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Flash flooding considerations aside: Knowledge brokering by the extension and advisory services to adapt a farming system to flash flooding

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ABSTRACT

The development of agriculture sector and livelihood in Bangladesh are threatened by various climatic stressors, including flash flooding. Therefore, Extension and advisory services (EAS) need to navigate the knowledge landscape effectively to connect various farm actors and help secure the optimum benefits of knowledge and information for making rational decisions. However, little is known how EAS can perform this task to combat various effects of climate change. This study investigates the means of brokering knowledge by the EAS to help the farming sector adapt to flash flooding. The research was conducted in the north-eastern part of Bangladesh with 73 staff of the Department of Agricultural Extension (DAE), the largest public EAS in Bangladesh. The results showed that DAE primarily dealt with crop production-related information. However, EAS did not navigate knowledge and information about flash flooding, such as weather forecasting and crop-saving-embankments updates, among the farming actors. Moreover, they missed the broad utilization of internet-based-communication channels to rapidly navigate information and knowledge about possible flash flooding and its adaptation strategies. This article provides some policy implications to effectively support the adaptation of farming system to flash flooding through EAS.

1. Introduction

The agriculture sector in Bangladesh is highly dependent on the higher amount of rice production in the haor areas [1]. Haors are large bowl-shaped flood plain depression located at the north-eastern part of Bangladesh and produce 16.5% of the total rice production of the country [2]. Rice is the staple food of the citizens of Bangladesh [3] and is cultivated more than 78% of the total cropped area for cultivation [4]. Rice production in Haor areas is extremely vulnerable to the effects of flash flooding [5].

Flash floods are sudden, localized floods that occur when there is a heavy amount of rainfall over a short period of time (a few hours to a day) within a catchment and produce rapidly rising and fast-moving river flows [6,7]. Flash flooding remains the top-ranked hazard in Haor areas, damaging the primary production sector (Boro rice-a winter rice) almost every year [8] and lead to negative consequences to the food security and national economic condition of the country [9]. It has tagged the agricultural livelihood as the

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most vulnerable (M [10]. which is reflected in the poverty scenario of Haor citizens with 29.56% below the Lower Poverty Level (LPL) (Centre for Environmental and Geographic Information Services, 2012). Flash flood usually visits in early monsoon, i.e., April to May, due to heavy rainfall in the Haor areas and upstream catchment of Meghalaya hills in India [7]. The rivers of the Haors are extremely flashy, with sudden rise in the water level and wide variations in flow. With excessive rain in the upstream Indian hilly areas, water quickly flows towards Haor areas through a number of rivers and canals [11]. However, other causes of Flash floods are sedimentation in the river and reduced navigability, the building of upland road and water management structures, deforestation and cutting of hills, landslide, poor drainage, and the consequences of climatic variability [12].

Early flash flood coincides with the harvesting period (March–April) of Boro rice, and recently flash flood has been occurring 2–3 weeks before the harvesting of standing Boro rice [9,13]. The planting time of Boro rice has been shifted to mid-December- mid January and harvesting time shifted to mid-April - mid May (M [10]. Besides, the cultivation of modern rice varieties in Haors have been doubled compared to ten to twelve years back [14]. These rice varieties seek a few days more (*e.g.*, BRRI Dhan-29 needs 30 days) to harvest and therefore struggle from the engulfing of early flash flood almost every year (A U [15]. Rainfall of more than 150 mm in Haor areas late March to the beginning of April could invite flash flood and in 2017, it crossed the previous record with an amount of 625 mm rainfall (M. R [16].

The increased intensity and variability of flash flood is linked to climate change (C. E [17]. The future challenges of flash flood on Boro rice production in the nexus of climate change is going to be worse since several studies on the projection and simulation model confirm the early and more frequent flash flood in the Haor area. Global Circulation Model (GSM) predicts the pre-monsoon (March–May) rainfall will be increased by 6.77–22.78% in 2050 [18]. During 2080, average rainfall will increase up to 36% from March to May [19]. At the end of twenty-first century increase in RX1 (1 day maximum rainfall) and RX5 (5-day maximum rainfall) during the pre-monsoon season depicts a probability of flash flood with high volumes [20]. Cherrapunjee region (North to the Haor areas) has already shown a rising trend of high intensity rainfall in the pre-monsoon season [21]. Since 2000 up to 2017, Haor areas faced devastating flash flood six times, (i.e. (i) April 30, 2000; (ii) April 19, 2002; (iii) April 15, 2004; (iv) April 3, 2010; (v) April 17, 2016; and (vi) March 27, 2017) which also demonstrate the early fashion of flash flood (M. R [16]. The tectonic depression of the Haor basin is being pushed down as the Indian plate collides with the Eurasian plate, and the Sylhet sub-basin is sinking 2.1 cm every year [22]. However, evidence from sediment thickness analysis depicts that the sinking rate could be 2–4 mm every year [23]. In addition, increased deforestation in the Meghalaya hills, Indian border and Haor areas could invite flash flood ten to fifteen days earlier [24].

Enhancing agricultural innovation is critical to adapt rice farming in Haor areas to flash flooding [25]. Agricultural innovation is an interactive process that evolves through connecting various forms of knowledge and sharing, negotiation and co-creation of knowledge among various actors [26]. Therefore, enabling innovation requires establishing connections and relationship among heterogenous actors [27]. However, scholars have argued that developing connections among various actors that are critical for knowledge sharing is very challenging in most contexts [28,29]. The process of enhancing innovation in developing countries is largely ineffective, with the limited role of Extension and Advisory services in connecting heterogeneous forms of knowledge sources [30]. In Bangladesh, scholars have identified such a gap of EAS in performing knowledge brokering role to enhance innovation to adapt to flash flooding [31,32]. As such, knowledge brokering is a role of EAS that involves seeking farmers' needs, providing farmers with information to solve farm problems and facilitate joint knowledge production among the farming actors through social learning [33,34].

Extension and advisory services (EAS) are considered as an engine to enhance innovation [35]. Traditionally, EAS largely focused on technology transfer from research organizations to farmers by disseminating technical knowledge and information of farming [30]. Due to a linear understanding of the innovation process, this technology transfer approach is largely ineffective in response to complex issues and wicked problems [36], such as flash flooding adaptation. In this vein, enhancing innovation to address complex issues calls for connection between various ideas, information and forms of knowledge and understanding instead of transferring only scientific knowledge [37]. The understanding that enhancing innovation requires a broader perspective beyond transferring scientific information and knowledge and establishing connections between various knowledge sources, has developed new roles of EAS in enhancing innovation [38].

In Bangladesh, the necessity to embrace new roles by EAS is evident with the failure of current technology transfer approach to help rice farming adapt to flash flooding [5,31]. However, little empirical research has been conducted systematically in Bangladesh to investigate the new roles of EAS, to explore the ways EAS can perform knowledge brokering roles in helping the rice farming community adapt to flash flooding. Until recently, no study is conducted to explore how EAS navigate and utilize the knowledge landscape that existed around them. Exploring the navigation of the knowledge landscape by the EAS can be a critical avenue to better understand how EAS may effectively perform those knowledge brokering tasks. This is the originality of this study.

The objective of this research is to investigate the means of brokering knowledge by the EAS to help rice farming community adapt to flash flooding. To achieve this objective, we have formulated two research questions. 1) What type of information and knowledge does the DAE staff collect and share with various actors to help flash flooding adaptation? 2) How do DAE staff communicate with various actors to receive and share information and knowledge for flash flood adaptation?

2. Methods

2.1. Innovation and knowledge brokering

In this study, innovation was conceptualised as a process whereby: "Individuals or organizations bring existing or new products, processes, and forms of organization into social and economic use to increase effectiveness, competitiveness, resilience to shocks or environmental sustainability, thereby contributing to food and nutritional security, economic development, and sustainable natural resource management" [39]). To enhance innovation, EAS needed to embrace a number of roles including demand articulation, institutional support, network brokering, capacity building, innovation process management and knowledge brokering [40].

- Demand articulation denotes supporting the stakeholders to explore innovation challenges and opportunities.
- Institutional support describes facilitating and lobbying for change in policy, favourable business models and enhance relationships among various actors.
- Network building denotes exploring and connecting heterogenous actors.
- Capacity building describes facilitating and strengthening various organizational forms
- Innovation process management denotes synchronization, interaction and supporting negotiation and learning among the actors.
- Knowledge brokering describes exploring the needs of knowledge, navigating and disseminating knowledge and information from various sources [40].

Knowledge brokering was considered a traditional role of EAS that EAS has been performing for a long time a conventional role to disseminate technical knowledge and information and help adopt new technologies in the farming sector [41]. This traditional role is largely draws on the innovation diffusion approach of Rogers [42]. However, as described above, knowledge brokering is a critical role of EAS in enhancing innovation to solve complex and wicked issues in the agricultural sector [41]. However, this knowledge brokering goes beyond only linear transfer of technology through disseminating information and knowledge [43]. In this study, knowledge brokers were conceptualised as "intermediaries that occupy boundary positions, sitting on the periphery of different worlds and creating an interface between the various actors in innovation networks" [41]. Knowledge brokering is about supporting knowledge co-construction [34]. The knowledge brokering roles of EAS largely include three functions such as articulating and voicing the demand of users, supplying information, and facilitating knowledge co-construction [34].

- Articulating and voicing demand of users denotes identifying the needs and demand of farming communities and others actors for technical and other type of knowledge. It also emphasizes the communicating the demand directly to innovations support services from advisory, research and training organization, i.e., matching between demand and supply.
- Supplying information describes providing farming actors with various information and knowledge to help solve farm problems and respond to the needs of the farming actors.
- Facilitating knowledge co-construction denotes involving and supporting various farming actors (*e.g.* farmers, private sectors and researchers) in knowledge sharing, negotiation and knowledge generation by facilitating need-responsive research and communicating local knowledge [34].

To perform these knowledge brokering functions, however, EAS need to navigate the knowledge and information landscape effectively. These knowledge and information can be in various forms, including scientific, technical, discursive, implicit, contextual and indigenous [44]. The capacity of a farming system to innovate is largely determined by how well and effectively different knowledge sources are connected and interacted [45]. To this end, knowledge partnership is very critical to investigate and addresses development concerns, such as flash flood risk and adaptation, by bringing various types of knowledge and information together in a systematic way [46]. As such, knowledge partnership offers the means to connect the knowledge and experiences of farmers, extensionists, researchers and private sectors to comprehend and solve issues together [46]. Therefore, EAS needs to support knowledge partnerships for performing various knowledge brokering roles to enhance innovation in a flash flooding context.

2.2. Description of the study area

The research was conducted in Sunamganj district, a north-eastern haor district in Bangladesh [47]. A total of 133 out of 423 Haors were located in this district [48]. Haor area occupied more than 73% of the total area of Sunamgonj district [48]. This district had a dominant cropping pattern of Boro Rice-Fallow-Fallow. This cropping pattern was followed in 86% of the total agricultural cultivable land in Sunamganj district [48]. A total of 223,330 ha of land in this district was cultivated for Boro rice (a winter rice cultivated from November to April) [49]. The Sunamgonj district produced profuse amount of rice and the Boro rice production of this district was 901, 474 metric tons in 2021 [49]. In Bangladesh, flash floods most severely affected the Boro rice of Sunamganj district (Mondal et al., 2019). Flash flooding completely destroyed more than 6658 ha of land cultivated for Boro rice of this district in 2022 [50]. A map of the study area is shown in Figure - 1.

2.3. Data collection and analysis

To examine the means of brokering knowledge by the EAS to help rice farming community adapt to flash flooding A mixed-method social research approach was used [51]. To achieve the research objective, an egocentric network approach was adopted [52]. In this study, data was collected with the staff of the Department of Agricultural Extension (DAE), which was largest public Extension services in Bangladesh [53]. The DAE was responsible for implementing national Extension polices and has special programs and strategies to combat flash flooding in the haor region of Bangladesh [54]. To achieve the research objective, DAE staff's information and knowledge receiving networks and information and knowledge sharing networks were investigated.

Rice farming involves various stages of cultivation, such as agronomic and harvesting stage [55]. Flash flooding adaptation called for securing various types of knowledge and information such as weather forecasting and updates of local crop-saving- embankments

[5]. Regarding weather forecasting, information about rain in the haors and nearby hilly areas were critical [56]. Regarding cr,op saving embankment, information about water level outside the crop-saving-embankment and fragility of the embankment were important to make informed decisionthe about paddy harvesting [57]. In this research, information and knowledge landscape about agronomic and harvesting activities and, weather forecasting and crop-saving-embankment were explored.

Data were collected from March to July 2022. Initially, informal discussion was conducted with DAE staff to get an overview of their activities, information and knowledge about flash flood adaptation and various communication channels used to navigate that information. Therefore, DAE staff were asked to name at least five actors important to them to collect information about agronomic activities, harvesting activities, weather forecasting and flash flooding [58]. Similarly, they were asked to name at least five actors important to them to share information. Next, DAE staff were asked to name at least five communication channels useful for them to collect and share information. This process resulted in two list of communication channels, one for collecting information and another for sharing information.

An interview schedule was developed, having questions for information collecting and sharing actors associated with agronomic activities, harvesting activities, weather forecasting and crop-saving embankment. Questions for communication channels used to collect and share information were also included in the interview schedule. It also contained questions about demographic characteristics of the DAE staff including age, education level, job length and job position. Every DAE staff in the Sunamganj district were invited to answer the interview schedule. A total of 73 out of 107 DAE staff participated in the survey. The responded were asked to identify the actors from whom they collect information about agronomic activities, harvesting activities, weather forecasting and crop-saving embankments as mentioned in the list. Similarly, they were asked to identify the actors with whom they share information about agronomic activities, harvesting activities, weather forecasting and crop-saving embankment, as mentioned in the list. The respondents were requested to select the communication channels they used to collect and share that information with various actors. After that, key informant interviews were conducted with eight DAE staff to understand their knowledge brokering roles, ways of receiving weather forecasting and reasons for a lower degree of sharing flash flooding information. Moreover, a focus group discussion was conducted with 10 DAE staff to understand the common trends, such as more use of face-to-face communication channels and less use of ICT based channels. Data of KIIs and FGD was audio recorded.

From the survey data, the identified and non-identified actors were coded as 1 and 0, respectively. Similarly, for the communication channels, selected and non-selected channels against various actors were coded as 1 and 0, respectively. The responses on education level were coded as 1,2,3, and 4 for Diploma, B·Ag.Ed, Honours and Master, respectively. The responses on job position were coded as 1,2,3, 4 and 5 for SAAO (Sub Assistant Agriculture officer), SAPPO (Sub Assistant Plant Protection Officer), AAEO (Additional Agriculture Extension Officer), AEO (Agriculture Extension Officer) and UAO (Upazilla Agriculture Officer), respectively. The data were inserted in the statistical package for social science software, and descriptive statistics were performed. The difference in number of actors between in-neighbourhood and out-neighbourhood networks about agronomic activities, harvesting activities, weather forecasting and crop-saving embankment was measured through the *t*-test [59]. The ego centric network maps for in-neighbourhood and out-neighbourhood were drawn using UCINET software.

The KIIs and FGD data were transcribed verbatim and coded using NVIVO software using the codes such as agronomic activities, harvesting activities, weather, flash flooding, sharing, source, communication channels, ICTS. The coded texts were organised under themes such as information securing sources, information sharing sources, face-to-face communication channels and ICT-based communication channels to investigate the research objective [60].

3. Results

3.1. Demographic characteristics of the DAE staff

The DAE staff had average age 36.59 years with standard deviation 7.44 (see Table-1). Their mean job length was 7.03 years with standard deviation 7.72. Almost 70% of the DAE staff had Diploma degree in Agriculture and 15.1% of DAE staff had Master degree. Among the DAE staff, near about 70% were frontline officers, including 61.6% SAAO and 8.2% SAPPO and rest of the staff were administrative officers, including 8.2%, 6.8% and 15.1% AEO, AAEO and UAO, respectively.

3.2. DAE staff's knowledge and information receiving networks about agronomic activities

DAE staff had a total of 10 actors in the networks to secure knowledge and information about agronomic activities (see Fig. 1).

Table 1
Demographic characteristics of the DAE staff.

Demographic characteristics	Mean	Standard deviation			
Age	36.59	7.44			
Job length	7.03	7.72			
Demographic characteristics	**Percentage of respondents**				
Education level	Diploma = 69.9	Honour = 8.2	B·Ag.Ed = 6.8	Master = 15.1	
Job position	SAAO = 61.6	SAPPO = 8.2	AEO = 8.2	AAEO = 6.8	UAO = 15.1

However, most of the DAE staff secured agronomic information for rice cultivation from DAE, AIS (The Agriculture Information Service), Research institutions and PI (Project implementation) wing. In a focus group discussion, a DAE staff mentioned that *"We secure most of the needed agronomic information from DAE. We participate in a formal training fortnightly at our office. Our senior officials (e.g. AEO/UAO) conduct this training on the contemporary issues of rice farming that are assigned by the higher authority of DAE. We also get info from research institutions, if any new technology or strategies about rice cultivation are developed."* A small number of DAE staff collected agronomic information for rice cultivation from Private companies, NGOs, University teachers, friends, ICT (Information and Communication Technology) ministry and farmers (see Fig. 2).

3.3. DAE staff's knowledge and information sharing networks about agronomic activities

DAE staff had a total of 10 actors in the networks to share knowledge and information about agronomic activities. However, a large number of DAE staff shared agronomic information for rice cultivation with farmers, input dealers, public representatives and other DAE staff. In a KII interview, a DAE staff mentioned *"I mainly share current issues of rice cultivation with farmers. When I go the shops of local input dealers or meet local representatives (e.g., Chairman and members of the lowest administrative unit of Bangladesh), I share with them about the issues as well."* A small portion of DAE staff also shared agronomic information for rice cultivation with Upzailla administration personnel, NGOs, religious leaders, elite persons, School teachers and private companies (see Fig. 3).

3.4. DAE staff's knowledge and information receiving networks about harvesting activities

DAE staff had a total of three actors in the networks to secure knowledge and information about harvesting activities. However, most of the DAE staff secured harvesting information for rice cultivation from the DAE. A few of them collected harvesting information for rice cultivation from various research institutions and private companies (see Fig. 4).

3.5. DAE staff's knowledge and information sharing networks about harvesting activities

DAE staff had a total of five actors in the networks to share knowledge and information about harvesting activities. However, a large portion of DAE staff shared harvesting information for rice cultivation with farmers. A small portion of them also shared harvesting information for rice cultivation with public representatives, DAE staff, Upazilla administration personnel and religious leaders (see Fig. 5).

3.6. DAE staff's knowledge and information receiving networks about crop-saving-embankments

DAE staff had a total of four actors in the networks to secure knowledge and information about crop-saving-embankments.

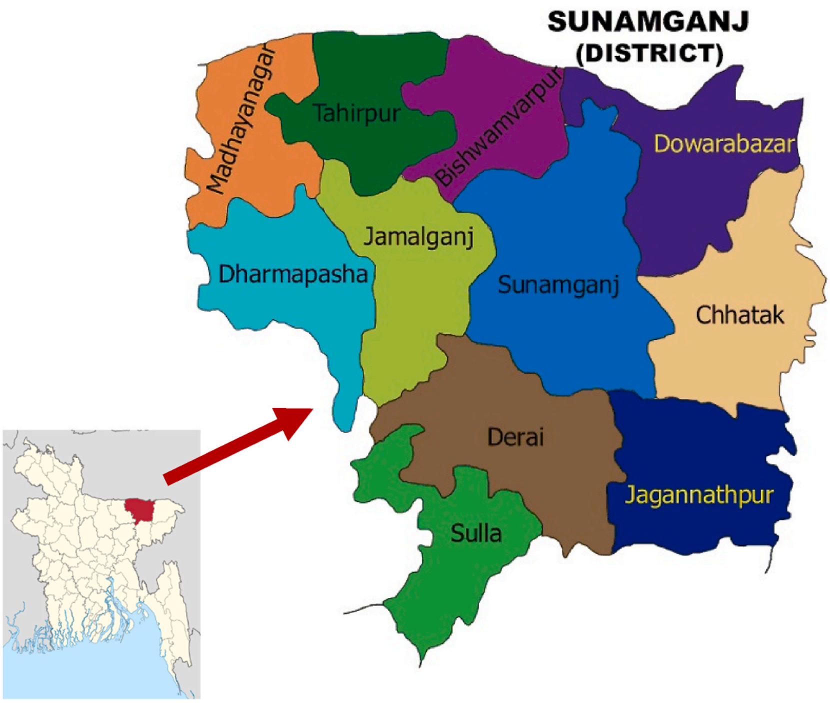

Fig. 1. Sunamgonj district in Bangladesh (Wikimedia Commons, 2023 [61,62].

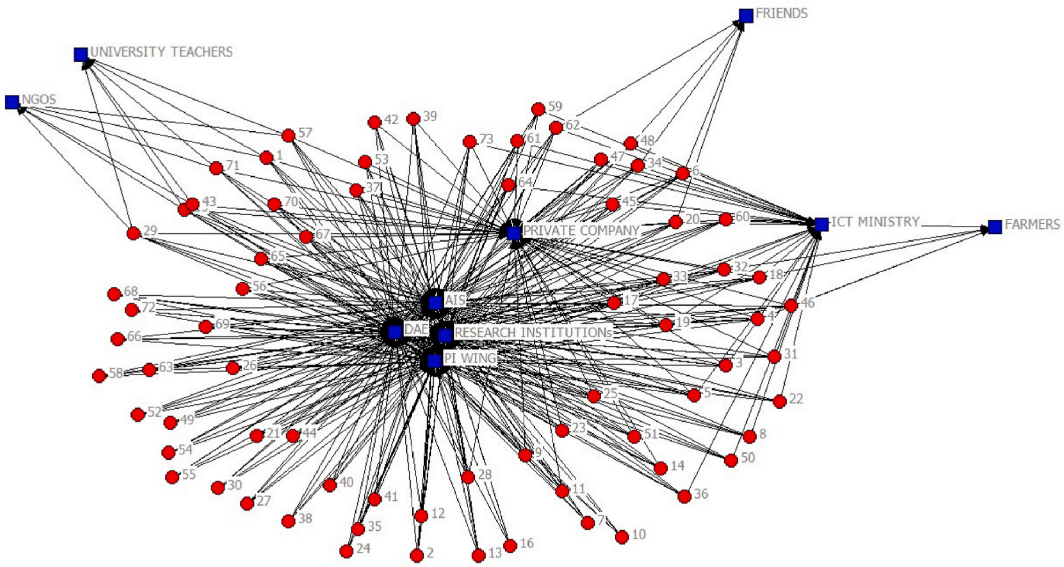

Fig. 2. DAE staff's knowledge and information receiving networks for agronomic activities.

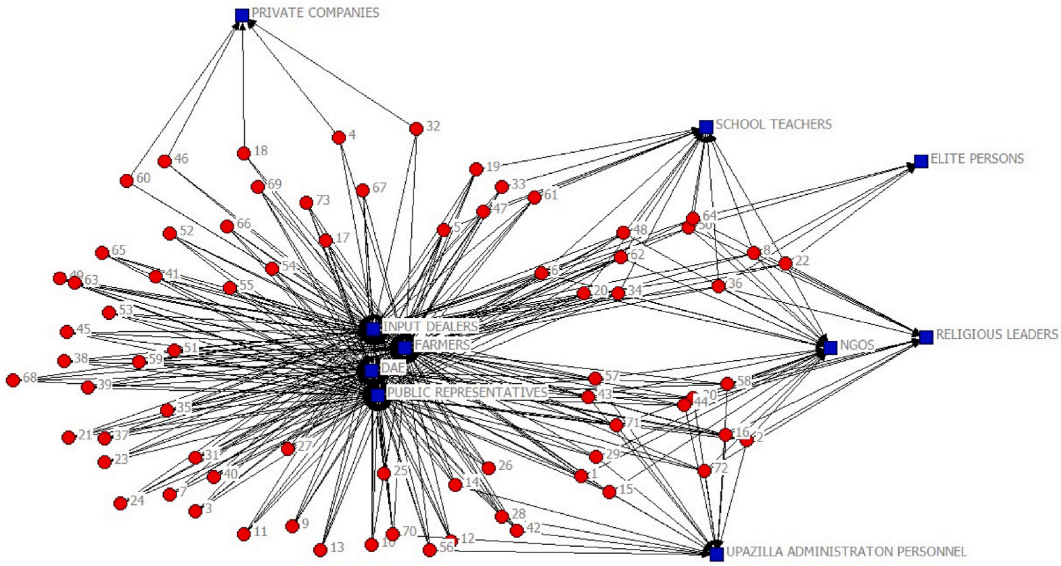

Fig. 3. DAE staff's knowledge and information sharing networks for agronomic activities.

However, most of the DAE staff did not collect information about crop-saving-embankment for rice cultivation in the haor areas. A small number of DAE staff secured information about crop-saving-embankment for rice cultivation from embankment guards, other DAE staff, farmers and PICs (Project Implementation Committees for the construction of crop-saving-embankments) (see Fig. 6). In a Focus group discussion, DAE staff noted that "Local people, such as members of PICs and embankment guards, look after the crop-saving-embankments. SAAOs (Sub Assistant Agriculture Officer-frontline DAE staff) have good connection with those people. SAAOs secure the updated condition of embankment, such as just after rain, from these people."

3.7. DAE staff's knowledge and information sharing networks about crop-saving-embankments

The findings revealed that no DAE staff shared information about crop-saving-embankment for rice cultivation with any actor in the haor areas. In a KII, one DAE staff member mentioned that "local people look after and save the (crop-saving) embankment by themselves, we don't have much responsibility there. For instance, in my working area, local people monitor their own (crop-saving) embankments. But to prepare and save (crop-saving) embankments, all the responsibilities go to the Water Development Board and

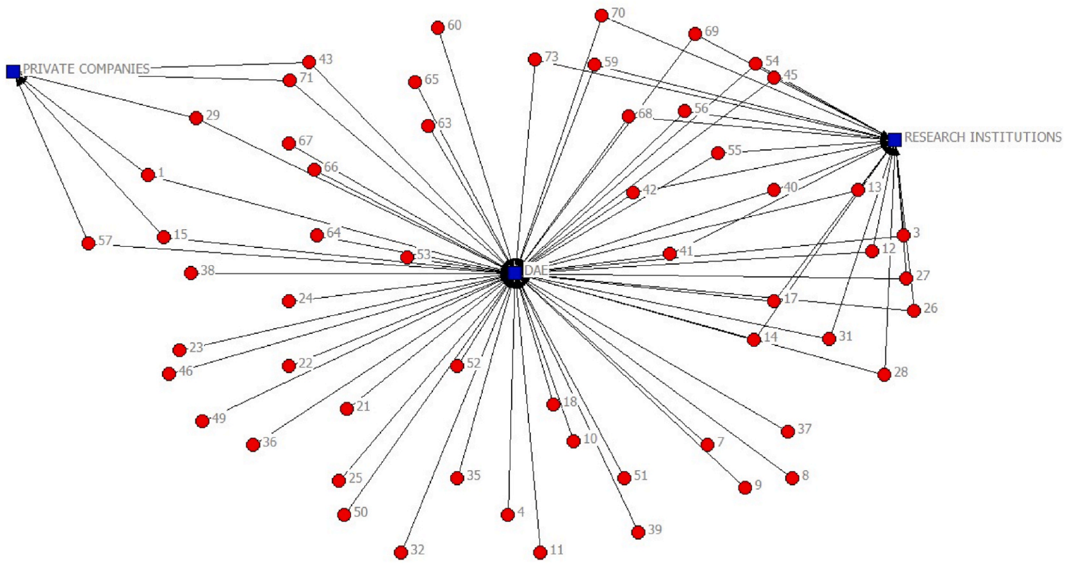

Fig. 4. DAE staff's knowledge and information receiving networks for harvesting activities.

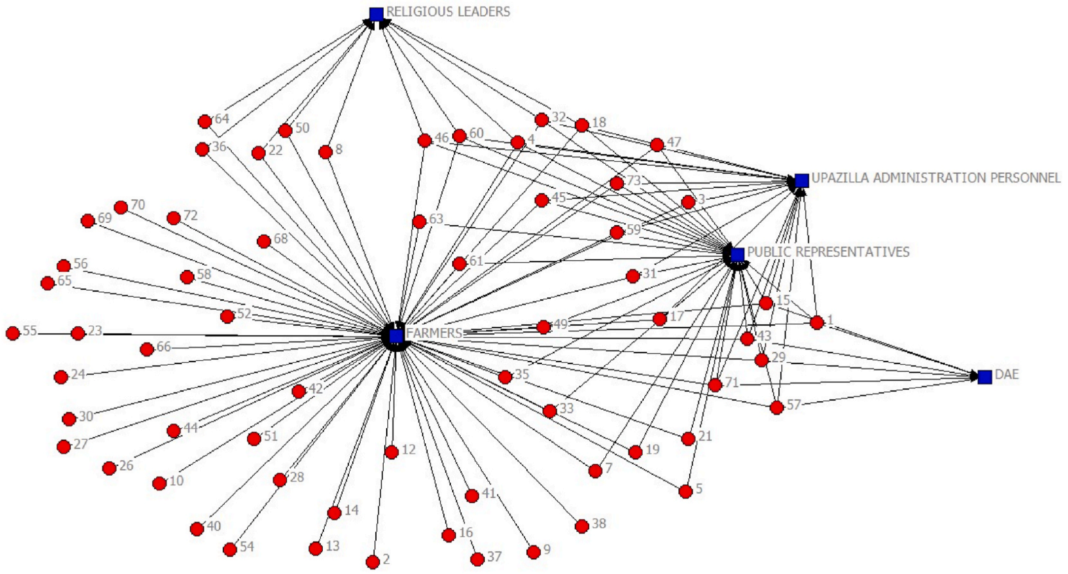

Fig. 5. DAE staff's knowledge and information sharing networks for harvesting activities.

Upazilla (sub-district) administration. We are also members of Upazilla administration, but we secure (crop-saving) embankment information because it will affect rice cultivation."

3.8. DAE staff's knowledge and information receiving networks about weather forecasting

DAE staff had a total of two actors in the networks to secure knowledge and information about weather forecasting (see Fig. 7). However, a large number of the DAE staff secured weather forecasting information of the haor region from DAE. A small portion of DAE staff collected weather forecasting information of the haor region from the Meteorological Department (see Fig. 8). The findings from both Key Informant Interviews and Focus Group Discussion suggest that the Meteorological Department forecasted weather and rain fortnightly and shared the information with the Ministry of Agriculture (MoA). The MoA sent a copy of the forecasting to the DAE, and DAE communicated that information to DAE staff through proper channels in a descending order. One DAE staff mentioned that *"DAE field level officers have no direct contact with the Meteorological Department. Therefore, it takes 15 days to receive the weather forecasting once it is forecasted. Sometimes, it takes even one month to reach the weather forecasting at the field level officers of DAE."*

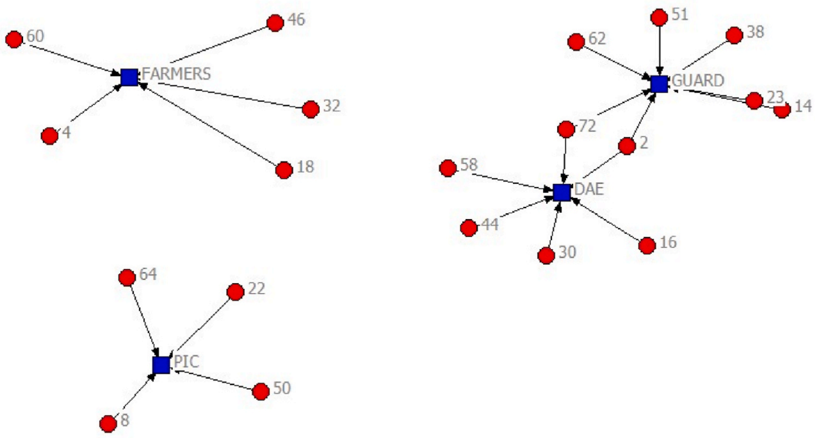

Fig. 6. DAE staff's knowledge and information receiving networks for crop-saving-embankments.

Fig. 7. DAE staff's knowledge and information sharing networks for crop-saving-embankments.

3.9. DAE staff's knowledge and information sharing networks about weather forecasting

DAE staff had a total of four actors in the networks to share knowledge and information about weather forecasting. However, a small portion of the DAE staff shared weather forecasting information of the haor region with other DAE staff. A negligible number of DAE staff shared weather forecasting information of the haor region with farmers, public representatives, Upazilla administration personnel (see Fig. 9).

3.10. Difference in number of actors between knowledge and information receiving and sharing networks of DAE staff

DAE staff secured agronomic information for rice cultivation from an average 5.23 actors and shared with an average of 4.67 actors, and there was no significant difference in the number of actors among these two groups of actors (see Table-2). However, DAE staff shared harvesting information for rice cultivation with significantly more actors (mean value 1.68) compared to the number of actors they used (mean value 1.15) to collect harvesting information for rice cultivation. On the contrary, DAE staff utilised significantly a greater number of actors (mean value 0.32) to secure information about crop-saving-embankment for rice cultivation than the number of actors they shared (mean value 0.00) the information about crop-saving-embankment for rice cultivation in the haor areas. According to the findings from Key informant interviews and Focus group discussion, the DAE staff argued that sharing and dealing with the crop-saving-embankment information is not the main job role of DAE staff. They only secured crop-saving-embankment information because it might influence flash flooding and hamper rice harvesting. DAE staff shared weather forecasting information with a significantly smaller number of actors (mean value 0.49) compared to the number of actors (mean value 1.00) they used to secure

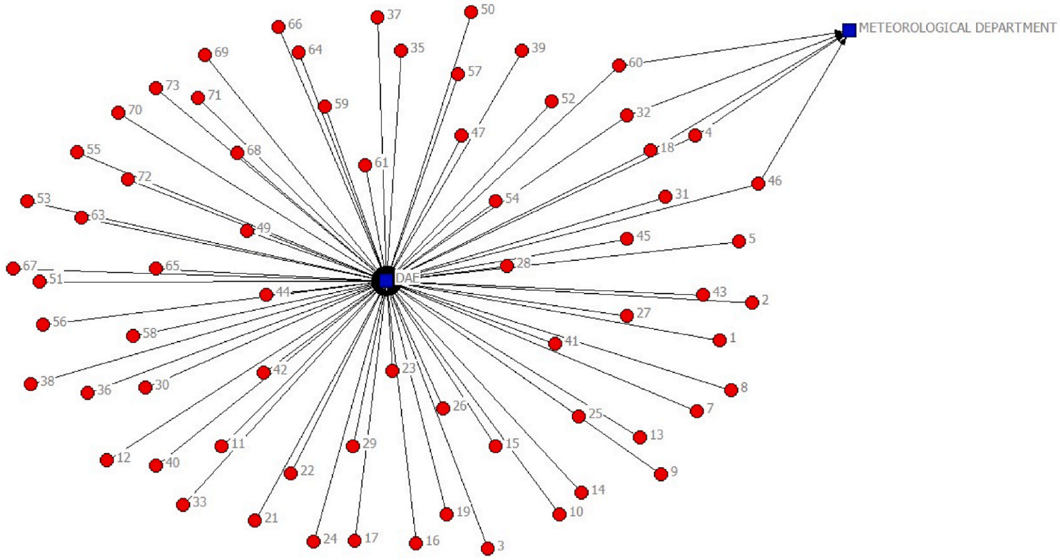

Fig. 8. DAE staff's knowledge and information receiving networks for weather forecasting.

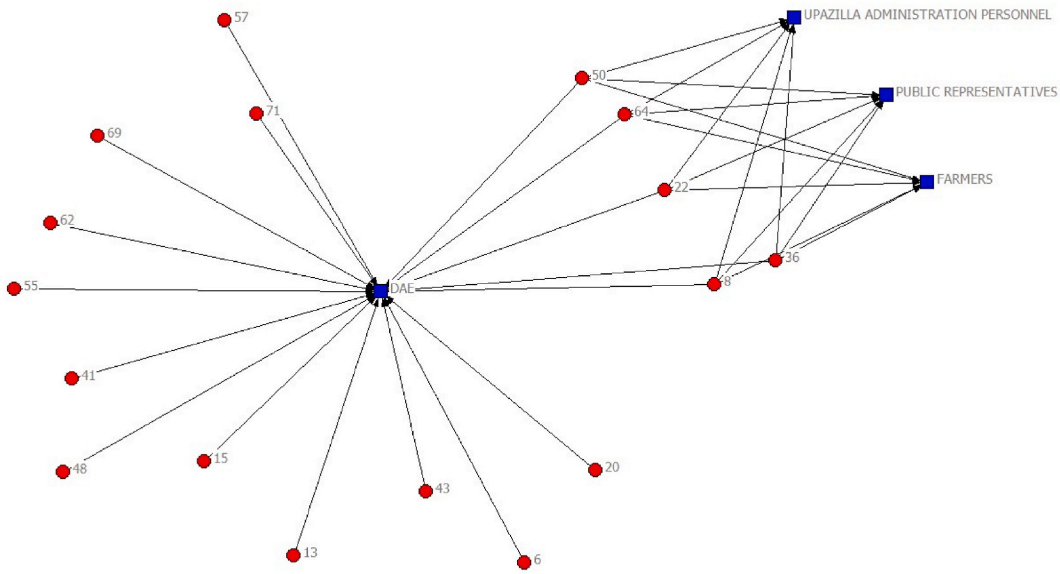

Fig. 9. DAE staff's knowledge and information sharing networks for weather forecasting.

Table 2
Difference in number of actors between knowledge and information receiving and sharing networks of DAE staff.

Type of knowledge and information	Number of actors used to secure knowledge and information (mean)	Information and knowledge shared with the number of actors (mean)	t value (mean difference)
Agronomic	5.23	4.67	3.149 NS
Harvesting	1.15	1.68	−3.110***
Crop-saving-embankment	0.32	0.00	5.139***
Weather forecasting	1.00	0.49	3.912***

Significance level: *** = $p < 0.001$, NS= Not significant.

Table 3
Communication channels used by DAE staff to receive knowledge and information.

Communication Channels	Actors (%)												
	Research institutions	AIS	PI wing	Private company	NGOs	ICT Ministry	Meteorological Department	DAE	PIC	Guards	Public Representatives	Farmers	Friends
Face to face	8.22	0.0	0.0	36.99	8.22	0.0	0.0	100	0.0	2.74	8.22	6.85	2.74
Cell phone calls	16.44	35.62	0.0	0.0	0.0	0.0	0.0	6.85	6.85	9.59	0.0	6.85	6.85
Books/manuals	86.30	13.70	65.75	42.47	0.0	0.0	0.0	58.91	0.0	0.0	0.0	0.0	0.0
Training	36.99	13.70	100	6.85	0.0	0.0	0.0	78.01	0.0	0.0	0.0	0.0	0.0
Leaflets	49.32	72.61	0.0	0.0	0.0	0.0	0.0	49.32	0.0	0.0	0.0	0.0	0.0
Seminar	8.22	0.0	8.22	0.0	0.0	0.0	0.0	15.10	0.0	0.0	0.0	0.0	0.0
TV/radio	0.0	0.0	0.0	20.55	0.0	35.62	6.85	0.0	0.0	0.0	0.0	0.0	0.0
Demonstrations	6.85	0.0	0.0	0.0	0.0	0.0	0.0	6.85	0.0	0.0	0.0	0.0	0.0
Apps	69.87		0.0	0.0	0.0	0.0	0.0	35.62	0.0	0.0	0.0	0.0	0.0
Websites	35.62	0.0	0.0	0.0	0.0	0.0	0.0	35.62	0.0	0.0	0.0	0.0	0.0
Facebook	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.61	0.0	0.0	0.0	0.0	6.85
Emails	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.85	0.0	0.0	0.0	0.0	0.0
Official letters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	0.0	0.0	0.0	0.0	0.0
Magazines	0.0	64.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

weather forecasting information of the haor region. Overall, DAE staff had a smaller number of actors in the networks to navigate information and knowledge about crop-saving-embankment for rice cultivation and weather forecasting that are highly relevant indicators for possible flash flooding in the haor region. It is also evident that DAE staff shared information and knowledge about flash flooding (including weather forecasting and crop-saving-embankment) with significantly smaller number of actors in the haor region (see Table-2).

3.11. Communication channels used by DAE staff to receive knowledge and information

DAE staff largely secured knowledge and information from various actors through face-to-face contact (see Table-3). They collected information from a total of eight actors in a face-to-face fashion. All the DAE staff secured information from DAE in a face-to-face fashion. According to one DAE staff member in a KII, *"After joining as a SAAO (front line DAE staff member), I have gathered various rice cultivation information from my senior officials e.g., Upazilla Agriculture Officers at their offices and during various field visits."* Among the DAE staff, 36.99%, 8.22%, 8.22%, 8.22%, 6.85%, 2.74% and 2.74% secured information from private company, research institutions, NGOs, public representatives, farmers, guards and friends, respectively, through face-to-face contacts. DAE staff used cell phone calls to receive information from a total of seven actors and 35.62% of them secured information from AIS thtough cell phone calls. The other actors were research institutions, DAE, PIC, guards, farmers and friends. DAE staff utilised written form of communication channels to secure information from a considerable number of actors. More than 86% of the DAE staff collected various information from research institutions through books and manuals. In a KII, one DAE staff noted that *"Bangladesh Rice Research Institute (a research organization in Bangladesh) sends various books and leaflets to our offices. These materials contain updated information about newly developed rice varieties. We get the idea of modern rice cultivation from these books and materials."* They secured information from a total of three actors through leaflets, including AIS, research institutions and DAE.

However, DAE staff received knowledge and information from a few actors through internet-based communication channels. In the case of using various apps (applications), DAE staff used apps to collect information from only two actors i.e., research institutions (69.87% and DAE (35.62%). According to one DAE staff, *"to know the fertilizer dose of various rice varieties, we take help from krisoker Janala app (A Digital Completion and Standardization of Plants' Problem Identification System developed by DAE)."* They only utilised websites to secure information from research institutions (35.62%) and DAE (35.62%). Through Facebook, DAE staff secured information from only two actors i.e., DAE (58.61%) and friends (6.85%). They only used Emails to receive information from DAE (6.85%). It is evident that DAE staff lacked in using internet-based communication channels to secure information from diverse actors.

3.12. Communication channels used by DAE staff to share knowledge and information

DAE staff largely shared knowledge and information with various actors through face-to-face contacts (see Table-4). They communicated information with a total of ten actors in a face-to-face fashion. All the DAE staff shared information with local representatives in a face-to-face fashion. They also used face-to-face contact to communicate with farmers, other DAE staff, religious leaders, school teachers, NGOs, Upazilla administration personnel, input dealers, private companies and local elites. DAE staff used cell phone calls to share information with a total of five actors, and 50.69% of them shared information with local representatives through cell phone calls. All the DAE staff communicated various information to farmers through organising training programmes. DAE staff shared information by distributing various leaflets with a total of four actors.

However, DAE staff shared knowledge and information with a negligible number of actors through internet-based communication channels. In the case of using various apps (applications), DAE staff used apps to share information with only one actor i.e., farmers (20.55%). They shared websites to communicate information with only farmers (6.85%). The findings from Key Informant interviews and Focus Group Discussion revealed that DAE staff believed that farming actors are not capable to operate internet-based channels and navigate required information and knowledge from various apps and websites. One DAE staff noted that "It is tough for most of the farmers to use these (internet-based) sources. But those who are younger farmers, I tell them to use these websites and browse them time to time." In regard to the sharing of various apps to the farming actors, another DAE staff mentioned that "If you give farmers these apps, they cannot use them to identify whether it is a disease or insect attack (in rice field). Farmers don't have the basic (scientific) knowledge on diseases and insects and how to operate the apps to identify insect/disease attack (in rice cultivation). For example, the photos for the symptom of blast (disease) are too close to the photos for the symptom of brown spot disease. Farmers cannot clarify this confusion but I can do. So, if I share apps with them, it does not mean that they can solve their problems by themselves." It is evident that DAE staff lacked in using written form and internet-based communication channels to share information with diverse actors.

4. Discussion

The findings indicate that DAE staff navigated less knowledge and information about flash flooding and its possible adaptation strategies. They had a few actors in their networks to secure information about crop-saving-embankments and weather forecasting. The research also showed that DAE was less effective to share crop-saving-embankments and weather forecasting information with the farming actors. But this information is very critical to help farming actors make informed decision about paddy harvesting and adapt to flash flooding. Previous research also revealed that Haor farmers lacked timely updates on rain in nearby hilly areas and water levels in adjacent rivers [7]; Haque and Azad 2022; [63]. Haor farmers would be better prepared and make informed decision if they had real time information about probable flash flooding including crop-saving embankments, water level in the rivers and rain forecasting

Table 4
Communication channels used by DAE staff to share knowledge and information.

Communication Channels	Actors (%)									
	DAE	Farmers	Local representatives	Religious leaders	School teachers	NGOs	Upazilla Administration personnel	Input dealers	Private companies	Local elites
Face-to-face	84.93	8.49	100	13.70	20.55	8.22	45.21	91.78	6.85	6.85
Cell phone calls	8.22	34.25	50.69	6.85	0.0	0.0	0.0	6.85	0.0	0.0
Training	8.22	100	0.0	0.0	0.0	30.14	0.0	8.22	0.0	0.0
Leaflets	8.22	23.29	8.22	8.22	0.0	0.0	0.0	0.0	0.0	0.0
Field days	8.22	68.38	8.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Miking	0.0	21.92	0.0	6.85	6.85	0.0	0.0	0.0	0.0	0.0
Lesson plans	8.22	6.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uthan Boithok[a]	0.0	64.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Motivational tours	0.0	43.84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Fairs	0.0	8.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FIAC centres[b]	0.0	8.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apps	0.0	20.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Websites	0.0	6.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a] Uthan Boithok = Discussion at the farmers' home yard.
[b] FIAC centres = Farmers' Information and Advice Centre.

[64–66]. Therefore, EAS need to navigate flash flooding information and knowledge effectively.

Traditionally, EAS performs technology transfer roles and typically advises farmers on the technical aspects of rice cultivation, including fertilizer management, insect and disease controls. In the context of flash flooding, it is evident that dealing with only technical issues of rice cultivation is not enough to secure sustainability in rice farming. To perform knowledge brokering role effectively, EAS staff needs to embrace new mandates and perform a variety of functions beyond research uptake and technology transfer. It is evident from this study that dealing with crop-saving-embankments and weather forecasting are beyond the traditional tasks of EAS staff and apparently outside of their focal points. Therefore, EAS staff might face the ambiguity of functions while embracing new roles in a flash flooding context. EAS staff might confuse whether they need to go beyond technical agriculture issues and work on embankment and weather issues. In addition, there might be significant concerns about the legitimacy to deal with crop-saving-embankments and weather forecasting information for flash flooding adaptation. Other organizations and actors who already deal with crop-saving embankments and weather forecasting by their own might be less interested in cooperating EASstaff and supporting knowledge partnership with them. But previous research has strongly emphasized the significance of knowledge partnership by the EAS staff to help farming sector adapt to climate change risks and uncertainties [46]. Moreover, farming actors who usually perceive EAS staff as agents for dealing with technical issues of rice cultivation might not accept EAS staff as a legitimate and credible authority to perform these "out of the box" role and deal with flash flooding information. These issues of legitimacy were also acknowledged by other studies where EAS staff faced legitimacy concerns while working with government and other actors to perform knowledge brokering and enhance innovation [34,67].

To perform knowledge brokering roles in a flash flooding context, EAS staff need to decide on their mandates and functions. Consequently, EAS staff should clarify other farming actors about EAS roles, make farming actors aware and prepare what to expect from the EAS staff [67]. Moreover, to establish legitimacy among the farming actors, EAS staff should refrain from over management and control over knowledge landscape and allow every actor to achieve their respective interests and goals [68]. Historically, EAS staff work and live with the farming communities in the rural areas that allow EAS staff to secure field level information and knowledge and vice versa [69]. Therefore, EAS staff can utilize their local position and connection as an opportunity and establish themselves as effective knowledge brokers to deal with issues beyond technology transfer and research uptake in a flash flooding context.

The results revealed that DAE staff used internet-based communication channels to secure and share information and knowledge from a few actors. But internet-based communication channels have a number of significant advantages over other forms of communication channels [70,71]. Internet-based communication channels can be utilised to secure and share information and knowledge from a mass number of people and actors [72]. Moreover, these channels are critical to collect and communicate information within a very short time [73]. Flash flooding adaptation requires real time information of the rainfall in the nearby hilly areas, water level in the haor rivers and crop-saving embankments. Therefore, internet-based communication channels can reach real time information about probable flash flooding among mass people so that they can be well prepared and make informed decisions to combat flash flooding. Consequently, EAS staff should widely use internet-based communication channels to navigate knowledge and information about flash flooding adaptation effectively. Previous studies also argued that internet-based communication channels and sources play important roles for the EAS staff to perform various knowledge brokering tasks and enhance innovation in the farming sector [74–76].

EAS staff should raise the issue of using internet-based communication channels to the policy makers and secure the required funding, resources, infrastructure and support for capacity building of both EAS staff and other farming actors to use these channels effectively. The findings revealed that farming actors had a lack of capacity to use various apps and websites to navigate the required information for flash flooding adaptation. Previous studies also identified that farmers have a lack of capacity to get access and utilize various extension services provided through internet-based communication channels [77]. EAS staff should make the farming actors aware about the availability of various apps and websites associated with rice cultivation and flash flooding adaptation. EAS staff need to jointly implement various extension approaches and programmes with other organizations, such as research institutes, Information and Communication Technology (ICT) ministry, to build the capacity of the farming actors to deal with various inter-based communication channels and secure the required knowledge and information. In addition, EAS need to share various knowledge and information about flash flooding adaptation among the farming actors through internet-based communication channels.

5. Conclusion

The objective of this research is to investigate the means of brokering knowledge by the EAS to help farming sector adapt to flash flooding. The results show that DAE staff contacted a large number of actors to collect and share rice production- and harvest-related knowledge and information. On the contrary, they secured and shared less information about possible flash flooding including weather forecasting and crop-saving-embankments. The findings also revealed that DAE staff mostly communicated with various actors through face-to-face fashion. They missed the opportunity to use internet-based communication channels to rapidly navigate information and knowledge about possible flash flooding and its adaptation strategies.

Policymakers need to develop policies to broaden the roles of EAS staff that go beyond research uptake and include various knowledge brokering tasks. Adequate policy and necessary arrangements are needed so that EAS staff can navigate knowledge and information from other actors, such as the Meteorological department for weather and rainfall forecasting. Policy makers and donors should provide fundings, resources, and facilities and develop infrastructure for the broad utilization of internet-based communication channels and resources by the EAS staff and other farming actors.

Future research is critical to investigate what particular capacity and skill sets are required by EAS staff to deal with non-technical aspects of farming (*e.g.* crop-saving-embankments, weather forecasting) in a flash flooding context. It is also essential to understand how EAS staff can effectively manage misinformation while navigating knowledge and information through internet-based communication channels in a flash-flooding context.

Author contribution statement

Md Kamruzzaman: Data curation, Formal analysis, Resources, Conceptualization, Methodology, Software, Visualization, Writing –original draft, Writing –review & editing.. Ataharul Chowdhury: Conceptualization, Methodology, Resources, Writing –re- view & editing.

Data availability statement

Data will be made available on request.

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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Appendix A. Supplementary data

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