Agricultural practices amid climate change: empirical evidences from diverse agro-ecologies in South Asia

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Abstract

While impacts of climate change on agricultural systems have been widely researched, there is still limited understanding of what agricultural practices evolves over time in response to both climatic and non-climatic drivers and how actors mobilize their resources, institutions and practices in South Asia. Through eight case studies and a survey of300 households in 15 locations in India, Nepal and Bangladesh, this paper generates empirical evidence on emerging agricultural interventions in contrasting socio-economic, geographical and agro-ecological contexts. The study shows that several farm practices emerge out in response to multiple drivers over time; some of them can be further adjusted to the challenge of climate change by planned adaptation programs. Most actors, however, have considered private risks in the short run. Although there has been some progress in streamlining climate change into strategic planning in different countries of South Asia, policy, research and extension systems lack adequate attention to wider resilience of the system. Based on this analysis, we recommend that adaptation policies should complement farmers' responses to climate change through informed research and extension systems and pro-poor government policies that improve adaptation and coordinate activities of different actors.

Key words: Innovation, Climate change, South Asia, Socio-economic drivers, Adaptation

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1. Introduction

The smallholder farmers in South Asia face several issues in agriculture livelihoods and climate change adds another layer of complexity to already existing challenges in agriculture production systems(Gitz and Meybeck 2012).With around one fourth of global population (FAO 2013) and 40% of the world's malnourished children and women (Aggarwal et al. 2013), South Asia is one of the most vulnerable regions to the impacts of climate change (Sivakumar and Stefanski 2011). Despite various stresses and shocks such as rainfall variability, droughts, floods and cyclones(Bhattacharyya and Werz 2012; WorldBank 2009; Cruz et al. 2007) and with longer-term stresses such as population increases and the degradation of natural resources among others(Sivakumar and Stefanski 2011), farmers in South Asia are constantly seeking ways and measures to adapt to multiple stressors including climate change (Ojha et al. 2013).

At the local level, adaptation interventions are not exclusively in response to climatic stimuli alone(Jodha et al. 2012; Smit et al. 2001; Smithers and Blay-Palmer 2001) as adaption is are driven by a range of different pressures acting together that are difficult to isolate (Chhetri 2012; Chhetri et al. 2012). The intangible processes such as policies and governance, the promotion of innovation and experimentation, and the use of new opportunities and the institutional arrangements are equally important in understanding adaptive capacity of the farmers. Since climate change potentially brings unpredictable changes in weather, the local/national institutions should promote the adaptive capacity of society and let society to modify its institutions corresponding with the rate of environmental change (Gupta et al. 2010).

There lacks adequate understanding of what farm interventions have been emerging in response to both climatic and non-climatic stimuli and how agricultural actors mobilize the available resources, institutions and practices in response to climate change and variability (Mall et al. 2006). We evaluate emerging farm practices, mostly pursued at the local level as a way to examine agricultural adaptation to climate change and its socio-economic stressors. This study aims to 1) explore emerging agricultural practices in relation to climatic and non-climatic drivers at different levels of social system; 2) how various actors in the agricultural landscapes catalyze farm level changes and at what extent are these changes adaptive; and 3) the key issues and gaps in the dynamics of agricultural practices so as to enhance the adaptability and resilience of agricultural systems to climate change in South Asia. The study also identifies opportunities for institutional learning and policy reforms that are needed in support of the climate adaptive practices in agriculture.

2. Conceptual framework

Current approaches to understanding agricultural adaptation are mainly dominated by technical models which focus on impacts of climatic parameters on biological potential of crops. These models rarely consider farmers innovativeness and agriculture actors at different levels. What farmers do is affected by what happens at market, policy, and research and at a whole set of social networks. Accordingly, adaptation responses are substantially shaped and mediated by their relationships with markets, research and extension and other institutions, all of which together constitute what we name 'innovation interface' spanning multiple levels (Figure 1). The policy and governance environment, and how innovation and experimentation is being promoted by private and/or public sector actors, market and price-related stimuli, and the organizations and institutional arrangements supporting food system actors all influence farmers' decisions as to whether and how to change their agricultural practices. In this research we aim to explore different farm interventions over time and the agricultural stakeholders at different levels under varied agro-ecologies in South Asia.We use the term innovation as a proxy of farm interventions emerged over time in response to both climatic and non-climatic drivers. The term innovation in this study is defined as the agricultural practices that are new to the farm households, irrespective of whether they are new to their competitors, their country, or elsewhere(WorldBank 2006; Spielman 2005; Mytelka 2000).

A wide range of improved practices that have been shown to increase agricultural productivity and adaptation to climatic variability at the farm level include resource-conserving technologies (Gupta and Seth, 2007; Harington and Hobbs, 2009; Ladha et al., 2009), various approaches for enhancing agricultural water use efficiency (Ngigi et al., 2000), expansion of areas under cultivation to compensate for reduced yields during droughts, and switching to more drought tolerant crops (Mongi et al., 2010). Other farming innovations that help deal with climatic risks are improved pasture and livestock management strategies, introduction of crop cover or mulching, planting trees on-farm (agroforestry), and the adoption of new crop varieties that are flood tolerant, disease and pest resistant, or shorter cycle, among others (Kristjanson et al., 2012).

We emphasize linking emerging changes in agriculture in response to different stimulus, and in the interface between climate, socio-economic and market drivers (Figure 1). We see that adaptive practices could exist, but not all of them could be climate adaptive or necessarily innovative. But there is definitely willingness or pressure for adaptive practices at different levels, and it would be worthwhile for the enabling policy system to keep track of these as part of the goal of enhancing agricultural adaptation to changing circumstances including climate change.

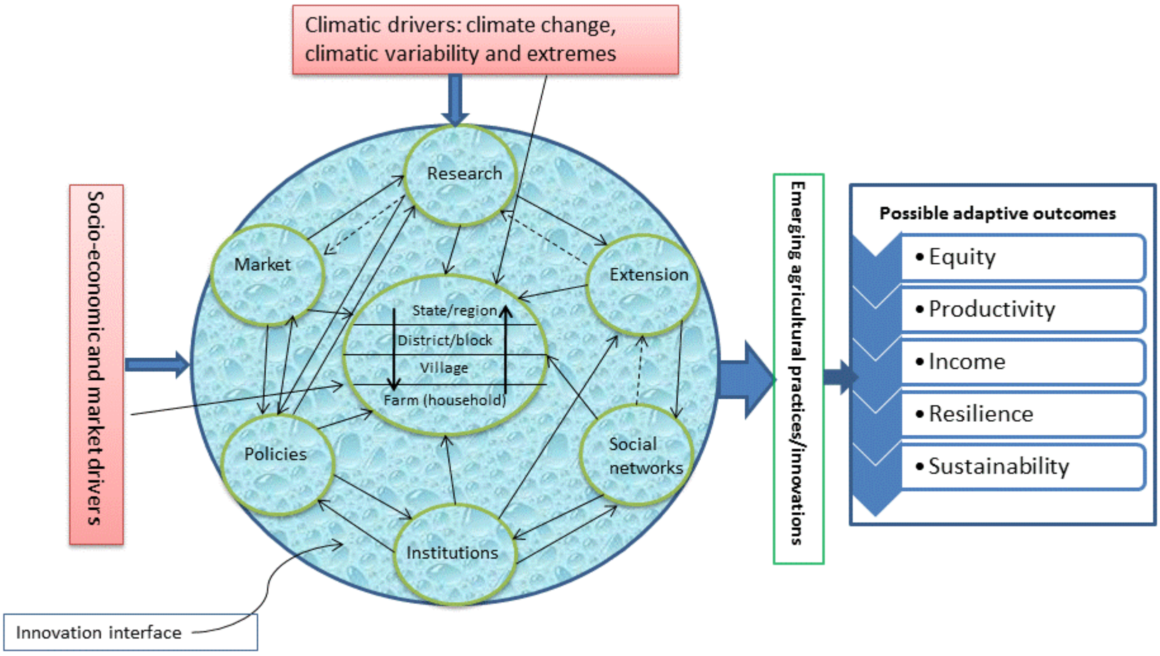

Figure 1. Conceptual framework

3. Study sites and methodology

3.1 Site characteristics

We conducted the case studies in the eight sites and a survey of 300 households in 15 locations in three countries of South Asia (India, Nepal and Bangladesh). The study sites represent diverse climate stresses (flood and salinity prone areas of coastal Bangladesh to landslide prone area of Nepal's mountain and over-exploited groundwater resources of Punjab, India), agro-ecological systems (from humid Terai, Nepal to semi-arid Udaipur, India), socio-economic and institutional settings (from high poverty region of Bihar to well-off location in Punjab, weak and poorly accountable local institutions in Bangladesh and Nepal to relatively more responsive local public agencies in Punjab), and the innovation dynamics (technology-focused in Punjab to more institutional innovations in Nepal and Rajasthan). All sites are depicted in Figure 2 and an overview of key characteristics of the case study sites is presented in the Table 1.

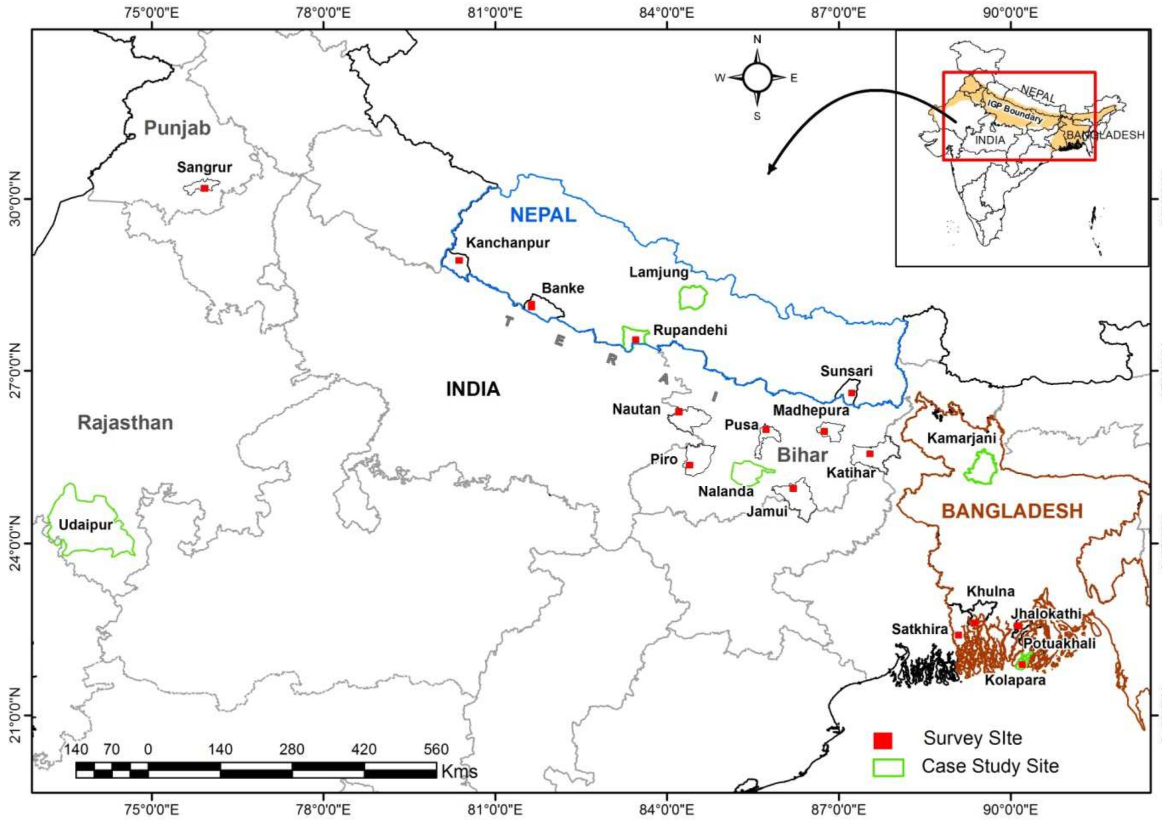

Figure 2. Case studies and household survey sites

Table 1. Overview of case study sites

Sites	**Agro-climatic features**	**Agricultural systems**	**Climatic risks**
Lamjung, Nepal	Mid-hills, altitude 1800 m, humid temperate area, annual rainfall	Subsistence agriculture, maize-millet cropping pattern, decline in transhumance and slash and burn	Variable rainfall, frequent hailstones, heat stresses, landslides and erosion, foggy

	around 3200 mm	systems	days and cold spells
Rupandehi, Nepal	Fertile lands, altitude 83m, humid sub-tropical climate, annual rainfall 1455 mm	Rice-wheat pattern,market-oriented vegetable production, average landholding 0.9 ha	Uncertain monsoon, rainfall variability, foggy days and prolonged cold spell, terminal heat stresses
Sangrur, Punjab, India	Low lying plains of Sutlej river, altitude – 236m, tropical climate, semi-arid region with annual rainfall around 700 mm	Rice-wheat system, groundwater irrigated, highest cropping intensity in India, highly mechanized farming, high fertilizer and pesticide use, average land holding is 4.32 ha	Erratic rainfall, declining groundwater table, increased wind velocity, terminal heat stresses, declining soil fertility
Udaipur, Rajasthan, India	Aravali mountain range and valleys, altitude 600m, semi-arid region with annual rainfall around 640 mm	Livestock based livelihoods, dairy farming, rainfed and ground water irrigated, very sparse vegetation	Highly drought prone, land degradation, declining ground water resources, heat stresses– affecting dairy performance and fodder production
Nalanda, Bihar, India	Alluvial plains, altitude 63 m, tropical climate, average rainfall 1000mm	Rice-wheat cropping pattern, rainfed and ground water irrigated, share cropping and lease farming, average land holding<0.5 ha	Erratic rainfall, rise in winter temperature, increased incidence of drought
Madhepura, Bihar, India	Alluvial plains of Koshi, altitude 41m, tropical climate, average rainfall 1300 mm	Rice-wheat cropping pattern, maize is also an important crop, rainfed and sub-surface irrigation, average land holding<0.5 ha	Flood and drought prone, decline in annual rainfall, increased temperature and humidity
Kamarjani, Gaibandha, North west Bangladesh	Active floodplains and attached char (submerged during monsoon)	Monsoon rainfed rice, cash crops in charlands, three cropping seasons (two rainy and one dry), landless and poor farmers seek access to charland	Flood and drought risks, river bank erosion, cold spells, high rainfall variability
Kolapara, Potuakhali, coastal Bangladesh	Tropical floodplain of Ganges, altitude up to 3 m	Rainfed rice, limited winter crops, around 65% depend on farming and rest on fishing and labors, lease farming	Rising tide levels, lack of fresh water in dry/winter season, floods, cyclone and salinity, foggy days and cold spells

3.2 Sampling and data collection

A scoping exercise comprising key informants at the sub-national and district levels was done to prepare a refined list of possible sites in respective countries and locations. Considering both diversity and climatic risks, we selected eight case study sites(Table 1). Once the study sites were selected, a key informant (local leaders, teachers and development workers) discussion in each site was done to generate critical information on innovation dynamics and adaptation. We conducted household interviews to explore household level behavior in relation to emerging agricultural practices in different case study sites. This included 5 households in each site – covering extremely poor, upper class, women headed and well-off households. Community level participatory exercises were also done to find the community level actions in the context of climatic and non-climatic drivers.

We further selected 15 additional sites (7 sites from India, 4 from Nepal and 4 from coastal Bangladesh; each 10 km X 10 km block designed by CCAFS for participatory action research) for household survey. These sites compare diverse agro-ecologies and risk profiles.We first selected four villages in each site (one closest to the centre of the block, one towards south west, one towards North West and one towards south east of the block). With the help of key informants, we listed out relatively large land owners and small/marginal farmers and we randomly selected 2 and 3 large and smallholder farmers respectively from each village. Therefore, total sample size in each site was 20. Structured questionnaire was developed and administered to the selected households to collect the relevant information. The study blended qualitative and quantitative methods – combining case studies with survey research methods. Qualitative method was used for data collection and analysis, spanning the household, community and district levels through focus group discussions at community level and expert interactions at district level.

4. Results

4.1Responses of farmers to climatic variability and socio-economic drivers

Over the past several years, a number of farm level changes have taken place in all studied locations in response to several drivers including climate change and variability. Households were queried about what changes they had made over the last five years with respect to a wide range of practices in agriculture. The total number of changes made gives an indication of experimental actions and exploration of adaptive practices and is thus used as a proxy of innovativeness.

Farm level changes are categorized into seven groups ranging from land preparation to marketing. Land related changes encompass new time and method of land preparation, and soil management and method of pond preparation. Changes in crops/varieties/breeds imply the introduction of new crops and/or new varieties and new farm animals and/or breeds. Sowing innovation covers new time and method of sowing/transplanting of the crops. Changes in agro-inputs include new time and method of irrigation, farm manure preparation and application of other agro-inputs. Mechanization refers an introduction of farm implements in agriculture. Innovations related to harvest include new time and method of harvesting of the crops and post-harvest technology. Market-related changes cover the method of marketing farm surplus and structural arrangement for marketing and/or alteration of existing value chain.

Household survey results show that a large number of farmers in coastal Bangladesh (around 90%) introduce new method and timing of land preparation while only around 12% of the farmers do so in Sangrur, Punjab. Around 50% of the households introduce new crops/animals and/or varieties/breeds across all areas. Mechanization is more prevalent in Sangrur (as >50% farmers reported) compared to other areas. Changes in agro-inputs (irrigation, fertilizers, pesticides and manure) are very high in Terai, Bihar and coastal Bangladesh as reported by around 90% of the farmers in each site.

We estimate the variance of different factors affecting innovativeness of the farmers. The data were analyzed using the explanatory variables presented in Table 2. We run both a General Linear Model (GLM) and log-linear model using same set of explanatory variables. Based on residual analysis, both modelingapproaches showed a satisfactory fit to the data. We only use the results of the GLMin this paper. The model was evaluated with a Wald test (RWALD). The advantage of RWALD is that the model does not have to be refitted (excluding each variable) to calculate F statistics and probability(Kristjanson et al. 2012). It thus provides a much more efficient method of assessing the model. Variables with a

Wald statistic below 10% level of significance were excluded from the model if their inclusion resulted in a change in the percentage variance accounted for (R^2), to prevent over fitting of the model. Other variables that were above the 10% significance level, but without an effect on the overall R^2 of the model, were kept in the model for reasons of comparison.

Table 2. Variable description

Variables	Description
Innovations (dependent variable)	Number of farm interventions introduced in the last five years (practices in land, soil and livestock management; crop and/or variety; livestock species and/or breed; time, method and techniques of sowing/transplanting; changes in irrigation, fertilizer, pesticides and manures; method of harvesting and post harvest operations; and new mode of marketing)
Livelihood sources	Number of on-farm and off-farm livelihood sources (agriculture, job, remittances, livestock, pension, wage)
Site	Six sites from Bihar and one from Punjab states of India, four sites from Terai of Nepal and four sites from coastal Bangladesh
Owned land	Total land (ha) owned by the farm household
Nature of farming	Type of farming operation (either subsistence or market-oriented farming)
Family size	Number of family members in the households
Membership	Whether a household is a member of any group (farmers group, community based organizations, cooperatives etc)
Participation	Whether a farm household has participated in any kind of farm experiment/demonstration such as varietal selection, resource conservation and management, farmers field schools etc over the past five years
Visit	Whether a farm household has visited any demonstration sites or improved agricultural farms to get ideas on agricultural technology over the past five years
Meetings	Number of meetings related to climate change and agriculture over the past five year organized by several organizations
Government program	Whether a farm household is aware of any government programs or rules that help better adapt with the effects of climate change
Finance	Whether a farm household has access to financial services to undertake new improvements in agriculture
Policy	Whether government policies/rules affected the choice of farm household on agricultural practices over the last five year

The results of modeling the set of factors explaining variation on innovations across households showed that the data is better in explaining differences in innovativeness, with 65% of the variance accounted for. The site explained 43% of the variation in innovativeness between households, land size explained

21%, membership explained 31%, climate change and agriculture training/meetings attended explained 196%, number of livelihood sources explained 22% and access to finance explained 21% (Table 3). The results infer that climate change and agriculture-related training brings higher level of variability in terms of farm level innovation. Below et al. (2010) also reported that all sorts of practical trainings for farmers and agricultural extension officers affect adaptive capacity of the farmers.

Table 3. Results of GLM (Innovation: dependent variable, adjusted R^2= 65%)

Variables	Mean Square	F value	Significance
Sites	43	12.8	<0.001
Land owned	21	6.15	0.014
Nature of farming	10	3.00	0.085
Family size	0.43	0.13	0.721
Membership	31	9.29	0.003
Participation	10	2.97	0.086
Visit	2	0.46	0.500
Climate change training	196	58.4	<0.001
Government program	3.52	1.05	0.307
Sources of livelihoods	21.76	6.48	0.011
Access to finance	21.26	6.33	0.012
Government policy	10.07	3.00	0.084

We also pooled information on farm innovations from the case study sites and we found that there are five key motivations behind farm level changes: transformative learning, adapting to climatic variability, risk reduction through farm experiments, market-orientation and social learning (Table 4). The important point in our analysis is that the various ways in which adaptive innovation emerge are not confined to any one level of organization. Hence, Table 4 analyzes responses at three levels: the household, the community and the district. The first category of responses implies the learning to live with change and uncertainly- learning from extreme events, building portfolio of livelihood options and developing coping strategies. The second category of responses covers the processes of learning and adapting including institutional diversity and farm experimentation (Dietz et al. 2003). The third category of responses encompasses creating opportunity for wider resilience.

Certain weather-related events provide an opportunity for transformative learning for the farm communities. For instance, farmers started shifting cropping patterns and the timing of shearing sheep wool following repeated and unexpected hailstones in Lamjung, Nepal. In Udaipur, recurrent droughts in 1990s and early 2000 and increasing resource degradation brought the communities together to form collaborative action groups for common pool resources regeneration. Building a portfolio of livelihood options is seen in many areas, particularly in Madhepura and Lamjung. In the context of increasing rainfall risks, farmers in Madhepura replaced rice-wheat by maize-wheat- a safer cropping pattern in terms of water and labor requirements(Gathalaa et al. 2013).

In everyday explorations of options to adapt to multiple drivers, farmers have developed ways and methods to experiment innovative solutions, which largely operate at the farm and community levels, but is often supported and informed by social networks. Local networks provide multiple functions in reducing vulnerability and enhancing adaptive capacity (Below et al. 2010). New adaptive strategies such as avoid planting same crops in the same field in the consecutive years (Kamarjani), zero tillage of wheat and direct seeded rice (DSR) (Punjab and Rupandehi), system of rice intensification (SRI) (Bihar) and community-based weather stations (Udaipur) are part of such learning, and farmers have experimented these innovations in the field to learn and adapt.

The third category of responses helps create opportunity for self-organization and promote adaptation at a wider scale. For instance, restoration of embankment and measures to reduce inflow of saline water following 2007 Cyclone Sidr (Kolapara), Farmers Field Schools (Rupandehi), soil and moisture conservation machines (Punjab), community management of forest resources (Lamjung), community group regulating fisheries (Kolapara) and community pasture land management (Udaipur) are some of the notable examples in this category. Collective action provides ample scope for social learning and enhances adaptive capacity at a wider scale (Thomas et al. 2007). However, it should not be understood that all community actions evolve through the action of the community members only. Most of these initiatives have been promoted by NGOs and government institutions. For instance, the local government formulated new rules of resource allocations which led to the abolition of slash and burn (locally called *khoria*) and evolution of community forest groups to manage forest resources sustainably in Lamjung, FFS has been promoted by the Government of Nepal as an effective mode of extension, State Government of Rajasthan promoted community management of pasture lands and NGOs promoted cultivation in charlands in Kamarjani.

Market remains a highly visible driver of change in agriculture in South Asia. It is not just the market of agricultural inputs or outputs but also the opportunity costs or the relative value of substitutes for producing agricultural commodities. Accordingly, changes can be observed in the crop varieties, cropping pattern, agro-techniques and marketing arrangement. Although external drivers such as marketing opportunity may enhance income generating ability of a household, they may not promote adaptation. For instance, off-season vegetable production and formation of cooperative groups for banana farming (Rupandehi), mechanical plowing in charlands (Kamarjani) and input subsidy (Punjab) are some of the interventions which are less adaptive.

4.2 Responses of agricultural institutions and actors supporting farmers

Key agricultural stakeholders involved in extension, research, market, technology and policy have also undertaken diverse responses to help farmers to adapt to the changing circumstances. The actual response is mixed and conditioned by prevailing institutional, policy and economic contexts. Here we focus on key actors: research, extension and policy-related institutions.

Research system in agriculture has shifted its focus from on-station experiment to participatory action research, but this has remained less attentive to issues related to adaptation. Farmer participation has remained limited to providing feedback. Examples of climatic considerations in agricultural research include: zero tillage machine development by Punjab Agricultural University, on-farm testing of laser land leveling (LLL) equipment in Punjab, exploring water harvesting structures and identification of fodder grasses resistant to drought in Rajasthan, development of drought tolerant varieties in almost all sites and participatory research on zero tillage in Rupandehi and Bihar. Scientists in Bangladesh Rice Research Institute and Bangladesh Institute of Nuclear Agriculture developed the low-yielding varieties (BR-33 and BINA-7) to adjust timing of the crop harvest with critical food scarce periods (locally known as *Monga*) in the north including Kamarjani (MoEF 2011). Their choice of research goal seems to be quite different from those of others - focus on year round productivity rather than maximizing productivity of a single crop. The improved crop varieties have considerable potential for strengthening adaptive capacity(Lybbert and Sumner 2010; Boko et al. 2007).

There have been little structural changes in agricultural extension system in the region, but a number of functional changes have emerged, some of which have the potential to contribute to climate resilience of agricultural system. Six most notable climate change related extension innovations found in the case study areas include – a) weather advisory services offered by Sangrurand Bihar Krishi Vigyan Kendra (KVKs) to the registered farmers through SMS; b) assistance provided by Sahayog Sansthan to set up community-based weather monitoring stations in Udaipur; c) NGOs providing advice and inputs to cultivate floodplains during winter in Kamarjani; d) introduction of dry season crops and a rice variety that can be harvested before salinity becomes severe in Kolapara; e) NGOs, community-based organizations and government institutions providing training and extension services through FFS in Rupandehi; and f) community management of forest resources introduced by the government in Lamjung.

There are also less obvious and perhaps not so overtly climate-conscious ways in which farmers are receiving innovative advice from the extension system - stopping straw burning and avoiding overuse of fertilizer in Sangrur, support in community action to manage common lands in Udaipur, training of farmers by NGOs on compost preparation in the context of declining soil quality resulting from excessive use of chemical fertilizer in Kamarjani and Madhepura, promotion of zero tillage in Rupandehi and SRI in Bihar, floating gardens (beds) and cage fish culture to turn the flooding from a threat to opportunity in Kamarjani, and community management of water resources in Udaipur. However, government extension service remains weak in providing required technologies and information on climate change and agriculture. The linkage between research–extension–farmers has not been strong (Ojha et al. 2013) and thus, the dissemination of successful innovations is limited. It is more usual to have NGOs and government not to coordinate, and in the prevailing context of donor funding strategies (short term support and frequent shift in priority), NGO-led activities have remained short-lived, as seen in the context of dysfunctional farmer groups in Rupandehi. Extension system in the study areas lacks enough scientific research backing. Some of the innovations promoted by extension organizations could be enhanced if research system offers additional back up.

The effectiveness of the cooperatives, NGOs and local government institutions such as village committee/Panchayat are more instrumental in bringing more awareness and technological information to the farmers as compared to District Agriculture Office and NARS in case study and survey sites. For instance, farmers in the surveyed sites accord first rank to the cooperatives followed in order by NGOs, local government, District Agriculture Office and research centres in terms of their importance in providing technological information related to agriculture and climate change. Technical training on initiation of floating beds in flooded areas of Kamarjani by Practical Action is one of the best examples of NGO supported activity (DAE 2013).

Policy responses in the case study sites have remained mixed, but largely ignorant of the current and future effects of climate change on agriculture. Punjab's ground water regulation seems to be at the forefront, though the agricultural development plan of Sangrur district does not see this as a climate problem. Pastureland management rights in Rajasthan rest with local Panchayats. Rajasthan State Water Policy 2010 intends to function from the new perspective of Integrated Water Resources Management, which is holistic and includes a bottom up approach. There is also an active process to implement country specific action plan (NAPA) in all countries, location specific adaptation plans (LAPA) in Nepal and State Level Action Plan on Climate Change in Bihar and Rajasthan, to combat climate change and increase resilience of farming communities. These policies have strong components of climate change adaptation. However the impact on the ground is very limited till now.

Input services such as breeder seeds, equipments, fertilizer, credits are critical to farmers, and there is still a limited policy mechanism to deliver these in needed quantities, in time and in right quality. This varies across regions, states and countries, but Indian state of Punjab appears to be far more generous to farmers in terms of subsidies and support compared to others. For instance, government policies and market forces both promote mechanization in Punjab. But the production focus is not clearly articulated with longer-term adaptation to climate change.

On average, around 50% of the farm households reported that the government rules/policies/programs helped them to adapt to climate change across the surveyed areas (Figure 3). In Punjab, only 20% of the farmers reported that they are benefitted by government rules/policies in terms of climate change adaptation while almost 80% of the household in the coastal Bangladesh responded that government rules/program helped them to adapt to climate change. In terms of government programs affecting the choice of agricultural practices, the farmers of Punjab affected more (reported by 80%) compared to other sites. The results show that government programs help farmers to adapt to climate change to a large extent but these programs also affect the farmers' choices of agricultural practices simultaneously. Punjab is the particular case as government minimum support price (MSP) of rice and wheat makes farmers cultivate these crops every year using huge amount of agro-inputs to get market benefit at the cost of environmental degradation. Water table in Punjab is falling approximately by 1 m per year (Lal 2004; Humphreys et al. 2010). Two main reasons for falling water table in Punjab have been the early transplanting of rice (Singh 2009), and low and flat rate prices for electricity to power wells and absence of property rights to groundwater (Kerr 1996). While the Punjab Preservation of Sub Soil Water Act 2009 helped minimize groundwater use by sowing paddy nursery after mid May and transplanting after mid June that subsequently minimized groundwater depletion to some extent (Singh 2009), the injudicious use of groundwater is still prevalent.

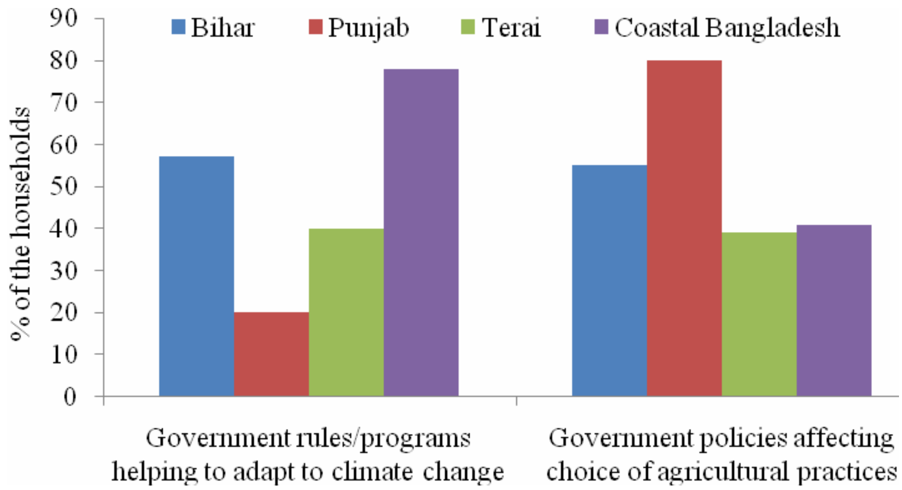

Figure 3. Percentage of households reporting government policies helped farmers to adapt to climate change and affected choice of agricultural practices over the last five years

5. Discussions

The result section shows that in South Asia a range of changes in agricultural practices have occurred at the farm and community levels and some of these changes are innovative in terms of technical and social outcomes. Here we discuss whether emerging practices are adaptive to climate change and equitable in distributional outcomes.

Farmers in South Asia have responded to climatic and socio-economic drivers to agriculture, which involve a wide range of social, technological, environmental adjustments(Levine et al. 2011), often in association with a wide range of agricultural stakeholders in the region. But all of these changes may not be climate adaptive. For an agricultural practice to be climate adaptive, it has to be informed by the expected change in climate. It should also involve rethinking of social relations among the actors interacting with the environment.

Most actors have considered private risks in the short run. Farmers lack scientific advice that is grounded on the analysis of past and future trends of climate risks. There is a predominance of market logic(Ojha et al. 2013). Policy and research systems still focus on productivity aspects and fail to capture wider resilience of the system. For instance, mechanization in Udaipur has reduced the traditional shallow plowing. The traditional system encouraged minimum tillage and made sowing of small acreage possible. The mechanized and deep plowing adversely affects soil structure and promotes wind erosion(Narain and Kar 2005). Growing dairy farming in Udaipur has enhanced livelihoods of the farmers but unsatisfactory nutritional status and lack of knowledge of balanced feeding and the scarcity of fodder make livestock-based livelihood unsustainable (Rohilla et al. 2004) and contribute higher emissions compared to traditional system (Chhabra et al. 2009). In order to enhance productivity and reduce emission, investment on scientific breeding, feeding and management are required (Staal et al. 2008; Nin et al. 2007).

Some of the practices such as excess use of agro-chemicals and that in the predominant cropping pattern may create problems of nutrient mining. While farmers can get short-term higher profit using excessive agro-chemicals, the production system becomes ecologically vulnerable (Singh et al. 2008). New technology also risks increasing costs and requires more careful thinking and applied research before introducing it to the farmers. This is evidenced in Kamarjani where intensification of cropping in charland (traditionally fallow lands) has created difficulty in cattle rearing and promoted the use of inorganic inputs. Ecological rethinking (for instance in Punjab) has begun in terms of reducing straw burning and sustainable exploitation of groundwater resources. But this has not been translated into a bold new strategy of 'ecologising' agriculture while maintaining farmers' benefits. Some innovative techniques such as SRI in Bihar have been emerged. Similarly, DSR has the potential to provide several benefits (mainly saving water and labor) to the farmers and environment (Balasubramanian et al. 2013; Kumar and Ladha 2011). Zero tillage and SRI can be other adaptive agriculture options in water scarce areas. However, it still remains to be seen how the institutional framework evolves to catalyze changes not only at the technological level but also at the organizational processes. There is also a need to replicate these adaptive and innovative practices to other feasible agro-ecologies through on-farm experimentation.

Community-based activities helped farmers make collective decisions on resource management and hence are more adaptive resource management strategies. Community water harvesting strategy in Udaipur is one of the adaptive options under increasing drought events. Similarly, community management of forest resources in Lamjung and across Nepal has proven sustainable resource management strategy. Community active participation in managing wasted and unused pasture lands into productive pasture land is another successful and adaptive measure in Udaipur. The knowledge and experience gained on these private pasturelands and community management of forest resources can then be replicated to wider areas in the region. However, it remains to be validated whether the community groups will manage to enforce the established common property regimes in the face of increasing stresses on resources due to climate change.

Adaptability of agricultural practices also depends on their ability to deliver equity and fairness. Although there are diverse groups making decisions on innovation and adaptation – including farmers' groups, institutions, and governments - all such decisions 'privilege one set of interests over another and create winners and losers' (Adger 2003). Farmers in the case study reported that new farm related practices helped them increase their marketable surplus of major cereals, vegetables and fruits. However, it is the large landholders who got mostly benefitted as they are the ones introducing majority of farm interventions in relation to socio-economic and climatic drivers. For instance, equipment such as laser land leveler, zero till, happy seeder and rotavator are generally expensive and it is difficult for individual farmers especially the small and marginal farmers to purchase without any financial support from the government. Though the Government of Punjab provides 50% subsidy to the farmers and co-operative societies to purchase these equipments, their usage is limited. Lack of awareness and training, high cost of these equipments and lack of high power tractors have all constrained wider adoption of these equipments.

Many technological innovations have not adequately addressed the workload of women. New technology on farming has resulted into an increased workload of the women farmers in all survey sites. Although a large number of the households (58%) reported that there has been either no change or decrease in the workload of women due to an adoption of new technologies, yet around 42% of the households reported an increased workload of women (Table 6).

Table 6. Women's workload as a result of changes in agricultural practices over the last five years

Agricultural activities	Percentage of household reporting		
	Increased	Decreased	No change
Agro-inputs (n=164)	34	19	47
Field preparation (n=180)	39	23	38
Sowing/transplanting (n=186)	49	6	45
Intercultural operations (n=145)	38	8	54
Harvesting (n=173)	46	18	36
Post harvest operations (n=155)	37	25	38
Marketing (n=140)	11	24	66
Overall workload (n=300)	42	22	36

The agricultural policy approach in South Asia continues to be top-down and linear, while there is an increasing need for 'a comprehensive and dynamic policy approach, covering a range of scales and issues' (Howden et al. 2007) in the context of climate change. Strong gaps exist between perceptions of climate change and the adaptive actions among both the farmers and local stakeholders, suggesting the deficit of processes and institutions to translate information into adaptive actions. In some cases, especially when farmers have access to services and information, farmers have resorted to adaptive and innovative practices – such as changing cropping patterns and technological changes (such as SRI in Bihar and Rupandehi). But again, such innovations lack backing by adaptation thinking.

Farmers' ability to engage in innovative practice is substantially shaped and mediated by the stakeholders operating at micro and meso levels. The capacity of a household to cope with climate risks depends to some degree on the enabling environment of the community(Smit and Wandel 2006). But meso level institutions demonstrate much less adaptive response than the farmers in all sites. Although farmers and extension organizations at different levels have been able to identify, experiment and develop innovative actions, there is still a lack of framework to understand and catalyze adaptive responses in such a way that it is informed by long term trends in climate change, as well as recognize the local socio-cultural contexts. In order to facilitate learning and innovation, science must adapt, too, by continuing to review research needs and providing effective tools for decision making (Howden et al. 2007). By fostering conditions that are conducive to learning, especially the transformative learning, farmers would likely be more open to new ideas and practices that promote adaptation in the face of environmental change. But the situation in South Asia is much less conducive to fostering learning between scientists, farmers and policy makers, partly because of the culture of hierarchy.

The agriculture policy (such as minimum support price for rice and wheat and subsidy in fertilizers in Punjab) focuses on higher productivity. The political economy of paddy and wheat cultivation in Punjab hence favors continued growing of these crops and unless similar incentives (MSP, full procurement and high profits) are given to other crops, strategies to promote diversification won't yield results.

6. Conclusion

Findings from the study provide evidence that there is usually has been a great deal of experimentation and exploration of adaptive practices in agriculture. These potential options should be seen as resulting from dynamic learning and innovation processes that have taken place within and around an agricultural system. In all the study areas, responses to the changing circumstances including climate change and variability tend to be both proactive and reactive. For instance pastureland management, zero tillage, system of rice intensification, laser land levelling, community rules for fisheries management and legume incorporation in dryland farming represent some of the proactive actions, and out migration, on-farm diversification and restoration of embankment are some of the reactive actions. Most of the farm level interventions are driven by support services and market forces and they are socially less equitable. These changes are not fully informed by longer-term trends and projected scenarios of climate change.

Variety and yield-focused agricultural research in South Asia leave many aspects of agricultural system unexplored. While new varieties and crops play an important role, the range of relevant practice and technologies is much broader than this. Creating necessary agricultural technologies and harnessing them to enable farmers to adapt their agricultural systems to changing climate will require innovations in policy and institutions as well. Given that local institutions such as cooperatives are more instrumental in responding to various risks and adaptation to changing conditions, an attention should be given to strengthen these institutions in the areas of climate adaptive agriculture and link them with the local government, extension and research institutions to ensure their greater role in climate change adaptation.

There is also a need that government, development partners and community-based institutions design the projects considering how people will be able to adapt in the future. Planning and intervention design should use people's own ability and practice of experimentation/innovativeness as an entry point. In the areas where participatory approaches such as farmers' field school (FFS) have been successfully piloted, attempts to adapt this approach to the new challenge of climate change should be considered, for instance by transforming FFS into Farmers Climate Schools (FCS). The success of FFS could be transpired through FCS and farmers would get significant insights on changes in climatic parameters and associated impacts on their livelihoods once they are exposed to FCS.

The evidence has demonstrated that a community-based approach to develop and manage commons (for instance, common pasture lands in Udaipur and forest resources in Lamjung) is viable and can be sustainable. Building these management systems has created a broader basis for joint community action towards improving livelihood resources and dealing with multiple stresses, including those related to climate variability and change. All these community-based approaches emerged over long periods of handholding support and promoting these types of adaptation would require public investments of a huge scale. Although there has been some progress in streamlining climate change into strategic planning in different countries of South Asia- such as community resource management, water harvesting, on-farm experimentation of adaptive technologies and so on- policy, research and extension systems lack adequate attention to wider resilience of the system. As a result, productivity focused interventions have got higher merit for wider dissemination and resilient interventions have not out scaled to the extent it should be. Further researches on eco-efficient technologies focusing on economic, social and ecological context considering longer term trends and projected scenarios of climate change are required before up scaling them in a larger scale. We recommend that adaptation policies should complement farmers' responses to climate change through informed research and extension systems and pro-poor government policies that improve local adaptation and coordinate activities of different actors.

Table 4. Observed agricultural practices in relation to several drivers in case study sites

Key motivations	Key variability/opportunities	Observed changes in different sites	Scale[†]		
			HH	Village	District
Transformative learning from extreme events	A severe hailstone in 2000 damaged one but not other varieties of wheat	Varietal and crop diversification (Rupandehi)	**	*	*
	Recurrent droughts in 90s and early 2000	Collaborative action for common pool resource regeneration (Udaipur)	-	**	**
	Koshi flood in 2000	Off-farm livelihood diversification, mainly out-migration (Madhepura)	**	**	**
	Cyclone Sidr 2007	Restoration of embankment and measures to reduce inflow of saline water (Kolapara)	-	**	**
	Repeated and unexpected hailstones	Shifting time of shearing sheep wool and declining wheat cultivation (Lamjung)	**	*	*
	Heavy flood in 2007	Focus more on dry season crops (Kamarjani)	**	*	*
Adjusting farming with the uncertain cycle of weather events	Uncertain incidence of floods	Raise multiple varieties of rice in the seedbeds in charlands (Kamarjani)	**	*	-
	Uncertain cyclones	Cultivation of dry season crops (Kolapara)	**	*	*
	Rainfall risks	Introduction of legumes in the rainfed fields (Lamjung)	**	**	**
		Replacement of rice-wheat by maize-wheat (Madhepura)	**	*	-
		Use of less water requiring varieties (local cultivars) of crops (Udaipur)	**	*	-
	Salinity issue	Re-excavation of silted up canals and embankments to prevent intrusion of saline water (Kolapara)	-	**	-
Experimental actions to reduce the risks	Flood risks	Prepare seedbeds in the higher ground and use late varieties to cope with the post flood cultivation, fodder storage for flood season and avoid planting the same crop in the same plot in consecutive seasons (Kamarjani)	**	*	*
	Unfavorable field environment during planting (mainly due to temporary flooding)	Zero tillage of wheat (Rupandehi); zero tillage garlic, women farmers floating beds in waterlogged area, leave paddy residue in the field, seed storage in plastic containers instead of bamboo bags, replace goat by sheep which can withstand wet environment (Kamarjani)	*	-	-
	Declining groundwater table	Soil and moisture conserving machines (zero till, happy seeder, rotavator), underground pipelines and laser land leveling (Sangrur)	**	**	**
	Rainfall and drought risks	Water storage tanks, and install pipelines to reduce water wastage and shift to sturdier breed of goats (Udaipur)	**	*	-

		SRI (Nalanda and Rupandehi)	*	*	-
		Direct seeded rice (Rupandehi, Punjab)	*	*	-
Market opportunities	Ecotourism	Moving away from transhumance and replace cereals with cash crops (Lamjung)	**	**	*
	Better prices of milk and vegetables	Commercial dairy and vegetables (Udaipur), replace traditional with improved breeds of cows (Madhepura)	**	**	*
	Comparative advantage	Replace rice with jute and women produce vegetables in monsoon (Kamarjani); smallholder farmers replace rice-wheat with vegetables and relatively larger sized farmers with banana (Rupandehi)	**	*	-
	Mechanization	Replace bull (used in the past for plowing) by cows or buffaloes and introduce mechanical tillage system (Nalanda and Madhepura), mechanization is introduced entirely (Punjab) and partly (Udaipur),	**	**	**
		Char areas (traditionally left fallow and under grass production) are being intensively cultivated using power tillers (Kamarjani)	**	**	*
	Involvement of market actors	Shift to cash crops (resilient to drought and salinity) - promoted by wholesalers of Dhaka, local dealers introduce high yielding varieties, farmers cultivate maize on fallow, barren and sandy charland (as maize demand increased due to poultry business) (Kolapara)	**	*	-
Collaborative actions for social learning and adaptation	Cooperative-based production, marketing and resource conservation	Banana and Dairy Cooperatives (Rupandehi)	-	**	*
		Leasehold farming (Rupandehi, Kamarjani, Nalanda, Kolapara)	**	**	*
		Coordinated individual business such as home stay tourist services (Lamjung)	**	**	-
		Community-based weather stations, community infrastructure (communal water tank) and pasture land management (Udaipur)	-	**	*
		Formation of Self Help Groups (SHGs) to collectively decide about technological adoption (Udaipur, Bihar and Rupandehi)	-	**	*
		Community regulation of fisheries (Kolapara)	-	**	-
		Saving credit groups to collectively decide the fund mobilization (Rupandehi and Udaipur)	-	*	-
		Community forestry group to conserve resources (Lamjung)	-	**	**
		Farmers field school (Rupandehi)	-	*	*

† HH: Household level; **: highly observed; *: observed; -: not observed/not applicable

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