

## Are farmers willing to pay for participatory climate information services? Insights from a case study in peri-urban Khulna, Bangladesh



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### ABSTRACT

Among technological adaptation options, climate information services (CIS) offers high potential as a means to offset climate change impacts and build resilience in farming areas of developing countries. This study explores the potential of CIS, by investigating the case of participatory CIS development in the Lower Ganges Delta of Bangladesh. Specifically, we examined the value farmers attached to a co-developed CIS as decision support tool and the price farmers were willing to pay for CIS subscriptions. Based on a hypothetical market for CIS, we used contingent valuation with a double-bounded dichotomous choice format to determine farmers' willingness to pay (WTP) for CIS. Two samples were included: an experiment group of farmers exposed to and trained in CIS use for farm decision-making and a control group of farmers without prior exposure to CIS. More than 90% of farmers in the experiment group expressed willingness to pay for CIS, compared to 75% of the control group. The annual subscription fees farmers were willing to pay ranged from 970.92 taka (US \$11.45) to 1387.20 taka (\$16.36). WTP was greater among farmers who had participated in CIS co-development. The main factors influencing farmers' willingness to pay were CIS cost and prior exposure and training to CIS. Given that Bangladesh has more than 16.5 million farm households, these findings suggest huge market potential for CIS. Based on the high potential of participatory CIS, governmental institutions, the private sector and social entrepreneurs are called upon to develop CIS for smallholders, to unlock smallholders' agriculture potential.

### Practical implications

Peri-urban areas of urbanizing deltas offer ideal conditions for agriculture, due to their agro-ecological richness and good access to markets. However, farming communities in low-lying, deltaic coastal zones face major challenges in crop production linked to increasing weather and climate variability due to climate change. Farmers' difficulty in adapting to the changing climate is often attributed to their poor understanding of climate variability, combined with lack of access to meaningful climate and weather information in formats suitable for supporting on-farm decision-making.

The WATERAPPS project (<http://www.waterapps.net/>) engaged in participatory development of climate information services (CIS) with and for smallholder farmers in the rapidly urbanizing Lower Ganges Delta of Bangladesh. The aim was to improve resilience and contribute to sustainable agriculture. Specifically, Farmer

Field Schools (FFS) were initiated in which farmers co-designed and co-developed CIS, while simultaneously building their adaptive capacity to manage their farming operations in the face of increased hydroclimatic variability and weather extremes. We engaged with FFS participants on a weekly basis throughout the 2019 cropping season (mid-May to mid-October). Face-to-face interactions consisted primarily of (i) general discussions and comments on the weekly-provided forecast information (7-day, 14-day and 3-monthly); (ii) group elaboration and discussion of the forecasts to promote learning; and (iii) agricultural advisory services and decision-making support based on the forecasts. Activities were conducted in collaboration with the local Agricultural Extension Office (DAE), which became very active in the experiment.

Upon completion of the FFS, we assessed farmers' willingness to pay (WTP) for participatory climate and weather information services, considering various motivational and socio-economic factors that could potentially influence farmers' WTP. Specifically, we considered farmers' previous exposure to CIS, gender,

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age, education, family size and farm size. To study whether the participatory co-development process influenced farmers' WTP for CIS, the research included a control group of farmers who had not had training in or prior exposure to CIS. Applying double-bounded contingent valuation analysis, we found that more than 90% of the farmers who had received prior training and taken part in the co-development process expressed a willingness to pay for tailor-made CIS, compared to some 75% for the control group. Cost was found to be the main factor determining the probability of farmers' being willing to pay for CIS, followed by whether or not the farmer had received prior training and capacity building in climate and weather-related phenomena.

The monetary amount farmers were willing to pay for CIS subscriptions ranged from 970.92 taka (US \$11.45) to 1387.20 taka (\$16.36) annually. Given that Bangladesh has more than 16.5 million farm households, this suggests a huge market size for CIS, if similar willingness to pay for such services exists throughout the country. In addition to the high percentage of farmers indicating a willingness to pay for CIS in both the control and experiment groups, the involved extension service officers expressed keen interest in scaling up the FFS activities and in offering the climate and weather-related training more widely.

These findings indicate that the time may be ripe for social entrepreneurs and private sector participants to emerge as CIS providers in Bangladesh. With co-development of CIS, and fine-tuning of CIS to users' needs, there may now be an opportunity to implement tailor-made climate and weather information services to play a vital role in mitigating the risks associated with farming activities, while enhancing the climate resilience of Bangladesh's agricultural sector. Governmental organizations, such as the Department of Agricultural Extension (DAE), can play a key role in this regard, particularly by investing in programmes to build the capacity of farmers to interpret and use climate and weather information in their on-farm activities. To hasten the commercial development of CIS, private players or social entrepreneurs could be subsidized for a period of time, to assist in creating a viable market for CIS and stimulate private investment in tailor-made climate and weather information services. Our findings suggest that CIS could be an important piece of the climate adaptation puzzle, as these services could take some of the risk out of farming activities, thus enhancing the climate resilience of Bangladesh's agricultural sector and unlocking its agriculture potential, particularly in the peri-urban deltaic coastal zone.

## Introduction

Climate is a key driver of coupled ecological and economic systems, particularly the food production system (IPCC, 2014; Steiner et al., 2018). Yet, the climate is changing, evidently due to anthropogenic factors (Santer et al., 2018). Climate change significantly impacts agroecosystems around the globe (Ahmed et al., 2015; Davidson et al., 2019). The critical link between climate change and agricultural productivity, agricultural efficiency, farmland value and farmer income is well documented (Arshad et al., 2016; Chatzopoulos and Lippert, 2015; Hossain et al., 2020; Kurukulasuriya and Ajwad, 2007; Massetti and Mendelsohn, 2011; Moore and Lobell, 2014). For smallholder farmers, climate change impacts both household income and livelihood sustainability (Amjath-Babu et al., 2016). It reduces farm earnings directly, through diminished crop productivity (linked to unfavourable weather conditions) and more frequent crop failures (caused by extreme weather events). Indirectly, climate change reduces farm earnings by increasing production costs and seasonal unemployment (Alam et al., 2011; Banna et al., 2016; Masud et al., 2017; Siwar et al., 2009). For smallholders to achieve an adequate and sustainable livelihood, technological and ecosystem-level adaptations are needed to offset climate change impacts. Among the technological options, climate information services (CIS) is an emerging possibility.

CIS compile science-based climate and weather information, translating and transferring it for use by farmers to improve farm decision-making. CIS are considered a valuable tool for guiding adaptation practices linked to climate and weather and to assist agricultural development, especially in countries with high reliance on rainfed production (Antwi-Agyei et al., 2021; Singh et al., 2018; Vaughan et al., 2019). CIS can aid farmers in making adaptive operational decisions, to enhance the economic gains from their farming and reduce losses (Coulibaly et al., 2015; Dayamba et al., 2018; Jagtap et al., 2002; Muema et al., 2018; Tall et al., 2018; Vaughan et al., 2017; Vermeulen et al., 2012). To develop effective CIS requires communication between users, developers and scientists, so that information services are not only reliable but also tailored to users' needs (Vedeld et al., 2019). For this, co-design is a powerful approach. Co-design involves farmers in the creation of CIS to support adaptive agricultural decision-making.

To better understand the potential of CIS and co-design, the WATERAPPS project, led by Wageningen University & Research, was initiated in 2016 to co-develop tailor-made CIS for farmers in peri-urban Khulna District in the Lower Ganges Delta of Bangladesh. Specifically, the project sought to use CIS to build smallholder farmers' resilience to climate variability, thus contributing to food security and agricultural sustainability (Gbangou et al., 2021; Kumar et al., 2020b; Sarku et al., 2020). The project applied a co-design approach with three main goals: (i) to integrate scientific and local forecasting knowledge for improved weather predictability; (ii) to align information for adaptive decision-making with farmers' capacity to manage weather and climate-related phenomena; and (iii) to develop mobile applications for delivering CIS, applying insights from the co-design process. The project included Farmer Field Schools (FFS) in two communities of Khulna. These were held in the monsoon season (mid-May to mid-October), when rainfed agriculture was widely practised. Co-design and knowledge co-production were expected to offer significant opportunities for developing useful and actionable climate information, which is increasingly in demand in developing countries (Gbangou et al., 2020; Vincent et al., 2018).

The study area of Khulna is an ecologically rich and highly productive agricultural zone. Location- and time-specific information is crucial for farm decision-making here (Kumar et al., 2020b). However, the area's smallholders based their weather- and climate-related farming decisions mainly on traditional knowledge (e.g., farming calendars and practices) and observational knowledge (Ali et al., 2016; Chaudhury et al., 2012; Lebel, 2013; Moshed, 2007; Rahman and Alam, 2016). However, increased hydroclimatic variability (Al-Mamun et al., 2018; Hoque et al., 2011; Huq et al., 2015; Islam & Hasan, 2016; Islam, 2016; Mirza, 2002; Mondol et al., 2018; Shahid, 2010; Shahid, 2011), especially greater variability of monsoon rainfall (Ahsan et al., 2010; Hoque et al., 2011), has rendered traditional means of decision-making less effective. At the same time, lack of access to science-based hydroclimatic information in usable formats prevents farmers from benefitting from this source of climate and weather information. Our expectation was that well-defined, tailor-made climate and weather information services would have high potential as a risk assessment tool for rural farm households.

A transition from purely traditional means of decision-making to co-designed and co-developed CIS-based decision-making is particularly important in Bangladesh. Already, smallholder farmers here face heightened risks associated with temperature and rainfall variability, waterlogging, drought, storms and salinity intrusion (Gain et al., 2007; Hasan et al., 2018; Mondal et al., 2013; Rahman et al., 2011; Shahid and Behrawan, 2008). Moreover, the region's vulnerability to extreme climate events, higher temperatures and rainfall variability is expected to increase, given the global rise in CO<sub>2</sub> levels projected by the Intergovernmental Panel on Climate Change (IPCC, 2014). Hence, a transition to agricultural decision-making tools that are more reliable against the backdrop of climate change would be a meaningful advance for food and nutritional security in the country.

The current study focuses on farmers' perceptions of co-designed and co-developed CIS as a decision-support tool. Despite the importance of CIS in Bangladesh, very few studies have assessed farmers' willingness to invest in such services. Farmers' willingness to pay (WTP) for participatory CIS is likely to vary, depending on their socio-economic status and other motivational factors (Ahmed et al., 2015; Al-Amin et al., 2020). Identifying these factors and their influence, along with the kinds of information that farmers would be willing to pay for, can guide the development of effective CIS (Vincent et al., 2020). To this end, the WATERAPPS project provided experimental access to CIS co-developed with local farmers in the Batiaghata and Jalma subdistricts of Khulna. We subsequently administered a farm household survey to a subset of the farmers, and a control group, to assess users' WTP for the services. The main purpose of this study is thus twofold: to assess farmers' WTP for the participatory CIS in peri-urban Khulna and to identify factors that influence farmers' WTP for CIS.

## Material and methods

### The study area

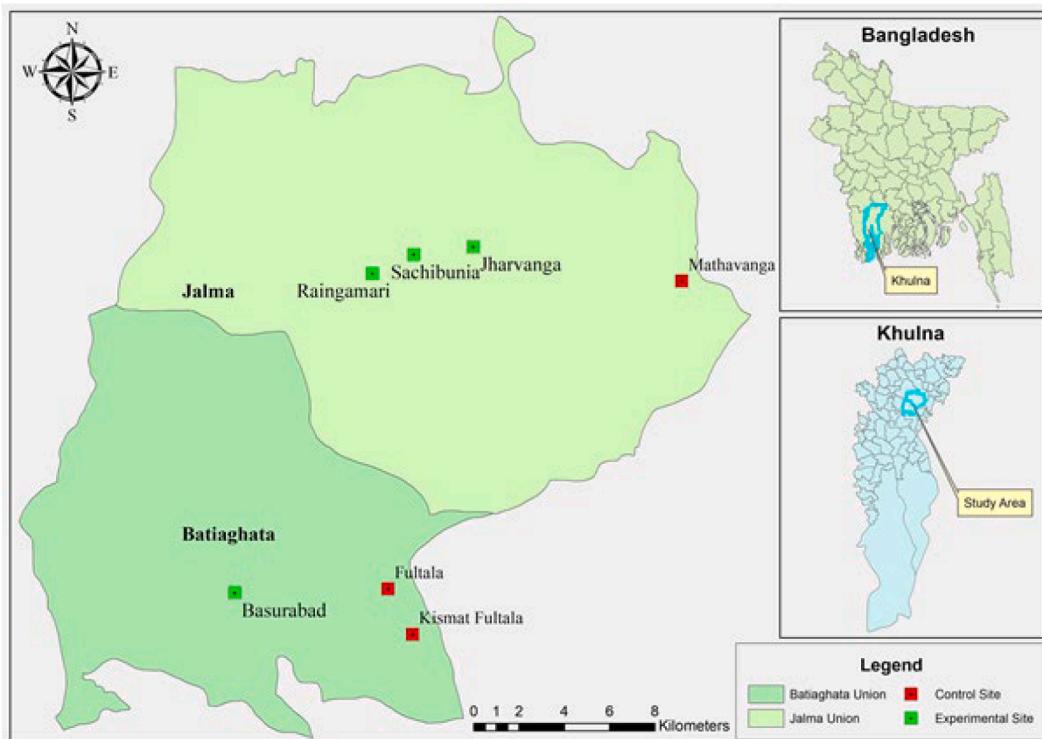
The study area is located in the south-west coastal region of Bangladesh. Geomorphologically, it lies in the lower region of the Ganges Delta. The city of Khulna is the third-largest metropolitan area of Bangladesh, and the capital of Khulna District. The city is surrounded by the rivers Rupsa, Bhairab, Pasur, Hatia and Mayur (Roy et al., 2005). It has a tropical savanna climate (Beck et al., 2018; Peel et al., 2007). Rainfall is abundant in summer, and scanty in winter. Kumar et al. (2020b) measured mean annual precipitation as 1752 mm and mean annual air temperature as 26.7 °C with a significant increasing trend from 1948 to 2018.

Khulna is a regional food production hub, as its topography, local climate and market access provide ideal conditions for peri-urban agriculture. Agriculture here is highly influenced by tidal inundation, as the district is located in the active and low-lying coastal zone of the Ganges Delta. Farming communities here are vulnerable to extreme

weather events linked to climate change, and farmers in Khulna face an increasing risk of weather-related challenges that threaten their food and livelihood security (Afroz and Alam, 2013; Huq et al., 2015). Farmers identified monsoon rainfall patterns, river discharge, tidal characteristics, salinity intrusion in soils, temperature stresses and weather extremes, such as thunderstorms and cyclones, as the major threats to their agricultural livelihoods (Kumar et al., 2020b). In the last 15 years alone, the region has experienced the devastating effects of multiple cyclones, including cyclone Sidr in 2007, Aila in 2009, Bulbul in 2019 and Amphan in 2020. All these extreme events have had lasting impact on the farming sector, both in the study area and in Bangladesh more widely (Ahmed et al., 2016; Islam et al., 2017).

### Experiment design

Our study was conducted in the Batiaghata and Jalma subdistricts of Khulna (Fig. 1). Here we selected an experiment group ( $n = 52$ ) of farmers who had access to co-designed and co-developed CIS, and a non-experiment (control) group ( $n = 59$ ) of farmers who had no access to CIS. Geographical locations and agricultural operations were similar for both groups. The farmers in the experiment group had participated in one of two FFS held in the villages of Basurabad and Sanchubunia during the 2019 cropping season, from mid-May to mid-October. Farmers in the experiment group had also received prior Participatory Integrated Climate Services for Agriculture (PICSA) training (Dorward et al., 2015). The PICSA training focused on providing locally appropriate climate information, while also engaging and training farmers to enable them to better understand and use weather and climate information in their farming decisions. Following the PICSA training, during which the participating farmers expressed their weather and climate information needs, we interacted with the 52 farmers in the experiment group on a weekly basis throughout the cropping season. We provided these farmers 7-day and 14-day meteoblue weather forecasts and seasonal meteoblue outlooks (3 months) (see <https://www.meteoblue.com>). We also offered training in forecast interpretation and advisory services, with the help of department of agricultural extension (DAE). Figs. 2–4



**Fig. 1.** Location of the study area in the District of Khulna, Lower Ganges Delta, Bangladesh.

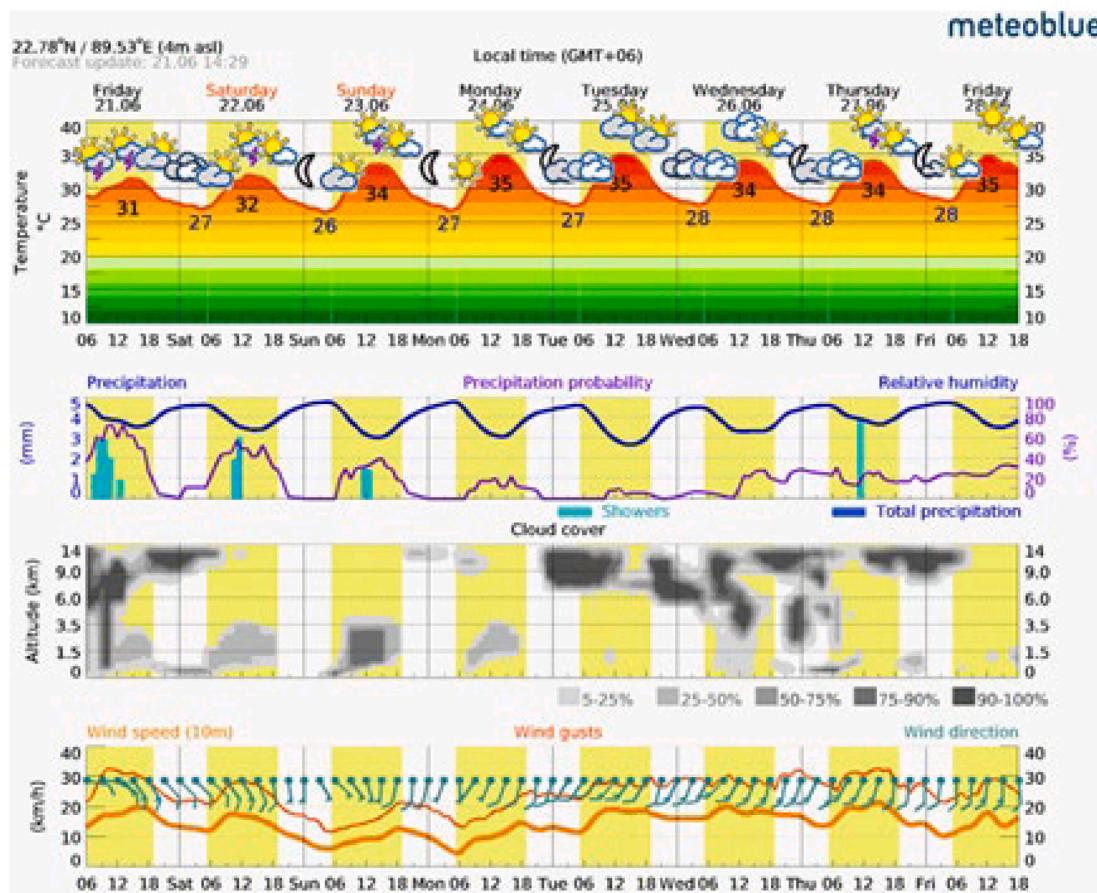


Fig. 2. Example 7-day forecast provided by meteoblue.

present examples of the provided meteoblue forecasts.

Three kinds of face-to-face interaction were provided through the FFS: (i) general discussions and comments on the weekly-provided forecast information (7-day, 14-day and 3-monthly); (ii) group elaboration and discussion of the forecasts to promote learning; and (iii) agricultural advisory services and decision-making support based on the forecasts, in collaboration with experts from the local agricultural extension department. Farmers in the control group resided in the villages of Fultala and Mathavanga, but with no FFS activities organized or PICSA training offered (see Fig. 1).

The experiment group farmers used the provided forecasts and tailor-made agro-meteorological advice generated weekly to guide their farm operations and plan activities. This included decisions on land preparation and seeding, as well as labour hiring. The hiring of farm labour had proved especially challenging in previous years, as farmers had often spent cash to hire workers who were ultimately unable to work due to extreme weather conditions. Agro-meteorological advisory services also assisted water level regulation and the timing of fertilizer and pesticide applications. The latter is another area that had proven challenging in recent years, as weather events reduced the effectiveness of fertilizer and pesticide applications, resulting in the need for additional rounds, escalating costs of cultivation, in addition to environmental impacts. Towards the end of the cropping season, farmers used the forecast information to plan harvesting, processing and storage activities. Some farmers reported that the tailor-made information helped them to secure their produce and retain its quality. They also reported using the CIS to align their harvesting and processing activities with market opportunities.

In February 2020, following completion of the FFS, we administered a farm household survey to assess farmers' WTP for CIS. Survey respondents were the earlier-mentioned experiment group ( $n = 52$ ) and

control group ( $n = 59$ ). To ensure a representative sample, these were selected using disproportionate random sampling. The survey questionnaire was structured in three parts. The first and second parts, respectively, elicited personal details about the respondent and socio-economic characteristics. Part three then presented double-bounded dichotomous choice contingent valuation questions. We used KoBo-Toolbox to collect the field data, completing the survey questionnaires during face-to-face interactions with the respondents.

#### *Contingent valuation for assessing farmers' willingness to pay*

To assess farmers' WTP for the co-designed and co-developed CIS, a hypothetical market was created using the contingent valuation method. Another method that could have been used to assess farmers' WTP was choice modelling. However, contingent valuation is considered preferable for estimating WTP for non-easily marketed environmental goods and services (Ahmed et al., 2015; Akter, 2006; Akter et al., 2009; Al-Amin et al., 2020; Amegnaglo et al., 2017; Arshad et al., 2016; Banna et al., 2016; Fonta et al., 2018; Fuks and Chatterjee, 2008; Mabe et al., 2014; Ouédraogo et al., 2018; Sarkhel and Banerjee, 2010). We chose contingent valuation because of its relative ease of design and execution, given the capacity and educational level of the participating farmers (Arshad et al., 2016; Markantonis et al., 2012). Nonetheless, Jin et al. (2006) and Bostan et al. (2020) concluded that both methods can be effective in assessing WTP in a hypothetical market.

The literature describes various contingent valuation approaches, including single-bounded dichotomous choice (SBDC), double-bounded dichotomous choice (DBDC), the open-ended format and stochastic payment card design (Fonta et al., 2010). We used DBDC, given our limited number of participants and DBDC's better performance in deriving WTP estimates within tighter confidence intervals, even with

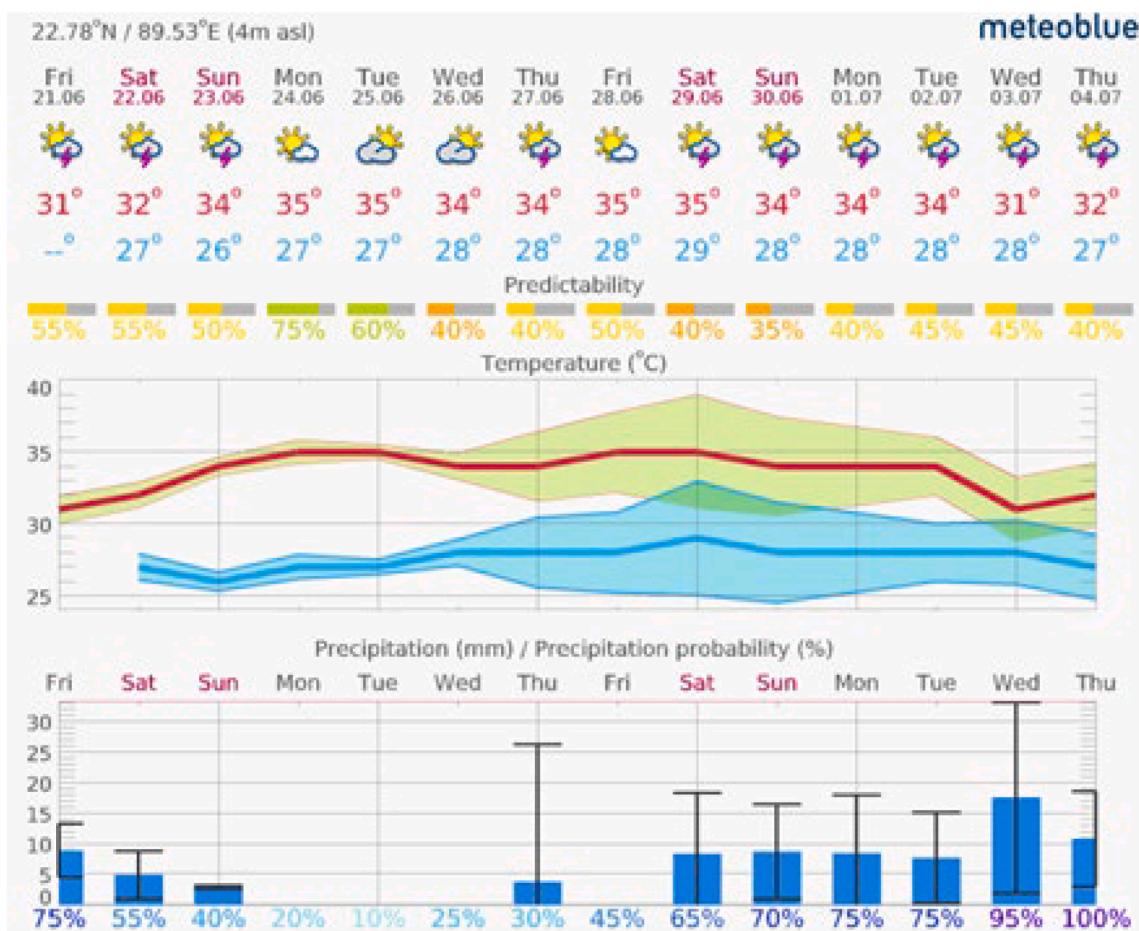


Fig. 3. Example 14-day forecast provided by meteoblue.

small sample sizes (Hanemann et al., 1991).

The DBDC approach consists of two consecutive WTP questions, both of which can be answered either 'yes' or 'no'. In each question, respondents are given a bid representing the payment required to access the CIS. If the response to the initial bid is 'no', then the follow-up question presents the respondent with a lower bid; a 'yes' response is followed up with a higher bid (Winden et al., 2018). Table 1 presents the bid amounts used in our study. The initial bids were 20, 40 and 100 taka (the taka is the Bangladeshi currency). The subsequent bids were half the initial amount for respondents who answered 'no', and twice the initial amount for those who answered 'yes'. Consequently, the follow-up lower or higher bids depended on which initial bid the respondent received.

The WTP bids were predetermined and assigned randomly across the participants of the experiment group and control group. Approximately one-third of the sample started with a 20, 40 and 100 taka bid, respectively, to avoid starting-point bias (Mitchell et al., 1989). Each participant was presented both an initial and a follow-up WTP question on the amount they would be willing to pay for CIS. The ways these were presented to the two study groups are described below.

For the experiment group: *Imagine that a private company is willing to provide you a CIS similar to the one you are currently receiving through the WATERAPPS project. To cover costs, the company is charging [initial bid amount] as a subscription fee per month. Would you subscribe to the service for that price? (yes/no) If the company charged [follow-up bid amount] would you subscribe? (yes/no)*

For the control group: *Imagine that a private company is willing to provide you with detailed 5- to 14-day weather forecasts. You can use the information in your agricultural work, for example, to set planting dates, to decide crop acreages, to select plant varieties, to plan land preparation tasks,*

*to schedule fertilizer and pesticide applications and to hire labour. To cover the costs, the company is charging [initial bid amount] as a subscription fee per month. Would you subscribe to the service for that price? (yes/no) If the company charged [follow-up bid amount] would you subscribe? (yes/no)*

The aforementioned questions yielded four possible outcomes:

- YY: Respondent accepts both the initial bid and the follow-up bid
- YN: Respondent accepts the initial bid and rejects the follow-up bid
- NY: Respondent rejects the initial bid and accepts the follow-up bid
- NN: Respondent rejects both the initial bid and the follow-up bid

Following completion of the experiment, we employed a double-bounded logit model to analyse the data. The response probabilities were obtained as follows (Arshad et al., 2016; Hanemann et al., 1991):

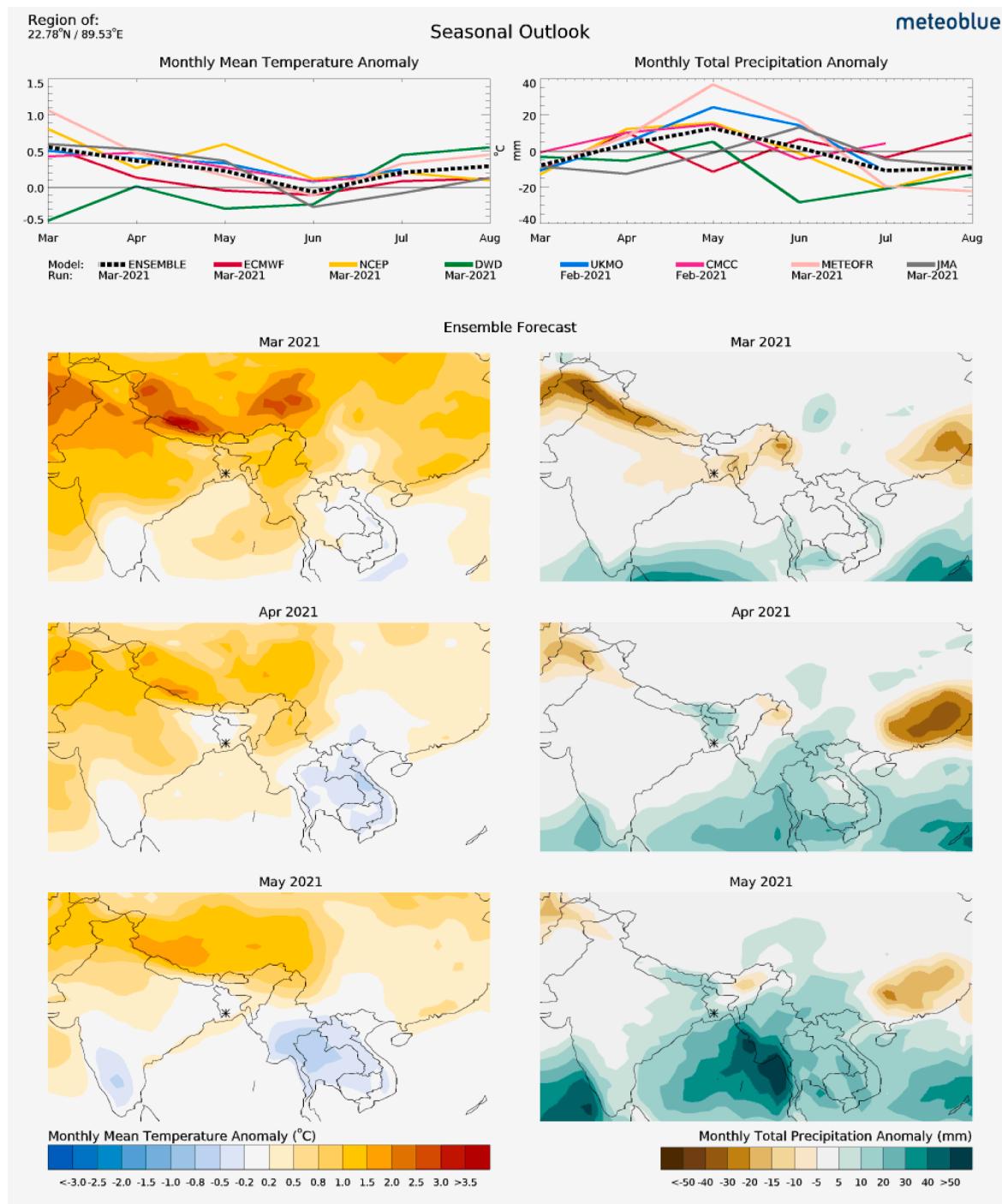
$$P_i^{YY} = \frac{1}{(1 + e^{-(a + \beta HighBID)})} \quad (1)$$

$$P_i^{NY} = 1 - \frac{1}{(1 + e^{-(a + \beta LowBID)})} \quad (2)$$

$$P_i^{YN} = \frac{1}{(1 + e^{-(a + \beta HighBID)})} - \frac{1}{(1 + e^{-(a + \beta InitialBID)})} \quad (3)$$

$$P_i^{NN} = \frac{1}{(1 + e^{-(a + \beta InitialBID)})} - \frac{1}{(1 + e^{-(a + \beta LowBID)})} \quad (4)$$

where *Initial bid* is the initial bid amount; *low bid* is the follow-up lower bid amount in case the respondent answered 'no' to the initial bid; *high bid* is the follow-up higher bid amount in case the respondent answered 'yes' to the initial bid.



**Fig. 4.** Example seasonal forecast provided by meteoblue.

**Table 1**  
Bid structures used in the current study, in Bangladeshi taka (1 taka = 0.012 US \$).

Initial bid	Follow-up lower bid	Follow-up higher bid
20	10	40
40	20	80
100	50	200

To estimate the probability of a respondent being willing to pay for the CIS, we used a double-bounded log-likelihood function:

$$L_{DB} = \sum I_i^{YY} \ln P_i^{YY} + \sum I_i^{YN} \ln P_i^{YN} + \sum I_i^{NY} \ln P_i^{NY} + \sum I_i^{NN} \ln P_i^{NN} \quad (5)$$

where  $i = 1, 2, \dots, 110$  and  $I_i$  is the response category of the individual respondent ' $i$ '.

Mean WTP was estimated following (Hanemann et al., 1991):

$$WTP^* = \frac{\ln(1 + e^\alpha)}{|\beta|} \quad (6)$$

where  $|\beta|$  is the absolute value of the bid coefficient.

The payment vehicle used in this study was the monthly subscription fee. In addition to the presented subscription fee, several other factors could potentially influence farmers' WTP, such as gender, age, educational level, family size and farm size. Table 2 presents these independent variables. For our analysis, we opted to run two separate models. Model 1 included both *bid* and a treatment variable (*treat*). For the experiment group – i.e. farmers who took part in the FFS and also received PICSA training – *treat* was assigned a value of 1, while control group members were given a value of 0. In Model 2, besides *bid* and *treat*, the additional independent variables were included.

## Results

### Respondent characteristics

Table 3 summarizes the socio-demographic characteristics of farmers in the experiment and control groups. The experiment group sample size was 52 and the control group numbered 59 (111 respondents in total). Among these, we collected 110 valid responses. The male–female ratio of participants was fairly even. The dominant age group of respondents was 40–49 years (35.6%) for the experiment group and 20–29 (42.4%) for the control group. Moreover, the majority of experiment group respondents had a primary (40.7%) or secondary (49.2%) education, while the majority of farmers in the control group had a secondary (34.6%) or post-secondary (40.4%) education. Furthermore, we asked respondents to indicate their years of farming experience. The dominant categories for the experiment group were 11–20 years (27.1%) and 31–40 years (25.4%), while in the control group, more than half (53.9%) of the farmers stated that they had 0–10 years of farming experience. Mean family size was 4.1 and 3.7 people, for the experiment and control groups respectively, while farm size was 3.0 and 3.2 acres, respectively.

### Farmers' willingness to pay and influencing factors

To further investigate whether the FFS and PICSA training played a significant role in farmers' WTP, Fig. 5 depicts the outcomes of the willingness to pay experiment for the control and experiment groups. Accordingly, YY cases ('yes' to both the initial and follow-up bids) were 57.8% in the experiment group and 44.2% in the control group, while

**Table 2**  
Variables included in the double-bounded dichotomous choice models.

Variable	Description	Category
<i>Dependent variable</i>		
Response to the willingness to pay (WTP) bids	WTP the subscription fee for climate information services (CIS)	Four possible outcomes: 'yes-yes', 'yes-no', 'no-yes', 'no-no'
<i>Independent variables</i>		
Treat	Indicates whether the respondent participated in Farmer Field School and Participatory Integrated Climate Services for Agriculture (PICSA) training	1 = experiment group 0 = control group
Bid	Amount of money farmers said they were willing to pay	Ranges from BDT 10 (minimum bid) to 200 (maximum bid)
Gender	Respondent's gender	1 = male; 2 = female
Age	Age of household head	1 = 20–29; 2 = 30–39; 3 = 40–49; 4 = 50–59; 5 = 60 and above
Education	Education of household head	1 = no formal education; 2 = primary school; 3 = secondary school; 4 = post-secondary education; 5 = tertiary education
Family size		Number of household members
Farm size		Total area of the farm

**Table 3**  
Respondent characteristics, experiment and control groups

Demographics	Experiment group (n = 52, results in %)	Control group (n = 59, results in %)
Gender		
Male	74.6	57.7
Female	25.4	42.3
Age		
20–29	5.1	42.4
30–39	18.6	32.6
40–49	35.6	15.4
50–59	13.6	3.8
60 and older	27.1	5.8
Education		
Primary	40.7	5.8
Secondary	49.2	34.6
Post-secondary	3.4	40.4
Tertiary	6.8	5.8
Farming experience (yrs)		
0–10	16.9	53.9
11–20	27.1	28.9
21–30	13.6	9.6
31–40	25.4	3.8
40 or more	16.9	3.8

YN (yes–no) or NY (no–yes) cases were 32.6% in the experiment group and 32.2% in the control group. NN (no–no) cases were 9.6% in the experiment group and 23.7% in the control group. Fig. 5 reveals that 90.4% of the respondents who had participated in the FFS and PICSA training were willing to pay to receive climate information to help them manage their agricultural activities, while 76.3% in the control group indicated being willing to pay.

The outcomes of the WTP experiment, depicted in Fig. 5, indicate that more than 90% of the farmers who had taken part in the FFS and PICSA training expressed at least one 'yes' response, compared to slightly above 75% for the control group. Thus, prior exposure to CIS, in our case under the WATERAPPS project, indeed seems to have induced a higher WTP among the respondent farmers. Nonetheless, the majority of the participants in both groups were willing to pay for CIS, regardless of whether they had participated in co-development of the CIS, suggesting the commercial potential for CIS in the study area. Tables 4 and 5 present the results of the double-bounded logit models. Model 1 includes only *bid* and *treat*, while Model 2 includes all independent variables mentioned in Table 2.

The coefficient values ( $\beta$ ) presented in Tables 4 and 5 indicate the importance of the predictors in the probability of a respondent being willing to pay a monthly subscription fee for CIS. The tables also present the average amount that farmers indicated being willing to pay and confidence intervals thereof. Results from the two models are largely congruent. The coefficient of *treat* (Model 1:  $\beta = 1.2649$ , Model 2:  $\beta = 0.95$ ) was positive and significant in both models, indicating that the FFS and PICSA training positively influenced farmers' WTP for CIS. The coefficients of education ( $\beta = 0.089$ ), family size ( $\beta = 0.062$ ) and farm size ( $\beta = 0.019$ ) were also positive but not significant. The coefficient for *bid* was significant and negative in both models, in line with theoretical expectations (Model 1:  $\beta = -0.0263$ , Model 2:  $\beta = -0.0026$ ).

The monthly subscription fee (*bid*) was found to be the predominant factor influencing farmers' WTP for CIS. This implies that WTP for CIS was mainly determined by the cost of accessing these services and farmers' awareness of them and ability to use them, rather than gender, age, family size or farm size. Female and male farmers were equally willing to pay for CIS. At the same time, treatment – i.e. prior exposure to the information service – is the variable that had the strongest positive influence in terms of explaining farmers' probability to express willingness to pay. According to Model 1, with only *bid* and *treat* as explanatory variables, the mean amount that farmers were willing to

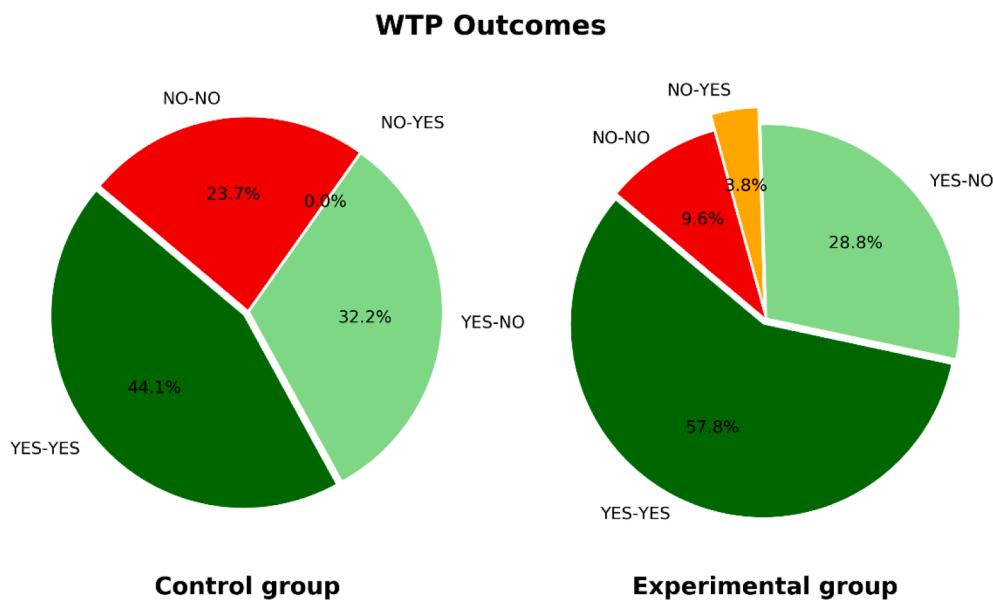


Fig. 5. Outcomes of the willingness to pay experiment in control and experiment groups.

**Table 4**  
Model 1, including only bid and treatment variables

Variable	Coefficient ( $\beta$ )	Std. Error	t- statistic
Constant	1.8499	0.3245	5.701
Bid	-0.0263	0.0036	-7.204
Treat	1.2649	0.4214	3.002
Restricted WTP point estimate	95.82 taka (US \$1.13*)		
Krinsky and Robb confidence intervals (95% CI)	81.75–116.23 taka (US \$0.96–1.37)		

\* Exchange rate as of 27 April 2021.

**Table 5**  
Model 2, including bid and treatment variables, as well as all independent variables

Variable	Coefficient ( $\beta$ )	Std. Error	t-statistic
Constant	2.33	1.2550	1.86
Bid	-0.002689	0.0038	-7.123
Treat	0.95065	0.5243	1.813
Gender	-0.0736	0.4681	-0.1572
Age	-0.01868	0.0179	-1.044
Education	0.08945	0.3505	0.2553
Family size	0.06281	0.1475	0.4258
Farm size	0.01926	0.4068	0.04735
Restricted WTP point estimate	95.35 taka (US \$1.12)		
Krinsky and Robb confidence intervals (95% CI)	80.91–116.23 taka (US \$0.95–1.37)		

pay for climate and weather information services was 95.82 taka (US \$1.13) per month or 1149.84 taka (\$13.56) per year. The confidence intervals for the amount farmers were willing to pay ranged from 981 taka (\$11.57) to 1394.76 taka (\$16.45) per year. Model 2, which included the explanatory variables gender, age, education, family size and farm size, indicates that farmers were willing to invest 95.35 taka (\$1.12) per month or 1144.20 taka (\$13.50) per year. Here, confidence interval calculations indicated a range from 970.92 taka (\$11.45) to 1387.20 taka (\$16.36) per year. Thus, both models produced similar estimates.

## Discussion

### Factors affecting farmers' willingness to pay

Both models estimated very similar mean willingness to pay among the respondent farmers. In the experiment group as well as the control group, the most important factor affecting farmers' WTP for CIS was the bid variable; that is, the monthly subscription fee set for accessing the service within the hypothetical market. The negative sign for this variable indicates that higher subscription fees were correlated with a smaller chance for a positive response. According to Fonta et al. (2018), this might be due to a differential between the bid amount presented and the value that an individual attaches to the services, which has a significant policy implication for governments. Both models reveal cost of service to be the main determinant of farmers' willingness to invest in CIS. The negative correlation found between the cost (subscription bids) and farmers' willingness to subscribe to these services also indicates that farmers were seriously considering payment, and not simply responding affirmatively to the questions. In rolling out CIS to farmers in the study area and more widely, government agencies in Bangladesh may have a contributing role to play. For example, they might invest in climate and weather information services to make them more affordable for farmers or provide subsidies for CIS for the agricultural sector, particularly if low willingness to pay for CIS becomes an obstacle to their widespread provision and use. Low willingness to invest in CIS subscriptions might especially be an issue in the initial years of establishment of such services. Our results also indicate that once farmers are exposed to CIS, their willingness to pay significantly increases. A suggestion here would be for the Bangladeshi government or corresponding agencies, such as the Department of Agricultural Extension, to either provide CIS themselves or subsidize at least a couple of years of service to promote private entities offering such services.

The relationship between the probability of farmers being willing to pay and the proposed cost of CIS (*bid*) found in the current study is consistent with findings from previous research (Akter et al., 2009; Arshad et al., 2016; Fuks and Chatterjee, 2008). Besides bid, age was also negatively correlated with willingness to pay, though it was not significant. Previous studies, such as Ouédraogo et al. (2018) in Burkina Faso, indicate that farmers who are willing to pay for CIS tend to be younger people. This could be attributed to the fact that younger people have more frequent access to information technology through their smartphones, and they are more capable of interpreting climate and

weather information. In the experiment group, participation in the FFS and PICSA training seems to have offset the age effect, highlighting the fact that bridging the digital gap between young and old, at least in the case of CIS for agriculture, can be achieved by FFS, PICSA and perhaps similar types of training.

Education is another aspect found to positively influence smallholder farmers' WTP for CIS. Ahmed et al., 2015; Al-Amin et al., 2020; Banna et al., 2016; Masud et al., 2017 found that education greatly influenced farmers' WTP, and farmers with a higher level of education and concern about climate change were more willing to pay for climate adaptation programmes. In the current study, education was found to have a positive but insignificant relation to the probability of farmers being willing to pay for CIS. Though education could help raise awareness among farmers about weather and climate extremes (Moore and Lobell, 2014), the treatment variable in this study indicates that farmers who received prior training in CIS were more willing to pay for those services, irrespective of their formal educational level. The main reason is that through engagement and capacity building farmers became more knowledgeable and thus more aware of the increased hydroclimatic variability and its implications for their agricultural livelihoods. The training and information farmers received during co-design and co-development of the CIS enabled those in the experiment group to better understand and interpret the weather information and thus use it to make more sophisticated decisions on agricultural activities, resulting in economic benefits and thus increased adaptive capacity.

Additional physical, environmental and socio-economic parameters could be considered in assessing WTP for CIS. For example, Meza et al. (2008) argued that the value of seasonal forecasts for agriculture depends on many factors including farmers' risk attitudes, insurance, the policy environment and the scale of adoption. Moreover, Zongo et al. (2016) assessed farmers' perception and willingness to pay for climate information in Burkina Faso, finding that besides education, awareness of CIS also had a significant positive effect on farmers' WTP. This is confirmed by the outcomes of the current study. Uddin et al. (2016) investigated farmers' WTP for agricultural extension services in the coastal region of Bangladesh and found that the quality of the provided service influenced payment decisions and the type of services that farmers were willing to invest in. Besides service quality, (Kumar et al., 2020a) identified lack of ICT knowledge among farmers as a barrier to farmers' willingness to pay for CIS at a similar study site in Khulna, Bangladesh. However, ICT has significantly expanded since the beginning of the WATERAPPS engagement. Yet, despite the potential value of participatory CIS for farmers, useful services adapted to rural users' needs and social context have remained lacking (Islam and Grönlund, 2011; Paparrizos et al., 2020). The WATERAPPS approach of co-developing tailor-made CIS with and for local farmers to build resilience to weather variability and climate change offers a possible model for social entrepreneurship, especially given the willingness to pay expressed by both participant and non-participant farmers.

#### *The influence of capacity building and participatory co-development on willingness to pay*

A key characteristic of the provided CIS was the participatory process by which it was developed at the study site under the WATERAPPS project. Multiple scholars have remarked that participatory co-production of CIS has become increasingly common in recent years (Beier et al., 2017; Gbangou et al., 2021; Goodess et al., 2019; Hewitt et al., 2017; Simelton et al., 2019; Taylor et al., 2017; Willyard et al., 2018). Moreover, evidence is building of the value of CIS developed in a bottom-up fashion, with strong involvement of farmers and interested stakeholders from the supply chain, in a co-production mode aimed at customizing services to users' priorities and practical requirements (Georges et al., 2017). However, high service quality must be a priority, to ensure that farmers will be willing to pay subscription fees. The PICSA training and farmers' subsequent involvement in co-development

of the CIS through the FFS increased their capacity to interpret weather and climate-related information in relation to their agricultural requirements.

The capacity of local agricultural extension officers was also improved by their participation in the FFS (Bijlmakers and Islam, 2007; Kabir and Rainis, 2015; Kumar et al., 2020b). Following finalization of the WATERAPPS FFS they expressed interest in expanding the FFS initiative to reach, enable and build the capacity of more farmers to take informed decisions about their agricultural livelihoods. In general, formal institutions, such as the agricultural extension service, via their user communities can play an important role in building capacity for adaptive agriculture (M. T. Islam and Nursey-Bray, 2017). In this case, the extension officers expressed interest in scaling up CIS offerings within Bangladesh and developing the capacity of farmers to interpret climate and weather information. Capacity development is indeed a critical component of CIS, as it enables users to participate in co-design and co-development for tailor-made CIS.

#### *Way forward*

Climate and weather information services could support sustainable and resilient agricultural development in Bangladesh by providing tailor-made information to enhance agricultural production, mitigate farm losses, increase farm earnings and improve food security. It is recommended that the Government of Bangladesh, the Bangladesh Meteorological Department (BMD), the Agricultural Extension Department (DAE), alongside a range of other stakeholders and private weather forecast providers and farmers, pursue a coordinated and cooperative approach to produce and deliver CIS that are meaningful and effective for end-users. Participation of farmers who are expected to be the end-users of a CIS product in development is especially important. Farmers can be engaged in co-design and co-development processes to create CIS that are tailor-made to their needs. As they invest time and resources in the procedure, they gradually come to consider the output product as 'theirs' and are likely to make full use of it, to invest in its maintenance and to recommend it to peers who did not take part in the development process. Additionally, they are more likely to continue investing in and relying on the services, even if minor setbacks occur from time to time due to forecast uncertainty. A particularly noteworthy finding of the current study regards the commercial potential of CIS and its economic viability in the study area. This is yet another reason why governmental and private organizations might consider investing in such services.

The way forward suggested by these findings is a focus on building and increasing farmers' capacity to manage weather and climate-related phenomena by providing training, initiating weather schools and promoting social entrepreneurship to create commercially viable CIS. Building climate resilience should be seen as a participatory process that includes active engagement and empowerment of farmers, key stakeholders, researchers, and governmental and private organizations. Enhancing knowledge and capacity to interpret and use the outputs of participatory climate and weather information services is a promising technology solution to advance the adaptation process. To this end, the agricultural extension agency of Bangladesh could play an especially important role in capacity building, as it has the network and resources to support and scale up climate and weather information services and thereby contribute to sustainable agriculture.

#### **Conclusion**

The current study examined farmers' willingness to pay for participatory climate information services in the peri-urban area of Khulna District, in the Lower Ganges Delta of Bangladesh. This is a rich agro-ecological zone that is also highly vulnerable to the increased hydroclimatic variability brought by climate change. To conduct the research, we selected two study groups: an experiment group of farmers who were involved in co-designing and co-developing CIS within the scope of the

WATERAPPS project and a control group of farmers without prior exposure to CIS. Several explanatory variables were examined that might affect farmers' willingness to pay for CIS. These were the cost of the CIS, previous exposure to CIS, gender, age, education, family size and farm size. The analysis showed that more than 4 out of every 5 farmers were willing to pay to receive tailor-made weather information that could assist them in dealing with the effects of hydroclimatic variability on their agricultural operations. Specifically, they expressed willingness to pay for information that would help them take more sophisticated and tactical decisions on everyday agricultural activities. The experimental group of farmers who received prior exposure to and training in climate and weather information services, participated in a FFS and the co-development of agricultural advisory information based on provided weather and climate forecasts, were highly (90%) willing to pay for climate service. After completion of the FFS, perceiving the socio-economic benefits that were generated, the farmers expressed a need for the services to continue. Indeed, they established a weather club (<http://www.waterapps.net/en-us/bangladesh-updates/weather-club-a-new-horizon-of-smallholder-farmers-in-the-ganges-delta/>) to ensure continuation of the services. Furthermore, agricultural extension officers expressed great interest in scaling up the FFS activities. Willingness to pay was high (75%) in the control group as well, indicating that these farmers, despite their lack of prior training and capacity building in CIS, were also willing to invest in these services, as they could no longer rely on traditional means of decision-making.

This study found that farmers were willing to pay 95.35 taka (US \$1.12) per month or 1144.20 taka (\$13.50) per year in CIS subscription fees, or an amount ranging from 970.92 taka (\$11.45) to 1387.20 taka (\$16.36). Given that Bangladesh has more than 16.5 million farm households, the market size for CIS would seem huge if a similar willingness to pay for such services exists throughout the country. Farmers' overall high willingness to pay for tailor-made CIS, regardless of whether they had prior exposure and training in weather and climate-related information-based decision-making in agriculture, indicates how vital these services are for local farmers. It also highlights the inability of farmers to depend on traditional decision-making practices, given the increasing hydro-climatological variability in their region. This suggests that the Bangladeshi government should consider investing in these services to make them more affordable to farmers and promote social entrepreneurship to provide tailor-made CIS to farmers. Governmental organizations, such as the Department of Agricultural Extension (DAE), can play a key role in this regard, particularly in building the capacity of farmers to interpret and use climate and weather information in their on-farm activities. To hasten the commercial development of such services, private players or social entrepreneurs could be subsidized for a period, to assist in creating a viable market for CIS and to stimulate private entities to invest in tailor-made climate and weather information services. Our findings suggest that CIS could be an important piece of the climate adaptation puzzle, as these services could take some of the risk out of farming activities, enhancing the climate resilience of Bangladesh's agricultural sector and unlocking its agriculture potential.

#### CRediT authorship contribution statement

**Spyridon Paparrizos:** Conceptualization, Formal analysis, Writing - review & editing, Visualization. **Uthpal Kumar:** Investigation, Formal analysis, Resources, Data curation, Writing - review & editing. **T.S. Amjath-Babu:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Fulco Ludwig:** Supervision, Project administration, Funding acquisition, Writing - review & editing.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

the work reported in this paper.

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