much to do, other options, such as working in the garment factories on the fringes of Phnom Penh, become attractive and the recipe for rural flight is laid. With little choice left than to turn to where the income opportunities are, households in *Koul* cannot be said to have high adaptive capacity either. Even if progress is made in terms of providing agricultural options for secondary crops the doubt remains whether these would be able to outweigh the lure of fast cash earned in the factories. The story would be a different one if *Koul* were given access to a perennial supply of irrigation water. In this case livelihoods could be re-built around agricultural production in the community. These resources, however, would require major investments by the government as the situation is not one that the community itself can resolve on its own.

In sum, both communities suffer from the lack of opportunities to adapt. While *Chey Ressey* is locked into a cycle of borrowing, provision of inputs and guaranteed buy-back, which it

finds hard to break, the situation in *Koul* responds to the lack of adequate local resources. While they have both adapted to their current situation, adaptive capacity in both cases remains low due to their inflexibility to respond to new situations arising due to climate change. For example, *Chey Ressey* will find it difficult to respond to increased flooding by introducing new, flood-tolerant varieties due to its fixation on VN504. Similarly, *Koul* will only be able to respond to increasing climate variability by sending off more seasonal migrants who will eventually turn into temporary or permanent migrants, thus adding to decreased adaptive capacity in the urban hubs[21].

8. Differential Adaptation

Even when dealing with slow-onset impacts of climate change, such as the dominating issue of salinity, the adaptive capacity in *Kapalfuli* can be assessed as higher due to the higher levels of economic diversification in the community. Risk is mitigated through a focus on subsistence and surplus marketing. In addition, the diversity of agricultural products leads to lower dependency on a particular supply chain as is the case in *Labonkhola.* Cattle, dry season crops, fish, prawn and even shrimp are sold off to markets without needing to buy inputs, get credit, or sell to a certain trader. Farmers in *Kapalfuli* will sell when they need to and may 'shop around' for the best available price. Due to their better connectedness to the district market they have access to a range of buyers and use competition among traders to their advantage. The focus on food security even allows them not to sell should they not produce sufficient amounts or decide to use them for self-consumption.

Social relations in *Kapalfuli* further increases adaptive capacity as traditional local dependencies create a culture of looking after fellow villagers, even if the relationships are inherently exploitative. The fact that people are known personally, and villagers share their private as well as public lives in the well-integrated village leads to households supporting each other in order to maintain the relationship after the crisis, which is often of mutual benefit.

On the other hand, shrimp farming in *Labonkhola* is unsustainable and is crowding out other forms of land use and therefore decreasing diversity of resource use in the community. This, combined with the monopolistic economic structure of the shrimp production system decreases their adaptive capacity to a degree that alternative resource use becomes impossible. In a situation lacking other options, if resources required in shrimp production deteriorate, e.g., due to heat stress or disease, households are left with little else to make a living.

Any adaptation strategy in the study area needs to target the entire livelihood portfolio of the communities' households. Rather than searching for "silver bullet" solutions adaptation must cross-cut the various activities households engage in. This promotes mitigation of risk and increases the probability of adaptation success. Contrary to "revolutions" (green, blue) experienced in past decades it seems indicated that remaining true to the term "adaptation" is more likely to be successful, i.e. gradual, incremental change according to what the current situation and the foreseeable future demands. The following section looks into the areas of potential adaptation developments.

[21] For the increasing vulnerability of urban populations to climate change see IPCC (2007); for initial research on the relation between climate change and urbanisation see Kolmannskog (2009).

Extreme climatic variability is dwindling agricultural production and leads to long-term degradation. The Third IPCC report identifies crop production in low-lying developing countries to suffer most from adverse agro-climatic conditions (IPCC 2007). In order to mitigate such enormous financial and environmental loss farmers of different household types in the studied villages have diversified their livelihood options along with cropping. Any future strengthening of adaptive capacity needs to take current adaptation into account for three reasons: (a) adaptation strategies, especially technical adaptation strategies, are inefficient if they are imposed upon farming households already struggling to make ends meet. Transaction costs are high and ownership is low. Only the most desperate will engage with the level of risk involved; (b) current adaptation strategies are, by definition, adaptations to an ongoing process of change. By having adapted, it shows that farming households have capacity to do so, even if adaptations have not proven successful; and (c) screening current adaptations regarding their suitability seems more cost-efficient than introducing new practices. In addition, even when introducing new technologies it seems reasonable to look for locally acceptable entry points rather than forcing resource-disadvantaged populations into high-risk transitions.

Cropping

Agriculture plays a crucial role in the rural livelihoods context of Bangladesh. Different types of farm households diversify their livelihood options based on agriculture as these options are more available to them as they have good knowledge and experience of activities like livestock rearing, poultry, renting of agricultural equipments and so on. The on-farm livelihood options for different types of households are described below.

Cropping or growing of seasonal crops is still the most prominent option of livelihoods in the salinity-prone coastal belt. In both communities, cropping is the main livelihood option for advantaged, medium and disadvantaged households types as farming has been handed down from generation to generation. The advantaged farmers of both villages earn sufficient income from cultivating their *6-10 bighas* (0.8-1.3ha) of arable land.

The medium and disadvantaged household types achieve lower yields than advantaged farmers due to poor capability to adopt better equipment and practices. However, the location of land is also important with some advantaged farmers producing less due to the close proximity of their croplands to the Polder and/or salinity-prone zones.

Cropping is currently not an option for the marginal farmers and landless as they have so far been unable to purchase land due to disadvantaged financial capital and the distrust of other villagers.

Rent out farm machineries

Renting out agricultural equipment such as tractors, shallow tube wells, pumps and power tillers have become crucial secondary income source during crisis periods. This is predominantly an option for the advantaged farmer type as the initial investment makes it less viable for disadvantaged and medium household types. In both villages, machines are rented

on an hourly basis. For instance, shallow machines cost around 60-70 tk (approx. USD 0.8-0.9) per hour, whereas a tractor costs around 700 tk (approx. USD 9.5) per hour.

Homestead gardening

Growing vegetables is also profitable, with the price of vegetables increasing due to low yields from other agricultural crops. Women have started with homestead gardening around ponds or other available space. Common products grown include gourd, beans, *brinjal*, peas and spinach.

Growing vegetables has the dual purpose of meeting subsistence needs, with the option to sell excess on the market. The larger land area available to advantaged and medium class household types mean this is a viable option for them. In contrast, the extent of home gardens in disadvantaged and marginal types is much smaller due to land and time constraints.

Aquaculture/fishing

Fish culture and fishing in water bodies is an alternative livelihood option for households in the coastal belts. Fishing and shrimp cultivation has been a prominent livelihood option in *Labonkhola* village (see Box 4 for an example of fishing as a main livelihood activity). Advantaged household types used to cultivate prawn on their own *gher* in order to guard against theft and increase profits. Medium and disadvantaged types pooled resources to cultivate on *gonogher* – community-based ponds - and shared profits.

Box 4: The economics of fishing

Along with agriculture, Boral Morol (60) also engages in fishing to secure his livelihood. During Bengali months Bhadro and Ashin he catches Hilsha fish. He used to have his own boat and fishing nets, but now he rents a boat from other people. He has to provide 1,000 tk (approx. USD 13.5) as rent and earns around 10,000 to 20,000 tk (approx. USD 135-270) in the 2 months he goes fishing. Buyers take the catch each day and pay the money the following day. Recently, he lost an expensive, 2,000 tk (approx. USD 27.0) fishing net when it collapsed in deep water.

Source: *Household interviews conducted by SERDI staff in 2011*

However, salinity concerns and perceptions of environmental degradation have caused a reassessment of this livelihood option as socially unacceptable. There is a desire to return to more traditional farmer identities and cease prawn and shrimp farming. Over the last two years in *Labonkhola,* an increasing number of villagers are refusing to cultivate shrimp. Though the yield of agricultural crops is low due to salinity levels, they engage in rice cultivation in addition to growing saline-tolerant marketable crops, such as cowpea, sesame and watermelon (Rashid Bhuyan2010). More recently, the Department of Fisheries is promoting the "rice-fish" system to diversify income sources (see Box 5).

Box 5: The Rice-Fish system: a viable adaptation option?

The Department of Fisheries in Bangladesh are heavily promoting a system of *integrated rice-fish production* in Khulna District as a way to wean farmers off shrimp cultivation and provide an alternative income source. In fact, legislation nominally discourages shrimp (not prawn) cultivation because of its relation to problems with salinity. However, ex-shrimp farmers struggle to find alternative income sources.

For rice-fish to be feasible canals must be dug between the rice field and bunds (see Fig.1.). The surrounding canals breed fish, such as *bethi, monosex tilapia, mirror carp* or *nilotina*. Fertilisers used in rice cultivation also serve as feed for fish. In turn, fish faeces have fertilisation effects on rice production.

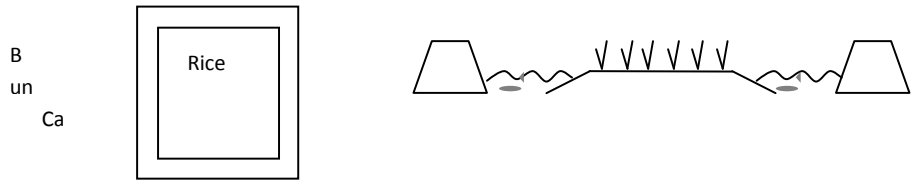


Figure 1: *Bird's-eye and transect sketch of the rice-fish system as promoted by the Fisheries Department of Khulna District.*

According to the district fisheries official interviewed, the system requires an initial investment in landscaping for the farmer and only works in moderately saline fields. Fish fingerlings are available from commercial hatcheries. The Fisheries Department regards the fish-rice system as a viable alternative to shrimp and it is catching on slowly among ex-shrimp cultivators. The system reduces rice production area by 20-25%, which is offset by expected benefits from fish sales. The initial costs are high (excavation, purchase of fingerlings) and farmers need training and cash for start-up. There are various options for single species or multiple species management including three species of fish or carp plus prawns. One limiting factor, however, is that fresh water needs to be available for 8-10 months per year. Fingerlings also need to be available at the right time from the hatchery.

According to Tuong and Hoanh (2009) rice cultivation is a low-risk enterprise but limits opportunities for income generation. Shrimp cultivation, on the other hand, can be profitable but depends on the supply chain and risks involved are higher (prices, disease). Rice-fish may be a combination, which ensures food security for farmers but allows for profits from fish without too many environmental trade-offs and risks involved. *Polyculture*, if managed sustainably, can increase overall food production and contribute to the development of coastal areas (Ahmed and Garnett 2011; Tuong and Hoanh 2009).

Nevertheless, there are some factors that inhibit scaling-out of rice-fish: (a) the above-mentioned initial investment costs; (b) higher production costs (input costs) than monoculture rice; (c) lack of farmers' technical knowledge concerning the management of fisheries; (d) risks associated with flood and drought in the deltas; (e) poor water quality; (f) fish mortality due to heavy use of pesticides or rising temperatures. It seems, however, that rice-fish is a viable option to deal with the issues associated with shrimp as well as providing benefits to smallholders in terms of alternative income generation (cf. Ahmed *et al.* 2011; Ahmed and Garnett 2011).

In *Kapalfuli* all types of farmers have ponds near their homestead. Fishing and aquaculture is important for household consumption and where supply allows, for additional profit through sale. Open access to the river in both villages means fishing is a livelihood option for marginal household types.

Poultry

Poultry farming is emerging as a common adaptation option in response to increasing rates of soil and water salinity (see Box 6 for an example). In both villages, farmers of all types of households are moving towards poultry farming on large scales to support or supplement household income.

Like other livelihood options the advantaged households have an advantage in poultry raising due to higher investment capacity. However some advantaged households lease their poultry out to medium and disadvantaged household types. In this situation, the owner bears the cost of the chicks, feed and medicine while the other household looks after the animals on a daily basis. When chickens are sold, profits are shared equally. Almost all households rear a small number of chickens and ducks for household consumption. Some households are also raising poultry in conjunction with ponds or other water bodies, where they are culturing salt and fresh water fish along with poultry.

Box 6: Investments into livestock rearing

Atul Bairagi (60), a large farmer, started his poultry business by investing 30,000 tk (approx. USD 405.00). He earns around 194,000 tk (approx. USD 2,622) and needs to invest around 84,000 tk (approx. USD 1,135) for feed and maintenance of broiler chicken and 10,000 tk (approx. USD 135) with an investment of 92,000 tk (approx. USD 1,243) on local chicken each year.

Source: Household interviews conducted by SERDI staff in 2011.

Livestock rearing

Livestock rearing plays an important role to cope with any disasters or times of crises. However over the last ten years, livestock rearing has been in decline. According to the villagers of *Kapalfuli*, the decline is due to extreme heat, which has reduced fodder available for cattle. Previously, 1 bundle of straw cost 20tk (approx. USD 0.3), now it can cost up to 200tk (approx. USD 3.00). Land use change and conversion of grazing areas to shrimp ponds may be another factor. In addition, power tillers have replaced cattle to plough land and cattle are thereby losing their previous multi-functionality.

In *Labonkhola* the situation is more extreme since the disadvantaged and marginal household types lack enough financial capital to invest in cattle, while the extreme salinity of the soil restricts the cultivation of forages. Some households in the advantaged household type have entered into shared cattle arrangements with medium and disadvantaged households, sharing equal profits when cattle are sold.

Business

Due to increasing climatic hazard, villagers of both areas do not get optimal levels of return from on-farm activities[22]. As a result they secure cash income with on-farm activities. The following off-farm activities are preferable additional livelihood options regardless of agriculture activities.

Business is the fastest-evolving livelihood option in both communities. Advantaged households are involved in stock businesses, grocery and also renting out agricultural equipment. In some instances, these households are able to store excess paddy and sell it in the local market during the peak demand at a higher price. The other types do not have the resources to undertake this type of activity, however, as with share-poultry and livestock, the opportunities of the advantaged household type often filter down to others.

Some medium households act as brokers and sell paddy that has been stored by advantaged farmers at the local market and receive a small portion of the profit. Disadvantaged households may have petty/small scale businesses, however, this is rare as they lack financial capital to start up a business of their own. Rather, they most often rely on employment by others.

Small official jobs

Involvement in small official jobs in the rural areas of Bangladesh ensures better livelihood security. In both villages many of the advantaged and medium farmers are involved in small official jobs, such as teaching, working in banks, NGOs etc. This is an option for a minority of disadvantaged households, whereby low literacy rates of marginal household types rule them out of contention for these jobs.

Handicraft

Making and selling homemade products to local agents enhances empowerment and mobilization of rural women and contributes to household income. Unlike the advantaged farmer households women of medium and disadvantaged class in *Labonkhola* village sew *Nakshikathas* and mats after receiving training from local NGOs. However, women of landless classes are not involved in such handicrafts due to shortage of time since they usually work in wage labour. Through involvement of local NGOs such handicrafts are also emerging in the *Kapalfuli* village.

Wage labour/Rickshaw or van pulling

Working as labourers on other people's land, rickshaw-van pulling or migrant labour enhances the secondary income options and also mitigates the damage from agriculture sources due to increased salinity level in the rural areas (see Box 7 for an example). In both villages, farmers of medium, disadvantaged, and marginal classes earn better livelihoods during the off seasons. They usually migrate to neighbouring districts to work as day labour. Due to social and cultural barriers migration is not an option for the advantaged household types.

[22] Or, as it increasingly happens, no return due to cyclone destruction (see "Introduction", above).

Box 7: Labour migration

Devtul Morol (50), small farmer, migrates to neighbouring villages due to decreasing crop production. He migrates during the Bengali month *Bhadro*, when crops are planted in one village, and to different villages during the Bengali months *Ashin* and *Karthik* to help with harvesting.

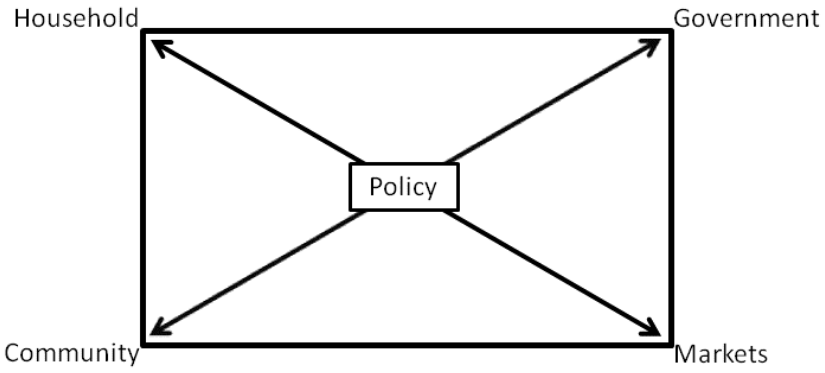
Source: Household interviews conducted by SERDI staff in 2011

Lower and marginal class farmers are mostly day labourers or rickshaw-van pullers. These farmers do not have any strong network with the upper or affluent household types. Most of them live on day-to-day earnings. The disadvantaged farmers of *Labonkhola* are also migrating to repay back their loans and along with the farming activities, they are working as day labour.

9. Lessons for policy development

Policy recommendations targeted at improving adaptive capacity towards climate change can be divided into four fields covering the social reality of resource use by smallholding and landless households: (a) the households themselves; (b) Government; (c) the community; and (d) markets (see Figure 2).

Figure 2: Areas of social reality affected by policy to increase adaptive capacity



Source: Authors.

When interviewing villagers and local officials, demands towards the Central Government are often voiced. The impression is that, if only the Government would allocate resources to certain problematic areas they would automatically be fixed. While the Government (or the "State") has an important role in setting a regulatory environment that allows adaptation options to develop as well as investing into public infrastructure it cannot enforce adaptive capacity. The community, on the other hand, constantly needs to react to and has the ability to develop adaptations to certain environmental (and others, including State-induced) stresses, as does the household. Lastly, markets, in their role mediating global demands on local products as well as creating supply chains that offer economic options to rural farmers can assume roles of either promoting or inhibiting local adaptive capacity (Lea and Chaudhri 1983; Bebbington *et al*. 2006; Smit and Wandel 2006).

Policy cannot refer to national policy alone. Otherwise, the sort of *hand-out mentality* alluded to above prevails. Instead, policy needs to focus on creating an environment that promotes and supports active adaptation by the community. Regulations and incentives devised by policy must be able to encompass visions, targets, and strategies set by the communities as policy is not able to reflect local specific requirements and development aims. Focusing on national policy development alone may create a type of dependency, which potentially reduces adaptive capacity and inhibits self-determined adaptation. The four areas reflected in Figure 2 therefore represent areas of policy development along different hierarchies (household – community – state) as well as markets, which are, in itself, multi-level and strongly affect local economic practices. While levels and dimensions can be added, e.g., levels of governance or dimensions of culture, the four identified have the most direct effect on building local adaptive capacity.

The issues in decreased adaptive capacity have been identified in the above case studies: single-dimensional social integration along industrial supply chains; monopolistic land use and monoculture that precludes alternative land uses due to environmental degradation (salinisation) and supply chain dependency; as well as lack of community action and community solidarity and remoteness. From these issues, follow a set of policy principles and a number of possible strategies for policy development. According to each strategy, examples are given as to how the actual policies may be realised. It must be stated, however, that this is a research paper and that concrete policies can only be developed with the inclusion of stakeholders and policy-development institutions and follow the respective process in policy development, depending on the country.

Policy principles

The data presented in this paper suggests that adaptive capacity is highly volatile and depends on a vast number of factors and influences even in a general area considered 'vulnerable'. Megadeltas are in itself vulnerable areas, but adaptive capacity, in the cases presented above, depends on geography, economic dependency, community action, and social structure. It follows that large-scale programs devised onto vulnerable areas are unlikely to increase adaptive capacity as they cannot take local specifics into account. Rather, policy should be able to allow for local variation within vulnerable areas and thereby create the space needed by communities to become active in their adaptation processes.

From the community cases described above, it becomes evident that the observation and analysis of adaptive capacity cannot be separated from processes of global change. As we look at adaptive capacity in any particular community of a developing country, rapid development occurs simultaneously, as do environmental change, industrialisation, rural-urban migration, etc. For these reasons, assessments of adaptive capacity become historic as soon as they are completed due to the social dynamics occurring at a more rapid pace. Two lessons must be derived here: (a) assessments of adaptive capacity (and vulnerability) are mere snapshots of development and must be treated as such by policy; and (b) adaptation occurs as part of global change and therefore needs to be mainstreamed by policy into other policy development rather than treating it as a separate matter. Hence, adaptive capacity needs to be weaved into rural development policy, economic policy, environmental policy, etc.

Policy strategies

Having stated that adaptive capacity is highly diverse some overarching strategies, however, emerge by comparison among the four very different communities in Bangladesh and Cambodia. Hence, the following policy strategies can support policy development along the four dimensions suggested above in Figure 2.

In order to prevent dependencies arising such as those to the supply chains of shrimp and rice, economic *diversification* seems to generally strengthen adaptive capacity, at least at the low capitalisation level of communities investigated in this study. We are dealing with communities at the threshold between subsistence and market agriculture. Investing people's efforts into a single income source to escape poverty seems attractive to them but entails a number of emerging properties that lead to detrimental effects for both standard of living as well as adaptive capacity. Monocropping, especially, can lead into lock-in situations that initially require heavy investments, which may not pay off if the effects of climate change or other external shocks preclude harvesting the returns. Communities that remain risk-averse, keeping one foot firmly in subsistence agriculture to ensure local food security have the ability fall back on it in times of need. Similarly, if investment capital is spread across different business ventures, such as cash crops, rickshaw driving, handicrafts, etc., then dependencies are prevented should the supply chain ever fail.

Local adaptive capacity can only be supported through *strengthening local institutions*. National level policies are too broadly conceived to respond to local requirements or specific needs. National policies can, however, strengthen national institutions to support local institutions for informed decision making. Local institutions, on the other hand, are able to identify needs, report them, set targets, and build strategies around them. Local institutions could be Government institutions (e.g., local offices of line ministries, such as agricultural extension) but could also be community institutions, such as farmer groups, water management committees, community advisory boards, etc. Furnished with clear objectives, mandates and resources, such institutions could act as the 'eyes and ears' on the ground and detect deficiencies as well as recommend solutions. Creating equitable and representative local institutions can support community solidarity and working towards common goals. They could also act as monitors to assess the efficiency of national policy when implemented locally.

National policies on adaptive capacity need to shy away from patronising communities. Rather they should work towards *creating an enabling environment* for adaptive capacity to develop. Just as the community is dependent on policy directions by the state, the national Government is dependent on local communities to adapt to current and future climatic change. Any policy on adaptive capacity, therefore, must take into account the mutual dependencies between various levels of governance rather than using communities merely as playing fields for policies to pan out.

The following sections provide a few examples for possible policies along each of the four dimensions, namely (a) household; (b) community; (c) Government; and (d) markets (Figure 2).

Household

The household level is the locus of specific measures of adaptation. One of the more successful ones has been mentioned in the report, above. The adoption of rice-fish systems as an alternative to detrimental shrimp cultivation has proven viable to farming households while still following the principles introduced through shrimp. Fish production provides real income to households (albeit initially at lower levels than shrimp) while rice ensures food security. As added benefits, households are less dependent on monopolistic traders for their product but can make use of trader competition or even choose to sell locally. Rice-fish has far less negative effects on soils and water than shrimp and households do not depend heavily on the industry to provide inputs. These insights are slowly catching traction in Bangladesh, both, among the shrimp-producing households as well as government offices, such as the Department of Fisheries, which promotes rice-fish and offers training to convert rice paddies.

Community

This study shows that community action and community structure can make the difference between high and low potential adaptive capacities. Hence, there needs to be a focus on functioning and integrated communities to provide opportunities for adaptation strategies. As in the case of sluice gate management, the community is able to manage such resources at the local level. A high degree of community solidarity and well-integrated horizontal networks support common-property resource management and thereby improve adaptive capacity. Farmer groups or water management committees could enable autonomous management of water run-off and storage when needed and provide water to those who need it. Such clearly identifiable institutions have the additional benefit of being able to be targeted by NGOs or national government for support in order to further strengthen adaptive capacity.

Government

Government must assume the responsibility to maintain *protective infrastructure*, such as Polders, irrigation canals and stormwater drainage. No single community can afford to maintain infrastructure on this scale and it is crucial for adaptive capacity to be able to adequately access the critical resources land and water. Large infrastructure performs that task, however, only if it is adequately maintained and protected. Under this prerequisite there are various ways of enacting infrastructure maintenance, such as co-investing into infrastructure maintenance costs (state, community, and industry), establishing repair funds, direct intervention, etc.

In remote areas *connectedness* makes a huge difference in the potential for adaptive capacity. If we accept the assumption that adaptive capacity is essentially a function of livelihood diversity and opportunities, interconnectivity with markets and service provision is key. It usually falls into the responsibility of government at various levels to allocate budgets to road construction and diligent planning in this area is crucial.

To assist farmers in adapting agricultural activities to changing weather patterns it appears crucial to make efforts in providing them with up-to-date information on forecasts for as long a period as possible. While research is improving the capacity for *seasonal forecasting of weather patterns* this information must be provided to farming households timely and easily understandable.

Most governments entertain agricultural research organisations to improve production of this sector. It seems mandated, today, that increasing production cannot be the only objective of these organisations. Rather, they need to include climate projections and their on-ground symptoms into their analyses and *solutions development*. For example, CARDI in Cambodia is putting stronger emphasis on developing flood and drought tolerant varieties and disseminating them to farmers. Similarly, BRRI and BARI in Bangladesh are experimenting with salinity tolerance of existing market crops, such as cowpea, mungbean, watermelon, and sesame. The challenge lies in integrating the latest in climate science with agricultural development and extension to assist farming households with knowledge and skills to bolster adaptive capacity.

Communities experiencing dependency on single supply chains, as in the examples of shrimp farming or the Vietnamese rice varieties often face the issue of unstable land tenancy as they are battling debt and fending off land grabbing. For example, the expansion of shrimp farming in Bangladesh promotes more advantaged farmers to expand their landholdings as more disadvantaged households must retract because they cannot afford the required inputs. While some revert to labouring in the fields of larger farmers others choose to migrate to urban centres, which puts their land under risk of being usurped by farmers striving to extend their land resources. Government needs to intervene in such cases and *establish land security* for farming households to appropriately manage their resources.

Markets

Markets play a crucial role in providing opportunities to farming households. Provided markets allow fair pricing and equitable access to rural households they can act as a major catalyst to improving adaptive capacity. This study contains two cases of quasi-monopolistic structures (*Labonkhola* and *Chey Ressey*), which has led to a decrease in adaptive capacity among the affected communities. If markets remain open and households are given opportunities to choose between varying sets of livelihoods the critical parameters of diversity and options can be maintained. Government regulation can support this process. In the case of *Chey Ressey*, Government has banned export of the variety produced by the community. Instead, it has enabled 10 local varieties to be exported, which ensures quality control, pest management, and responding to international markets. In the case of *Chey Ressey*, however, the lack of enforcement leads to market failure and, thus, the unfavourable situation the community finds itself.

Another possible measure, trialled elsewhere under the UNDPs “Access to Information Programme (A2I), is active promotion of price transparency to prevent quasi-monopolistic structure to emerge. Programs that deliver daily price updates to cotton farmers in West Bangladesh through text messaging services (SMS) have proven successful as farming households are able to decide when and to whom to conduct their sales to achieve the best price. In this way, market imbalances and intransparency of information are mitigated and farmers can achieve a fairer share of their product.

10. Conclusions

The comparison of case communities in this study covers communities situated at the top (Mekong) and the very bottom (Sundarban) of a delta. While all are vulnerable, the analysis of adaptive capacity has shown that communities with higher adaptive capacity show a higher diversity of resource use portfolios, horizontally integrated social structure, mature economic structure and the vicinity to market hubs. These communities are more likely to withstand shocks as well as adapt to slow-onset effects of climate change. The recommendations presented here, however, do not imply that communities with lower adaptive capacity should strive to become like the ones identified to have higher adaptive capacity. Such a goal would be highly unrealistic because of different levels of exposure as well as particular characteristic specific to each community. We can, however draw some lessons through the comparison and extract policy goals that could be achieved and improved in both communities.

The communities analysed and compared in this report lie within 'vulnerable' megadeltas (IPCC 2007) and, thus, it could be assumed that similar sets of policy may apply homogenously to develop and support their adaptive capacity to deal with current and prospective climate change symptoms. The study has shown that, while all communities need to deal with the new sets of drivers originating from the changes in global climate, the magnitude of exposure as well as the ability to react to it is significantly different according to local geography, infrastructure, social structure, and economy. Vulnerable areas therefore need to be re-assessed according to differential potentials of adaptive capacity as well as risks involved in inducing social change through policy.

Several dimensions of community reality can be observed to generate a richer picture of adaptability, such as agricultural technology, water management, market interventions and household capabilities. This means that it might become necessary to focus future research on internal capabilities, skills, coping mechanisms, and institutions in addition to already well-researched exposure and vulnerability data, such as changes in natural phenomena, frequency of occurrences, and number of (poor) people living in vulnerable areas (cf, e.g., UNDP 2010).

Finally, the issue that becomes most apparent when looking at communities affected by climate change, such as those in SW Bangladesh or SE Cambodia, is that it can become virtually impossible to differentiate between processes due to climate change and other external drivers. This is a *messy reality* that scientists and planners do not appreciate sufficiently as they pose complex problems to analysis and intervention development. Salinity, for example, can be attributed to rising seawater levels. However, there is also a causal link to decreasing run-off due to upstream infrastructure development (Mirza and Sarker 2004). The problem is exacerbated by poor water management and conflicting interests in water usage. The salinity issues, thus becomes one not directly attributable to one cause but also one of climate, environmental, developmental, and social processes as well as power relations. The emergence of such *wicked problems* (cf. Rittel and Webber 1973) requires *clumsy solutions* (cf. Verweij *et al*. 2006), which are complex, require inter- and transdisciplinary approaches and constant reformulation of the problem narrative. An approach to deal with such problems has been put forward by the *postnormal science* movement (cf., e.g., Funtowicz and Ravetz 1993; Giampietro 2004).

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