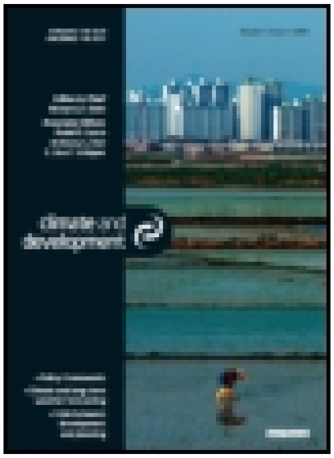

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RESEARCH ARTICLE

Coping with weather adversity and adaptation to climatic variability: a cross-country study of smallholder farmers in South Asia

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Concerns over climate change and climatic variability are growing in South Asia because of the potential detrimental impacts of these phenomena on livelihoods. Such growing concerns demonstrate a need to assess how farmers simultaneously cope with extreme events and adapt to climatic variability. Based on household surveys of 2660 farm families conducted in Nepal's Terai, coastal Bangladesh, and the Indian state of Bihar, this paper seeks to (1) explore farmers' coping strategies under adverse weather events; (2) identify key adaptation measures used by farmers; and (3) explore the policy interventions required to adjust agriculture to climatic variability. The study reveals that migration is the most important coping strategy of the households in Bihar and coastal Bangladesh, while reliance on credit markets is the most important in Terai. Farmers in the areas with higher rainfall variability pursue a higher number of coping strategies compared to farmers in areas with lower rainfall variability. Food available months are also higher in areas with higher rainfall variability. Across all sites, the most frequently mentioned adaptive practices are changing cropping patterns and adoption of resilient crop varieties. A large number of farmers place emphasis on breeding crop varieties that tolerate adverse weather. Governments should implement a number of planned activities to cope with adverse events, with the aim that these activities would be synergistic with adaptation to climate change.

Keywords: adaptation; climate change; coping strategies; rainfall variability; South Asia

1. Introduction

Concerns over climate change including climatic variability are growing in South Asia (ADB, 2010; Aggarwal, Joshi, Ingram, & Gupta, 2004; Bartlett, Bharati, Pant, Hosterman, & McCornick, 2010; Sivakumar & Stefanski, 2011; Turner & Annamalai, 2012). Two main reasons drive these concerns: first, the region hosts a large number of smallholder farmers with per capita arable land availability of less than 0.1 ha (FAO, 2013), and second, this area is highly prone to climatic extremes such as floods, droughts, cyclones, heat/cold waves, and storms (Bhattacharyya & Werz, 2012; World Bank, 2009), which are projected to increase (Lal, 2003). With around one-fourth of the global population (FAO, 2013) and 40% of the world's malnourished children and women (Aggarwal, Pathak, Kumar, & Sharma, 2013), and reliance of many livelihoods on climate-sensitive sectors, particularly agriculture and fisheries (Ahmed, Hassan, Etzold, & Neelormi, 2012; Kumar & Viswanathan, 2012), South Asia is one of the most vulnerable regions impacted by climate change (Sivakumar & Stefanski, 2011). An increase in the inter-annual variability of daily precipitation, particularly during the monsoon season, characterizes the region (Giorgi & Bi, 2005; Lal, Meehl, & Arblaster, 2000; May, 2004). Given that approximately three-fifths of the cultivated area in South Asia is rainfed, the rainfall variability (as one of the most significant climatic indicators) is a critical factor in determining the livelihoods of people (Ahmed et al., 2012; Burke & Lobell, 2010) and the migration decisions of vulnerable households (Rademacher-Schulz et al., 2012). Variability also makes production risky and it inhibits risk-averse farmers from undertaking broader adaptation measures (Burke & Lobell, 2010).

Despite various climate- and non-climate-related stresses and shocks, farmers in South Asia have been coping with and adapting to the local circumstances over many years (Ojha et al., 2014). Coping and adaptation strategies vary in both spatial and temporal scales. Generally, these strategies involve adjustments in a specific action (e.g. migration, and distress sale of the assets), systematic change (e.g. on- and off-farm livelihood diversification,

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and changes in cropping pattern), or institutional reform (e.g. provision of social safety nets), or they can involve processes (e.g. learning about risks, evaluation of response, or creating an enabling condition) (Conway, 2009; Leary, Conde, Kulkarni, Nyong, & Pulhin, 2008). Several ex-post coping strategies found in South Asia and Africa to adjust to specific extreme events include migration, consumption loans, distress sale of the assets, livelihood diversification, and reliance on formal or informal credit markets (Ahmed et al., 2012; Brockhaus, Djoudi, & Locatelli, 2013; Burke & Lobell, 2010; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Kelkar & Bhadwal, 2007; Morton, 2007). Most of these ex-post strategies over the period of time are incorporated into the nature of the farming system.

While coping strategies are a spontaneous reaction to the extreme events, mostly emerging out of a local survival strategy (Osbahr, Twyman, Adger, & Thomas, 2008), adaptation strategies are often planned with longer term actions to adjust to the climatic variability (Ravera, Tarrasón, & Simelton, 2011). Although enhancing the capacity to cope with current stress can help adapt to future changes to some extent (Kelkar & Bhadwal, 2007), moving from coping to adapting is a challenging task for smallholder farmers because of their relative deprivation in terms of land, income, and access to information (Brockhaus et al., 2013). Determining whether or not the observed strategies are examples of coping or adaptation is dependent on the particular context in which they are observed (Vincent et al., 2013). The capacity to adapt to climatic variability and access of strategic adaptation options are also conditioned by economic resources, technological factors, and enabling policies and infrastructures.

As aforementioned, South Asia faces frequent extreme weather events together with increasing climatic variability over time. Two questions, however, remain unanswered: first, to what extent have adverse weather events influenced farmers to explore different coping strategies, and second, to what extent has the climatic variability influenced adaptive action of the farm households. Studies assessing the potential effects of climate change on South Asian agriculture are national or sub-national, yet coping strategies are place based, more often individual based, and require the use of place-specific strategies (Kurukulasuriya & Mendelsohn, 2008; Lobell et al., 2008). There is a need to assess how farmers in South Asia simultaneously cope with extreme events and adapt to climate variability. This study attempts to provide empirical evidence on farmers' coping strategies to the extreme weather events, their agricultural adaptation over the time, and policy interventions required to improve the livelihoods of the farmers under volatile climatic conditions through an investigation of a household survey carried out with 2660 farm families in three countries of South Asia (the Indian state of Bihar, coastal Bangladesh, and Nepal's Terai).

2. Methods and data

2.1. *Description of the sites*

This paper is part of a larger baseline study implemented by Consultative Group of International Agricultural Research (CGIAR) Program on Climate Change, Agriculture and Food Security (CCAFS) in 2010–2011 for three contrasting agro-ecological sites of Indo-Gangetic Plains (IGP) of South Asia (Figure 1) with an average annual rainfall varying from 900 to 3100 mm (CRU, 2013). Spanning from coastal Bangladesh to the fertile plain of Nepal, the survey sites constitute the study blocks established by CCAFS to explore the potential of implementing 'climate-smart agriculture interventions' and subsequently to monitor agricultural adaptation dynamics to climate change over time (Foerch, Kristjanson, Thornton, & Kiplimo, 2011). The annual and monsoon rainfall in these sites varies from almost 963 and 781 mm in Piro, Bihar, to 3349 and 2771 mm per year in Cox's Bazar, Bangladesh. Similarly, the annual and monsoon rainfall variability vary from 14% and 15% in Patuakhali, Bangladesh, to 25% and 29% in Kanchanpur, Terai of Nepal.

Sites in the Indian state of Bihar represent a hot subhumid climate with highly fertile soils. At most sites, the dominant cropping pattern is rice, followed by wheat. This state has a notable high level of poverty in India, accounting to almost 53% of population below poverty line (Anand, Tulin, & Kumar, 2014). Farmers in the State possess small size of land (<0.5 ha) and almost half the population is landless (Erenstein, Thorpe, Singh, & Varma, 2007). Frequent floods and droughts, increasing temperature, and decreasing rainfall characterize the study sites. Almost 4.25 m ha of land is liable to flood risk in the State (Attri & Tyagi, 2010).

With distinct rainfall gradient from east to west, sites in Terai of Nepal are the country's food basket region. The Terai is low-lying floodplains of Nepal with a sub-tropical humid climate. The dominant cropping pattern found in this region is rice, followed by wheat. The climatic risks in Terai are frequent floods and droughts, westerly wind during wheat grain filling stage, and increasing cold spells and foggy days.

The research sites in coastal Bangladesh represent very low levels of development and high levels of poverty. Key livelihood options are agriculture, fisheries, and wage labour. Coastal Bangladesh is highly vulnerable to climate change and climate-induced hazards. There is an acute shortage of freshwater for irrigation in the dry season. The salinity intrusion experienced by the coastal area of Bangladesh has serious implications for the quality of soil in areas that were traditionally used for growing rice (Huq & Ayers, 2008). The agricultural activities as well as cropping intensities in coastal areas have been changing (Shamsuddoha & Chowdhury, 2007) and soil salinity is a key constraint for low cropping intensity in the area.

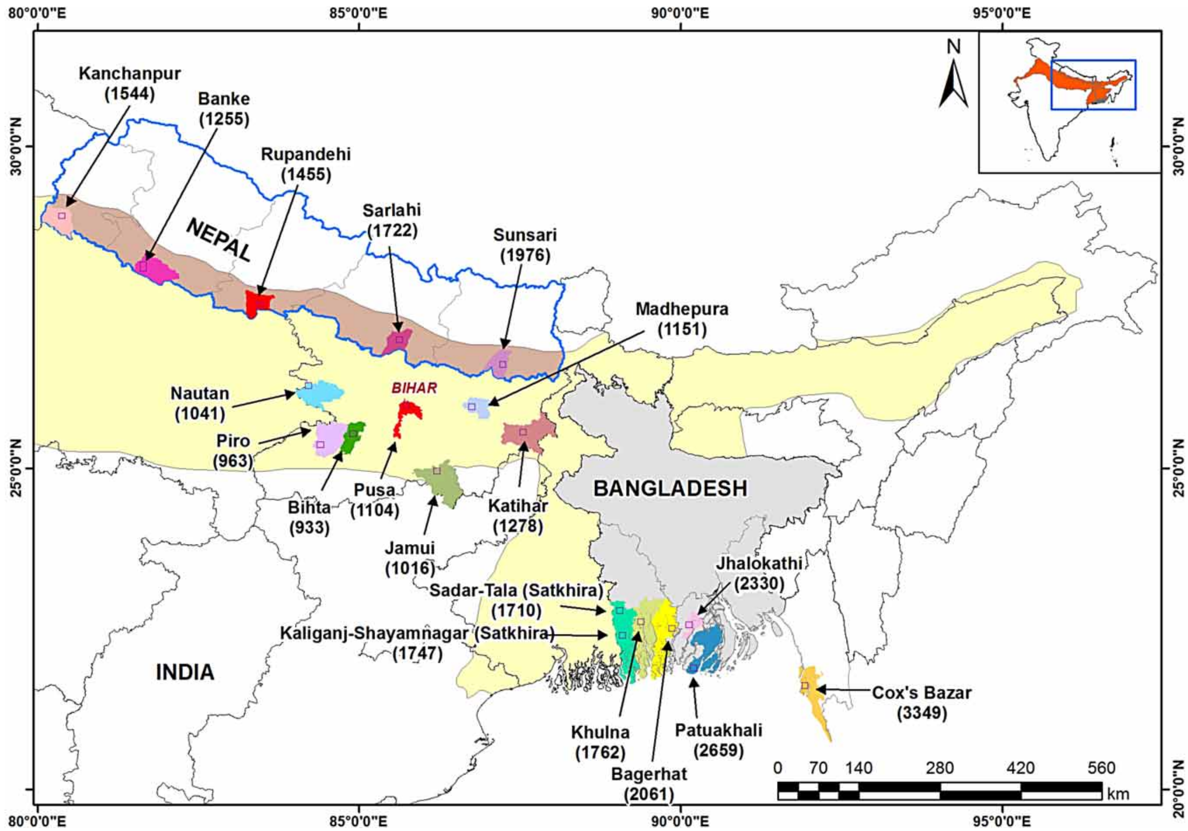

Figure 1. Surveyed sites in IGP (values in parentheses indicate average annual rainfall in millimetre derived from CRU, 2013).

2.2. *Sampling and the survey instrument*

The survey, designed by CCAFS to explore the potential for implementing climate-smart interventions, considered three important criteria for selecting the sites: rainfall amount, salinity gradients, and the network of regional partners who can facilitate scaling out climate-smart agriculture interventions. The sampling process was done at different stages. In the first stage, a broader region (area) with different climatic and non-climatic risks was selected (Bihar in India, Terai in Nepal, and southern coastal area in Bangladesh), followed by the selection of smaller areas (mostly districts) based on distinct rainfall and salinity gradients, and finally layering a sampling frame in each site (10 km × 10 km). All villages within the sampling frame were enumerated and seven villages were selected randomly from each frame. Following simple random sampling, 20 households within each village were chosen. The total sampling size was 980 each in Bihar and coastal Bangladesh and 700 households in Terai.

A highly structured questionnaire was designed and pretested in each region. Before implementing the surveys, survey team leaders and enumerators were given intensive training to ensure a high level of precision and consistency in sampling, data collection, and data entry across all regions. The questionnaire has different components: socio-demographic information, sources of livelihoods, changes in farming practices, including livestock and fisheries over the last 10 years, reasons for changing farming practices, household food availability, key coping strategies during adverse weather events, adaptation measures to climatic variability, and key policy expectation to facilitate adaptation to adverse weather conditions.

2.3. *Data analysis*

The study blended qualitative and quantitative research methods to collect information and process the data on coping strategies and adaptive options amid climatic variability in the region. The rainfall data during 1961–2010 were extracted from the Climate Research Unit (CRU) gridded database. CRU time-series data sets are month-by-month variations in climate over the last several decades. The data set comes on high-resolution (0.5 × 0.5 degrees) grids (CRU, 2013).

The respondents were asked to pinpoint one or more coping strategies to extreme events and adaptive measures to adjust climatic variability over the period of time, and rank the coping strategy that they thought to be the 'most important'. The ranked strategies were finally used to calculate an index considering up to 5th rank (see Table 2 for details). The relationship between on-farm food availability and number of coping strategies with rainfall variability was tested. However, because of multiple factors affecting food availability, the interest is not to capture a causal relationship but to see whether any trend can be observed across the regime of rainfall variability. Following the classification used by Singh, Kumar, and Woodhead (2002), farm households owning, on average, less than 1 ha of land (including landless households) were categorized as marginal farmers ($n = 1523$), those owning 1–2 ha as smallholder farmers ($n = 514$), those owning 2–5 ha as medium-holder farmers ($n = 202$) and more than 5 ha as large holders ($n = 54$). Since the number of large-holder farmers is negligible (almost 2%), they were mostly excluded. In this research, land availability per household was considered the best proxy for household wealth. Thus, land availability is used to understand farmers' coping strategies, adaptation measures, and policy interventions.

3. Results and discussion

3.1. *Rainfall variability in the region*

In considering climate change, the major climatological elements to be taken into account are rainfall, temperature, wind, frost, cloud, and evaporation. All these factors are interdependent, but with regard to smallholder subsistence agriculture that largely predominates South Asia's agricultural activity, rainfall is the most important factor. Furthermore, monsoon rainfall is even more important as the region is dominated by rainfed farming systems. Changes in climatic parameters including rainfall and mean values will bring additional complications to smallholder farmers (Gregory, Ingram, & Brklacich, 2005).

In order to see rainfall variability across three regions (Bihar, coastal Bangladesh, and Terai), monsoon rainfall over different sites in each country was added to calculate average rainfall in each region. It should, however, be understood that the amount and variability mentioned in this paper provide a general trend in the respective region and it does not exactly represent the area as a whole, as the computed value comes from the sites under study. In reality, however, these areas constitute several villages with some variations in terms of rainfall amount, and can be used to understand the impact of changing climate on smallholder farming systems.

Although there are considerable variations across the sites within each country, the mean monsoon rainfall in coastal Bangladesh, Bihar, and Terai during last 50 years (1961–2010) was 2220, 1150, and 1485 mm, respectively. The results of rainfall trends during the growing season (mainly rice) from June to September show a high range of anomaly for the last 50 seasons (Figure 2). Monsoon rainfall in Terai of Nepal and Bihar state of India gradually declines from 1985 to 2010 with higher inter-annual variability, whereas the reverse is true in the case of coastal Bangladesh, showing a gradually increasing trend. The data also corroborate with that of Agrawala, Ota, Ahmed, Smith, and van Aalst (2003) who reported that precipitation will increase in Bangladesh during the summer monsoon. If mean monsoon rainfall over a period from 1961 to 2010 is considered the optimal amount, it becomes apparent that between 1960 and 2010 coastal Bangladesh, Bihar, and Terai, respectively, have for 20, 17, and 22 out of 50 years experienced rainfall below the optimal range, and for 16, 23 and 23 years above optimal rainfall.

Rainfall variability in the past had a substantial impact on local livelihoods. In 2010, when north India received a very good amount of monsoon rain (Pathak, Aggarwal, & Singh, 2012), there was around 22% rainfall deficit in Bihar, and Katihar (one of the surveyed sites in Bihar) had around 30% less rainfall during the same season (Sarthi, 2011). This caused a huge loss in grain yield of rice. Cyclones Sidr 2007 and Alia 2009 affected almost all study areas of coastal Bangladesh (Ahmed et al., 2012; Haq & Ayers, 2008). The floods of 1988, 1998, and 2004 were particularly catastrophic, resulting in large-scale destruction and loss of lives in Bangladesh (Greenpeace, 2006). In the year 2005–2006, the Terai region faced a rainfall deficit; nearly 10% of agricultural lands were left fallow due to low rain and crop production declined by 12.5% nationally (Regmi, 2007). The mid-western Terai in the same year, however, experienced heavy rain with floods, which reduced production by 30% (Regmi, 2007).

A higher variability during the pre- and post-monsoon periods signifies that farmers need to adjust planting time of the crops during the season. It may cause lengthening or shortening of the growing period. For example, sowing of wheat gets delayed due to high variability of rainfall during the month of October and November, mainly in the low-lying areas of Terai and Bihar. A large amount of the variability in rainfall is related to the occurrence of extreme rainfall events and their intensities (Guhathakurta, Sreejith, & Menon, 2011). Later start of rain than in the normal sowing period means possible shrinking of the growing season and increasing moisture and heat stresses to the crop.

3.2. *Socio-demographic information of the farm households*

Table 1 depicts the household characteristics of the farm respondents. The average household size in coastal Bangladesh is lower than that in Bihar and Terai. Households across the three regions are male dominated. The dependency ratio, however, is somewhat higher in Bihar (0.24%), when compared to the other regions where there is not much difference. In terms of education, a large number of households in Bihar (12%) do not have a formal education when compared to households in

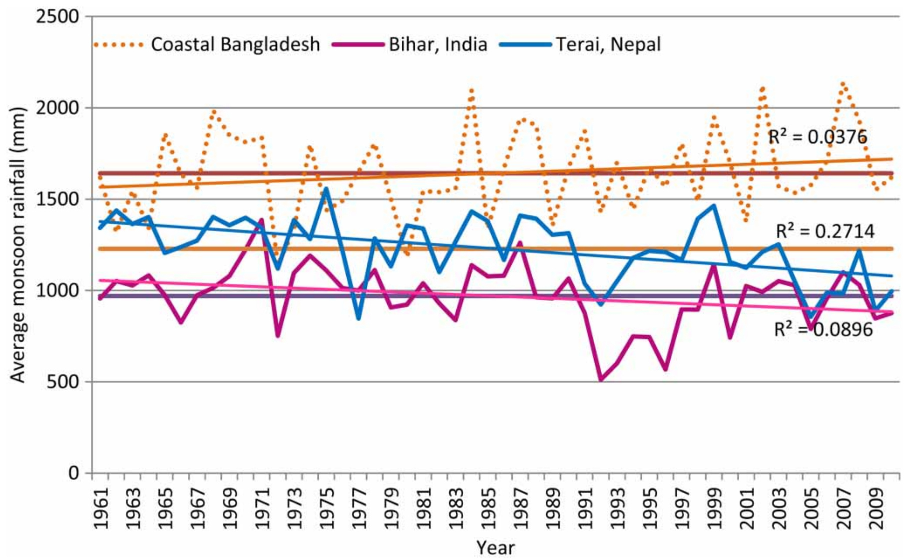

Figure 2. Monsoon rainfall anomalies compared with the mean in the three different parts surveyed (average over sites in each country) from 1961 to 2010.

coastal Bangladesh (4%) and Terai (3%). The number of households with the highest education level (post-secondary) is higher in Terai (36%), followed by coastal Bangladesh (29%), and then Bihar (24%). The average landholding per household is higher in Terai (1.37 ha) as compared to Bihar (0.86 ha) and coastal Bangladesh (0.63 ha). Almost 48% of the farm households in Terai have irrigation sources well in place. Distress migration is higher in coastal Bangladesh (35%) compared to Bihar (23%). Coastal Bangladesh faces the synergistic challenge of frequent climatic events such as floods, cyclones, and sea level rise (Nicholls et al., 2007), and increasing climatic variability such as erratic rainfall and droughts. These factors contribute to the vulnerability of the production system and to a large extent determine migration decision of the households. The risk of out-migration is higher in villages with unfavourable agro-climatic conditions than in villages with a favourable production environment (Henry, Schoumaker, & Beauchemin, 2004).

3.3. *Coping strategies of the farmers in response to the extreme events*

Historically, farmers in South Asia have developed multiple strategies to cope with the adverse events such as floods, droughts, cyclones, and heat waves. Many such local strategies can (and should) be considered as coping mechanisms, because they are reactive to external events. For instance, the majority of the farm families in coastal Bangladesh (77%) introduced female labour during adverse weather events in the past; however, currently, migration seems to be the most preferred strategy (Table 2). This study focuses on short-term migration (either labour migration or the migration to make a

Table 1. Socio-demographic characteristics of the farm households across the region.

Characteristics	Bihar, India	Terai, Nepal	Coastal Bangladesh
Average household size	7.76	7.4	5.0
Household type			
Male headed	952 (97)	666 (95)	946 (97)
Female headed	28 (3)	34 (5)	34 (3)
Average dependency ratio	0.24	0.19	0.20
Education level			
No formal education	120 (12)	22 (3)	34 (4)
Primary level	324 (33)	134 (19)	276 (28)
Secondary level	302 (31)	293 (42)	389 (40)
Post-secondary level	234 (24)	251 (36)	281 (29)
Average land size (ha)	0.86	1.37	0.63
Number of farm households with irrigation	277 (28)	337 (48)	292 (30)
Number of farm households with distress migration in the past	221 (23)	–	345 (35)

Note: Values in parentheses indicate percentage.

Table 2. Coping strategies followed by the farmers during adversities.

	Number of responses						Index (%) and (total responses up to 5th rank)		
	Bihar, India		Coastal Bangladesh		Terai, Nepal		Bihar	Bangladesh	Terai
Coping strategies	1st rank	2nd rank	1st rank	2nd rank	1st rank	2nd rank			
Migration	289	83	260	131	0	0	17.7 (454)	18.8 (685)	0 (0)
Distress sale of animals and/or assets	75	123	96	144	10	21	10.1 (296)	10.8 (381)	5.5 (129)
Loan from lenders or relatives and/or formal credit markets	201	199	197	157	326	170	22.2 (641)	16.4 (572)	38.4 (554)
Shift from agriculture to daily wage	172	79	150	52	77	114	12.6 (342)	8.3 (246)	26.7 (526)
Sell or mortgage land	33	54	36	20	29	35	6.1 (213)	2.5 (80)	20.0 (515)
School dropout of children	1	6	9	17	0	0	8 (36)	1.5 (57)	0.5 (28)
Introduction of female labour	3	12	94	284	0	0	0.9 (31)	0.199 (763)	0 (0)
Reduction in personal expenditure	186	158	11	27	0	0	20.2 (615)	6.1 (329)	7.8 (364)
Reduction in food intake	48	69	177	136	0	0	9.4 (343)	15.9 (582)	1.1 (44)

Note: Index was computed by considering responses up to 5th rank. Index = $\sum(K_i \times n)/\sum(K_i \times N)$, where K_i is the rank number (1–5 in this table), n is the number of responses for ith rank, and N is the total number of responses for ith rank.

family living) under climatic adversity. The climate-induced distress migration from agriculture could largely manifest in the short term (Kumar & Viswanathan, 2012). Labour migration in the context of climatic risks, seasonal food insecurity, and structural inequality is one of the most important coping strategies of rural households in northern Bangladesh (Etzold, Ahmed, Hassan, & Neelormi, 2014). Bangladesh notably suffers from extreme weather events (cyclones, floods, and droughts) that force people to migrate. Migration, as a coping strategy, is perceived as a necessary action, but an undesirable form of adaptation for farmers (Kelkar & Bhadwal, 2007). Migration is generally implemented by men (Ahmed et al., 2012) and it is an adaptive response to climate-related vulnerability (Ahmed et al., 2012; Brockhaus et al., 2013; Brooks, Grist, & Brown, 2009). In general, women in Bangladesh work within the home for most of the time (Braun & Saroar, 2012). Once male members within the household migrate as an aftermath of an extreme weather event, and/or farm work requires more labour to complete the remaining farm activities, women have to bear additional burden in the household and on the farm. This may be one of the reasons why the households have to introduce female labour after extreme events have occurred. In the Bihar region, reduction in personal expenditure as a coping strategy in response to the past adverse weather events was reported by the majority of farmers (64%), as well migration was the most preferred coping strategy. In Terai, the majority of farmers borrowed loans from moneylenders or relatives, and/or from formal credit market during adverse events in the past.

Terai, in general, exhibits a different picture when compared to the other two regions. For instance, the introduction of women labour and migration are not considered as coping strategies by any household. It may be because most of the family farms are run by women due to out-migration of men. The Maoist conflict period that occurred from 1996 to 2006, a key driver of out-migration, and subsequent exodus of men from villages put additional burden on women to take the sole responsibility of agricultural production (Gartaula, Niehof, & Visser, 2010; WOCAN, 2010). Migration of youngsters and adult members leaving women, children, and older people in the household also compel women to move away from agriculture (Gartaula et al., 2010). Migration in Nepal is mainly for better economic opportunities in foreign countries (Maharjan, Bauer, & Knerr, 2012) as cities in Nepal cannot absorb a large number of migrants due to low level of industrialization. Since a large number of respondents in Terai are relatively well educated (78% with some secondary and post-secondary level of education) compared to those in coastal Bangladesh (69%) and Bihar (55%) (Table 1), educated people have a tendency to migrate to foreign countries for higher education and/or for better economic opportunities. Since most of the family farms are managed by women and their counterparts are temporarily away from home, out-migration and further women's involvement in agriculture during adversity cannot be considered a feasible coping strategy in Terai.

Expenditure smoothing remains the 2nd, 3rd, and 4th important coping strategy, respectively, in Bihar, coastal Bangladesh, and Nepal. Similarly, smoothing in consumption is also an important strategy followed by the farmers during adverse years. Both of these strategies include cutting down expenditure on food and/or fewer intakes of food and other items. In some cases, such as during severe flooding, expenditures will shift from food consumption to shelter and medicine. In other cases, farmers with large holdings attempt to reduce expenditure by cutting back on labour hiring. This indicates that the poorest households in particular are often unable to fully shield consumption from the impact of adverse events (Burke & Lobell, 2010; Morton, 2007). Households cope by reducing food intake to maintain their food supplies for the duration of the flood (Kelkar & Bhadwal, 2007). Cutting expenses on food and other items might be a good coping strategy, but will likely result in a low-quality of life and livelihood (FAO, 2010). Reduced expenditure on less essential items such as social and religious functions may not have much welfare implications. However, reducing expenditures on basic items such as food and medical treatment may likely result in adverse short- and long-term consequences.

Introduction of female labour appears to be the second important coping strategy in coastal Bangladesh, while in Terai the second important coping strategy appears to be shifting from agriculture to daily wage earning occupation. Distressed liquidation of productive assets such as livestock and/or land is one of the strategies followed by the farmers in South Asia during adverse events that can provide consumption relief in a particular year, but may worsen food production situation in later years (Burke & Lobell, 2010). Under extreme cases, school dropout of the children is also found in some areas. After an adverse event, children often have to assist with domestic tasks and also household chores rather than attending school. For instance, 40% school dropouts were recorded in one of the villages in Orissa, India, during a flood event (Kelkar & Bhadwal, 2007).

Coping among the households are largely autonomous, but respondents also rely, to varying degrees, on some resources and services from the local government, NGOs, and other institutions (e.g. cooperatives). Many of the aforementioned strategies used by the households help them to cope with the adverse situation. However, if farmers are unable to recover once the adversity is over, their livelihoods may be further impoverished. For instance, poor and smallholder households under a stressful situation may sell their productive assets such as livestock and/or land at a lower price, but usually they fail to restock after the shocks are over. This may dampen the subsequent productivity and food security in future (Burke & Lobell, 2010). Consequently, there is a trade-off between coping with current problems and adapting in the long term.

The results of this study also show that the number of coping strategies farmers use varies based on the annual rainfall variability. In areas where there is increasing rainfall variability, the number of coping strategies increases, although marginally (Figure 3). This means that farmers in the areas of lower rainfall variability pursue fewer number of coping strategies under adverse events, whereas the opposite is true in areas with more variable rainfall. As well, the on-farm food availability increases with increasing annual rainfall variability. Although there is a relationship between rainfall variability and food availability ($R^2 = 40\%$), the cause of this relationship is not obvious. Climate variation is just one of the several interacting factors that affect food security (Gregory et al., 2005; Misselhorn, 2005) and in general, it is difficult to disentangle other non-climatic factors. Thus, lower rainfall variability does not necessarily mean that farmers are better off in terms of agricultural production, but what is important is how farmers cope with and adapt to such variability. One possible reason is that with increasing rainfall variability, the number of coping strategies increases (as observed in Figure 2) and farmers with more coping strategies can be in a better position to produce more and hence they have more food available months in a year. For instance, by investing a portion of remittance or credit on better agro-technology, and/or increasing adaptive capacity, farmers in more variable rainfall areas may increase food availability. The households that are pursuing adaption strategies are enhancing their food security (Kristjanson et al., 2012). Location is another possible reason. For example, rainfall variability is lower in many sites of coastal Bangladesh, but these sites suffer from multiple stresses in agriculture such as salinity, flooding, sea level rise, and lack of freshwater for irrigation in dry season. Climate change is expected to increasingly affect the livelihoods of farmers, especially those who are economically more vulnerable (Etzold et al., 2014; Manandhar, Vogt, Perret, & Kazama, 2011). Food availability also depends on land size and irrigation availability. For instance, average land holding in coastal Bangladesh is way lower (0.63 ha) than that in Terai (1.37 ha) and Bihar (0.86 ha). Similarly, only 30% of the households have irrigation in coastal Bangladesh (Table 1). Weather events such as droughts during the critical crop growth

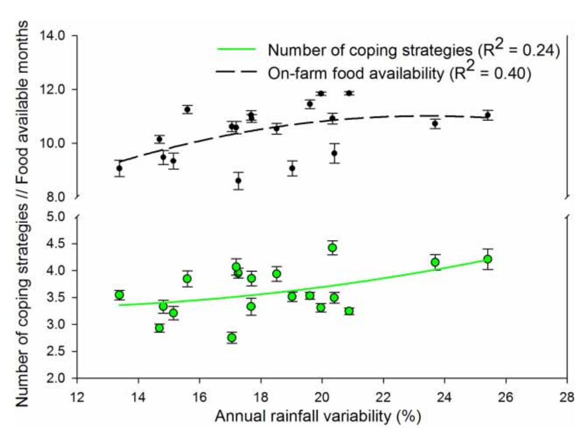

Figure 3. Relationship of the number of coping strategies under adverse events and food available months in a year with annual rainfall variability (error bars indicate the 95% confidence interval of the mean).

stage decrease households' own food production, mainly if there is a lack of irrigation facility. Thus, this study reveals that there is a link between rainfall variability, on-farm food availability, and the number of coping strategies farmers pursue. This linkage, in turn, entails that if farm households cannot cope with or adapt to the production risks owing to climatic and non-climatic factors, the livelihood of farmers will become further exacerbated. Further research is required to investigate whether a portion of the remittance and credit is invested on adaptive agro-technology and human capital development, and how different coping strategies would affect the livelihood of farmers under varied climatic conditions.

3.4. *Reasons that preclude farmers from migrating under adverse events*

Despite considerable climatic variability and multiple adverse events in the study areas, members of some households experience barriers to migration irrespective of weather adversities. It is very difficult to pinpoint the exact reason that preclude farmers from migrating under extreme events, because these reasons could be socio-demographic, economic, and cultural (Etzold et al., 2014). Household poverty levels may decrease the possibility of migration to more favourable regions (Goldberg & Frongillo, 2001). Cultural constraints and social networks are also very important determinants of migration decisions (Sherbinin et al., 2008). Figure 4 shows the different reasons farmers emphasized as per the land size (a proxy of household wealth). A large percent of the marginal farmers do not migrate simply because of concerns for their family (around 52%). These concerns vary socio-economically and spatially. The common concerns, however, could be the fear of the loss of family cohesion, issues related to child and family health, child education, and looking after elderly people, among others. Marginal and landless farmers derive their livelihoods by contributing family labour in others' farms, and even under adverse weather events, they still expect to contribute their wage labours to the large landholders. Although extreme events impact everyone in a particular area, it may be possible that members of relatively large farm owners, who do not out-migrate in response to adverse event, may require more farm labours to accomplish the remaining farm work. This increases labour demand at the farm. Flooding, for instance, increases labour demand for river-based activities such as fishing, and landless and marginal farmers bridge the gap by contributing their surplus labour.

Social stigma and security of the assets such as livestock, household items, and land, as well as emotional attachment with the land resources, as the determinants of migration decisions become more prominent, while family concern becomes less important as land size increases. Land ownership in rural areas determines the asset for production as well as access to credit, and those with higher land size enjoy higher social power (FAO, 2002). Smallholder farmers are mostly subsistence oriented and they do not have adequate food reserve in the event of adversity. The results also show that around 30% of farmers with medium-sized farms do not migrate because they have adequate food reserve to support themselves under adverse events. This is intuitive as farmers with relatively larger holdings are able to produce surplus food.

Farmers with larger land holdings hope to recover even if they lose a significant portion of their farm produce due to an environmental crisis (Gray & Mueller, 2012). As a

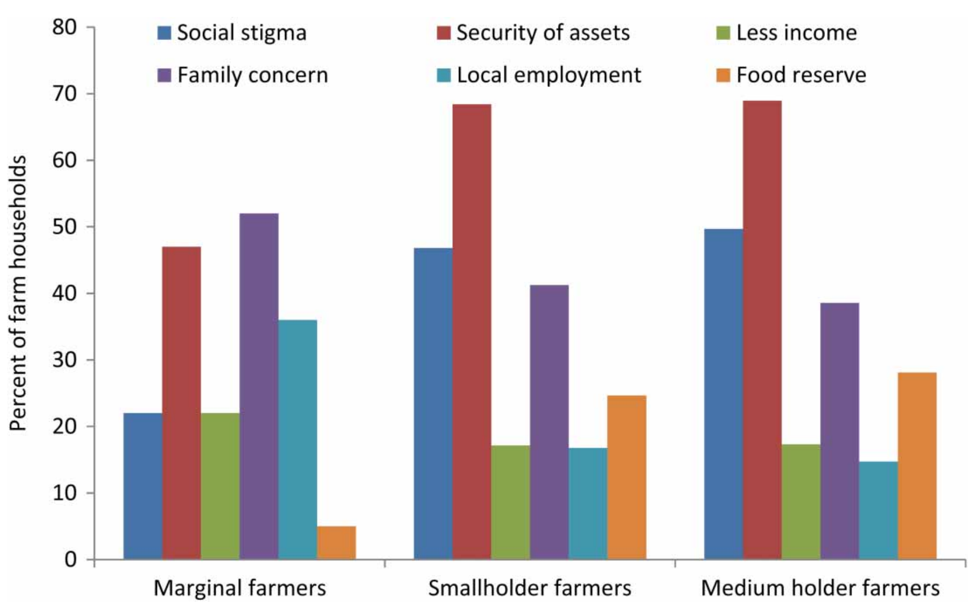

Figure 4. Reasons preventing farmers from migrating during weather adversity.

matter of fact, they would like to struggle with the local situation. Economic inequality as a driver of migration also interrelates with environmental change to impel movement from the origin to other areas (Andrew & Somerville, 2013). While people at the upper end of the socio-economic spectrum may be tied up with their household capital or are emotionally attached to their land resources which would help them resist climate change-induced hardships (Ahmed et al., 2012), the people at the lower end of the spectrum (poor, landless, and low asset owners) may easily be displaced by climate hardships (Ahmed et al., 2012; Kumar & Viswanathan, 2012). For the smallholders, poverty entails not only a dearth of capital resources to invest, but also that any investment from those meagre resources involves a higher risk than would a similar investment by a wealthy farmer (Singh et al., 2002).

3.5. *Climatic variability and local adaptation*

Farm households in IGP are constantly seeking ways and measures to adapt to changing circumstances including climate change and variability. In an anticipatory mode of learning, farmers are increasingly engaged in active experimentation in agriculture, which largely operates at the household level, but are often supported and informed by community-level learning networks (Chhetri, Chaudhary, Tiwari, & Yadav, 2012). The local understanding is that climate is continuously changing and getting worse over time. Bad years are becoming more frequent than before, resulting in the worsening of local livelihoods. Farmers across different rainfall regimes have experienced a decreasing number of rainy days and increasing temperature over the years.

Farmers were asked how changes in climatic variability during the last two decades affected them, mainly in terms of agricultural adaptation. Multiple adaptive options such as distress migration, livestock dependency, and changes in cropping pattern, variety/breeds, and management practices are recorded across different land holding size. Around 20% of the marginal farmers sold their livestock and/or had distress migration during the last two decades due to climatic variability (Figure 5). Similarly, almost 20% of the farmers increased their dependency on livestock. Since marginal and landless farmers often do sharecropping and/or leasehold farming, a small percentage of these farmers changed cropping pattern (17%), varieties (14%), and plant and livestock management practices including adjustment of planting dates (14%) in response to increasing climatic variability. With increasing land size, households' tendency to pursue adaptive measures such as distress sale or migration declines. The richer farm households (land as a proxy measure) are less sensitive to climatic variability as they have relatively large landholding and possess alternative source of income outside agriculture. Even under precarious climatic conditions, they are more food secured and hence they do not have a motive to migrate. However, some members of such households often migrate mainly for availing better education and/or employment. In contrast, households with smaller/marginal lands, who mostly depend on rainfed farming, are severely exposed to climatic variability and their food security gets worsened with increasing rainfall variability. As a matter of fact, they choose migration as an effective adaptation measure to resolve the problem of seasonal food insecurity.

The percent of farmers who changed varieties and/or livestock breeds over the last 10 years to adjust to climatic variability increased with land size and around 18%, 25%, and 30% of the marginal, smallholder, and medium-holder farmers changed crop varieties, respectively. In certain parts of Nepal's Terai and India, many farmers have shifted to rice varieties that require less water and that can be sown at a later date to adapt to rainfall variability (Dixit, Upadhya, Dixit, Pokhrel, & Rai, 2009; Lambrou & Nelson, 2010). Strategies such as adjusting planting dates and varieties could help adapting to climate change to a certain extent (Aggarwal et al., 2004; Larson, 2013). Similarly, almost one-third percent of the smallholder and medium-holder farmers changed their cropping pattern. Changes in plant and livestock management such as improved irrigation, adjusting planting times, residue incorporation, and the use of inorganic agro-inputs, organic manure, feed, and fodder are more frequent with smallholder and medium-holder farmers compared to marginal farmers.

Changes in cropping patterns and land use have also been influenced by relatively large land owners shifting their livelihoods away from just dependence on farming, and on a greater willingness of small and marginal farmers to cultivate higher value crops (Chhetri et al., 2012). Changes in cropping pattern for agricultural adaptation is reported by around 30% of the respondents; it is, however, important to investigate whether the changed pattern has the potential to adjust to future climate and how it contributes in distributional outcomes in terms of gender equity, food security, sustainability, and long-term adaptation.

3.6. *Policy supports required to facilitate adaptation under adverse weather conditions*

Farmers were asked to point out different policy options to facilitate agricultural adaptation under adverse weather events. Relief measures in terms of cash (direct cash transfer or cash given in person by government or non-government institutions) or in kind (subsidy in the farm inputs, restoration of infrastructures, food aids and support to the school children, etc.) are considered the first priority for landless and marginal farmers (83%). Since marginal farmers own a very small parcel of arable land, they are hit the hardest under extreme events. Around 46% of the

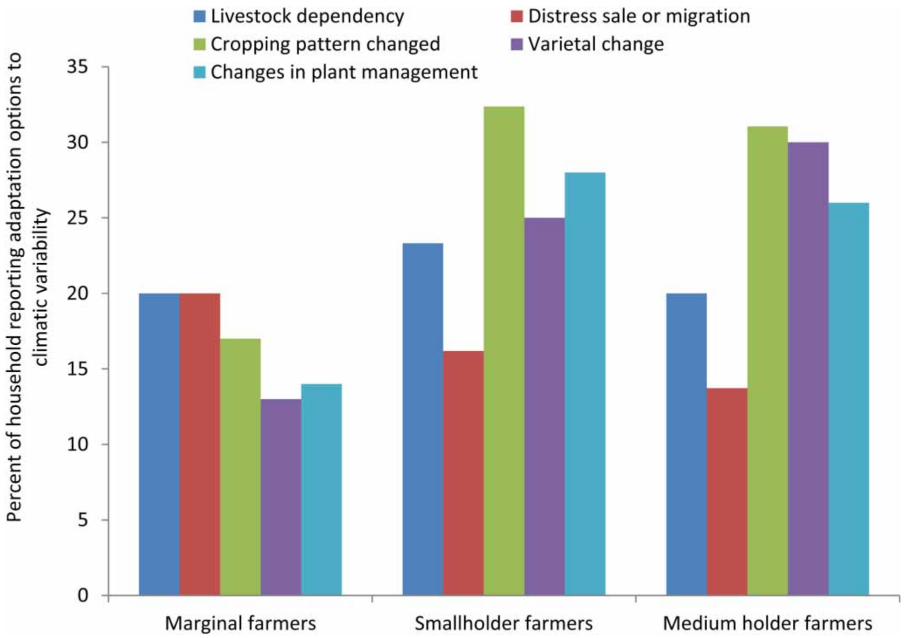

Figure 5. Key adaptation options followed by different types of farmers in response to climatic variability observed over the last two decades.

marginal farmers expect insurance of their crops and/or livestock in the event of adversity. As the land size increases, the percent of farmers expecting relief measures decline, while their need for tolerant seeds increases (Figure 6). A majority of the smallholder and medium-holder farmers (around 69% and 74%, respectively) emphasize a need for adverse weather-tolerant varieties of crops. On an average, requirement of tolerant crop varieties was given highest preference (around 60%) across all sites. It is notable that research institutions in India, Nepal, and Bangladesh have already released several varieties of crops that are tolerant to adverse weather conditions. However, continued innovation of resilient varieties of several crops is necessary considering the agro-ecological context, current climatic variability, and future projection of climatic trends.

Similarly, other efforts that farmers require include early warning system for bad weather events, insurance of the on-farm enterprises to spread market risks, and better land management techniques. Provision of an early warning system is stressed more in coastal Bangladesh. Since farmers frequently face extreme events such as floods and cyclones, provision of such a system will assist farmers to get prepared in advance. Bangladesh,

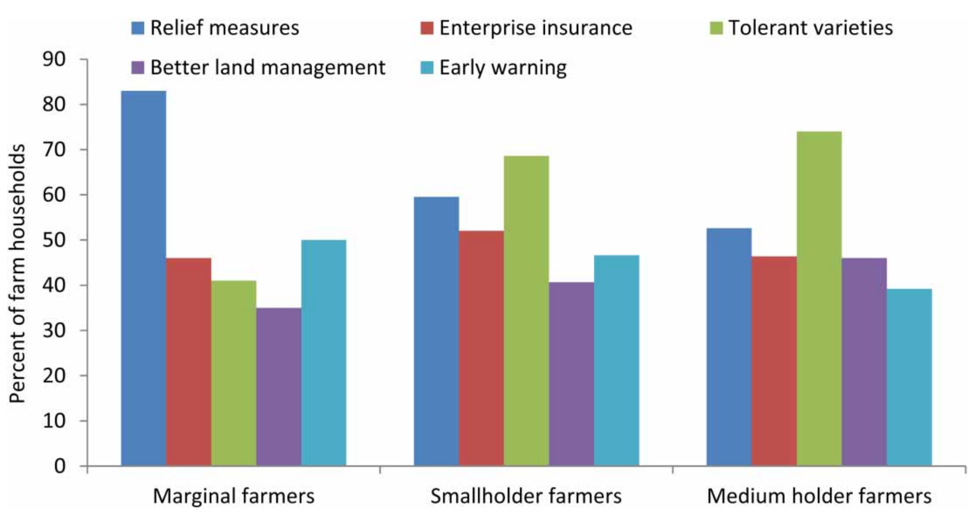

Figure 6. Farmers' expectations from the government/scientists to facilitate management of adverse weather.

currently, has a good early warning system and cyclone shelters have been constructed along much of the coast, yet infrastructure and livelihoods are still threatened and severely affected by these adverse events, hampering further development of the coastal areas (Huq & Ayers, 2008).

4. Conclusion

Smallholder subsistence agricultural systems in South Asia, especially those located in the areas of climatic risks, are often characterized by livelihood strategies that have been evolved (i) to manage the impacts of extreme events (ex-post coping strategies) and (ii) to reduce overall vulnerability to climatic variability (adaptive strategies). Most of these strategies are important for survival under extreme events and adjustment to variable environmental conditions. What start as coping strategies in years of extreme weather conditions can become adaptations for households in the future (migration and livestock dependency, for instance). Both coping and adaptation strategies are place specific and what is the best measure in one place may not be an appropriate measure in another. For instance, migration is perceived as one of the most important coping strategies during extreme events in Bihar and coastal Bangladesh, while a high dependence on formal and informal credit markets ranks a higher priority in Terai.

To reiterate, many of the coping strategies followed by farmers help them to cope in an adverse situation; however, if they are unable to pull through, once the adversity is over, it will impoverish the livelihood situation. For instance, distressed liquidation of productive assets such as livestock and/or land at a lower price can provide consumption relief in a particular year but may worsen food production situation in later years. Similarly, consumption smoothing affects the nutrition of the family members. An increase in school dropout of children during adverse events would prevent them from developing their human capital for better livelihoods in future. Thus, there is a trade-off between coping with current problems and adapting in the long term. Better understanding of how climatic factors affect migration choices and other coping strategies is important to help shape adaptation investments and policies to ensure that the strategies households use contribute to increased resilience to climate change. Another important finding of this study is that with increasing annual rainfall variability, the number of coping strategies under adverse events increases and so does on-farm food availability. Although causality is not obvious, further research on farmers' coping capacity under variable weather events, different adaptation measures, and on-farm food availability would give some policy signal.

Adaptation options in response to climatic variability in the study areas range from livestock dependency to changes in plant management. While a large number of landless and marginal farmers develop their dependency on livestock and pursue distress migration to adjust to increasing climatic variability, the key options for the large number of smallholder and medium-holder farmers are changes in cropping pattern, variety/breeds, and management practices. The results envisage that a larger investment in crop breeding, climate-smart agro-technology, and financial instruments is needed in considering the current climatic trend and future projection of climate change and variability. Since a change in cropping pattern to adapt to volatile climatic regimes is reported by many respondents, it is, however, important to examine whether the changed pattern has the potential to adjust to future climate and whether it contributes to distributional outcomes in terms of gender equity, sustainability, and long-term adaptation to climate change.

Overall, the findings provide indications that relatively deprived households require attention in order to regulate or control migration and/or to make their livelihoods better by developing their human capital. A set of social safety nets should be strengthened to deal with climate-related shocks to food systems, particularly for resource-poor farmers. Governments should contemplate to implement a number of activities during and post-extreme events, with an objective that these planned activities would be synergistic with adaptation to climate change and ensure the transition from coping with shocks towards more adaptive resilient systems that can confront future climate extremes.

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