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Research article

Comparison between meteorological data and farmer perceptions of climate change and vulnerability in relation to adaptation

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ABSTRACT

How farmers perceive climate change has an influence on how they adapt to climate change. Climate change perception and vulnerability were assessed based on the household survey information collected from randomly selected 118 farmers of Kalapara subdistrict in Bangladesh. This paper identified the socio-economic covariates of climate change perception and vulnerability in relation to agricultural adaptation. It was also determined whether their perception was consistent with meteorological information. Findings revealed that the farmers had a moderate level of perception of and vulnerability to climate change. An overwhelming majority (98%) of the respondents perceived a warmer summer and 96% of them observed a colder winter compared to the past. Among the farmers, 91% believed that rainfall had increased and 97% thought that the timing of rainfall had changed. The belief of increase in soil salinity and associated loss was prevailing among 98 and 99% of them, respectively. Observed climate data were mostly aligned with the farmers' perception with respect to temperature, rainfall, floods, droughts and salinity. Positive correlations were found among the perception of climate change, the perception of vulnerability and the number of adopted adaptation practices. Farmers' level of understanding of climate change, vulnerability and adaptation practices could be improved by involving them in different organizations, such as climate field school and farmer associations. It could accelerate the dissemination of agricultural adaptation practices among them to cope with adverse agricultural impacts of climate change.

1. Introduction

Are farmers really able to detect climate change? It is questionable for several reasons. Firstly, climate change is a long-term change in atmospheric conditions, while the farmers rely on a short-term experience while responding to climate-related interrogations. Secondly, they rely on their past memories of atmospheric conditions without using any devices. Thirdly, climate change is a slow process only detectable with meteorological instruments (Weber, 2010). Despite these facts, scientists (e.g. Abidoye et al., 2017; Alam et al., 2017; Dubey et al., 2017; Elum et al., 2017) have been trying to comprehend how farmers understand and interpret climate change. The researchers are, in some cases, cautious in using the term 'climate change'; rather they used 'climate variability' (Ayal and Leal Filho, 2017; Kibue et al., 2016) or 'climate uncertainties' (Nguyen et al., 2016) or a combination of 'climate change and variability' (Lamsal et al., 2017; Moniruzzaman, 2013; Shameem et al., 2015) to mean the same phenomenon of climate change.

Farmers could have an inadequate concern about climate change and their information sources might not be sufficiently credible. As a consequence, appropriate scientific facts of climate change are not always properly communicated to farmers (Weber, 2010). Whether we can expect farmers to recognize climate change cannot diminish the importance of climate change perception on adoption of adaptation strategies. Perception of climate change is a subjective evaluation (Bickerstaff, 2004) that involves individual interpretations that drive actions concerning climate change (Niemeyer et al., 2005). Before responding to climate change, one must perceive climate change. This perception should necessarily tally with actual climate change for effective adaptation, although the farmers cannot be expected to detect the immediate climate changes (Maddison, 2007). The evidence is unclear whether coastal farmers perceive climate change properly,

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particularly in Bangladesh.

Perception being a psychological variable, it is quite vague to ask whether climate is changing in a dichotomous (yes/no) fashion (Abidoye et al., 2017). Perception of climate change is a multidimensional phenomenon and has been investigated with an emphasis on causes, impacts and adaptation in different studies (e.g. Alam et al., 2017; Haque et al., 2012; Kabir et al., 2016; Moniruzzaman, 2013; Shameem et al., 2015; Uddin et al., 2014). None of these studies have included quantitative analysis to assess the covariates of climate change perception. Besides, the perception of vulnerability to climate change issue has been almost untouched. Some studies, for example, Ahsan and Brandt (2014) in Bangladesh, Mase et al. (2017) in the USA, Patt and Schroter (2008) in Mozambique, Cullen and Anderson (2017) in Vietnam and Woods et al. (2017) in Denmark, assessed climate risks but those were descriptive in nature where associated factors were not identified. Very few studies conducted in Bangladesh have compared farmers' perception with meteorological data of climate change. Rural people's climate change perception and observed extreme climate events are claimed to be consistent with the scientific evidence (Alam et al., 2017) but deviated from consistency for long-term climatic variations (Shameem et al., 2015).

The Bangladeshi coastal farmers have been practicing different agricultural adaptation techniques to cope with climate change (Hasan et al., 2018). Extension agents have been promoting the practices with the farmers through climate field schools (CFS). These practices had adaptation, resilience and mitigation abilities in a changing climate as exemplified in FAO (2013, 2014) and Sain et al. (2017). How their adoption is influenced by climate change perception was not explored. Li et al. (2017) found that adaptation behavior was driven by the awareness of extreme weather events. Despite the contribution of social memory in shaping community resilience (Wilson et al., 2017) towards environmental security (Loring et al., 2013; Penn et al., 2017), understanding the individual farmers' perception of climate change and vulnerability would be useful for the formulation of adaptation strategies (Alam et al., 2017; Altschuler and Brownlee, 2015). Besides, coastal areas are considered as most vulnerable to climate change because of their more frequent exposure to extreme climate events like cyclones, flooding, drought and salinity (Ahsan and Brandt, 2014; Islam et al., 2011; Shameem et al., 2015). The importance and originality of this research were that it explored the perception and vulnerability of coastal households from multidimensional perspectives. It is expected that it would contribute to a deeper understanding of farmers' perception of climate change and its consistency with scientific information. Weber (2010) emphasized the investigation of perception of slow events along with the most studied temperature and rainfall variables. Therefore, this paper focuses on the assessment of perceptions of climate change (temperature, rainfall, floods, droughts and salinity) and vulnerability to climate change from multidimensional contexts which are lacking in the existing scientific discussions. Correlations between the perception of climate change and the adoption of agricultural adaptation practices are also included in this article.

2. Materials and methods

This study collected primary data during April–May 2016 from farmers and agriculture officers, and secondary data from local weather stations, government reports and scientific articles. Respondent farmers were selected randomly from three villages of Kalapara sub-district of Patuakhali district of Bangladesh. This area is in the coastal zone of Bangladesh that directly connects with the Bay of Bengal. Kalapara has an area of 492 sq. km with 247 villages (Bangladesh National Portal, 2017). Three villages were purposively selected because only those villages in Kalapara had climate field schools (CFS) established by the Department of Agricultural Extension (DAE). The DAE had fully operational 156 CFS throughout the country in 2013 to inform farmers about climate change and adaptation (Ajij et al., 2014). Each of the CFS was composed of 25 farmers from 25 households who had an opportunity to attend a fortnightly on-farm training (Ajij et al., 2014). Three CFS had 75 households that we tried to interview. However, we surveyed available 59 CFS households. To make a comparison, we also interviewed 59 general non-CFS households. Finally, the sample included 13% ($n = 118$) of a total of 902 households in the selected villages. Focus group discussions (FGD), personal face to face interviews and key informant interviews (KII) were performed to collect relevant data. Oral and/or written consent was obtained from the interviewees before starting the interview. Participants were not granted any rewards for their interviews.

The interview schedule was composed of a wide range of variables, including demographic characteristics, farm-related information, socio-economic variables, adaptation practices and perception of climate change and vulnerability (Habtemariam et al., 2016). Demographic variables were the farmer's age, education and family dependency ratio (number of non-earning members ÷ number of earning members in a family). Farm-related variables were the number of farm enterprises (out of five categories: crops, vegetables, livestock/cattle, poultry and fish), own farm area and number of own cattle (cow/ox/buffalo). Socio-economic variables included the annual family income, credit received (from formal and informal sources), organizational affiliation (years of involvement with farmer associations), training experience (number of days of attendance), use of hired labour (total man-days of employed farm labour in the last season), number of types of farm equipment owned, walking distance to markets (in minutes), access to farm information (score) and number of known farm adaptation practices. To measure the access to farm information, a three-point rating scale was used to assess how frequently (not at all, sometimes and frequently) a farmer accessed the 14 different farm information sources. The information sources were neighbors, friends, relatives, input dealers, bulk buyers, extension service providers, NGO personnel, group meeting, demonstration plot, poster/leaflet/bulletin, newspaper, radio, television and mobile phone.

The agricultural adaptation practices were identified through FGD with the farmers and KII with the agricultural officers. The identified 17 practices were saline-, flood- and drought-tolerant varieties, early maturing rice, vegetables in a floating bed, 'sorjan' method of farming, pond-side vegetable cultivation, the cultivation of watermelon, sunflower or plum, relay cropping, urea deep placement, organic fertilizer, mulching, use of pheromone trap, rainwater harvesting and seed storage in plastic bags or glass bottles (see Hasan et al. (2018) for details of these practices). In this study, we assessed the adoption of adaptation practices in terms of the number of practices implemented by the farmers.

The perception was defined as how the resource-poor coastal farmers understand climate change. Likert scale is widely used to measure the perception of farmers. This scale consists of several statements against which respondents' extent of agreement or disagreements are sought and scored with 5, 7 or higher number of scale points (Roy, 2000). Modified scales with questions instead of statements (Gbetibouo, 2009; Leiserowitz, 2006) and an even number of scale points instead of an odd number are also used (Brody et al., 2008). In this study, 6-point Likert scale (do not know, very low, low, medium, high and very high) has been used to measure the farmer's perception of climate change. The questions containing 26 items (c.f. Section 3, Table 2) focused on the belief and mental images of probability, causes, consequences, effects and adaptation strategies of climate change (Bonatti et al., 2011; The Asia Foundation, 2012). All the questions had a 'not sure (do not know or unchanged)' option to reduce response bias in the interview and cognitive burden on the respondents (Hitayezu et al., 2017).

A similar scale was used to measure the perception of household vulnerability to climate change against a total of 21 question items (c.f. Section 3, Table 2). Three aspects were considered for vulnerability, namely adaptive capacity, exposure and sensitivity to climatic events (Adger et al., 2003). Adaptive capacity is an ability of an entity to adjust to probable damage, to utilize opportunities, or to act based on impacts of climate change (IPCC, 2014). Adaptive capacity has three elements: adaptation efficacy, self-efficacy and adaptation cost. The adaptation efficacy is a belief that an adaptive measure could protect from threats. The self-efficacy refers to the person's technical skill to perform adaptive measures. The adaptation cost is the ability to bear the costs (time, labor and money) of undertaking any adaptive measures (Grothmann and Patt, 2005). Exposure was measured based on the responses of farmers regarding how they felt the closeness of climatic events that could affect them. Sensitivity was revealed based on the perceived proneness of the households to be adversely affected by the climatic events.

Local temperature and rainfall data from the Bangladesh Meteorological Department (1974–2014) for Khepupara station (Kalapara sub-district) were used in this study. Time series of temperature had 1.93% and rainfall had 1.54% missing values. Although missing data in climate time series is normal, these are required to be complete to be used for analysis (Aslan et al., 2010). Imputation of missing values in climate datasets is a nonlinear problem (Schneider, 2001). Since the temperature and rainfall have seasonality in Bangladesh (Shelley et al., 2016), we used 'seasonally split missing value imputation' technique (Moritz and Bartz-Beielstein, 2015). After decomposing the time series, we plotted the trends to have a clear picture of long-term changes in temperature and rainfall (Moritz et al., 2015).

Data analysis was undertaken using RStudio (Version 1.1.383) (R Core Team, 2016) along with some additional packages, such as 'ggplot2' (Wickham, 2016), 'ggpubr' (Kassambara, 2018) and 'ggcorrplot' (Kassambara, 2016). Calculations of data imputation were undertaken using 'imputeTS' R package (Moritz and Bartz-Beielstein, 2015).

3. Results

3.1. Socio-demographics of the farmers

Two groups of farmers were included in the sample whose salient features are shown in Table 1. Respondent farmers were dominated by middle-aged groups ($M = 46$ years, $SD = 12.8$ years). The average age of the farmers was statistically the same for both the CFS and general farmers. The farmers had mostly primary and secondary level education. The general and CFS farmers had the same level of dependency ratio. Average dependency ratio ($M = 2.5$) indicates that each of the earning members of the households provided financial support to more than two non-earning members who were either unable to work or did not have any work.

Farming was a major earning source of the farmers. Over three-quarters (78%) of the households had crop cultivation (rice, wheat, maize, soybean, watermelon and sunflower) whilst the others had vegetable growing, cattle raising, fisheries and poultry rearing as major farm enterprises. The number of farm enterprises of the CFS farmers was significantly higher than the general farmers. However, households with only one farm enterprise were rare (only 4 of 118) among the sampled farmers. Average farm area and number of cattle owned by the general farmers were significantly smaller than the CFS farmers. Among the general farmers, 59% had cattle whereas this figure was 78% for the CFS farmers. This difference was also reflected in their annual household income. The CFS farmers had an average annual income that was 500 Euro higher than the general farmers. Similarly, utilization of credit money was less common among the general farmers as indicated by smaller mean value though it was not statistically significant.

More than half (56%) of the general farmers did not have any organizational affiliation in different associations (e.g. farmer field school, agricultural project, farmer society and NGOs). Consequently, the CFS farmers had on average 5.5 years longer involvement in different organizations working with them for promoting farming activities. The farmers involved in CFS had significantly longer training experience than the general farmers. The majority (59%) of general farmers did not have any training experience. Though the average man-days of hired labor used by the general farmers seem to be lower than the CFS farmers, it was not statistically significant. However, the number of types of farm equipment (plow, sickle/spade, hand hoe, power tiller, seeder, sprayer and thresher) owned by the CFS farmers was significantly higher than the general farmers. On average, the CFS farmers

Table 1
Socio-demographic and economic characteristics of the farmers.

Characteristics (measurement unit)	Farmer groups	Observed range	Mean ± SE	Median	t-values (df = 116)	P-values
Age (years)	General	22–80	47.1 ± 1.7	45	0.96	0.340
	CFS	26–85	44.9 ± 1.7	40		
Education (years of schooling)	General	0–20	5.6 ± 0.6	5	0.34	0.730
	CFS	0–18	5.3 ± 0.5	5		
Dependency ratio	General	0–7	2.4 ± 0.2	2	−0.59	0.560
	CFS	4–7	2.6 ± 0.2	2		
Number of farm enterprises	General	1–5	3.2 ± 0.1	3	−3.75***	0.000
	CFS	2–5	3.9 ± 0.1	4		
Own farm area (ha)	General	0–2.9	0.43 ± 0.1	0.3	−2.53*	0.013
	CFS	0–2.8	0.73 ± 0.1	0.6		
Number of cattle	General	0–9	2.6 ± 0.3	2	−2.25*	0.027
	CFS	0–15	3.9 ± 0.5	3		
Annual family income ('000' Euro)	General	0.3–5.2	1.7 ± 0.1	1.6	−2.27*	0.025
	CFS	0.2–6.8	2.2 ± 0.2	1.9		
Credit received (Euro)	General	0–1138	109.7 ± 29.0	0	−1.61	0.110
	CFS	0–5692	282.8 ± 103.9	22.8		
Organizational affiliation (years)	General	0–20	2.8 ± 0.6	0	−6.00***	0.000
	CFS	2–33	8.3 ± 0.7	8		
Training experience (days)	General	0–61	5.7 ± 1.5	0	−5.70***	0.000
	CFS	1–180	36.2 ± 5.1	17		
Use of hired labor (man-days per season)	General	0–360	33.8 ± 8.9	10	−1.13	0.260
	CFS	0–360	47.4 ± 8.2	20		
Farm equipment owned (number)	General	0–5	2.8 ± 0.1	3	−2.89**	0.005
	CFS	1–5	3.4 ± 0.1	4		
Walking distance to markets (minutes)	General	0.6–71.3	19.1 ± 2.4	15	−2.50*	0.014
	CFS	1.8–105	28.2 ± 2.7	26.3		
Access to farm information (score)	General	1–21	6.3 ± 0.6	4	−3.75***	0.000
	CFS	2–24	10.1 ± 0.8	9		
Known farm adaptation practices (number)	General	9–19	13.9 ± 0.4	13	−8.50***	0.000
	CFS	14–19	17.4 ± 0.2	18		
Adopted farm adaptation practices (number)	General	1–13	5.4 ± 0.4	5	−3.77***	0.000
	CFS	2–17	8.6 ± 0.5	8		

*, ** and *** denote significant at 5%, 1%, and 0.1% level of probability.

needed 9.1 min longer time to reach different markets on foot for selling agricultural products or purchasing household commodities. Compared to the general farmers, the CFS farmers had more frequent access to farm information and they knew a greater number of adaptation practices to cope with climate change. The coastal farmers were used to adjust their farming activities with climate change through various adaptation practices. Out of 17 selected agricultural practices, on average the CFS farmers adopted three practices more than the general farmers and this difference is statistically significant (Table 1). Further comparisons between the general and CFS farmers concerning the adoption of adaptation practices are highlighted in Fig. 1. From the figure, it is apparent that a greater number of general farmers adopted a lower number of adaptation practices, whereas the number of CFS farmers substantially dominated in case of a very high number of adopted practices.

3.2. Perception of climate change and household vulnerability

Among the 118 farmers, 106 had heard about climate change and 105 believed that climate is changing. Farmers understood climate change by different indicators. Among the sampled farmers, 29 farmers perceived climate change by increased tidal cyclones, 27 by increased warming, 17 by an increase in flood, 9 by a change in rainfall, 9 by an increase in soil salinity and 24 by combinations of two or more of these indicators. Perception scores could vary from 0 to 130, whereas the observed scores ranged between 27 and 118 with an average of 80.2 ($SD = 18.8$). The majority (61%) of the farmers had a medium level (score 46 to 90) of perception of climate change.

Perception of climate change variable was split into five dimensions, namely belief, causes, consequences, effects of and adaptation to climate change that were explored by 26 different statements. The average scores for each of the statements varied from 1.82 to 4.01 (Table 2). There was a moderate extent of the belief that climate is changing ($M = 2.97$ in a continuum of 0–5). Deforestation was the topmost perceived cause of climate change while the top scored consequence of climate change was warmer summers. Farmers perceived that climate change would mainly result in production loss and could be tackled by awareness building and tree plantation. Average scores for different dimensions of climate change perception showed that farmers were more aware of adaptation strategies than causes or consequences of climate change. They understood the effect of climate change to the least extent compared to other elements.

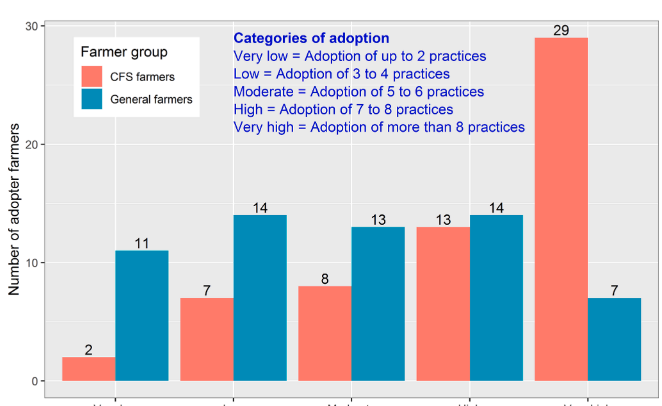

Fig. 1. Number of farmers in different adoption categories.

Table 2
Average perception scores for different statements of climate change and vulnerability.

Dimensions and items of climate change perception	Average score[a]	Dimensions and items of vulnerability perceptions	Average score[a]
A. Belief	*2.97*	*A. Exposure*	*3.01*
Climate is changing	2.97	Observe severe floods	2.64
B. Cause	*3.18*	Observe frequent floods	2.84
Automatic/nature	2.75	Observe severe droughts	3.22
Human influence	3.20	Observe frequent droughts	3.27
Deforestation	3.44	Observe salinity	3.36
Mills/industry/car smoke/CO_2	3.32	Observe cyclone	3.29
C. Consequence	*3.12*	Observe tidal surges	2.46
Warmer summer	3.93	*B. Sensitivity*	*2.85*
Colder winter	2.95	Loss and damages from floods	2.85
Increased rainfall	2.82	Loss and damages from droughts	3.15
Change in timing rainfall	3.69	Loss and damages from salinity	3.25
Increased cyclones	3.11	Loss and damages from cyclones	2.86
Tidal surges	2.39	Loss and damages from tidal surges	2.16
Rising sea/river water	2.61	*C. Adaptive capacity*	*1.87*
Coastal flooding increase	2.84	*i) Adaptation efficacy*	*1.73*
Drought increase	3.48	Possibility to tackle climate change	1.73
Salinity increase	3.42	*ii) Self-efficacy*	*2.24*
D. Effect	*2.78*	Ideas and skill to tackle floods	2.26
Production loss	3.92	Ideas and skill to tackle droughts	2.25
Damage to houses/roads	2.75	Ideas and skill to tackle salinity	2.64
Loss of trees	3.04	Ideas and skill to tackle tidal cyclones	1.81
Loss of livestock	2.49	*iii) Adaptation cost*	*1.65*
Death of people	1.82	Resources to tackle floods/drought/salinity	1.75
Disease incidence	2.65	Resources to tackle tidal cyclones	1.54
E. Adaptation	*3.32*		
Tree plantation	3.84		
Using organic fertilizer	2.81		
Change in agriculture	2.79		
Causing less smoke (CO_2)	3.14		
Awareness raising	4.01		

[a] Average scores in a 5-point rating scale.

The variable ‘perception of household vulnerability to climate change’ looked at the susceptibility of the farmers to climate change. The observed scores of vulnerability perceptions ranged from 24 to 83 against a possible range of 0–95. The farmers perceived a moderate level of household vulnerability to climate change ($M = 49.34$, $SD = 12.40$). Three-quarters of them had a medium level (score 31 to 60) of perception of the vulnerability. Three components of vulnerability were investigated to explore the perceived household vulnerability to climate change; these were exposure, sensitivity and adaptive capacity. Data from Table 2 demonstrates that the farmers observed fewer floods and tidal surges, but a greater extent of drought, salinity and cyclones compared to 5–10 years back. According to the farmers’ opinion, the loss and damages from cyclones were slightly larger than the previous periods while the loss and damages from droughts and salinity had increased to a greater extent. However, the loss and damages from cyclones, tidal surges and floods were less than that from droughts and salinity due to the construction of polders/embankments and sluice gates to control flood water and protect from tidal surges.

Finally, the perceived adaptive capacity was again disaggregated into adaptation efficacy, self-efficacy and adaptation cost. Farmers' perception was that there was less possibility to tackle climate change events ($M = 1.73$). Self-efficacy of the farmers was also low because most of them mentioned that they had fewer ideas and skills to tackle climate change. The last component, adaptation cost bearing ability was in very low condition. Over 90% of the farmers thought that they had a very low amount of resources to tackle the climatic events, such as flood, drought, salinity and tidal cyclones.

The average perception scores of general farmers (78.1) and that of CFS farmers (82.3) were not statistically different, t (116) = 1.21, $p = 0.23$. Likewise, the average vulnerability perception of general farmers (51.0) was apparently higher than that of CFS farmers (47.7), but this difference was not found to be statistically significant, t (116) = 1.46, $p = 0.15$. Therefore, both the farmer groups possessed the same level of climate change and vulnerability perceptions.

3.3. Comparison between farmers' perception and meteorological data

Farmers' perceptions of climate change regarding temperature (increasing temperature, warmer summer and colder winter), rainfall (increase and seasonal change) and soil salinity (increase in magnitude and loss of crops) were compared with the available meteorological data from local stations closest to the study area. Of the 118 sampled farmers, 27 mentioned that temperature was increasing, and other farmers were unsure of overall temperature change. Most of the farmers, as in Fig. 2a, perceived that summer temperature was higher but winter temperature was lower compared to the past.

Farmers' perception of change in temperature was compared with the daily temperature data for the period of 1974–2014. In Bangladesh, summer and winter seasons are distinct with regard to temperature and rainfall (BBS, 2017). After removing the seasonality and random components from the temperature time series, a decreasing trend (−0.013 °C/year) was observed from 1974 to 2014 (Fig. 2b). This overall decreasing trend of temperature was not consistent with the belief of at least 23% of the farmers who perceived that the temperature had an increasing trend. However, there were two different sections in the temperature trend as we can see from Fig. 2b. The average June temperature in 1977 was 37.8 °C which made it the warmest year with a mean annual temperature of 27.90 °C. The average temperature from 1974 to 1990 ($M = 26.40$ °C) was higher than that of from 1991 to 2014 ($M = 26.06$ °C). The decreasing trend of temperature was not apparent after 1990, instead, we find an increasing trend (0.002 °C per year) in this period. Therefore, farmers' perception of increasing temperature was also consistent with the observed data.

Farmer perceptions regarding the trends of winter and summer temperatures were verified by plotting the month-wise temperature trends (Fig. 2c). The colder months (October to March) showed a decreasing trend but the warmer months (April to September) except May and June had an increasing trend of temperature. The temperature trends of May and June did not follow other warmer months because of abnormally higher temperatures during these months in 1977. Therefore, farmers' perception of both summer and winter temperatures coincided with the scientific observations in the study locations.

In case of rainfall, the majority (44%) of the farmers perceived that rainfall had moderately increased and over two-thirds of them opined that the timing of rainfall had changed (Fig. 3a). The local station data also showed that rainfall had an increasing trend of 0.035 mm per year for the period from 1974 to 2014 (Fig. 3b). If we look at the monthly rainfall trends (Fig. 3c), the drier months (November to April) had a negative trend except January; and among the wetter months (May to October), July, September and October had a positive trend of rainfall.

It can be seen from the charts (Fig. 4a) that most of the respondent farmers believed that floods and droughts have increased compared to the past years. Hydrological information collected by Hofer and Messerli (2006) from the Bangladesh Water Development Board shows an insignificant decreasing trend of floods from 1954 to 2004 (Fig. 4b). Rahman and Lateh (2016) estimated meteorological droughts in Bangladesh using standardized precipitation index and geographic information system. Their estimated number of drought events (Fig. 4c) shows a slightly decreasing trend of drought but increasing trend during February to April from 2001 to 2010. However, Rahman and Lateh (2016) mentioned a positive trend of droughts around Kalapara sub-district. Therefore, farmer perceptions of flood occurrence were not consistent with the findings of Hofer and Messerli (2006), but drought perception had similarities with the estimations made by Rahman and Lateh (2016) at least for the February–April period of the recent years.

Regarding soil salinity, the majority (68%) of the farmers perceived a moderate to high level of salinity increase in their crop fields (Fig. 5a). Most (79%) of them thought that the loss in crop production increased to a moderate to a high extent. Dasgupta et al. (2015) reported that annual median soil salinity in Nilganj union of Kalapara sub-district increased from 3.7 to 4.4 dS/m between a period of 2001 and 2009. Salinity level of soil is classified into four levels (Ahsan, 2010): slight (S_1, 2–4 dS/m), moderate (S_2, 4.1–8 dS/m), strong (S_3, 8.1–16 dS/m) and very strong (S_4, >16 dS/m).

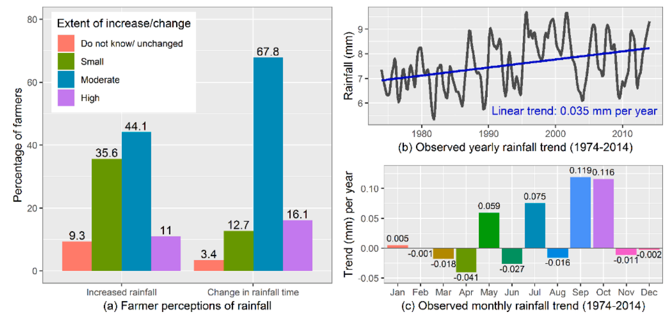

Fig. 3. Comparison between farmer perceptions and observed rainfall change.

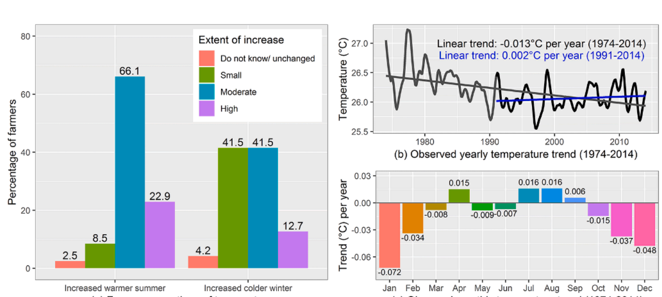

Fig. 2. Comparison between farmer perceptions and observed temperature change.

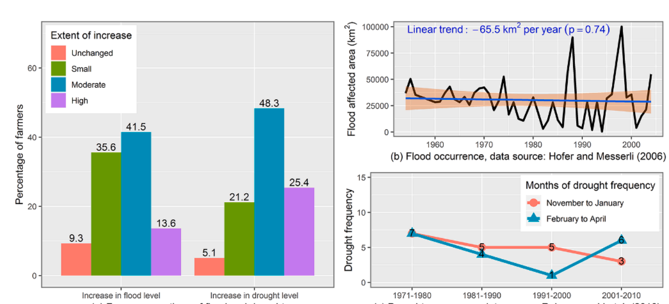

Fig. 4. Comparison between farmer perceptions and reported flood and drought occurrence.

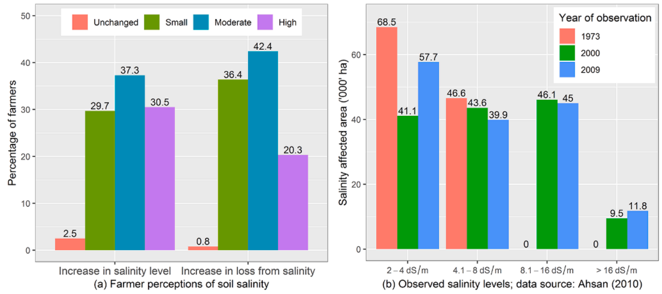

Fig. 5. Comparison between farmer perceptions and observed change in soil salinity.

The Fig. 5b shows that S_1 level of salinity decreased over a period of 37 years (1973–2009), noting the year 2000 as the lowest level of salinity in Patuakhali district. A decreasing trend of soil salinity was observed in case of moderate salinity level. We did not have any data of strong and very strong levels of soil salinity for the year of 1973. However, soil salinity level of S_3 slightly decreased while in the case of S_4 increased slightly from 2000 to 2009. During the last four decades, a total increase in salt-affected area was 35%, with a gradual increase from 115 thousand ha in 1973 to 139 thousand ha in 2000 and 155 thousand ha in 2009 (Ahsan, 2010). Regarding the loss in crop production due to salinity intrusion, Rabbani et al. (2013) found that rice production had decreased because of increase in soil salinity. Therefore, farmers' perceptions of change in soil salinity and loss caused by this change were seemingly aligned with what we found from the observed data and literature.

3.4. Relationship between farmers' socio-economic attributes and dependent variables

Because of the ordinal nature of most of the variables, Spearman rank correlation coefficients (rho) were computed to determine the bivariate relationship between the variables (Kraska-Miller, 2013; Zar, 1972) and presented in Table 3. Farmer perceptions of climate change significantly increased with an increase in the number of farm enterprises, number of cattle, annual household income, organizational affiliation, distance to the nearest marketplace, access to farm information and number of known adaptation practices. These characteristics, except the number of cattle owned by the farmers, also had a positive correlation with the perception of vulnerability to climate change. Besides, the vulnerability perception was better among the relatively younger-aged farmers and those who adopted a higher number of adaptation practices. The number of adopted practices was found to positively vary with an increase in their own farm area. The farmers involved in CFS tended to have a higher number of adopted practices. What stands out in Table 3 is the perception of climate change, the perception of vulnerability to climate change and the number of adopted practices were positively and significantly inter-correlated.

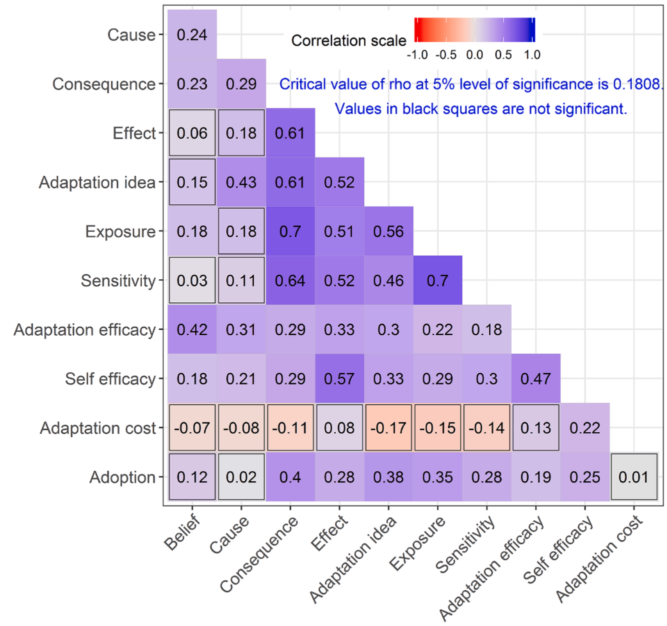

Fig. 6. Correlation matrix of adoption and components of climate change perception.

Finally, how the number of adopted agricultural practices was related to all the components of perception of climate change and vulnerability were assessed with the Spearman rank correlation coefficients (ρ) (Fig. 6). It is quite revealing that 'belief' and 'cause' of climate change perception and 'adaptation cost' of vulnerability perception were not significantly correlated with the adoption of adaptation practices. All other perception components were positively correlated with the number of adopted practices. Besides, substantial inter-correlations were detected among most of the dimensions of perception.

4. Discussion

The present study was designed to compare the coastal farmer perceptions (subjective assessment) concerning climate change and vulnerability with the scientific observations (objective assessment). Correlations among the adoption of adaptation practices, perception of

Table 3
Correlations between the variables based on Spearman rho coefficients.

Variables	Perception of climate change	P values	Perception of vulnerability to climate change	P values	Adopted adaptation practices	P values
Group (CFS/non-CFS)	0.15	0.10	0.14	0.13	0.44***	0.00
Age	−0.14	0.14	−0.31***	0.00	−0.22**	0.01
Number of farm enterprises	0.27***	0.00	0.11	0.22	0.30***	0.00
Own farm area	0.01	0.90	0.03	0.75	0.19*	0.04
Number of cattle	0.22*	0.02	0.10	0.29	0.19*	0.04
Annual household income	0.22*	0.02	0.21*	0.02	0.22*	0.02
Organizational affiliation	0.25**	0.01	0.28***	0.00	0.43***	0.00
Training experience	0.06	0.51	0.03	0.74	0.42***	0.00
Market distance	0.28***	0.00	0.27***	0.00	0.43***	0.00
Information access	0.47***	0.00	0.49***	0.00	0.52***	0.00
Known adaptation practices	0.35***	0.00	0.33***	0.00	0.60***	0.00
Perception of climate change	–	–	0.73***	0.00	0.40***	0.00
Perception of vulnerability to climate change	–	–	–	–	0.39***	0.00

*, ** and *** denote significant at 5%, 1%, and 0.1% level of probability.

climate change and socio-personal characteristics of the farmers were also investigated. A variety of perception items were explored to gain a detailed understanding of climate change and vulnerability. The sample comprised two groups of households: participants in training programs of CFS and general farmers not participating in CFS from the same villages. The current study found that the CFS farmers had more dependent family members per income-earning member, a greater number of farm enterprises, a larger size of own farmland and a higher number of cattle. The CFS farmers also had a higher annual household income, longer training experience and more organizational affiliation. They had greater access to farm information and had knowledge about a high number of adaptation practices. However, significant differences between the two groups of farmers were not evident in the case of age and personal education.

Despite a substantial difference between CFS and general farmers concerning the socio-economic attributes, their perceptions of climate change and vulnerability were at the same level. Both the groups had a moderate level of understanding of belief, causes, consequences, effects and adjustment of climate change. Similarly, they possessed a moderate level of perception of vulnerability with regards to exposure, sensitivity and adaptive capacity. The CFS farmers could be expected to possess a better perception of climate change because they received frequent advice, training and support from extension agents (Ajij et al., 2014). However, we did not find any significant differences in their perceptions of climate change. Bangladesh is a densely populated country and the density was 1265 people per sq. km in 2017 (World Bank, 2018). Therefore, the farmers had closer contact with their neighbors and fellow farmers. They had a better opportunity to share what other farmers thought about climate change. Knowledge spillover from the CFS farmers to general farmers could account for this similar level of understanding of climate change.

The most obvious finding to emerge from the analysis is that the farmer's climate change perceptions and meteorological data were mostly consistent. There are three distinct climatic seasons in Bangladesh: a hot summer (pre-monsoon) from March to May, a humid summer (monsoon/rainy) from June to October and a dry mild winter (post-monsoon) from November to February (Rahman and Lateh, 2016). The farmers perceived a warmer summer and colder winter compared to their experience. Local station climate data confirmed these summer and winter temperature trends in the study area. However, in contrast to the farmer' perception, the overall dry bulb temperature was in decreasing trend that was influenced by a higher level of temperature before 1990. The farmers mentioned that the temperature was increasing; and this opinion is consistent when we analyze the temperature trend after 1990. People usually remember the recent experience (Weber, 2010). Therefore, the recent temperature trend was in line with the farmer perceptions. However, the overall decreasing trend of annual temperature was not also consistent with the findings of other studies. Basak et al. (2013) and Karmalkar et al. (2010) reported an increasing trend of temperature. They used national-level data, but we analyzed the data from a local station in coastal areas. These results suggest that national and local level climate variability could be different.

Annual rainfall trend in the study area was found to be slightly increasing (0.35 mm per decade). This result mirrors the observations of Karmalkar et al. (2010). Both meteorological data and farmers' opinion confirmed that timing of rainfall had changed. Dry months were getting drier and wet months wetter because of a shift in rainfall time. These results further support the findings of other researches (e.g. Ahmed, 2006; Basak et al., 2013; Karmalkar et al., 2010). Another interesting finding was that the study area had an increasing rainfall trend in September and October that could have important implications for crop cultivation. During this period, transplanted aman (wet season) rice remains in the fields that could be subject to flash flooding. Land preparation for potato cultivation would be difficult that starts in mid-September (BBS, 2017). Although an increased rainfall in September would be beneficial for sowing winter crops, there would remain a possibility of loss for mung bean cultivation since it cannot tolerate waterlogging conditions.

Farmers had a belief that flood and drought levels had increased moderately in the study areas compared to the past. This perception of farmers was not supported by Brammer (2016) who concluded with an analysis of 50 years of national data that floods and droughts had not increased in frequency or magnitude in Bangladesh. Data of Bangladesh Water Development Board also did not show any significant trend of floods (Hofer and Messerli, 2006). However, floods in Bangladesh have been occurring each and every year with a different degree of severity and area coverage (Reliefweb, 2018). Moderate droughts were more frequent than severe and extreme droughts. Our study was confined to a small sub-district that was estimated to have a few numbers of severe and extreme droughts in 1979, 1981 and 2008 (Rahman and Lateh, 2016). Local level time series data was unavailable to us, which would be more useful to validate the farmers' perception of droughts and floods. Most of the farmers reported an increase in soil salinity and loss from soil salinity. It is encouraging to compare this figure with similar findings of a soil salinity report by Ahsan (2010) and a comparison of 2000 and 2008 salinity data by Dasgupta et al. (2014). Farmers of Shyamnagar (a coastal sub-district of Satkhira, Bangladesh) believed that loss from salinity intrusion had increased in terms of declining rice production (Rabbani et al., 2013). Therefore, the perception of salinity held by the farmers of this study tallied with other evidence.

The last objective of this study was to investigate the relationship between perception and adaptation and to determine their associated socioeconomic factors. The number of adopted agricultural adaptation practices was found to be significantly and positively correlated with the perception of both climate change and vulnerability. Although CFS and general farmers had the same level of perception, the CFS farmers were found to adopt a higher number of adaptation practices. This could be explained by the fact that the CFS farmers received training and advice on climate change adaptation from agricultural extension workers. They knew a greater number of adaptation practices that facilitated their adoption of those practices. This study reveals that adoption of adaptation practices was not only associated with the perception and CFS membership but also with other personal characteristics, such as age, number of farm enterprises, own farm area, number of cattle, annual household income, organizational affiliation, training experience, market distance, information access and number of known adaption practices.

We relied on the information furnished by the farmers to assess their perception of climate change and vulnerability. The survey took place during April–May 2016 before the monsoon rainfall. Though it was a dry season, we observed a broken dike/embankment in Pachjunia village that caused saline water intrusion in crop fields resulting in a huge loss of standing crops. These coastal embankments were built to protect farmlands from coastal inundation (Rahman and Rahman, 2015). No other unexpected natural calamities were in the study area during data collection that could influence their perception. Therefore, we assume that this study generated representative information concerning the perception of climate change in the study areas.

5. Conclusion

This study revealed that coastal farmers had frequent exposure to adverse climatic events like erratic rainfall, coastal flooding, seasonal droughts and salinity. An overwhelming majority of the farmers had heard about climate change and believed that it was happening. Most of the farmers mentioned a warmer summer and colder winter along with increased rainfall during wet season and decreased rainfall during dry season compared to the past. They experienced an overall increasing trend of annual temperature. These views of climate change tracked with what we found from the local meteorological information and scientific reports. Their perception of increased salinity was also consistent with the existing literature. However, farmers believed that floods and droughts were in increasing trends, which were not supported by the information obtained from climate data and reports. The two groups of farmers (CFS and general) differed in many socio-economic attributes but their perceptions of climate change were at the same level. The correlational analysis reveals that perception of climate change and vulnerability were positively associated with the adoption of agricultural adaptation practices. Three dependent variables, namely perception of climate change, perception of vulnerability to climate change and adoption of adaptation practices were correlated with different sets of farmer characteristics. However, annual household income, organizational affiliation, market distance and number of known adaptation practices were found to vary positively with all these dependent variables. The better the farmers understand climate change issues and adaptation practices, the more will be their adoption of adaptation practices to cope with climate change. Although the climate change perceptions were the same for both the CFS and general farmers, their increased organizational involvement with farm-related associations could improve their perception of climate change and vulnerability.

Declaration of interest

The authors declare that they have no conflict of interest.

Research data

Research data is confidential.

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References

Abidoye, B.O., Kurukulasuriya, P., Mendelsohn, R., 2017. South-East Asian farmer perceptions of climate change. Clim. Change Econ. 08, 1–8.

Adger, N., Huq, S., Brown, K., Conway, D., Hulme, M., 2003. Adaptation to climate change in the developing world. Prog. Dev. Stud. 3, 179–195.

Ahmed, A.U., 2006. Bangladesh Climate Change Impacts and Vulnerability: A Synthesis. Comprehensive Disaster Management Program, Climate Change Cell. Department of Environmental Component, Bangladesh, Dhaka.

Ahsan, D., Brandt, U.S., 2014. Climate change and coastal aquaculture farmers’ risk perceptions: experiences from Bangladesh and Denmark. J. Environ. Plann. Manag. 58, 1649–1665.

Ahsan, M., 2010. Saline Soils of Bangladesh. Soil Resource Development Institue, Dhaka.

Ajij, M., Haidar, M.L., Rahman, M.M., 2014. Climate Field School (CFS) Training Module. Department of Agricultural Extension, Dhaka.

Alam, G.M.M., Alam, K., Mushtaq, S., 2017. Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. Clim. Risk Manag. 17, 52–63.

Altschuler, B., Brownlee, M., 2015. Perceptions of climate change on the Island of Providencia. Local Environ. 21, 615–635.

Aslan, S., Yozgatligil, C., Iyigäun, C., Batmaz, I., Täurkes, M., Tatli, H., 2010. Comparison of Missing Value Imputation Methods for Turkish Monthly Total Precipitation Data, International Conference on Computer Data Analysis and Modeling: Complex Stochastic Data and Synthesis. Minsk, Belarus.

Ayal, D.Y., Leal Filho, W., 2017. Farmers’ perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia. J. Arid Environ. 140, 20–28.

Bangladesh National Portal, 2017. Ek Nojore Kalapara Upazila. Retrieved from. http://www.kalapara.patuakhali.gov.bd/site/page/96782943-17a2-11e7-9461-286ed488c766.

Basak, J.K., Titumir, R.A.M., Dey, N.C., 2013. Climate change in Bangladesh: a historical analysis of temperature and rainfall data. J. For. Environ. 2, 41–46.

BBS, 2017. Yearbook of Agricultural Statistics-2016. Bangladesh Bureau of Statistics, Dhaka.

Bickerstaff, K., 2004. Risk perception research: socio-cultural perspectives on the public experience of air pollution. Environ. Int. 30, 827–840.

Bonatti, M., D’Agostini, L.R., Schlindwein, S.L., Fantini, A.C., Martins, S.R., Plencovich, M.C., de Vasconelos, A.C.F., Hoffmann, A.F., 2011. Mudanças climáticas e percepções de atores sociais no meio rural. Geosul Florianópolis 26, 145–164.

Brammer, H., 2016. Floods, cyclones, drought and climate change in Bangladesh: a reality check. Int. J. Environ. Stud. 73, 865–886.

Brody, S.D., Zahran, S., Vedlitz, A., Grover, H., 2008. Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States. Environ. Behav. 40, 72–95.

Cullen, A.C., Anderson, C.L., 2017. Perception of climate risk among rural farmers in Vietnam: consistency within households and with the empirical record. Risk Anal. 37, 531–545.

Dasgupta, S., Hossain, M.M., Huq, M., Wheeler, D., 2014. Climate Change, Soil Salinity, and the Economics of High-Yield Rice Production in Coastal Bangladesh. The World Bank, Washington, D.C.

Dasgupta, S., Hossain, M.M., Huq, M., Wheeler, D., 2015. Climate change and soil salinity: the case of coastal Bangladesh. Ambio 44, 815–826.

Dubey, S.K., Trivedi, R.K., Chand, B.K., Mandal, B., Rout, S.K., 2017. Farmers’ perceptions of climate change, impacts on freshwater aquaculture and adaptation strategies in climatic change hotspots: a case of the Indian Sundarban delta. Environ. Dev. 21, 38–51.

Elum, Z.A., Modise, D.M., Marr, A., 2017. Farmer’s perception of climate change and responsive strategies in three selected provinces of South Africa. Clim. Risk Manag. 16, 246–257.

FAO, 2013. Climate-Smart Agriculture Sourcebook. Food and Agriculture Organization of the United Nations, Rome.

FAO, 2014. FAO Success Stories on Climate-Smart Agriculture. Food and Agriculture Organization of the United Nations, Rome.

Gbetibouo, G.A., 2009. Understanding Farmers’ Perceptions and Adaptations to Climate Change and Variability: the Case of the Limpopo Basin, South Africa. International Food Policy Institute, Washington, D.C.

Grothmann, T., Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Glob. Environ. Chang. 15, 199–213.

Habtemariam, L.T., Gandorfer, M., Kassa, G.A., Heissenhuber, A., 2016. Factors influencing smallholder farmers’ climate change perceptions: a study from farmers in Ethiopia. Environ. Manag. 58, 343–358.

Haque, M.A., Yamamoto, S.S., Malik, A.A., Sauerborn, R., 2012. Households’ perception of climate change and human health risks: a community perspective. Environ. Health 11, 1–12.

Hasan, M.K., Desiere, S., D’Haese, M., Kumar, L., 2018. Impact of climate-smart agriculture adoption on the food security of coastal farmers in Bangladesh. Food Secur. 10, 1073–1088.

Hitayezu, P., Wale, E., Ortmann, G., 2017. Assessing farmers’ perceptions about climate change: a double-hurdle approach. Clim. Risk Manag. 17, 123–138.

Hofer, T., Messerli, B., 2006. Floods in Bangladesh: History, Dynamics and Rethinking the Role of the Himalayas. United Nations University Press, Tokyo, New York, Paris.

IPCC, 2014. Climate change 2014: synthesis report, in: Core writing Team. In: Pachuary, R.K., Meyer, L.A. (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report. Intergovernmental Panel on Climate Change, Geneva.

Islam, M.B., Ali, M.Y., Amin, M., Zaman, S.M., 2011. Climatic variations: farming systems and livelihoods in the high barind tract and coastal areas of Bangladesh. In: Lal, R., Sivakumar, M.V.K., Faiz, S.M.A., Rahman, A.H.M.M., Islam, K.R. (Eds.), Climate Change and Food Security in South Asia. Springer, Dordrecht, pp. 477–498.

Kabir, M.I., Rahman, M.B., Smith, W., Lusha, M.A., Azim, S., Milton, A.H., 2016. Knowledge and perception about climate change and human health: findings from a baseline survey among vulnerable communities in Bangladesh. BMC Public Health 16, 266–275.

Karmalkar, A., McSweeney, C., New, M., Lizcano, G., 2010. UNDP Climate Change Country Profiles: Bangladesh. Retrieved from. http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Bangladesh/Bangladesh.hires.report.pdf.

Kassambara, A., 2016. Ggcorrplot: Visualization of a Correlation Matrix Using `ggplot2'. R Package Version 0.1.1.

Kassambara, A., 2018. Ggpubr: `ggplot' Based Publication Ready Plots. R Package Version 0.1.7.

Kibue, G.W., Liu, X., Zheng, J., Zhang, X., Pan, G., Li, L., Han, X., 2016. Farmers’ perceptions of climate variability and factors influencing adaptation: evidence from anhui and jiangsu, China. Environ. Manag. 57, 976–986.

Kraska-Miller, M., 2013. Nonparametric Statistics for Social and Behavioral Sciences. CRC Press, Taylor & Francis Group, Boca Raton, London, New York.

Lamsal, P., Kumar, L., Atreya, K., 2017. Historical evidence of climatic variability and changes, and its effect on high-altitude regions: insights from Rara and Langtang, Nepal. Int. J. Sustain. Dev. World Ecol. 26, 471–484.

Leiserowitz, A., 2006. Climate change risk perception and policy preferences: the role of affect, imagery, and values. Clim. Change 77, 45–72.

Li, S., Juhasz-Horvath, L., Harrison, P.A., Pinter, L., Rounsevell, M.D.A., 2017. Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. J. Environ. Manag. 185, 21–30.
Loring, P.A., Gerlach, S.C., Huntington, H.P., 2013. The new environmental security: linking food, water, and energy for integrative and diagnostic social-ecological research. J. Agric. Food Syst. Commun. Dev. 3, 55–61.
Maddison, D., 2007. The Perception of and Adaptation to Climate Change in Africa. The World Bank, Washington, D.C.
Mase, A.S., Gramig, B.M., Prokopy, L.S., 2017. Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers. Clim. Risk Manag. 15, 8–17.
Moniruzzaman, M., 2013. People's perception on climate change and variability: a study of Sabrang Union, Teknaf, Cox's Bazar, Bangladesh. ASA Univ. Rev. 7, 1–10.
Moritz, S., Bartz-Beielstein, T., 2015. imputeTS: Time Series Missing Value Imputation in R. R Package Version 0.4.
Moritz, S., Sardá, A., Bartz-Beielstein, T., Zaefferer, M., Stork, J., 2015. Comparison of Different Methods for Univariate Time Series Imputation in R arXiv:1510.03924.
Nguyen, T.P.L., Seddaiu, G., Virdis, S.G.P., Tidore, C., Pasqui, M., Roggero, P.P., 2016. Perceiving to learn or learning to perceive? Understanding farmers' perceptions and adaptation to climate uncertainties. Agric. Syst. 143, 205–216.
Niemeyer, S., Petts, J., Hobson, K., 2005. Rapid climate change and society: assessing responses and thresholds. Risk Anal. 25, 1443–1456.
Patt, A., Schroter, D., 2008. Perceptions of climate risk in Mozambique: implications for the success of adaptation strategies. Glob. Environ. Chang. 18, 458–467.
Penn, H.J.F., Loring, P.A., Schnabel, W.E., 2017. Diagnosing water security in the rural North with an environmental security framework. J. Environ. Manag. 199, 91–98.
R Core Team, 2016. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.
Rabbani, G., Rahman, A., Mainuddin, K., 2013. Salinity-induced loss and damage to farming households in coastal Bangladesh. Int. J. Glob. Warming 5, 400–415.
Rahman, M.R., Lateh, H., 2016. Meteorological drought in Bangladesh: assessing, analysing and hazard mapping using SPI, GIS and monthly rainfall data. Environ. Earth Sci. 75, 1026–1045.
Rahman, S., Rahman, M.A., 2015. Climate extremes and challenges to infrastructure development in coastal cities in Bangladesh. Weather Clim. Extrem. 7, 96–108.
Reliefweb, 2018. Disasters. Retrieved from. https://reliefweb.int/disasters?country=31&search=flood#content.
Roy, G.L., 2000. Research Methods in Social Sciences and Extension Education. Naya Prakash, Kolkata.
Sain, G., Loboguerrero, A.M., Corner-Dolloff, C., Lizarazo, M., Nowak, A., Martínez-Barón, D., Andrieu, N., 2017. Costs and benefits of climate-smart agriculture: the case of the Dry Corridor in Guatemala. Agric. Syst. 151, 163–173.
Schneider, T., 2001. Analysis of incomplete climate data: estimation of mean values and covariance matrices and imputation of missing values. J. Clim. 14, 853–871.
Shameem, M.I.M., Momtaz, S., Kiem, A.S., 2015. Local perceptions of and adaptation to climate variability and change: the case of shrimp farming communities in the coastal region of Bangladesh. Clim. Change 133, 253–266.
Shelley, I.J., Takahashi-Nosaka, M., Kano-Nakata, M., Haque, M.S., Inukai, Y., 2016. Rice cultivation in Bangladesh: present scenario, problems, and prospects. J. Int. Cooperat. Agric. Dev. 14, 20–29.
The Asia Foundation, 2012. Climate Change Perception Survey. The Asia Foundation, Dhaka.
Uddin, M.N., Bokelmann, W., Entsminger, J., 2014. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: a farm level study in Bangladesh. Climate 2, 223–241.
Weber, E.U., 2010. What shapes perceptions of climate change? WIREs. Clim. Chang. 1, 332–342.
Wickham, H., 2016. ggplot2: Elegant Graphics for Data Analysis, second ed. Springer-Verlag, New York.
Wilson, G.A., Kelly, C.L., Briassoulis, H., Ferrara, A., Quaranta, G., Salvia, R., Detsis, V., Curfs, M., Cerda, A., El-Aich, A., Liu, H., Kosmas, C., Alados, C.L., Imeson, A., Landgrebe-Trinkunaite, R., Salvati, L., Naumann, S., Danwen, H., Iosifides, T., Kizos, T., Mancino, G., Nolè, A., Jiang, M., Zhang, P., 2017. Social memory and the resilience of communities affected by land degradation. Land Degrad. Dev. 28, 383–400.
Woods, B.A., Nielsen, H.Ø., Pedersen, A.B., Kristofersson, D., 2017. Farmers' perceptions of climate change and their likely responses in Danish agriculture. Land Use Pol. 65, 109–120.
World Bank, 2018. Population density (people per sq. km of land area). Retrieved from. https://data.worldbank.org/indicator/EN.POP.DNST?locations=BD.
Zar, J.H., 1972. Significance testing of the Spearman rank correlation coefficient. J. Am. Stat. Assoc. 67, 578–580.