Environmental Management (2022) 69:906–918
https://doi.org/10.1007/s00267-022-01598-8

Role of Homestead Forests in Adaptation to Climate Change: A Study on Households' Perceptions and Relevant Factors in Bandarban Hill District, Bangladesh

Tarit Kumar Baul[1] · Tajkera Akhter Peuly[1] · Rajasree Nandi[1] · Shiba Kar[2] · Shyamal Karmakar[1]

Received: 16 August 2021 / Accepted: 13 January 2022 / Published online: 25 January 2022

Abstract
Homestead forests play an important role in climate change adaptation and mitigation. This study investigated homestead forest owners' perceptions on climate change and associated impacts, as well as the role that homestead forests could play to enhance households' climate adaptation in Bandarban hill district of Bangladesh. Methods involved randomly surveying a total of 176 homestead households at three different hill altitudes: low, medium, and high. We also analyzed the meteorological data on local rainfall and temperature for the period of 1990 to 2019. Results showed that most (76–94%) of the homestead forest owners perceived an increasing erratic pattern of annual temperature and rainfall which was supported by the analysis of local meteorological data. Forest owners´ perceptions towards changes in tree phenology, increase in food insecurity, landslides, and pest infestation, and decrease in crop production, soil fertility, and seasonal streamflow were revealed as pieces of evidence of climate change impacts that varied significantly with hill altitudes and associated ecosystems. About 66% to 97% of the housheolds perceived that homestead forests could play a pivotal role in enhancing their capacity to adapt with the changing climate by supplying diverse products, services, and environmental benefits. Understanding and perceptions of the environmental benefits of homestead forests also significantly varied with the type of households´ construction, income, and literacy of the household members. Our results will help policymakers to ensure these small-scale homestead forests are conserved since they could also provide multiple environmental benefits e.g., carbon sequestration in addition to enhancing community climate adaptation.

Keywords Climate change impacts · Climate adaptation · Conservation · Environmental benefits · Food security · Homestead forest

Introduction

Bangladesh, a very densely populated developing country, is considered one of the countries most vulnerable to climate change (MoF 2020; World Bank 2013). Extreme climatic impacts such as increasing heavy rainfall, frequent flooding, landslide, riverbank erosion, longer drought, storm surges, salinity intrusion, and waterlogging are adversely affecting the peoples´ livelihoods, food and water security, and infrastructure in the country (Alam 2016; Jordan 2015; Monirul Alam et al. 2017; Thomas et al. 2013). People living in the rural areas, where 64% of the total population live, are very vulnerable to climate impacts because of their fragile socioeconomic conditions that include small landholdings, inadequate education, and limited livelihood options and income (BBS 2018; Fakhrul Islam 2011; Rahman et al. 2015). Most of the rural households have no farmland but they have at least homesteads surrounded by forests that support the households' daily needs (Motiur et al. 2006; Muhammed et al. 2011). Over 20 million homestead forests in Bangladesh, comprising about 2% of the total land (Mukul et al. 2014; Salam et al. 2000), are considered as a safety net in crisis period such as flooding,

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00267-022-01598-8.

✉ Tarit Kumar Baul
tarit.ifes@cu.ac.bd

[1] Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh

[2] University of Illinois Urbana-Champaign, Champaign, IL, USA

drought, food crop failure due to the impact of climate change (Foysal 2013; Kabir and Webb 2009; Nath et al. 2015). Homestead forests as alternative livelihood options that provide diverse production potential of food, timber, fuelwood, fodder, non-timber forest products (NTFPs) can help increase rural households' climate-relevant adaptive capacity (Mattsson et al. 2015; Nath et al. 2015). Despite the important role that homestead forests could play in climate adaptation, very limited research is available on this topic (Baul et al. 2021a, b; Hanif et al. 2018).

Homestead forests are considered a well-established land-use system for the conservation of biodiversity while contributing to the rural economy second to agriculture (Kabir and Webb 2009). These forest ecosystems also help with conservation and improvement of soil and water quality, as well as reduction, and removal of carbon dioxide (CO_2) emissions (Alessandro and Marta 2012; Lumsden and Bennett 2005; Manning et al. 2009; Plieninger et al. 2004). Since homestead forests and their biodiversity are often managed by rural households, their perceptions on the contributions of these forests in adaptation to climate change and their involvements in assessing relevant climate change impacts warrant special attention (Alam et al. 2017).

Adaptation denotes the adjustments in the human-environment system against the adverse impacts of climate change by avoiding or reducing the consequent risks or realizing potential opportunities (Cramer et al. 2014; IPCC 2018). Rural households' experiences and perceptions towards climate change, including the changes in temperature, rainfall, and wind patterns, as well as changes in phenology and vegetation structure, are critical for a better understanding of their adaptation to climate change. Perception is the process of receiving information from the ambient environment and transforming it into physiological awareness for taking adaptation and mitigation strategies towards adverse impacts of climate change in the agroecological system (Bryan et al. 2009). However, this process could vary with the individual's past experiences, observations, and present attitudes, needs, and social circumstances and also depending on one´s livelihood, literacy, and settlement (Baul et al. 2013; Baul and McDonald 2015; Chapagain et al. 2009).

So far, several studies related to homestead forests focused primarily on floristic compositions and their utilization (Baul et al. 2015; Kabir and Webb 2009, 2008b, a; Zaman 2010), conservation and management of biodiversity (Alam and Sarker 2011; Bardhan et al. 2012; Muhammed et al. 2011; Roy et al. 2013), and households' perceptions of tree planting towards climate resilience (Alam et al. 2010; Motiur et al. 2006). Other studies found homestead forests as a major source of domestic fuel wood, and as an incentive for forest conservation (Mukul et al. 2014; Uddin and Mukul 2007), homestead forests and farming in mitigating droughts (Abdur Rashid Sarker et al. 2013; Alam et al. 2018; Alam 2015; Alauddin and Sarker 2014; Baul and McDonald 2014; Habiba et al. 2012; Hanif et al. 2018), and addressing climate challenges in low and saline-prone areas (Anik and Khan 2012; Hossain et al. 2012; Rashid et al. 2014). Jaman et al. (2016) and Nath et al. (2015) estimated the carbon sequestration potentials and investigated the role that the coastal homestead forests can play against disasters. However, they did not consider relevant socioeconomic factors affecting peoples´ perceptions of the role of forests' and many of these climate adaptation strategies may not be applicable in hilly areas.

To address the research gap, this study considered homestead forest areas of Bandarban, Chittagong Hill Tract (CHT), situated in the south-eastern part of Bangladesh. However, Bandarban is rated as the second most vulnerable district on climate impacts amongst the top 10 vulnerable districts in Bangladesh (Mani et al. 2018). The district is included as a new hotspot and will likely be the worst affected region by 2050 in terms of deforestation which has recently brought in major landslides and destruction of property (Mani et al. 2018). Considering the regional background and characteristics, this study focused on Bandarban district to investigate homestead forests-based local adaptation in changing climate. Specific objectives were to (i) investigate hilly homestead forest owners´ perceptions towards climate change and associated impacts they experience, (ii) explore purposes of and preferences for homestead trees, and (iii) owners´ perceptions towards benefits of homestead forests considering various socioeconomic factors of the respective households.

Materials and Methods

Study Area

We conducted this study in the homestead forests of Bandarban Sadar Upazila (sub-district) under Bandarban district located in the Chittagong Hill Tracts, Bangladesh (Fig. 1). This region of Bangladesh is located in a tropical climate, with mean annual rainfall and temperature of 2630 mm and 28 °C, respectively (BMD 2019). The public forests of Bandarban district are estimated as 797,542 km^2, which are managed by the Bangladesh Forest Department and district administration (BBS 2018). Prior to this, homestead forests were owned and managed by the homestead forest owners.

Bandarban Sadar Upazila is situated between 21°55' - 22° 2' N and 92°08' - 92°20' E. It has a total population of around 70,000 and occupies an area of 502 km^2, of which 85 km^2 is forest (Bandarban Sadar Upazila Office 2019). The land is classified as a high, medium-high, low hill, and valley, and

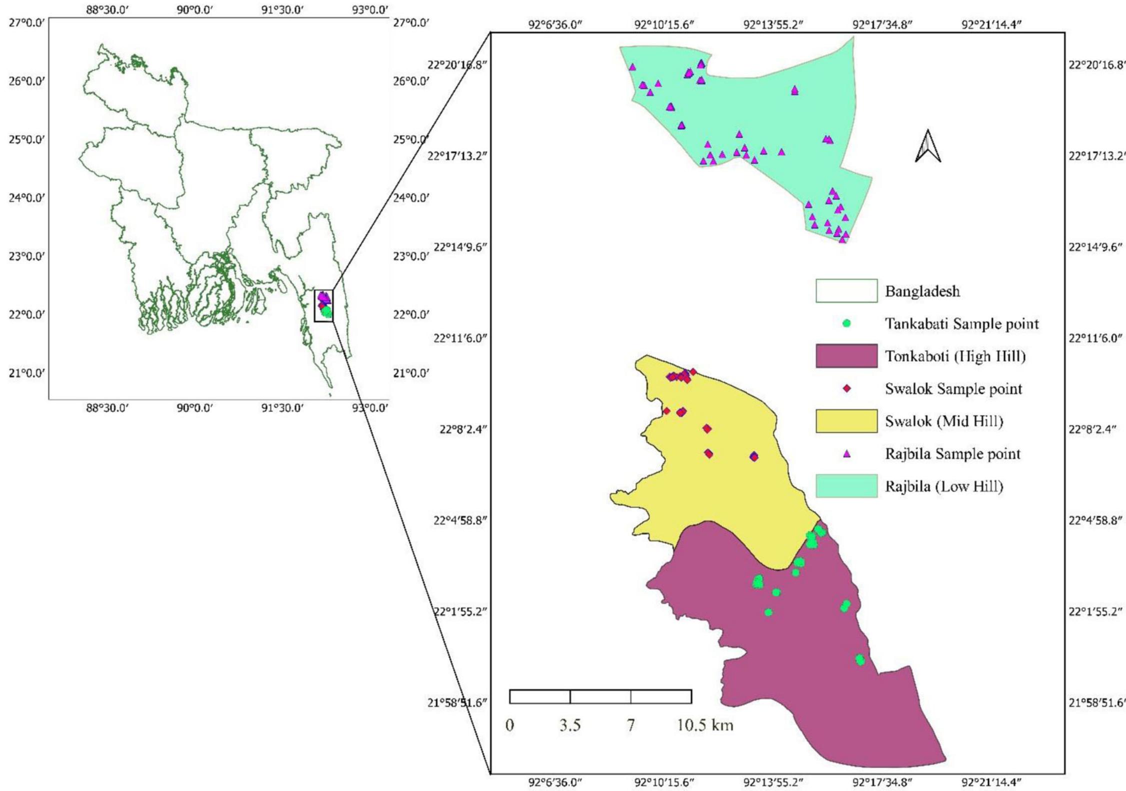

Fig. 1 Map of study areas: Rajbila, Swalok and Tonakboti Unions (second lowest admisnistrative unit) with sampling points of homestead forests of Bandarban Sadar Upazila (sub-distrcit) in Bandarban District (right panel) of Bangladesh (left panel). Map of Bangladesh (left panel) showing three Unions regraded as high hill, mid hill, and low hill in Bandarban district along with sampling points of homestead forests (right panel). The Maps are created using the Free and Open Source QGIS 3.1 0, http://www.qgis.org

high land, with dominant land uses including forest, agriculture, and shifting cultivation (SRDI 2018). The landscape consists of steep mountains with 90% of the soil´s texture ranging from sandy loam to clay loam soil (Osman et al. 2013). The local inhabitants are predominantly dependent on natural resources, for example, forests, lake, and associated tourism around them for their livelihoods.

Sampling Strategy and Homestead Forest Owners´ Interview

Out of five Unions (smallest administrative units), three sample unions, that were selected from low, mid, and high hills, were Rajbila, Swalak, and Tankabati, respectively. These Unions have an area of 10360, 7511, and 15281 ha, respectively (BBS 2018). The details of the methodology for sample selection were described in Baul et al. (2021a) (Fig. A1). Every household was assumed to own a homestead forest of either small or large size. From the lists supplied by the Sadar Upazila office, a total of 176 homestead forest owners were randomly interviewed at a sampling intensity of 5% (UNSD 2005) (Fig. 1). We also surveyed corresponding homestead forests to explore species composition and their contribution to the local economy, which was a related part of another study (Baul et al. 2021a). The coordinates of each homestead forest sampled were recorded by using GPS. Local guides enabled the researchers to locate and identify the samples from the lists of households.

Before we started the survey, the questionnaire was pretested with key informants with their clarity, comprehensiveness, and acceptability for the respondents (Rea and Parker 1997). A semi-structured questionnaire comprising both open and closed questions was used in the interview. The questionnaire had three sections including the socioeconomic background of the households, owners´ perceptions towards climate change and associated impacts, and benefits of homestead forests. Socioeconomic background data included respondent age, homestead forest, and total land areas, housing type, and household members´ education, profession, and income status. Perceptions towards climate change entailed regular weather conditions and impacts on biophysical conditions in the form of dichotomous questions. Finally, forest owners perceived their preferences for and purposes of homestead tree species and the environmental benefits of these. The purposes and preferences for homestead trees were asked in a dichotomous form. With regard to the environmental benefits, forest owners‘ perceptions were collected based on Likert scale (1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree) on each item of the benefits of homestead forests.

Data Analyses

Socioeconomic background of the sampled households of homestead forests

We calculated mean values for the respondent age, monthly income, size, literacy score, and homestead forests, and total land holdings (ha) of the households and compared them among three hill ranges. In calculating the household monthly income, the income of all earners recorded in Bangladeshi Taka (BDT) during the survey was converted into US dollars (US$) per household by applying the exchange rate of US$ 1 = BDT 84.5 (date of relevance: June 2019). In assessing literacy, the score based on the duration of every education level in Bangladesh was put against the education achieved by each member of the household and subsequently, all the scores were summed and averaged by the total number of the household members. The scores 0, 5, 10, 12, 16, 18 represented the illiterate, primary, secondary, higher secondary, graduate, and post-graduate levels of education, respectively. Moreover, the percentages of housing types and professions of all members in a household were calculated within the hill range.

Perceptions towards climate change and associated impacts and benefits of homestead forests

After analyzing within the hill site, forest owners´ perceptions towards climate change and associated impacts were expressed in percentage (%) by various options for each variable and compared among the groups. The purposes and preferences of forest owners for tree species were reported in percentage for all items within groups. Regarding the perceptions on benefits of homestead forests, agreement indices (AI) of the Likert scale used for all items were derived (Kumar et al. 2021) (Equation 1). In addition, the mean scores of the Likert scale used were calculated and reported by respondents´ age, housing type, and household members´ literacy.

$$\mathrm{AI}\,(\%) = ((\%\,\mathrm{agreed} + \%\,\mathrm{strongly\ agreed}) - (\%\,\mathrm{disagreed} + \%\,\mathrm{strongly\ disagreed})) \quad (1)$$

Meteorological data

We collected monthly recorded data of temperature and rainfall of Bandarban district for the period of 1990–2019 from the Bangladesh Meteorological Department. Temperature and rainfall data were analyzed and trends in the changes of annual, maximum, and minimum mean temperatures and annual rainfall amount were shown for the period of 1990–2019.

Analysis of 30 years of meteorological data (Fig. 2) illustrates a trend of increasing mean annual temperature from 1990 to 2019, while mean annual rainfall amount remained constant. Annual temperatures and rainfall amount increased by 0.4 °C and 14 mm, respectively, in 2019 compared to that in 1990, which, however, were insignificant (Fig. 2a, b). There were also warming trends, manifested by increasing maximum and minimum temperatures throughout the year, corresponding to 33.5–34.7 and 17.8–18.1 °C, respectively, in 2019 compared to that in 1990 (Fig. 2c, d).

Statistical analyses

One-way analysis of variance (ANOVA) and post hoc test (DUNCAN) were used to determine the significant variation in mean values of the socioeconomic background of the households among three hill ranges. Pearson Chai square Test was applied to understand the association between the perceptions of forest owners (%) on climate change and associated impacts, benefits of homestead forests, and purposes and preferences for trees and hill ranges. Additionally, the independent samples *t* test was used to determine the significant difference in benefits of homestead forests between the means of two independent groups of respondents' ages, gender, occupations, and households´ literacy, income, and housing types. For this analysis, we categorized respondents into two independent groups based on their age (<50 years and ≥50 years), and occupations (farming and non-farming). We also categorized them based on the literacy of the household members (primary, and secondary and above), household income (lower (≤150 $ month^{-1} HH^{-1}) and higher (>151 $ month^{-1} HH^{-1})), and housing types (*maccha*, and semi-*pucca* and *pucca*). All these statistical analyses were performed by using SPSS 26.

Results

Socioeconomic Background of the Households of the Sampled Homestead Forests

The survey revealed that the inhabitants in the sampled households at low and high hills are the indigenous peoples including the *Tanchangya*, the *Chakmas*, the *Marmas*, the *Mros* while in the mid-hill they are Bengalis. The mean age of the respondents and the size of the households varied from 44 to 53 and 4 to 5, respectively. People from low and high hills had primary level education (literacy scores 3, 5) and people from mid-hill had secondary level of education

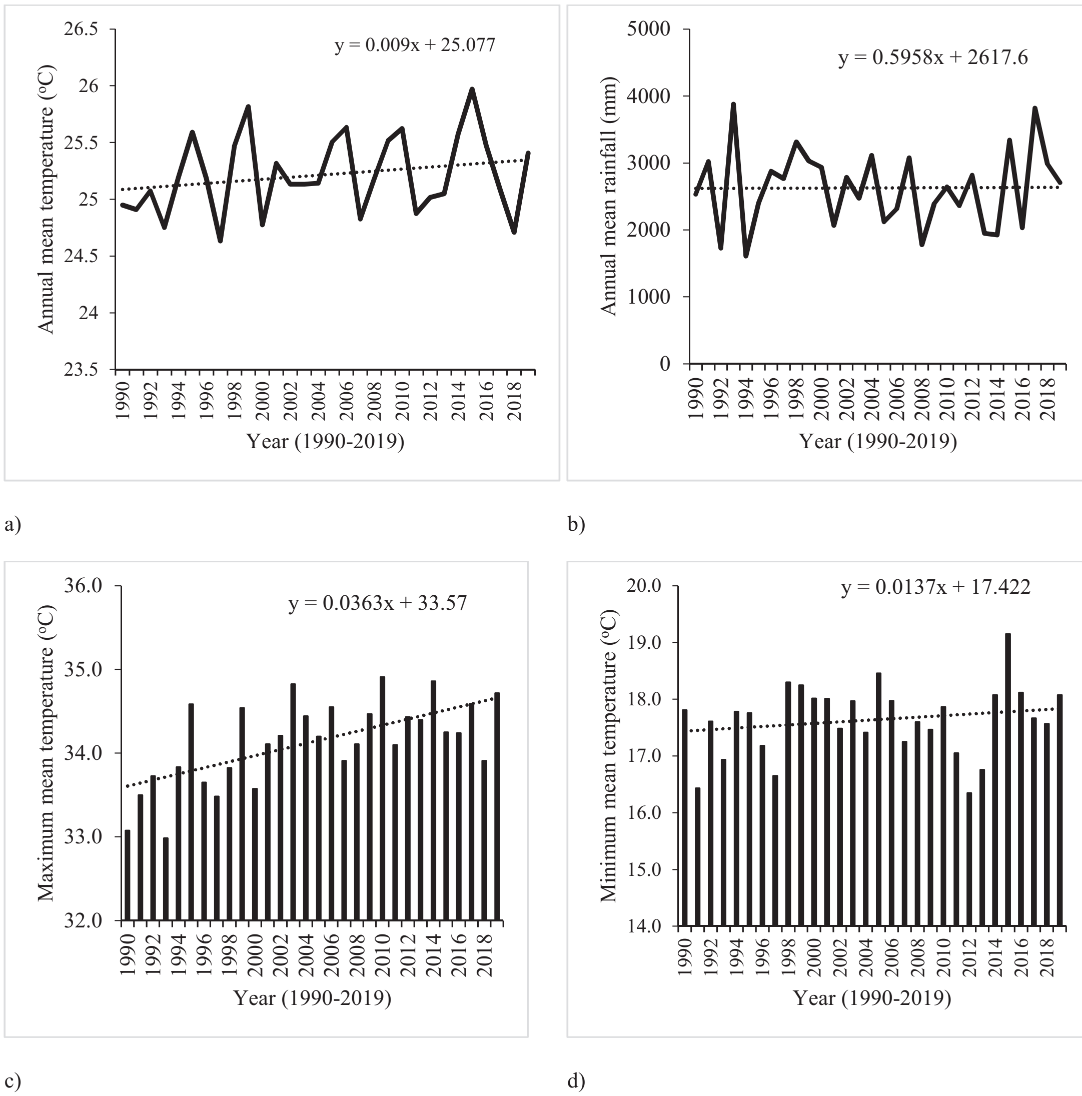

Fig. 2 Trend of annual mean temperature (**a**) and rainfall (**b**), mean maximum (**c**) and minimum (**d**) temperature during 1990–2019 of Bandarban district, Chittagong Hill Tract, Bangladesh

(score 7), with significant difference ($p \leq 0.05$) (Table 1). The highest percentage of people in the low and high hills were farmers and half of the people in mid-hill were businessmen, and thus contributed to mean highest income. The average monthly income in high and mid-hill significantly ($p \leq 0.05$) differed from that in the low hill (Table 1). With an increase in household income a decrease in the number of households with *maacha* (bamboo built) houses from the low to a high hill, opposite for the tin-built and *pucca* houses (Table 1).

Homestead Forest Owners´ Perceptions of Climate Change and Associated Impacts

The homestead survey results showed that homestead forest owners in the mid-hill were more aware of climate change compared to the other two hills (Table 2). In general, 76–94% of forest owners across three ranges perceived that temperature and erratic rainfall pattern has increased compared to the past 30 years. A total of 46% of owners perceived that the annual amount of rainfall has increased, with the respondents from the low hill being significantly highest (Table 2).

With regard to the impacts on physical conditions, in general, 82–94% of owners, with no significant differences among the hill ranges found an increase in the landslide and drying up of seasonal streams in the last 30 years (Table 2). Around half and a large majority of the forest owners´ perceptions were towards decreasing flood intensity and soil moisture, respectively. Regarding ranges, the forest owners´ perceptions in low hill toward increasing flood intensity was significantly higher than those in relatively high hill, who

Table 1 Socioeconomic background of the households related to the sampled homestead forests by hill altitude

Variables	Low hill	Mid hill	High hill	Across hill ranges
Respondent age (years)	50.02 (1.35)[a]	53.39 (1.99)[a]	44.48 (1.67)[b]	49.29 (0.99)
Homestead forest (ha)	0.04 (0.00)[a]	0.04 (0.00)[a]	0.04 (0.00)[a]	0.04 (0.00)
Total land holdings (ha)	0.79 (0.08)[a]	0.59 (0.09)[a]	0.83 (0.10)[a]	0.74 (0.05)
Household size (mean number)	4.47 (0.19)[b]	5.02 (0.15)[a]	4.59 (0.15)[ab]	4.68 (0.10)
Household literacy (mean score)	5 (0.39)[b]	7 (0.35)[a]	3 (0.36)[c]	5 (0.24)
Household income ($ month^{-1} HH^{-1})	165.49 (16.65)[b]	342.05 (45.64)[a]	254.40 (35.20)[a]	247.95 (19.65)
Household members' employment (%)*				
Farmer	64	29	73	58
Teacher	1	3	0	1
NGO worker	3	5	3	3
Services	5	12	8	7
Businessman	27	51	17	30
House type (%)*				
Maacha	67	37	70	59
Semi-pucca and pucca	15	32	12	19
Tin-built	18	31	18	22

Values within parenthesis indicate the standard error of means. Superscripts within a row (a, b, or c) indicate significant differences at $p \leq 0.05$ for each variable among three hill ranges

*Percentages were rounded off

(55–68%) contrarily, commented on decreasing trend of the flood. In case of the impacts on biotic conditions, most of the owners perceived that *jhum* crop cultivation intensity decreased compared to the past (Table 2). The majority of the owners commented on decreasing crop production as they perceived an increasing infestation of pests and diseases, with the people in low and high hills being significantly higher than those in mid-hill. On average, 82% of the forest owners believed that change in phenology of trees took place compared to the past 30 years, for example, change in falling and arrival of leaf and flowering in trees (Table 2).

Purposes of and Preferences for Homestead Trees

In general, about 55% of the households across the altitude ranges used homesteads for their consumption of products derived from trees. The majority of the households in low and high hills were found to use homestead trees for the consumption of products, compared to the mid-hill (Table 3). On the other hand, the majority of the households in mid-hill

Table 2 Homestead forest owners´ perceptions towards climate change and associated impacts by hill altitude

No	Variables		Responses (%) Low	Mid	High	Mean
A Climate change and regular weather condition						
i	Climate change knowledge χ^2 (2, $N = 176$) = 12.08, $p = 0.00$		35	59	29	40
ii	Annual temperature χ^2 (4, $N = 176$) = 9.01, $p > 0.05$	Decrease	0	4	9	4
		Increase	100	93	88	94
		Constant	00	4	4	2
iii	Annual rainfall amount χ^2 (4, $N = 176$) = 38.38, $p = 0.00$					
	χ^2 (1, $N = 71$) = 26.01, $p = 0.0000$	Decrease	20	68	38	40
	χ^2 (1, $N = 80$) = 29.16, $p = 0.0000$	Increase	70	15	46	46
		Constant	10	17	16	14
iv	Erratic and unpredictable rainfall χ^2 (4, $N = 176$) = 7.67, $p > 0.05$					
		Decrease	2	4	7	4
		Increase	86	69	71	76
		Constant	12	28	21	20
B Impacts on physical conditions						
v	Flood intensity χ^2 (4, $N = 176$) = 25.33, $p = 0.00$					
	χ^2 (1, $N = 90$) = 18.49, $p = 0.0000$	Decrease	26	68	55	51
	χ^2 (1, $N = 63$) = 20.25, $p = 0.0000$	Increase	59	24	27	36
		Constant	15	8	18	13
vi	Land slide χ^2 (4, $N = 176$) = 5.7, $p > 0.05$					
		Decrease	2	6	2	3
		Increase	99	89	95	94
		Constant	00	6	4	3
vii	Soil moisture χ^2 (4, $N = 176$) = 6.33, $p > 0.05$					
		Decrease	97	85	88	90
		Increase	00	7	5	4
		Constant	3	7	7	6
viii	Quick dries up of seasonal stream χ^2 (4, $N = 176$) = 4.46, $p > 0.05$					
		Decrease	11	6	7	8
		Increase	85	80	82	82
		Constant	5	15	11	10
ix	Soil fertility χ^2 (4, $N = 176$) = 8.97, $p > 0.05$					
		Decrease	56	57	61	58
		Increase	33	20	14	23
		Constant	11	22	25	19
C Impacts on biotic conditions						
x	Jhum intensity χ^2 (4, $N = 176$) = 9.53, $p = 0.05$					
	χ^2 (1, $N = 154$) = 8.41, $p = 0.0037$	Decrease	97	80	84	88
		Increase	00	7	5	4
		Constant	3	13	11	8
xi	Crop production χ^2 (4, $N = 176$) = 6.54, $p > 0.05$					
		Decrease	58	68	59	61
		Increase	35	17	25	26
		Constant	8	15	16	13
xii	Pest or disease infestation χ^2 (4, $N = 176$) = 9.53, $p = 0.00$					
		Decrease	14	17	14	15
	χ^2 (1, $N = 117$) = 11.56, $p = 0.0007$	Increase	76	48	73	66
	χ^2 (1, $N = 33$) = 13.69, $p = 0.0002$	Constant	11	35	13	19
xiii	Phenological change χ^2 (2, $N = 176$) = 5.96, $p > 0.05$		85	72	89	82

Table 3 Forest owners´ purposes and preferences of homestead trees by hill altitude

Variables	Responses (%)			
	Low	Mid	High	Mean
Homestead trees used for χ^2 (4, $N = 176$) = 20.03, $p = 0.00$				
Own consumption χ^2 (1, $N = 96$) = 19.54, $p = 0.0000$	64	30	68	55
Sale	5	11	4	6
Both consumption and sale χ^2 (1, $N = 69$) = 13.18, $p = 0.0003$	39	59	29	39
Tree species preference for timber χ^2 (2, $N = 176$) = 2.5, $p > 0.05$	74	79	79	73
Tree species preference for fuelwood χ^2 (4, $N = 176$) = 18, $p = 0.00$	93	93	73	74
Preference for bamboo χ^2 (2, $N = 176$) = 1.7, $p > 0.05$	44	44	33	39
Tree species preference for MPTS χ^2 (2, $N = 176$) = 4.5, $p > 0.05$	82	82	65	74

Table 4 Forest owners' perceptions (agreement index, AI%) towards benefits of homestead forests by hill altitude

Benefits derived from homestead forests	Agreement index (%)			
	Low	Mid	High	Mean
Food security in crisis χ^2 (2, $N = 176$) = 0.45, $p > 0.05$	64	63	71	66
Moisture conservation χ^2 (2, $N = 176$) = 6.90, $p = 0.03$	100	89	100	97
Heat mitigation χ^2 (2, $N = 176$) = 2.5, $p > 0.05$	94	85	96	92
Protection against natural disasters χ^2 (2, $N = 176$) = 13.70, $p = 0.00$	−52	15	−18	−20
Soil conservation χ^2 (2, $N = 176$) = 15.6, $p = 0.00$	−42	30	−11	−10

used trees for more consumption and sale of products than those in the low and hill hills (Table 3). In addition to preferences for timber, MPTS, and fuelwood species, 39% of the forest owners preferred bamboo in their homestead for supplying weaving and building materials (Table 3). Homestead forest survey revealed a total of 968, 981, and 924 tree individuals belonging to 64, 63, and 64 species used for various purposes in the low, mid, and high hills, respectively.

Forest Owners´ Perceptions towards Benefits of Homestead Forests and Socioeconomic Factors

Two-third of forest owners (AI 66%) perceived that homestead forests contributed to food security in crisis (Table 4). Regarding environmental benefits, a large majority of the respondents (AI 92–97%) agreed with the benefits of homestead forests for conserving moisture and mitigating heat. However, up to 20% (AI −10% to −20%) owners, mainly in low and high hills significantly disagreed with the protective role of homestead forests against natural disasters and landslides (Table 4).

The perceptions were also supported by the mean scores of the Likert scale by socioeconomic factors of the households. For example, owners with secondary level of education and above (mean score 1.10) were more strongly agree to agree than those with primary level of education (1.02) for the item moisture conservation, which significantly $t(86.58) = -2.12$, $p = 0.04$ differed between them (Table 5). forest owners holding the primary level of education and *maacha* houses, and with lower income (2.41–2.63) tended to disagree whereas owners with a secondary level of education, *semi-pucca* and *pucca* houses, and with higher income (1.78–2.13) tended to agree for the two items, protection against natural disasters and soil conservation, and these significantly differed by literacy, housing type, and household income. Mean scores of the Likert scale did not significantly vary with the age, gender, and occupations of the respondents (Table 5).

Discussion

Homestead Forest Owners´ Perceptions of Climate Change and Associated Impacts

Not many homestead forest owners in the study area were aware of the term climate change. However, in most cases, their understanding of climate change and associated impacts were clear. For example, forest owners elicited their perceptions on the trend of increasing temperature and heavy and unpredictable rainfall, frequent landslides, drying up of stream, and decreasing soil moisture and fertility compared to the past 30 years. Their perceptions of increasing annual temperatures and rainfall amount corroborated with meteorological data that showed an increase in annual mean temperatures of 0.4 °C from 1990 to 2019. The local perceptions, thus, were in line with climate data found in Bangladesh and India (e.g., Alam et al. 2017; Baul et al. 2013; Halder et al. 2012). It is noted that forest owners were

Table 5 Forest owners' perceptions (mean score of Likert scale 1 = strongly agree, 2 = agree, 3 = disagree, 4 = strongly disagree) on benefits of homestead forests by owners´ age, gender, occupation, and households´ literacy, income, and house types

No	Benefits derived from homestead forests	Respondents´ age (years)		t test (p value)	Literacy		t test (p value)	Respondents´ housing types		t test (p value)
		Below 50	50 and above		Primary	Secondary and above		Maccha	Semi-pucca and pucca	
i	Food security in crisis	1.39 (0.08)	1.46 (0.09)	0.58	1.39 (0.08)	1.47 (0.09)	0.49	1.44 (0.08)	1.41 (0.09)	0.83
ii	Moisture conservation	1.10 (0.04)	1.03 (0.03)	0.16	1.02 (0.01)	1.10 (0.05)	0.04[a]	1.04 (0.02)	1.11 (0.05)	0.17
iii	Heat mitigation	1.22 (0.07)	1.09 (0.05)	0.12	1.16 (0.06)	1.16 (0.07)	0.98	1.12 (0.05)	1.22 (0.08)	0.27
iv	Protection against natural disasters	2.40 (0.09)	2.24 (0.11)	0.25	2.63 (0.08)	1.92 (0.11)	0.00[a]	2.50 (0.08)	2.07 (0.12)	0.00[a]
v	Soil conservation	2.28 (0.10)	2.13 (1.10)	0.29	2.53 (0.08)	1.78 (0.11)	0.00[a]	2.41 (0.09)	1.92 (0.12)	0.00[a]

No	Benefits derived from homestead forests	Respondents´ occupation		t test (p value)	Respondents´ gender		t test (p value)	Household income groups		t test (p value)
		Farming	Non-farming		Male	Female		Lower income	Higher income	
i	Food security in crisis	1.40 (0.09)	1.45 (0.08)	0.67	1.46 (0.08)	1.38 (0.09)	0.52	1.37 (0.08)	1.48 (0.09)	0.35
ii	Moisture conservation	1.04 (0.02)	1.09 (0.04)	0.23	1.03 (0.02)	1.12 (0.05)	0.09	1.04 (0.03)	1.09 (0.04)	0.32
iii	Heat mitigation	1.10 (0.05)	1.20 (0.07)	0.22	1.12 (0.05)	1.21 (0.08)	0.32	1.12 (0.05)	1.20 (0.07)	0.41
iv	Protection against natural disasters	2.44 (0.10)	2.23 (0.09)	0.16	2.28 (0.10)	2.38 (0.10)	0.48	2.52 (0.09)	2.13 (0.11)	0.00[a]
v	Soil conservation	2.32 (0.11)	2.11 (0.10)	0.15	2.19 (0.10)	2.22 (0.11)	0.82	2.46 (0.09)	1.94 (0.11)	0.00[a]

Values within parenthesis indicate the standard error of means

[a]Significant differences between the groups for benefits derived from homestead forests

much aware, from their long field experience with the local environment, that the local climate has changed, which was also reflected in farmers´ perceptions from other regions in Bangladesh and Nepal (Alam et al. 2017; Anik and Khan 2012; Baul et al. 2013; Khanal et al. 2018; Mahmood et al. 2010). They might be unaware of the global trend of climate; however, their understanding of changes in weather patterns (rainfall and temperature) over time helped them to adapt to climate change (e.g., Chapagain et al. 2009; Rahman and Alam 2016). These perceptions were also influenced by the altitude and local inhabitants, therefore they perceived different opinions of annual rainfall amount. For instance, the majority of the people living in the low hill were indigenous communities, who experienced an increasing trend of annual rainfall amount and flood intensity. In contrast, people living in the mid and high hills experienced a rather decreasing trend of annual rainfall amount and flood intensity. Earlier observation also indicated that individual's past experiences and present attitudes depend on their livelihood, culture, and ecosystem of settlement (Rahman and Alam 2016).

Changes in phenology of tree species appear as a biological indicator in understanding the climate change impacts (Menzel et al. 2006). In our study, forest owners reported early leaf fall and flowering, which were observed as good signs of climate change in the hill, consistent with the study of Sharma and Tsering (2009) who also similarly reported phenological changes as indicators in Nepalese hill. A significant number of owners often found flowering in *M. Indica* to be negatively affected by rainfall in recent years, reducing the yield of mango. Forest owners also observed an increase in an infestation of new types of and diseases and pests, such as discoloration of fruits and leaf, and a decrease in *jhum* intensity and crop production in comparison to 30 years. Such observation of diseases and incidence of pest attack was also made in developing countries including Bangladesh and Nepal (Baul and McDonald 2015; Pautasso et al. 2012; Saha and Azam 2004; Tol 2006). Thus, farmers´ traditional knowledge, observations, and experiences transmitted from generation enabled them to assess and understanding climate impacts on biotic factors as they live vicinity to natural resources, with an ability to realizing temporal and seasonal change (Anik and Khan 2012; Gyampoh et al. 2009; Mahmood et al. 2010). This traditional knowledge needs to be documented before getting lost as if to use it in the decision-making process (Byg and Salick 2009; Kirkby et al. 2018).

Purposes of and Preferences for Homestead Trees

Homestead trees were used by the households for their consumption of timber and NTFPs including fruits, fuelwood, bamboo, fodder. The consumption of these products enabled them to adapt in crisis time such as adverse impacts of climate change. For example, during crop failure caused by disasters, MPTS provided households with fruits, fodder, and other NTFPs for their existence. A respondent commented "during drought when there is no enough grass as animal feeds, I collect leaves from *Dalbergia sissoo, Mangifera indica*, and *Lannea* spp. used as animal fodder." In addition to household utilization, homestead tree products were sold as a source of income for their livelihood. In this regard, a commentary of a respondent from mid-hill was "when I have no money in my hand, I am used to sell timber and fruits derived from, *Artocarpus heterophyllus, Samanea saman*, *Swietenia mahagoni*, *Cocos nucifera* and bamboo as a means of earning income after meeting the demand of the household, and therefore I prefer planting of timber and MPTS species." This might also be the reason why people from mid-hill, who were mostly businessmen, had higher income compared to the other two hill ranges as higher percentage of the housheolds from mid-hill were used to both consume and sell tree products including timber and NTFPs. Therefore, in addition to timber, fuelwood, and MPTS, bamboo species were also preferred for supplying rawmaterials in small and mediun enterprises. Earlier studies also found homestead forests derived NTFPs and fuelwood for household utilization and economy in southern and eastern Bangladesh (Mukul et al. 2014; Uddin and Mukul 2007). Homestead forests in Bangladesh, Benin, and Ethiopia (Abdula 2021; Gbedomon et al. 2017; Nath et al. 2015) and NTFPs in India, Benin, and Kenya (Heubes et al. 2012; Sumukwo et al. 2013; Talukdar et al. 2021) were found to provide safety against adverse impacts of climate change while enhancing an adaptation to climate change. Our study on homestead forest-based adaptation is in line with Tuihedur Rahman et al. (2018) who studied adaptation-based decision making and found farming and non-farming strategies in Bangladesh.

Forest Owners´ Perceptions towards Environmental Benefits of Homestead Forests and Socioeconomic Factors

Homestead forests were opined to provide environmental benefits such as conservation of moisture, soil, and mitigation of heat, and protection against disasters. Many of the households plant trees that would reduce landslides, increase carbon sink and hold more soil moisture for other vegetation and crops. Our results also corroborate with the findings of the studies in the same homestead forests (Baul et al. 2021a, b) where the authors found the potential contribution of forests in carbon storage and environmental values from diverse tree species. These environmental benefits would help farmers to fight climate change impacts and make them resilient to the prevailing situations.

Integration of local strategies and scientific knowledge has been found as a key to promoting the adaptation of such vulnerable communities (Alexander et al. 2011; Green and Raygorodetsky 2010; Hiwasaki et al. 2014). However, the perceptions of the benefits of homestead forests were also affected by the socioeconomic background of the households. In our study, overall, up to 20% of owners disagreed with the benefits of soil conservation and protection from disasters; nevertheless, this disagreement may be varied due to the geographical location of their settlement. For instance, households in low hills were likely to be more affected by flood and landslide compared to the high altitude; therefore, some of the households in mid-hill agreed that homestead forests contributed to mitigating landslide or soil erosion and intensity of natural disasters including flood, strong wind. This disagreement was also in line with literacy, income, and housing type in the fact that households with *maccha* houses, low income, and low literacy disagreed with these benefits due to their much vulnerability to landslide and disasters, and they were mostly in the low hill. Socioeconomic factors such as education and financial condition of the farmers have been found as amongst the determinants in perceiving the impacts of adaptation to climate change in Nepal and South Africa (Hitayezu et al. 2017; Khanal et al. 2018). These changes in behavior on climate change perception are highly local social, cultural, and economic-specific (Patt and Schröter 2007).

Concluding Remarks and Policy Implications

We found that local perceptions were supported by the meteorological evidence about increasing annual temperatures and rainfall with an erratic pattern. Forest owners´ perceptions towards phenological change in trees and increase in food insecurity, landslide, pest infestation, drying up seasonal stream, and decrease in crop production, soil fertility, and moisture appeared as evidence of impacts of climate change. These perceptions of climate chnage impacts on biophysical factors and benefits people perceived varied with the hill altitudes and associated ecosystems, inhabitants, and the socioeconomic backgrounds of the households such as income, education, and housing types.

People in the hilly area perceived that homestead forests play a pivotal role in adaptation to climate change through supplying diverse products and services (multipurpose trees) which are contributing to food security, household utilization and economy, and environmental benefits including conserving moisture and soil and mitigating heat. These benefits of small-scale forests can be upscaled country-wise by incorporating local knowledge into formal science that could encourage preserving and expanding homestead forests not only in the hilly area and also in different parts under the action plans and policy. These types of studies could help policymakers assessing the need for monetary schemes and educational supports to conserve existing forests as Conservation reserve for at least 20 years that would also work as a carbon sink while providing other environmental benefits.

The national climate trust fund (Climate Change Trust Act 2010) could consider these small-scale forests and homesteads and provide them incentives to enhance and conserve more of these forests to reduce climate change impacts and enhance community adaptation. Realizing the importance of these forests in terms of economic and environmental benefits and carbon sink, REDD+ could also consider how these small forest holders can be accounted for in their mass programs as these small-scale forests are ignored in policy due to the lack of documentation. Our study findings can inform policymakers to take small-scale forest-based local climate adaptation strategies.

Acknowledgements The authors are highly thankful to the homestead forest owners for giving valuable time in the survey. In addition, Bangladesh Meteorological Department is highly acknowledged for providing local meteorological data of 30 years. The authors are also thankful to the government offices of the study area for providing secondary data. The Research Cell of the University of Chittagong, Bangladesh is cordially acknowledged for providing the grant.

Funding This work was mainly funded by the Research Cell of the University of Chittagong, Bangladesh.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Consent for Publication All authors have approved and agreed to submit this manuscript to this journal.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Abdula AH (2021) The role of homestead agroforestry practice on the climate change adaptation and mitigation: a review. Int J Food Sci Agric 5(4):617–622

Abdur Rashid Sarker M, Alam K, Gow J (2013) Assessing the determinants of rice farmers' adaptation strategies to climate change in Bangladesh. Int J Clim Chang Strateg Manag 5:382–403. https://doi.org/10.1108/IJCCSM-06-2012-0033

Alam GMM (2016) An assessment of the livelihood vulnerability of the riverbank erosion hazard and its impact on food security for rural households in Bangladesh. PhD Thesis 1–216

Alam GMM, 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. https://doi.org/10.1016/j.crm.2017.06.006

Alam GMM, Alam K, Mushtaq S, Khatun MN, Leal Filho W (2018) Strategies and barriers to adaptation of hazard-prone rural households in Bangladesh. Clim Chang Manag 11–24. https://doi.org/10.1007/978-3-319-64599-5_2

Alam K (2015) Farmers' adaptation to water scarcity in drought-prone environments: a case study of Rajshahi District, Bangladesh. Agric Water Manag. 148:196–206. https://doi.org/10.1016/j.agwat.2014.10.011

Alam M, Furukawa Y, Mika M (2010) Perceptions, preferences, and attitude of bangladesh farmers towardsp homegarden farming systems. Small-scale 9:213–226. https://doi.org/10.1007/s11842-010-9111-5

Alam M, Sarker SK (2011) Homestead agroforestry in Bangladesh: dynamics of stand structure and biodiversity. J Sustain 30:584–599. https://doi.org/10.1080/10549811.2011.571606

Alauddin M, Sarker MAR (2014) Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: an empirical investigation. Ecol Econ 106:204–213. https://doi.org/10.1016/j.ecolecon.2014.07.025

Alessandro P, Marta C (2012) Heterogeneity of linear forest formations: differing potential for biodiversity conservation. A case study in Italy. Agrofor Syst 86:83–93. https://doi.org/10.1007/s10457-012-9511-y

Alexander C, Bynum N, Johnson E, King U, Mustonen T, Neofotis P, Oettlé N, Rosenzweig C, Sakakibara C, Shadrin V, Vicarelli M, Waterhouse J, Weeks B (2011) Linking indigenous and scientific knowledge of climate change. Bioscience 61:477–484. https://doi.org/10.1525/bio.2011.61.6.10

Anik SI, Khan MASA (2012) Climate change adaptation through local knowledge in the north eastern region of Bangladesh. Mitig Adapt Strateg Glob Chang 17:879–896. https://doi.org/10.1007/s11027-011-9350-6

Bandarban Sadar Upazila Office (2019) Bandarban. Chittagong Hill Tracts, Bangladesh

Bardhan S, Jose S, Biswas S, Kabir K, Rogers W (2012) Homegarden agroforestry systems: an intermediary for biodiversity conservation in Bangladesh. Agrofor Syst 85:29–34. https://doi.org/10.1007/s10457-012-9515-7

Baul TK, Peuly TA, Nandi R, Kar SP, Mohiuddin M (2021a) Composition of homestead forests and their contribution to local livelihoods and environment: a study focused on Bandarban hill district, Bangladesh. Trees, Forests and People, 4, https://doi.org/10.1016/j.tfp.2021.100117

Baul TK, Peuly TA, Nandi R, Schmidt LH, Karmakar S (2021b) Carbon stocks of homestead forests of the Chittagong Hill Tracts, Bangladesh have a mitigation potential to climate change. Sci Rep 11:9254. https://doi.org/10.1038/s41598-021-88775-7

Baul TK, McDonald M (2015) Integration of indigenous knowledge in addressing climate change. Indian J Tradit Knowl 1(1):20−27

Baul TK, Ullah KMA, Tiwari KR, McDonald MA (2013) People's local knowledge of climate change in the middle-hills of Nepal. Indian J Tradit Knowl 12(4):585−595

Baul TK, McDonald MA (2014) Agro-biodiversity management: using indigenous knowledge to cope with climate change in the middle-hills of Nepal. Agric Res 3:41–52. https://doi.org/10.1007/s40003-014-0096-8

Baul TK, Rahman MM, Moniruzzaman M, Nandi R (2015) Status, utilization, and conservation of agrobiodiversity in farms: a case study in the northwestern region of Bangladesh. Int J Biodivers Sci Ecosyst Serv Manag 3732:1–12. https://doi.org/10.1080/21513732.2015.1050456

BBS [Bangladesh Bureau of Statistics], 2018. Statistical Pocketbook of Bangladesh 2017. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh

BMD [Bangladesh Metereological Department], 2019. Cox´s Bazar Metereological Station, Chittagong, Bangladesh.

Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ Sci Policy 12:413–426. https://doi.org/10.1016/j.envsci.2008.11.002

Byg A, Salick J (2009) Local perspectives on a global phenomenon-Climate change in Eastern Tibetan villages. Glob Environ Chang 19:156–166. https://doi.org/10.1016/j.gloenvcha.2009.01.010

Chapagain BK, Subedi R, Paudel NS, Editor P, Ojha HR (2009) Exploring local knowledge of climate change. Some J livelihood 8(1):106–112

Cramer W, Yohe G, Auffhammer M, Huggel C, Molau U, da Silva Dias MAF, Solow A, Stone DA, Tibig L (2014) Detection and attribution of observed impacts coordinating lead authors: contributing authors: review editors:, climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

Fakhrul Islam SM (2011) Decision support system for ex ante cost-benefit assessment of new agro-technology in the context of climate change. Int J Sustain Soc 3:82–106. https://doi.org/10.1504/IJSSOC.2011.038479

Foysal MA (2013) Economics of homestead forestry and their management activities at Fatickchari Upazila of Chittagong District, Bangladesh. Agric Fish 2:161. https://doi.org/10.11648/j.aff.20130204.12

Gbedomon RC, Salako VK, Fandohan AB, Idohou AFR, Glèlè Kakaï R, Assogbadjo AE (2017) Functional diversity of home gardens and their agrobiodiversity conservation benefits in Benin, West Africa. J Ethnobiol Ethnomed 13:1–16. https://doi.org/10.1186/s13002-017-0192-5

Green D, Raygorodetsky G (2010) Indigenous knowledge of a changing climate. Clim Change 100:239–242. https://doi.org/10.1007/s10584-010-9804-y

Gyampoh BA, Amisah S, Idinoba M, Nkem JN (2009) Using traditional knowledge to cope with climate change in rural Ghana. Unasylva 60:70–74

Habiba U, Shaw R, Takeuchi Y (2012) Farmer's perception and adaptation practices to cope with drought: perspectives from Northwestern Bangladesh. Int J Disaster Risk Reduct 1:72–84. https://doi.org/10.1016/j.ijdrr.2012.05.004

Halder P, Sharma R, Alam A (2012) Local perceptions of and responses to climate change: experiences from the natural resource-dependent communities in India. Reg Environ Chang 12:665–673. https://doi.org/10.1007/s10113-012-0281-x

Hanif MA, Roy RM, Bari MS, Ray PC, Rahman MS, Hasan MF (2018) Livelihood improvements through Agroforestry: evidence from Northern Bangladesh. Small-scale 17:505–522. https://doi.org/10.1007/s11842-018-9400-y

Heubes J, Heubach K, Schmidt M, Wittig R, Zizka G, Nuppenau E, Hahn K et al. (2012) Impact of future climate and land use change on non-timber forest product provision in Benin,West Africa: linking niche-based modeling with ecosystem service values. Econ Bot 66(4):383–397

Hitayezu P, Wale E, Ortmann G (2017) Assessing farmers' perceptions about climate change: a double-hurdle approach. Clim Risk Manag 17:123–138. https://doi.org/10.1016/j.crm.2017.07.001

Hiwasaki L, Luna E, Syamsidik, Shaw R (2014) Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities. Int J Disaster Risk Reduct 10:15–27. https://doi.org/10.1016/j.ijdrr.2014.07.007

Hossain MA, Reza MI, Rahman S, Kayes I (2012) Climate change and its impacts on the livelihoods of the vulnerable people in the south western coastal zone in Bangladesh. In: W. Leal Filho (Ed.), Climate change and the sustainable use of water resources, Climate change management, Part 2, pp. 237–259

IPCC. 2018. Summary for Policymakers. In: Global warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]

Jaman MS, Hossain MF, Shariful I, Helal J, Jamil MG, Mizanur, R. M (2016) Quantification of carbon stock and tree diversity of homegardens in rangpur district. Bangladesh Int J Agric 6:169–180. https://doi.org/10.5923/j.ijaf.20160605.01

Jordan JC (2015) Swimming alone? The role of social capital in enhancing local resilience to climate stress: a case study from Bangladesh. Clim Dev 7:110–123. https://doi.org/10.1080/17565529.2014.934771

Kabir ME, Webb EL (2009) Household and homegarden characteristics in southwestern Bangladesh. Agrofor Syst 75:129–145. https://doi.org/10.1007/s10457-008-9142-5

Kabir ME, Webb EL (2008a) Floristics and structure of southwestern Bangladesh homegardens. Int J Biodivers Sci Manag 4:54–64. https://doi.org/10.1080/17451590809618183

Kabir ME, Webb EL (2008b) Can homegardens conserve biodiversity in Bangladesh? Biotropica 40:95–103. https://doi.org/10.1111/j.1744-7429.2007.00346.x

Khanal U, Wilson C, Hoang VN, Lee B (2018) Farmers' adaptation to climate change, its determinants and impacts on rice yield in Nepal. Ecol Econ 144:139–147. https://doi.org/10.1016/j.ecolecon.2017.08.006

Kirkby P, Williams C, Huq S (2018) Community-based adaptation (CBA): adding conceptual clarity to the approach, and establishing its principles and challenges. Clim Dev 10:577–589. https://doi.org/10.1080/17565529.2017.1372265

Kumar T, Sarker A, Kumar T (2021) Restaurants' waste in Chittagong city, Bangladesh: current management, awareness on environmental hazard and perception towards potential uses. J Clean Prod 292:126073. https://doi.org/10.1016/j.jclepro.2021.126073

Lumsden LF, Bennett AF (2005) Scattered trees in rural landscapes: Foraging habitat for insectivorous bats in south-eastern Australia. Biol Conserv 122:205–222. https://doi.org/10.1016/j.biocon.2004.07.006

Mahmood SMS, Najneen F, Hoque KS, Rahman S, Shamim MM (2010) Climate change: a study on impact and people's perception (A case study on MonglaUpazila, Bagerhat District, Bangladesh). Bangladesh Res Pub J 4:153–164

Mani M, Bandyopadhyay S, Chonabayashi S, Markandya A, Mosier T (2018) South Asia's Hotspots: the impact of temperature and precipitation changes on living standards, South Asia's Hotspots: The impact of temperature and precipitation changes on living standards. https://doi.org/10.1596/978-1-4648-1155-5. Accessed 2 January 2021

Manning AD, Gibbons P, Lindenmayer DB (2009) Scattered trees: a complementary strategy for facilitating adaptive responses to climate change in modified landscapes? J Appl Ecol 46:915–919. https://doi.org/10.1111/j.1365-2664.2009.01657.x

Mattsson E, Ostwald M, Nissanka SP, Pushpakumara DKNG (2015) Quantification of carbon stock and tree diversity of homegardens in a dry zone area of Moneragala district, Sri Lanka. Agrofor Syst 89:435–445. https://doi.org/10.1007/s10457-014-9780-8

Menzel A, Sparks TH, Estrella N, Koch E, Aaasa A, Ahas R, Alm-Kübler K, Bissolli P, Braslavská O, Briede A, Chmielewski FM, Crepinsek Z, Curnel Y, Dahl Å, Defila C, Donnelly A, Filella Y, Jatczak K, Måge F, Mestre A, Nordli Ø, Peñuelas J, Pirinen P, Remišová V, Scheifinger H, Striz M, Susnik A, Van Vliet AJH, Wielgolaski FE, Zach S, Zust A (2006) European phenological response to climate change matches the warming pattern. Glob Chang Biol 12:1969–1976. https://doi.org/10.1111/j.1365-2486.2006.01193.x

MoF (2020) Chapter 15: Environment and Development, Bangladesh Economic Review 2019. Finance Division, Ministry of Finance. 261–271

Monirul Alam GM, Alam K, Mushtaq S, Clarke ML (2017) Vulnerability to climatic change in riparian char and river-bank households in Bangladesh: Implication for policy, livelihoods and social development. Ecol Indic 72:23–32. https://doi.org/10.1016/j.ecolind.2016.06.045

Motiur RM, Furukawa Y, Kawata I, Rahman MM, Alam M (2006) Role of homestead forests in household economy and factors affecting forest production: a case study in southwest Bangladesh. J Res 11:89–97. https://doi.org/10.1007/s10310-005-0191-6

Muhammed N, Masum MFH, Hossain MM, Chakma S, Oesten G, Von Detten R (2011) Floral composition and biodiversity conservation in homestead forests in Mymensingh, Bangladesh. Int J Biodivers Sci Ecosyst Serv Manag 7:247–257. https://doi.org/10.1080/21513732.2011.629211

Mukul SA, Tito MR, Munim SA (2014) Can homegardens help save forests in Bangladesh? Domestic biomass fuel consumption patterns and implications for forest conservation in south-central Bangladesh. Int J Res Land-use Sustain 1(1):18–25

Mukul SA, Biswas SR, M Manzoor Rashid AZ, Danesh Miah M, Enamul Kabir M, Belal Uddin M, Alamgir M, Ahmed Khan N, Shawkat Islam Sohel M, Shaheed Hossain Chowdhury M, Parvez Rana M, Ajijur Rahman S, Abu Sayed Arfin Khan M, Al-Amin Hoque M (2014) A new estimate of carbon for Bangladesh forest ecosystems with their spatial distribution and REDD+ implications. Int J Res Land-use Sustain 1:33–41. https://doi.org/10.13140/RG.2.1.4864.2166

Nath TK, Aziz N, Inoue M (2015) Contribution of homestead forests to rural economy and climate change mitigation: a study from the ecologically critical area of Cox's Bazar—Teknaf Peninsula, Bangladesh. Small-scale 14:1–18. https://doi.org/10.1007/s11842-014-9270-x

Osman KS, Jashimuddin M, Haque SMS, Miah S (2013) Effect of shifting cultivation on soil physical and chemical properties in Bandarban hill district, Bangladesh. J Res 24:791–795. https://doi.org/10.1007/s11676-013-0368-3

Patt AG, Schröter D (2007) Perceptions of environmental risks in Mozambique: implications for the success of adaptation and coping strategies. The World Bank Development Research Group,Sustainable Rural and Urban Development, Policy Research Working Paper 4417

Pautasso M, Döring TF, Garbelotto M, Pellis L, Jeger MJ (2012) Impacts of climate change on plant diseases-opinions and trends. Eur J Plant Pathol 133:295–313. https://doi.org/10.1007/s10658-012-9936-1

Plieninger T, Mainou JMY, Konold W (2004) Land manager attitudes toward man- agement, regeneration, and conservation of Spanish holm oak savannas (dehesas). Landsc Urban Plan 66:185–198

Rahman HMT, Hickey GM, Sarker SK (2015) Examining the role of social capital in community collective action for sustainable Wetland Fisheries in Bangladesh. Wetlands 35:487–499. https://doi.org/10.1007/s13157-015-0635-5

Rahman MH, Alam K (2016) Forest dependent indigenous communities' perception and adaptation to climate change through local knowledge in the protected area-A Bangladesh Case Study. Climate 4:1–25. https://doi.org/10.3390/cli4010012

Rashid MH, Afroz S, Gaydon D, Muttaleb A, Poulton P, Roth C, Abedin Z (2014) Climate change perception and adaptation options for agriculture in Southern Khulna of Bangladesh. Appl Ecol Environ Sci 2:25–31. https://doi.org/10.12691/aees-2-1-4

Rea LM, Parker RA (1997) Designing and Conducting Survey Research: A Comprehensive Guide. Jossey-Bass Publishers, San Fransisco, USA, p 27–62.

Roy B, Rahman MH, Fardusi MJ (2013) Status, diversity, and traditional uses of homestead gardens in Northern Bangladesh: a means of sustainable biodiversity conservation. ISRN Biodivers 2013:1–11. https://doi.org/10.1155/2013/124103

Saha N, Azam MA (2004) The indigenous hill-farming system of Khasia tribes in moulvibazar district of Bangladesh: Status and impacts. Small-scale Econ Manag Policy 3:273–281. https://doi.org/10.1007/s11842-004-0019-9

Salam MA, Noguchi T, Koike M (2000) Understanding why farmers plant trees in the homestead agroforestry in Bangladesh. Agrofor Syst 50:77–93. https://doi.org/10.1023/A:1006403101782

Sharma E, Tsering L (2009) Climate change in the Himalayas: the vulnerability of biodiversity. Biodivers Clim Chang Himalayas Sustain Mt Dev 55:10–12

SRDI (2018) Soil resource development institute. Annu Report Soil Resour Dev Institute, Dhaka, Bangladesh

Sumukwo J, Wario A, Kiptui M, Cheserek G, Kipkoech AK (2013) Valuation of natu- ral insurance demand for nontimber forest products in South Nandi, Kenya. J Emerg Trends Econ Manag Sci 4(1):89–97

Talukdar NR, Choudhury P, Barbhuiya RA, Singh B (2021) Importance of Non-Timber Forest Products (NTFPs) in rural livelihood: a study in Patharia Hills Reserve Forest, northeast India. Trees, For People 3:100042

Thomas T, Mainuddin K, Chiang C, Rahman A, Haque A, Islam N, Quasem S, Sun Y (2013) Agriculture and adaptation in Bangladesh: current and projected impacts of climate change. SSRN Electron. J. https://doi.org/10.2139/ssrn.2310087

Tol RSJ (2006) The stern review of the economics of climate change: a comment. Energy Environ 17:977–981. https://doi.org/10.1260/095830506779398911

Tuihedur Rahman HM, Hickey GM, Ford JD, Egan MA (2018) Climate change research in Bangladesh: research gaps and implications for adaptation-related decision-making. Reg Environ Chang 18:1535–1553. https://doi.org/10.1007/s10113-017-1271-9

Uddin MB, Mukul SA (2007) Improving Forest Dependent Livelihoods through NTFPs and Home Gardens: A case study from Satchari National Park. In: Fox J, Bushley B, Dutt S, Quazi SA (eds.) Making Conservation Work: Linking Rural Livelihoods and Protected Areas in Bangladesh. East-West Center and Dhaka: Nishorgo Support Project of Bangladesh Forest Department, Hawaii, p 13–35

UNSD (2005) Designing Household Survey Samples: Practical Guidelines. United Nations ST/ESA/STA, 264

World Bank (2013) Turn down the heat: climate extremes, regional impacts, and the case for resilience. A report for theWorld Bank by the PotsdamInstitute for climate impact research and climate analytics. World Bank, Washington, D.C

Zaman S (2010) Structure and diversity of homegarden agroforestry in Thakurgaon District, Bangladesh. Open Sci J 3:38–44. https://doi.org/10.2174/1874398601003010038