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Barriers, Challenges, and Requirements for ICT Usage among Sub-Assistant Agricultural Officers in Bangladesh: Toward Sustainability in Agriculture

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Abstract: The present work is the first detailed study of sub-assistant agricultural officers (SAAOs), who are key players in delivering agriculture extension services in Bangladesh. We determined the status of information and communication technology (ICT) usage, knowledge gaps, approaches and tools for information delivery, barriers and obstacles to ICT usage, requirements for adoption, and possible solutions for efficient agriculture extension advisory services. We surveyed key respondents (SAAOs, n = 117) from nine sub-districts under the six administrative districts of Bangladesh with a semi-structured questionnaire. We found that 73.2% of all extension officers had basic knowledge of ICT. We observed that the most effective tool for information dissemination was field visits (90.90%, Moulvibazar district) and the most frequent extension approach was training and workshops (77.31%, Dhaka district). The best sources for information collection were broadcast media and social media. While delivering information, difficulty was found due to technical obstacles in Gazipur district, Rajshahi district, Sylhet district, and Dhaka district among 60% to 70% of SAAOs. However, farmers' ignorance was reported in both Feni district and Moulvibazar district (36.36%). A shortage of computers in Gazipur district (56.25%) was an essential barrier to ICT usage for extension services. A major challenge in using ICT applications in Dhaka district was inadequate training support (64.51%). Mobile devices, internet connectivity, updated ICT applications, and a farmers' database were the most important supports needed for the SAAO's skilled advisory activities. In conclusion, our results and recommendations will help to redesign policies to improve infrastructure and allocate funding for capacity and skill development and ICT-based innovations in this sector to achieve sustainable extension and advisory services and attain food security in Bangladesh.

Keywords: ICT; SAAO; barriers and challenges; agriculture extension; Bangladesh; sustainable agriculture; transformation

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Citation: Ahsan, M.B.; Leifeng, G.; Safiul Azam, F.M.; Xu, B.; Rayhan, S.J.; Kaium, A.; Wensheng, W. Barriers, Challenges, and Requirements for ICT Usage among Sub-Assistant Agricultural Officers in Bangladesh: Toward Sustainability in Agriculture. *Sustainability* **2023**, *15*, 782. https://doi.org/10.3390/su15010782

Academic Editors: Constantina Costopoulou, Sotiris Karetsos, Maria Ntaliani and Konstantinos Demestichas

Received: 22 November 2022
Revised: 26 December 2022
Accepted: 28 December 2022
Published: 31 December 2022

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1. Introduction

ICT in agriculture is a developing field specializing in the enhancement of agricultural extension, which is referred to as "e-agriculture", through the use of applications from a rural perspective with a common focus on agriculture extension and advisory systems [1–4]. Agricultural information and communication technology and knowledge delivery services (including agricultural extension, consultancy, and agricultural information services) can

be used to disseminate new technology among extension agents to distribute new and current farming information that is transmitted within the agricultural sector [5,6]. This technology is supposed to play a role in fighting global poverty, including in the rural areas of developing countries, where mainstream survival is dependent on agriculture [7]. ICT applications can distinguish and address some of the many issues in the sector of agriculture to facilitate farming, such as extended droughts, outbreaks of pests and diseases, seasonality, the geographic dispersion of farming, knowledge asymmetry, and high transaction costs, with decision making that may be useful for rural development [8–10]. Agricultural technology is generated by research institutes, universities, government and non-government organizations, and business sectors [11]. However, because of weak links between studies and extension services and a lack of networking among scientists, researchers, and extension agents, the adoption of cutting-edge agricultural technology by extension workers has been hampered [12,13]. Agricultural advisory and extension services can be effective tools for dispersing timely and accurate information about weather, farming, and new technologies that could revolutionize rural communities and improve their livelihoods. [7,14].

Agricultural extension services consist of transferring quality information to farmers; guiding and educating extension officers for better production and income in terms of time, cost, and distance; and providing access to new technologies, production inputs, and market information [15–17]. Additionally, they have a direct and indirect effect on poverty alleviation and can help employ generations through the commercialization of agriculture [18]. Experts define ICT as a collection of applied sciences that combine factual technology devices such as phones and telecommunication networks, which are essential tools for accelerating the development of the economy in a wide range of contexts [19–22]. The majority of developing countries are currently shaping massive ICT infrastructures that can eventually transform extension officers into facilitators who serve as authorities in community organizations, develop human resources, find solutions, and instruct farmers [23,24]. Furthermore, extension agents play a modulating role in agricultural communication and service delivery for rural development [25].

The new extension policy in Bangladesh promotes strengthening public–private partnerships and researching farmer–field worker links based at each Union Parishad [26,27]. Bangladesh's agriculture extension system was primarily run by research institutions and universities that developed agricultural extension technologies [28]. Sub-assistant agriculture officers (SAAOs) are the field-level extension staff at the Department of Agriculture Extension (DAE) under the Ministry of Agriculture (MoA), Government of the People's Republic of Bangladesh. They provide extension services to farmers and local communities and serve as a link between farmers and government extension services. They are usually recruited by the government and have a basic educational background [29].

There are four groups (public, private, NGO, and scheduled bank farmers) of extension service providers, who approach extension through training, demonstration, field visits, and contract farming with group formation [30]. In Bangladesh, access to agricultural information sources is confined to agricultural libraries, analysis stations, and national and international agricultural information [31]. In recent years, ICT—as a true source of information provided by the government, NGOs, personal organizations, agricultural research organizations, and communication centers in Bangladesh—has become increasingly concerned with extension services tailored to the specific needs of grassroots farmers [30,32].

Different government organizations, such as the Department of Agriculture Extension (DAE) and the Agricultural Information Service (AIS), and non-government organizations, such as mPower and the Bangladesh Institute of ICT Development (BIID), have taken ICT initiatives to provide up-to-date information to SAAOs as well as to farmers [33]. TV channels, Bangladesh Betar (radio), community radios, and the DAE and AIS of the MoA are engaged together in providing ICT-based services to enhance extension officers' and farmers' support through their programs [34,35]. A2i (Access to Information), initiated by the Prime Minister's workplace; the Agriculture Information Communication Center

(AICC); the Farmers' Information and Advisory Center (FIAC); the Union Information Service Center (UISC); the Krishi Call Center; and a web-based site (www.ais.gov.bd) in Bengali also provide essential agricultural services to these extension officers throughout the country [36,37]. A number of organizations also offer support to people engaged in agriculture extension to enhance the multidirectional elements of rural livelihoods [38,39].

The majority of information seekers (extension agents and farmers) in rural parts of developing countries prefer informal to official sources of information [40]. In recent years, in Bangladesh, various tools have been used along with the training and visit program (T&V) and farmer field school (FFS), as well as without visiting farmers face-to-face. As the ratio of farm families to extension agents is inadequate, it is difficult to visit each farm family in a day [41,42]. Moreover, they are unable to make use of the advantages offered by public and private access to ICT due to a lack of regionally relevant material and content in their local and native languages [43]. In terms of searching, the use of global, national, and local sources depends on their need for information to embrace new technologies around them [44,45].

A study on the correlation between the age, income, and service experience in these officers and their communication exposure to e-agriculture was conducted, where related personal knowledge was considered a factor an organizational constraint in Bangladesh [46]. Another study showed that insufficient organizational support hindered the use of ICT by agriculture extension officers in Bangladesh; however, the detailed reasoning behind the intention to use this tool is unclear and unexamined [31]. In addition, Kamruzzaman et al. [47] investigated the preferences and purposes of using social media among extension officers in Bangladesh and recommended further research on detailed information and knowledge flow in social media for agriculture advisory services. Hamid et al. revealed detailed problems faced by these extension officers in Bangladesh, including personal, field- and farmer-oriented, ICT-related, and job satisfaction-related problems, among others. In addition, details on factors related to ICT were uncovered [48]. Although several studies have been conducted on ICT in extension, few have mentioned the needs and obstacles faced by sub-assistant agricultural officers while disseminating agricultural information to farmers. In this study, we focused on field-level sub-assistant agricultural officers who had a direct connection to farmers or farm families. The aim of this research was to identify the obstacles and barriers faced by these officers, along with their needs for ICT to address better integration in agriculture extension. In the Bangladesh context, it is necessary to assess the current approaches concerning their barriers and requirements, which may represent a possible solution for refining expertise by using ICT in agriculture [49].

This research was an attempt to determine the current status, barriers, and requirements of ICT usage and adoption by field-level sub-assistant agricultural officers (SAAOs), who provide agricultural extension services to farmers in Bangladesh. We aimed to:

(i) Identify the current situation of ICT usage in Bangladesh;
(ii) Identify extension officers' perceptions of the role of ICT in agriculture extension and how it helps fulfill their information needs;
(iii) Identify the obstacles, barriers, and challenges faced while using ICT tools;
(iv) Identify the ICT-oriented needs of the extension officers;
(v) Provide possible recommendations to address the ICT needs of SAAOs.

2. Materials and Methods

Our study consisted of three levels of operation: In the first step, we attempted to identify the barriers faced by sub-assistant agricultural officers in the field. Then, we pinpointed the needs and support necessary for sub-assistant agricultural officers that could help improve their work efficiency. Finally, we conducted focused group discussions with agricultural experts and professionals in relevant organizations. This study was based on primary data collected during 2018 by the present authors from 117 respondents (SAAOs, key respondents) who were approached at the venues of training programs at their workplace. The respondents were chosen from the Department of Agriculture Extension in sub-districts under the different administrative districts in Bangladesh. To

conduct this survey, agricultural patterns, seasons, soil types, tidal and coastal activity, and flooding patterns were all taken into consideration and used to determine agroecological zones in Bangladesh [50]. Nine sub-districts from the six administrative districts in the country were selected, belonging to four agroecological zones based on the following categories: (i) inland freshwater ecosystems (Figure 1A), (ii) terrestrial forest ecosystems (Figure 1B,C), (iii) artificial or man-made ecosystems (Figure 1D,E), and (iv) coastal and marine ecosystems (Figure 1F) [51]. The number of respondents (n) from the respective sub-districts is included in the caption of Figure 1. Respondents were asked a series of questions regarding their demographic characteristics and their use, needs, processes, approaches, barriers, challenges, and factors related to ICT usage in agriculture extension and advisory services in the selected sub-districts. The questionnaire was given hand-to-hand and used for data collection. In the questionnaire, a 'Likert scale analysis', i.e., multiple choice variables, was used to increase its user-friendliness and measure responses from the surveyed sub-districts. The different items in the questionnaire are shown in Table 1. A participatory ranking approach was implemented using a Likert scale ranging from strongly positive to strongly negative accordingly for each question (mentioned in the Results section) and evaluated by the selected respondents in all study districts. Suggestions were also listed by a focused group discussion between officials, experts, researchers, professors, and scientists from both public and private organizations from relevant fields during this study.

Before conducting the final survey, the questionnaire was reviewed by the relevant experts and field-tested in the Dhaka district. The results of the test were not included in this study. Using Microsoft Excel, collected data were analyzed through descriptive statistical methods, including mean values, percentiles, frequencies, bar graphs, column graphs, and pie charts.

Dependent variable: The adoption of ICT was the dependent variable in this study and was measured using a dummy variable.

Independent variable: The following independent variables were used in this study: gender, age, knowledge, use of ICT, farmers' needs, and mobile type. The descriptions, types, and measurements of the variables are presented in Table 1.

Table 1. Description of the variables used in the logit model statistical analysis.

Variable	Type	Definition and Measurement
Dependent variable		
Adoption of ICT	Dummy	Equal to 1 if they adopted, 0 otherwise
Explanatory Variables		
Gender	Dummy	Equal to 1 if male, 0 otherwise
Age	Continuous	Age (number of years)
Knowledge of ICT	Dummy	Equal to 1 if they have the basic knowledge, 0 otherwise
Use of ICT	Dummy	Equal to 1 if they already use ICT, 0 otherwise
Farmer's Need	Dummy	Equal to 1 if they have the need to use ICT, 0 otherwise
Mobile Type	Dummy	Equal to 1 if they use a smartphone, 0 otherwise

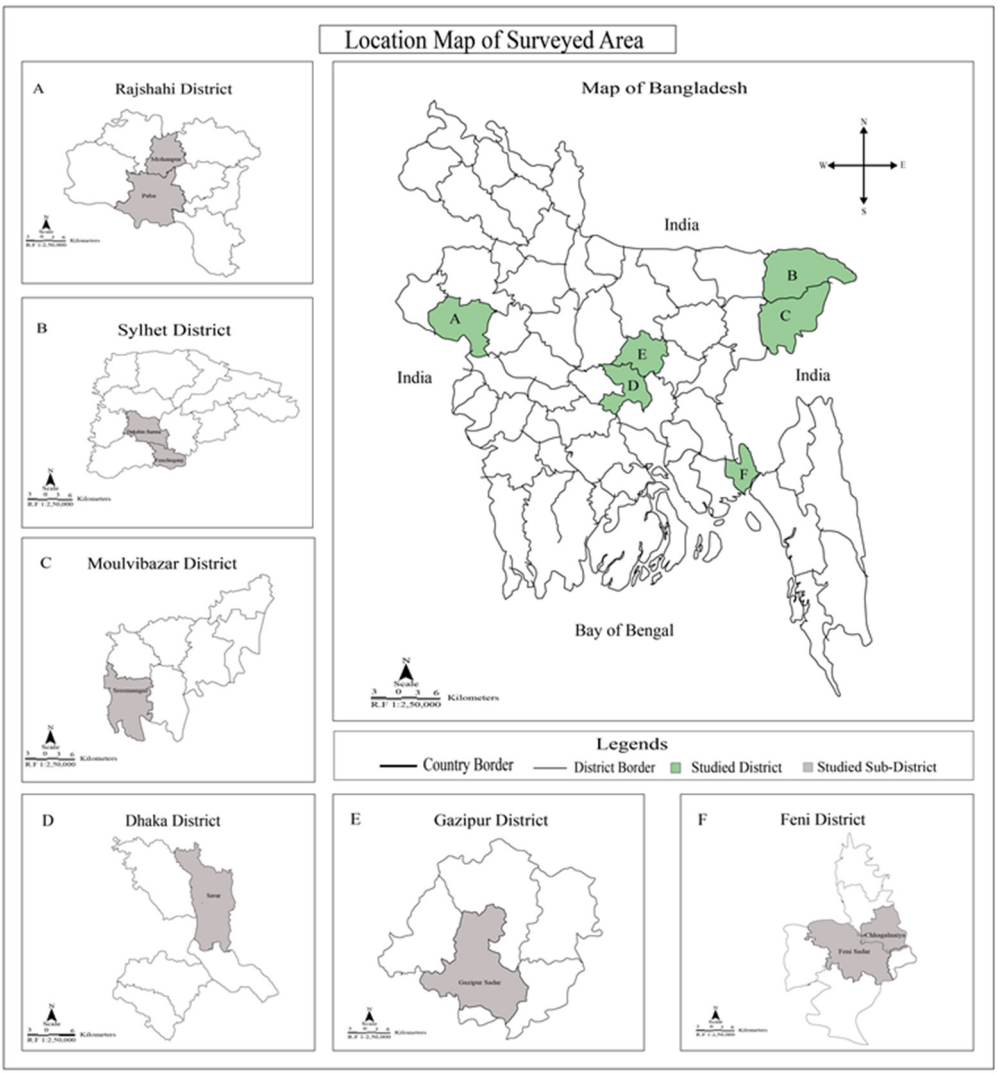

Figure 1. Study areas in Bangladesh. Studied districts are shown as green-colored regions on the map of Bangladesh. (**A**) Paba (n = 10) and Mohanpur (n = 9) sub-districts in Rajshahi district; (**B**) Dakshin Surma (n = 11) and Fenchuganj (n = 7) sub-districts in Sylhet district; (**C**) Sreemangal (n = 11) sub-district in Moulvibazar district; (**D**) Savar (n = 31) sub-district in Dhaka district; (**E**) Gazipur Sadar (n = 16) in Gazipur district; (**F**) Feni Sadar (n = 10) and Chhagalnaiya (n = 12) sub-districts in Feni district.

2.1. Data Analysis Model

When analyzing the determinants of ICT adoption among the SAAOs, the dependent variable was either binary or categorical. This implies that they either adopted or did not adopt ICT. Normally, this is represented by one or zero, where one represents adoption and zero represents no adoption. In addition to the logistic regression modeling framework, several other modeling frameworks can be used to model the relationship between a categorically dependent variable and a number of independent variables. These include probits, tobits, or even ordinary least squares or discriminant function analysis. Logit and probit are two binary choice models that are commonly used in the literature to analyze the adoption of ICT. In empirical work, both the logit and probit models provide consistent, efficient, and asymptotically normal estimates and produce very similar prediction results. Instead of attempting to determine their choice, we observed information about their choice (to adopt or not adopt) and their characteristics to estimate the probability of their choice conditional on their characteristics using the logit model, which has advantages such as good approximation to a normal distribution and analytical convenience [52,53].

In comparison to the preceding frameworks, the logistic regression modeling framework is more general, provided that the independent variable is not restricted to a categorical dependent variable or limited to a single independent variable [54]. Typically, when analyzing qualitative results, a choice must be made between the logit and probit models. The statistical similarities between the logit and probit models, according to Amemiya [55], make choosing between them difficult. According to Maddala [56] and Kmenta [57], many authors agree that the logistic and cumulative normal functions are very close in the mid-range, but the logistic function has slightly heavier tails than the cumulative normal functions. The logistic and probit formulations are quite comparable, as shown by Pindyck and Rubinfeld [58] and Gujarati [59], with the main difference being that the former has slightly fatter tails; that is, the normal curve approaches the axes faster than the logistic curve. According to Hosmer and Lemeshew [60], a logistic distribution (logit) has an advantage over others in the analysis of dichotomous outcome variables because it is a mathematically flexible and easily applied model that yields a meaningful interpretation. As a result, a logistic regression model was chosen as the best modeling framework. The dependent variable guided the estimation of the logistic regression model, as the goal was to identify the factors influencing ICT adoption. The independent variables included the socioeconomic characteristics of the SAAOs. A list of dependent and explanatory variables is displayed in Table 1.

2.2. Logistic Regression

The logistic regression (LR) model seeks to establish a link between an outcome-dependent variable (adopt or not adopt) and a set of its categorical and continuous characteristics. The cumulative logistic distribution function has a non-linear form, which gives rise to difficulty in interpreting the coefficients. For the purpose of interpretation, it is normal to write the model in terms of the log-odds ratio [61]. A binary choice model based on the method of maximum likelihood was specified. The dependent variable of this model was the adoption of ICT. Since the dependent variable was dichotomous, OLS could not be used. Therefore, the following type of logit model was used for this study, modified with a logit transformation so that the estimated model became a linear function of the explanatory variables. The logistic regression is depicted in Equation (1).

$$log\left[\frac{p_i}{1-p_i}\right] = \beta_0 + \beta_1 x_i + \beta_2 x_2 + \cdots + \beta_n x_n \quad (1)$$

Let *pi* be the probability of the default of an adopter i and β_0 represent the intercept term. β_i represents the respective coefficient in the linear combination of independent variables x_i for i = 1 − n, which include the SAAO's characteristics. The dependent variable is the logarithm of the odds of the ratio of the two probabilities of the outcome of interest, $log\left[\frac{p_i}{1-p_i}\right]$. Given the set of independent variables, the probability of a value of one (1) for the dichotomous outcome is shown in Equation (2):

$$\frac{p_i}{1-p_i} = \frac{1}{1+e^{-z}} \quad (2)$$

where,

$$z = \beta_0 + \beta_1 x_i + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon \quad (3)$$

The objective of logistic regression is to determine the conditional probability of a specific observation within a class given the values of the independent variables of the adopted applicant. The statistical software Stata (version 14.0) was used for analyzing data with the logit model to identify factors influencing the adoption of ICT by SAAOs.

3. Results

3.1. Demography of Key Respondents

The demographic distribution of the surveyed SAAOs is shown in Figure 2. Among the key respondents, the gender distribution showed that the number of females (65%) was higher than the number of males (35%; Figure 2A). On average, 1476.47 and 1475.37 farmers were served by each male and female respondent, respectively. In addition, the average age of both males and females in this study was above 41.03 ± 10.34 (mean ± stdev) years (Figure 2B).

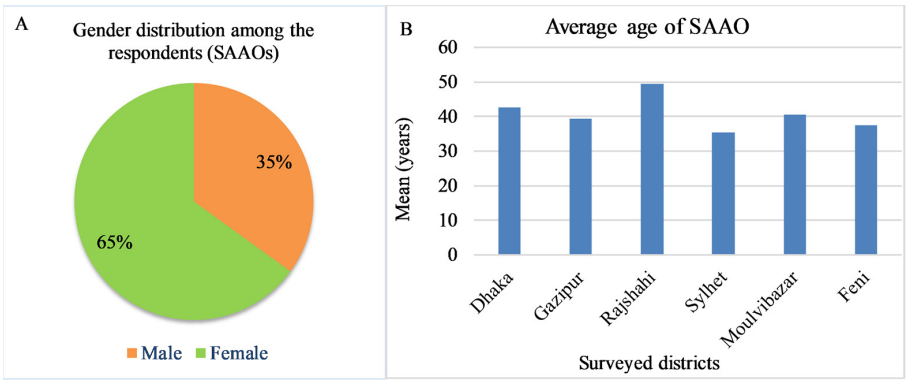

Figure 2. Demographic distribution of surveyed SAAOs. (**A**) Gender-based distribution in different districts. (**B**) Average age.

Among the surveyed districts, the average age was above 40 years in Rajshahi district (49.47 years), Dhaka district (42.61 years), and Moulvibazar district (40.45 years). However, the average age in the following districts was less than 40 years: Gazipur district (39.31 years), Feni district (37.59 years), and Sylhet district (35.5 years) (Figure 2B). The oldest and youngest SAAOs were from the Rajshahi district and Sylhet district, respectively. When we asked SAAOs about their basic knowledge of ICT, we found that 73.2% of all respondents agreed to having basic knowledge, while 87% of them confirmed that ICT is useful for the delivery of extension services to farmers. We also found that 45.16% and 42.10% of respondents used basic mobile phones in Dhaka district and Rajshahi district, respectively (Figure 3).

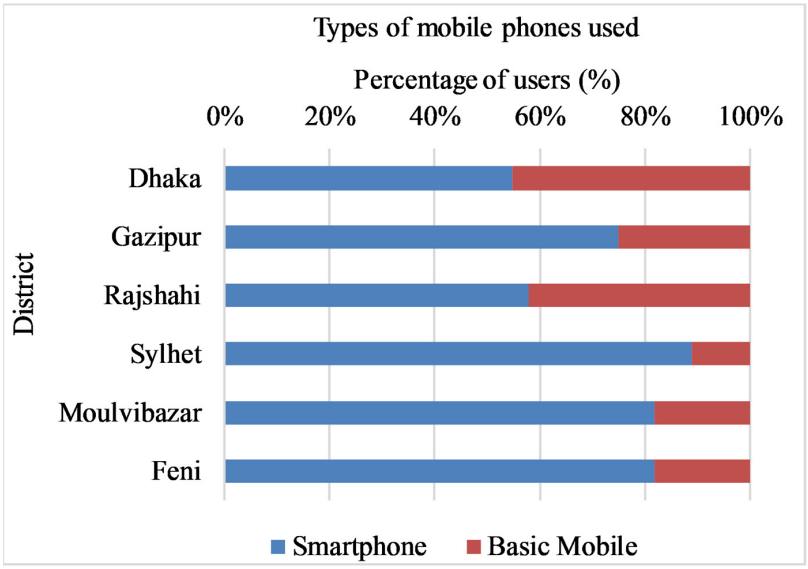

Figure 3. Types of mobile phones used.

3.2. Perception of Delivering Agricultural Information According to Farmers' Needs

Most of the SAAOs were found to be satisfied with their delivery of agricultural information to farmers. To investigate this, we calculated their perception ('yes' or 'no' query) of providing the necessary information to the farm families in those areas. In Figure 4, it can be seen that the highest positive response (95%) was observed in Sylhet district for delivering the information needed according to farmers' desires. However, SAAOs from Moulvibazar district, Gazipur district, Dhaka district, and Feni district felt that they could serve up to 82%, 75%, 65%, and 86% of the farmers' needs, respectively. Notably, they could only provide 58% of the information needed at the grassroots level in Rajshahi district.

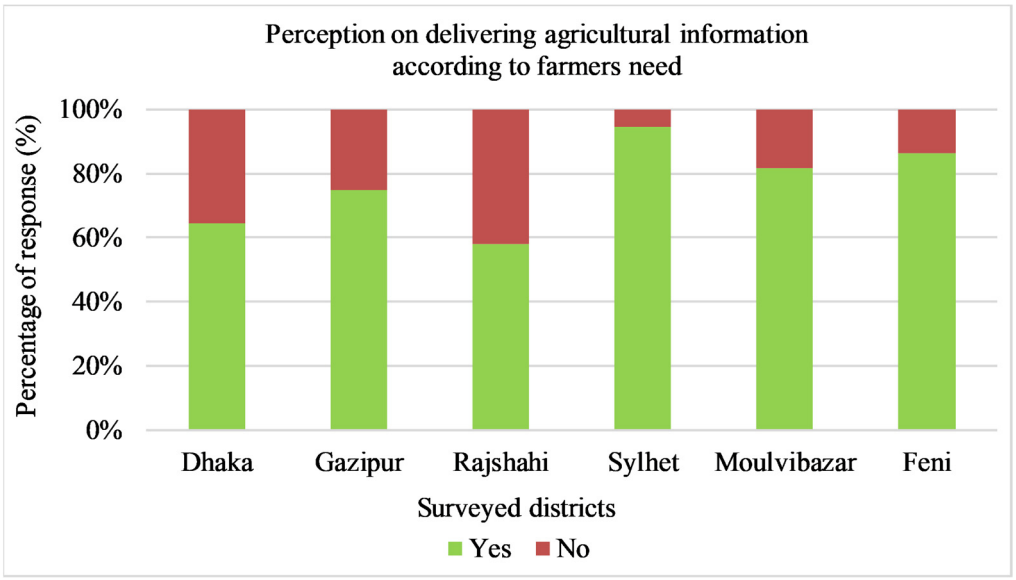

Figure 4. Perception of delivering agricultural information according to farmers' needs.

3.3. Effective Tools to Disseminate Agricultural Information

The graphical representation below shows that the dissemination of agriculture-related information among farmers varied depending on their choice of tools (Figure 5).

The evaluation of answers was carried out using a four-point Likert scale that ranged from 1 (most effective) to 4 (ineffective) in terms of sharing information with farmers. Here, field visits were found to be the most effectively utilized tool to disseminate agriculture-related information among the farmers in the surveyed districts, where responses of 90.90%, 81.25%, 77.77%, 73.68%, 72.72%, and 70.96% were observed in Moulvibazar district, Gazipur district, Sylhet district, Rajshahi district, Feni district, and Dhaka district, respectively. On the other hand, the training program was ranked as an effective tool in Sylhet district (66.66%), Moulvibazar district (45.45%), Dhaka district (32.25%), Feni district (31.81%), Rajshahi district (21.05%), and Gazipur district (18.75%). In contrast, according to the SAAOs, tool selection, mobile phones, and the internet are ineffective. In Sylhet district, Feni district, and Moulvibazar district, the sub-assistant agricultural officers ranked the internet as being highly effective; their responses were 88.88%, 86.36%, and 81.81%, respectively. In addition, using a mobile phone was ranked as an effective tool in Gazipur district (68.5%), Rajshahi district (52.63%), Dhaka district (48.38%), Feni district (45.45%), and Moulvibazar district (36.36%).

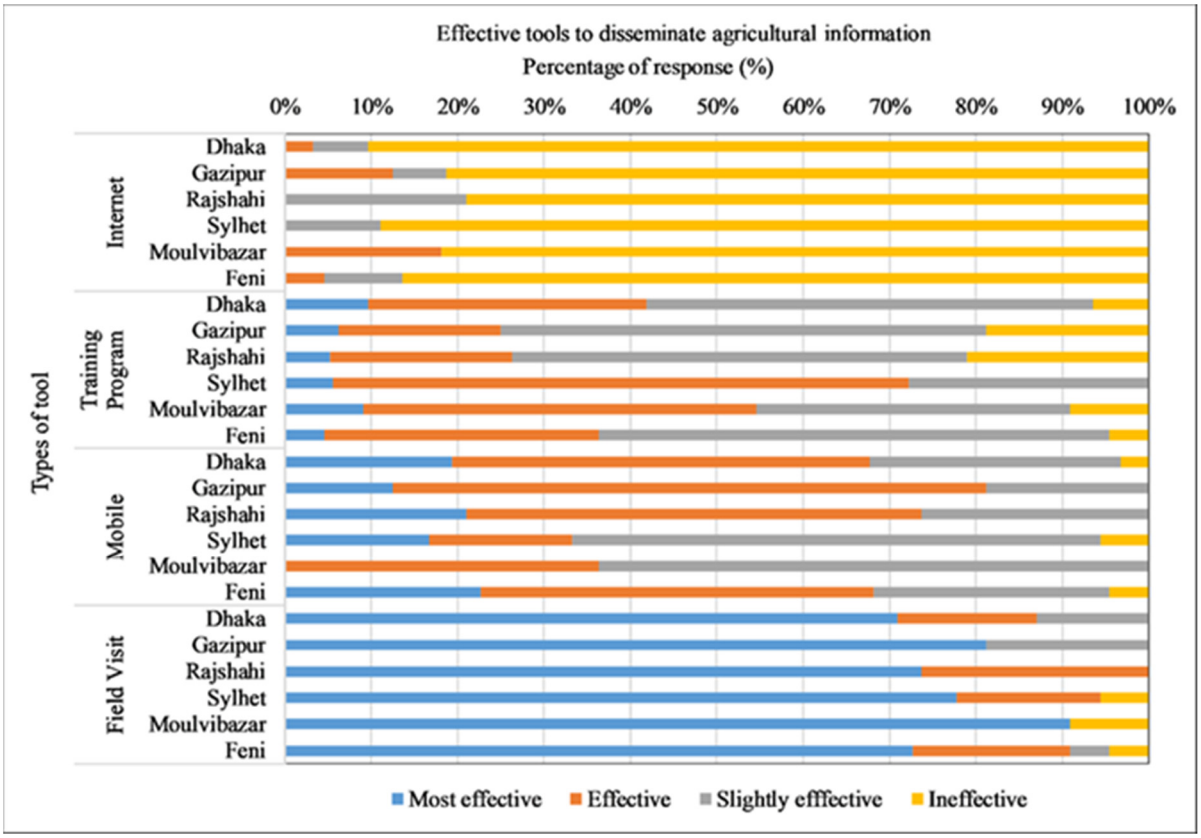

Figure 5. Distribution of the four-point Likert scale response types, expressed as percentages, for questions on the use of effective tools to disseminate agriculture information to the farmers.

3.4. Extension Approaches to Disseminate Agricultural Information to Farmers

Respondents' answers about the types of extension approaches used to disseminate agricultural information were measured on a three-point Likert scale that ranged from 1 (frequently) to 3 (rarely) (Figure 6). According to their regular use of extension approaches, training and workshops were frequently used in Dhaka district (77.31%), Moulvibazar district (90.90%), and Rajshahi district (63.15%). On the other hand, farmer field school (FFS) was frequently used in Sylhet district (72.22%), Gazipur district (75%), and Feni district (54.54%). Over 90% of respondents in all the districts evaluated projects as 'rarely' used for extension approaches, except in Dhaka district (9.67%, marked as frequently).

3.5. Satisfaction with Seeking Agricultural Information from Different Sources

In terms of satisfaction with sources for new information about agriculture, answers were measured on a five-point Likert scale that ranged from 1 (highly satisfied) to 5 (highly dissatisfied) (Figure 7). According to the results, it was reported that training and workshops were the best source in Gazipur district (81.25%), Rajshahi district (73.68%), and Moulvibazar district (72.72%). In contrast, the monthly newsletter was considered as a highly unsatisfactory information source in Sylhet district (94.44%), Dhaka district (87.09%), and Feni district (86.36%). Online/social media was found to be a satisfactory source for obtaining agricultural information in Gazipur district (50%), Rajshahi district (42.10%), Sylhet district (33.33%), and Moulvibazar district (27.27%). Among all districts, mass media and the monthly newsletter were rated as neutral or unsatisfactory sources of agricultural information. Mass media received a neutral response in Moulvibazar district (54.54%), Rajshahi district (47.36%), and Dhaka district (35.48%). The monthly newsletter was ranked as dissatisfied in Rajshahi district, Gazipur district, and Feni district at 15.78%, 12.5%, and 9.0%, respectively. The handbook was rated as highly unsatisfactory in Gazipur

district (18.75%), Sylhet district (5.55%), and Rajshahi district (5.26%); however, it was rated as highly satisfactory in Moulvibazar district (45.4%), Sylhet district (33.33%), Feni district (31.81%), Rajshahi district (26.31%), Dhaka district (25.80%), and Gazipur district (25%).

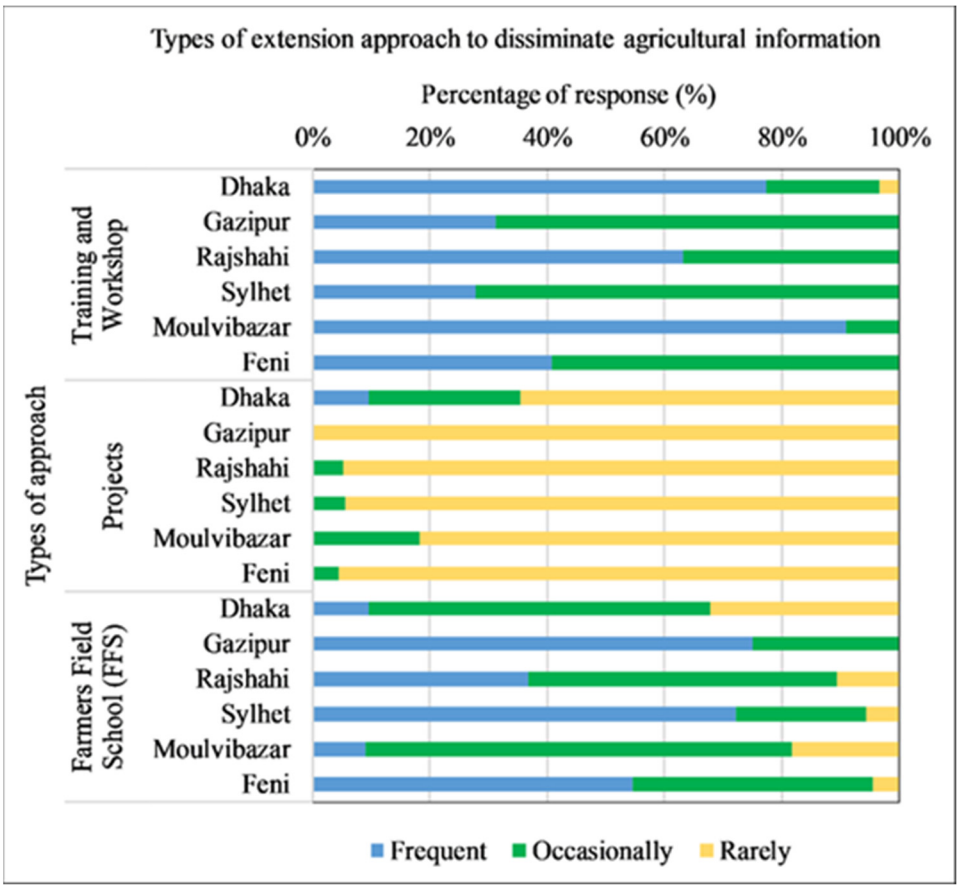

Figure 6. Distribution of the three-point Likert scale response types, expressed as percentages, for questions on the types of extension approaches used to disseminate information.

From Figure 8A, the advantages of using social media to obtain agricultural information were also supported by the respondents (88.88%). Among the sites commonly used were Facebook (68.3%), to seek agriculture-related information, and YouTube (24.7%), for video content (Figure 8B). From the responses to the open-ended question, it was determined that to keep pace with modern agriculture, it is necessary and useful for SAAOs to use social media. Hence, they mentioned the advantages of using social media (Table 2). Interestingly, the respondents in the Dhaka district reported not using social media, while the rest identified that through social media, they could easily be connected with recent and updated information about agriculture extension along with new technologies. In addition, they could easily connect with other colleagues from different districts, and sometimes they could also contact experts through social media. Their major resources from social media were crop-related information, fertilizer recommendations, crop diseases, and pesticides.

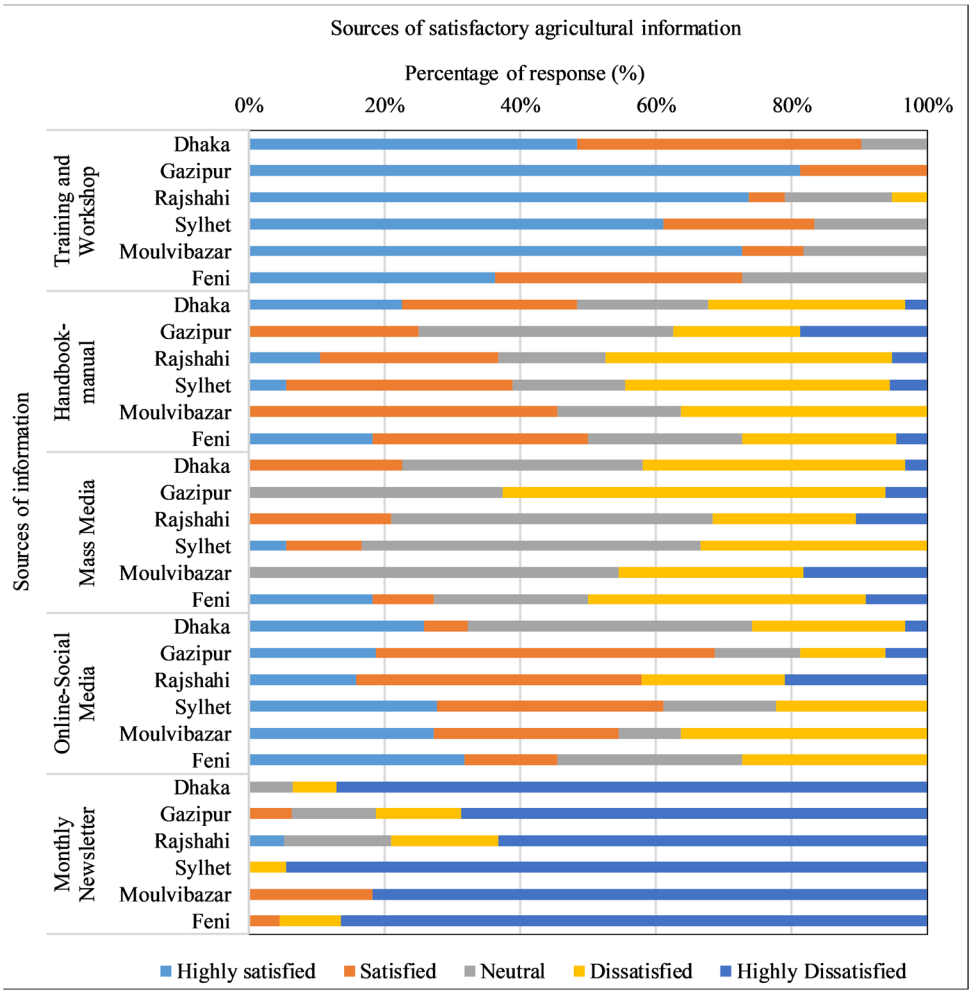

Figure 7. Distribution of the five-point Likert scale response types, expressed as percentages, for the questions on satisfaction with seeking agricultural information from different sources.

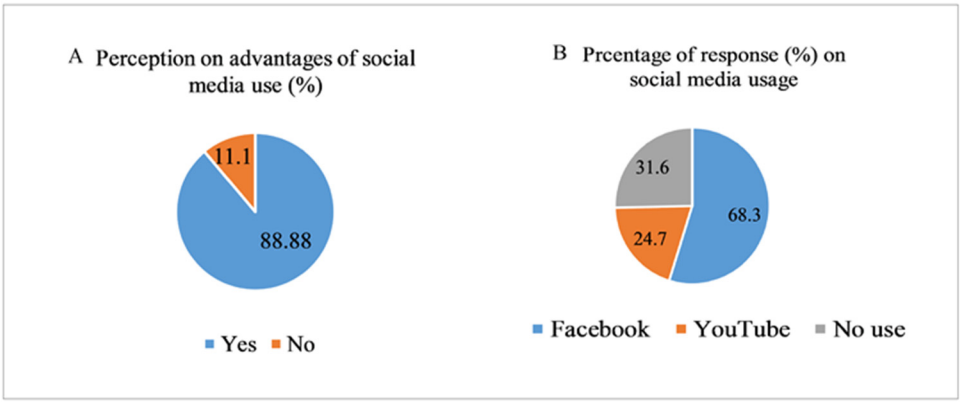

Figure 8. Social media usage. (**A**) Perception of advantages of social media use as percentages. (**B**) Percentage of responses about social media usage on different platforms.

Table 2. Utilization of social media in surveyed districts for agriculture-related information and communication.

Districts	Advantages of Using Social Media in Agriculture Extension
Dhaka	Most SAAOs did not use social media. Only a few described that they used it to know more about new agriculture technology (n = 9).
Gazipur	Quickly retrieves information and solutions related to agriculture extension (n = 8), can deliver instant responses to farmers' needs (n = 2), know about new technology and gain knowledge on ICT (n = 1), crop-related information (n = 1), fertilizer recommendations (n = 1), diseases (n = 1), and pesticides (n = 1).
Rajshahi	Easily retrieves agriculture-related information (n = 3) and agricultural technology (n = 3).
Sylhet	Convenient to obtain information (n = 5) along with solutions (n = 4), able to give prompt replies to farmers' queries (n = 3), know about new technology (n = 3), crop-related information (n = 1), diseases (n = 1), pesticides (n = 1), and the use of different fertilizers (n = 1).
Moulvibazar	Agricultural problems (n = 1), disease information (n = 1), easy to communicate (n = 1).
Feni	Give quick feedback to farmers' information needs (n = 3), keep up to date themselves with new agriculture technology (n = 4), watch agriculture programs (n = 2), agriculture apps (n = 1), and agriculture information (n = 1).

3.6. Collecting Agricultural Information Using Broadcast Media

Broadcast media is a vital resource for collecting agricultural information in rural areas. This includes television, radio, and community radio. In Figure 9, respondents' answers in terms of collecting agricultural information using broadcast media were measured on a five-point Likert scale that ranged from 1 (very likely) to 5 (very unlikely). It was identified that television was highly likely to be used to collect agricultural information, with 74.19% in Dhaka district, 68.42% in Rajshahi district, and 68.18% in Feni district. In comparison, the use of community radio as a broadcast medium was ranked as very unlikely in Rajshahi district, Moulvibazar district, and Dhaka district (94.73%, 90.90%, and 90.32%, respectively). In addition, radio was ranked as neutrally effective in Sylhet district (22.22%), Rajshahi district (21.05%), and Feni district (13.63%).

3.7. Difficulties while Delivering Agricultural Information

Here, we asked respondents to rank the difficulties faced while delivering agricultural information to farmers using a four-point Likert scale that ranged from 1 (completely) to 4 (rarely) in Figure 10. Technical obstacles were ranked as a completely difficult factor when delivering agriculture information in Gazipur district (68.75%), Rajshahi district (68.42%), Sylhet district (66.66%), Dhaka district (61.29%), Moulvibazar district (45.45%), and Feni district (36.36%). On the other hand, in Moulvibazar district and Feni district, farmers' ignorance was found to be substantial (36.36% in both cases) and was reported as a completely difficult issue to overcome. Subsequently, internet connectivity appeared to be most difficult in Moulvibazar district (63.63%), Sylhet district (55.55%), Rajshahi district (42.10%), Dhaka district (35.48%), Gazipur district (31.25%), and Feni district (22.72%). Electricity connections in Sylhet (55.55%), Gazipur district (43.75%), and Rajshahi district (42.10%) were particularly difficult during the dissemination of agricultural information. A high range of rarely difficult responses was observed in Sylhet district (61.11%), Rajshahi district (47.36%), Dhaka district (38.70%), Gazipur district (37.5%), Feni district (22.72%), and Moulvibazar district (18.18%).

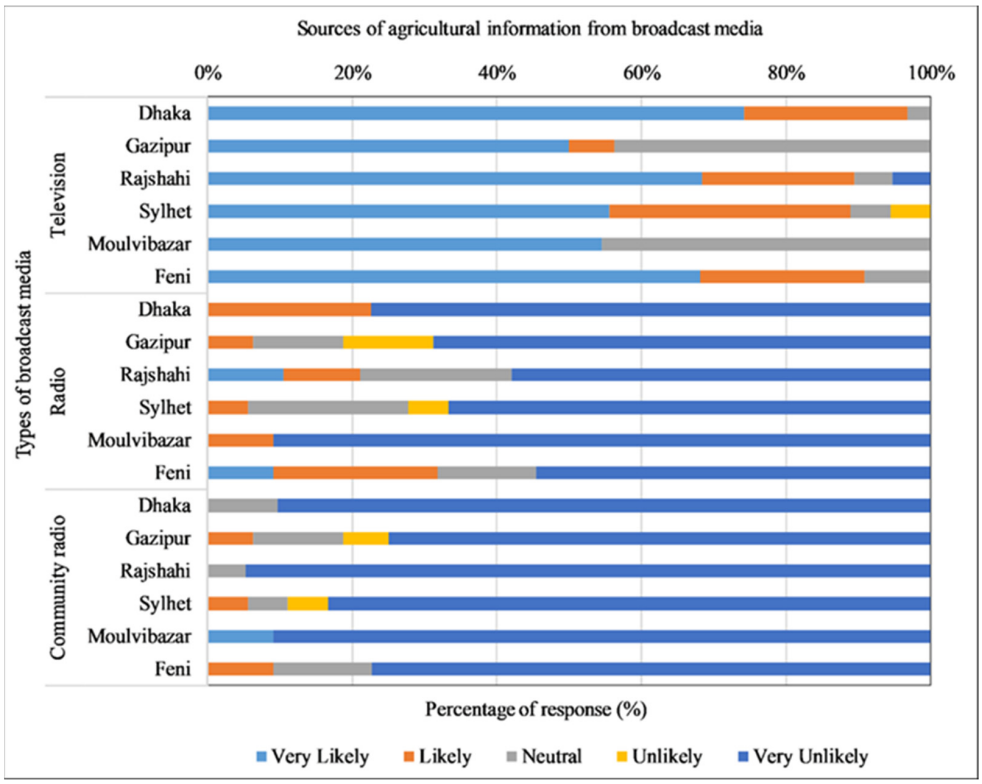

Figure 9. Distribution of the five-point Likert scale response types, expressed as percentages, for the questions on the sourcing of agricultural information from broadcast media.

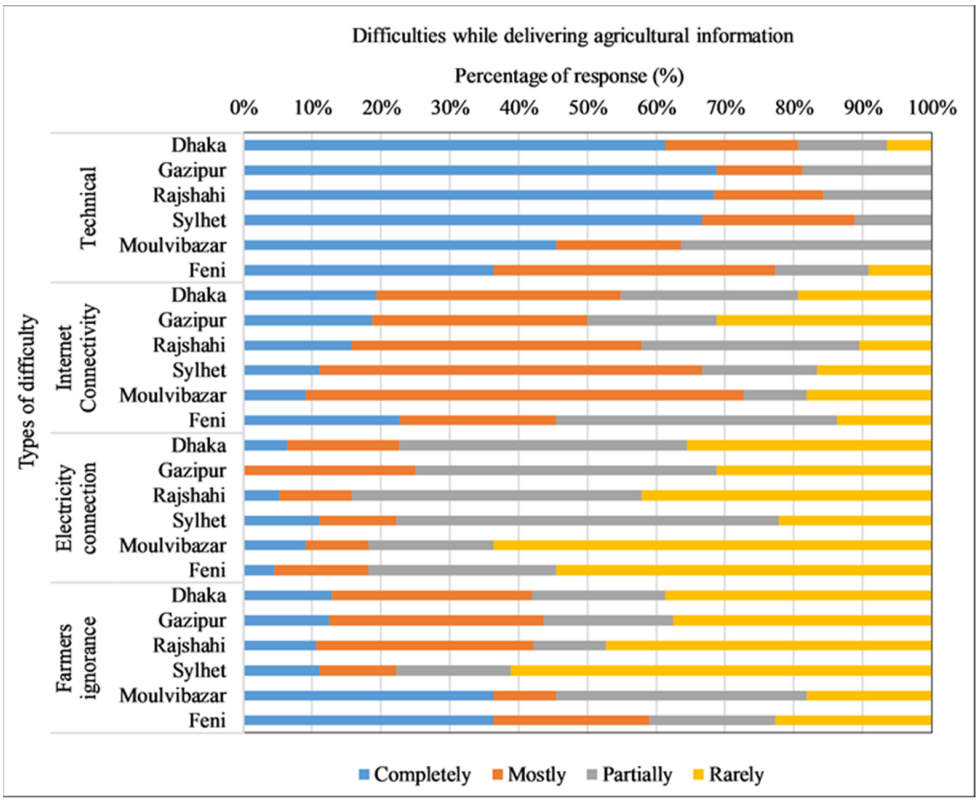

Figure 10. Distribution of the four-point Likert scale response types, expressed as percentages, for the questions on difficulties faced while delivering agriculture information.

3.8. Difficulties with Using ICT Applications

In Figure 11, the evaluation of responses was measured on a seven-point Likert scale that ranged from 1 (essential priority) to 7 (not a priority) in terms of difficulties with using the ICT applications. The shortage of computers was identified as an essential priority for overcoming the difficulties associated with the use of such applications. According to the results, responses received in Gazipur district, Sylhet district, Rajshahi district, Dhaka district, and Feni and Moulvibazar districts were 56.25%, 50%, 47.36%, 36.26%, and 18.18%, respectively. The lack of computer knowledge was ranked as a high priority in Moulvibazar district (36.36%), Feni district (31.81%), and Rajshahi district (31.57%). In addition, a lack of coordination in using these applications has become a moderate priority in Sylhet district (27.72%), Gazipur district (25%), and Dhaka district (19.35%). Awareness of ICT knowledge is also a demand among SAAOs but was ranked as a low priority to avoid difficulties in extension services in Sylhet district (27.77%), Moulvibazar district (27.27%), and Feni district (27.27%). Moreover, the unavailability of required information was shown to be a moderate priority in Sylhet district (27.77%) and Moulvibazar district (27.27%), while a lack of support from experts was not a priority. Apart from these, insufficient internet speed was identified as an essential priority for 27.27% in Moulvibazar district.

Moreover, in Moulvibazar district, SAAOs reported that they do not use computers for their needs, whereas computers were used between 30 min and an hour per day to search for agriculture information in Gazipur district (18.75%), Sylhet district (16.66%), and Feni district (9.09%). In addition, in the Feni district (9.09%), their computer usage was daily for 2 to 3 h.

3.9. Challenges Faced with ICT Application in Agriculture Work

These officers face potential challenges in using applications while disseminating and collecting agricultural information, which makes them less efficient in their work. In Figure 12, respondents' answers were measured on a four-point Likert scale that ranged from 1 (major) to 4 (insignificant) in terms of the challenges they faced. They marked inadequate training support as a major challenge in Dhaka district (64.51%), Feni district (63.63%), Gazipur district (62.5%), Sylhet district (50%), Rajshahi district (42.10%), and Moulvibazar district (27.27%). Moreover, Moulvibazar district (54.54%) and Rajshahi district (42.10%) showed that their major challenge for ICT application in service delivery was transportation. However, the transportation challenge was reported as a minor factor in the Sylhet district (44.44%). Language barriers to accessing resources were included as moderate challenges in Feni district (27.27%), Sylhet district (22.22%), and Rajshahi district (26.31%). Additionally, difficulties in accessing resources were also found to be a moderate challenge in Sylhet district (38.88%) and Dhaka district (51.61%).

3.10. ICT Support Required for Performance

According to the respondents' need to improve their work performance, their answers were measured on a four-point Likert scale that ranged from 1 (high priority) to 4 (low priority) in terms of the ICT services required for their performance. Our results showed (Figure 13) that mobile devices (smartphones) were a top priority for SAAOs in Rajshahi district (57.89%), Gazipur district (50%), Dhaka district (54.83%), Feni district (45.45%), and Moulvibazar (27.27%) to accelerate their work performance. After that, creating a farmers' database could help them access all the farmers' information online rather than keeping it manually. On a requirement basis, the online database of farmers was responded to as a high priority in Sylhet district (55.55%), Feni district (36.36%), Gazipur (31.25%), Moulvibazar district (27.27%), and Dhaka district (29.03%). Computer facilities were ranked as a moderate priority in Dhaka district (32.25%), Rajshahi district (31.57%), and Moulvibazar district (45.45%), while internet facilities were also ranked as moderate priority in Dhaka district (32.25%), Rajshahi district (36.84%), Gazipur (50%), and Feni district (50%).

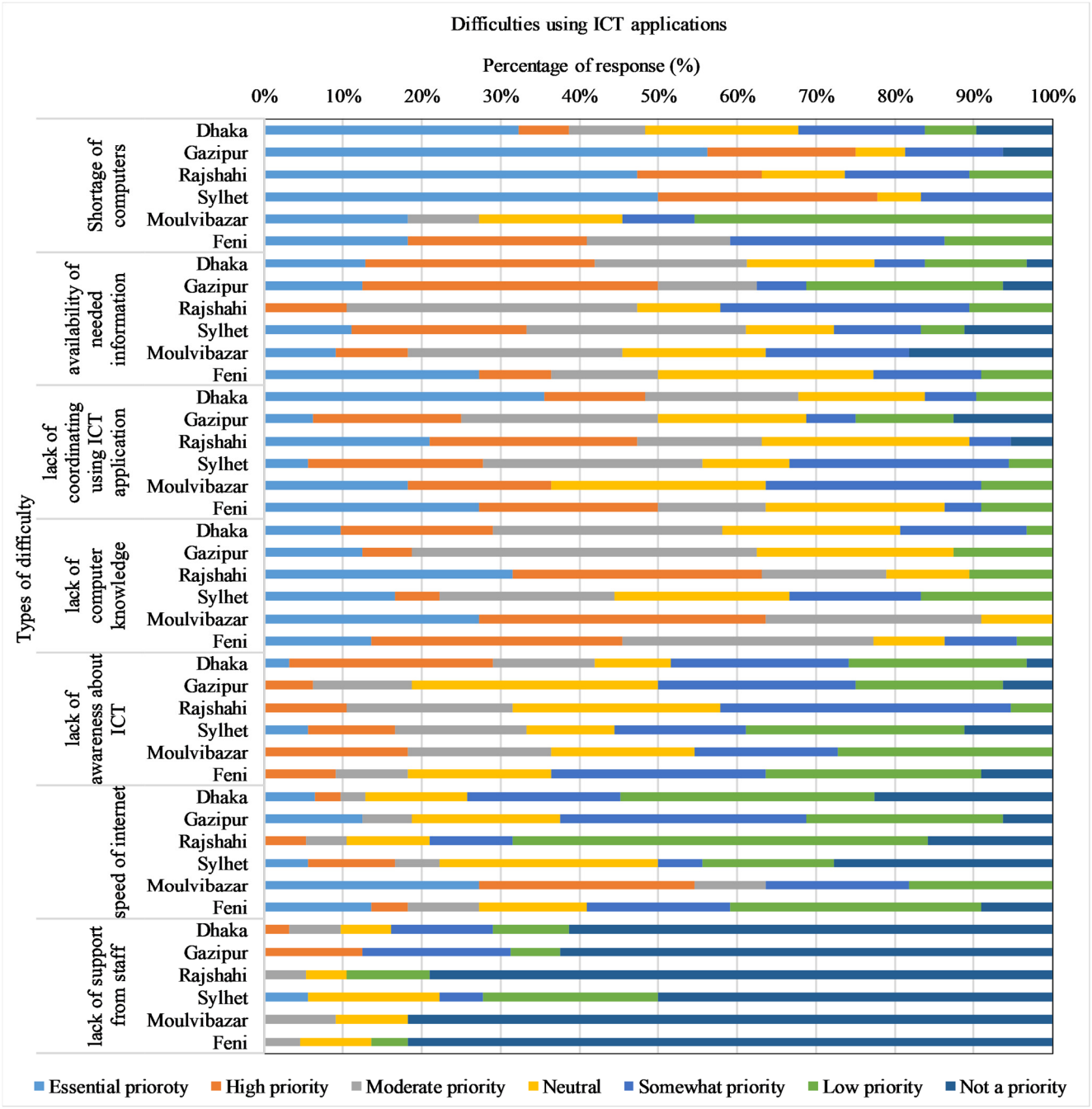

Figure 11. Distribution of the seven-point Likert scale response types, expressed as percentages, for the questions on difficulties with using ICT applications.

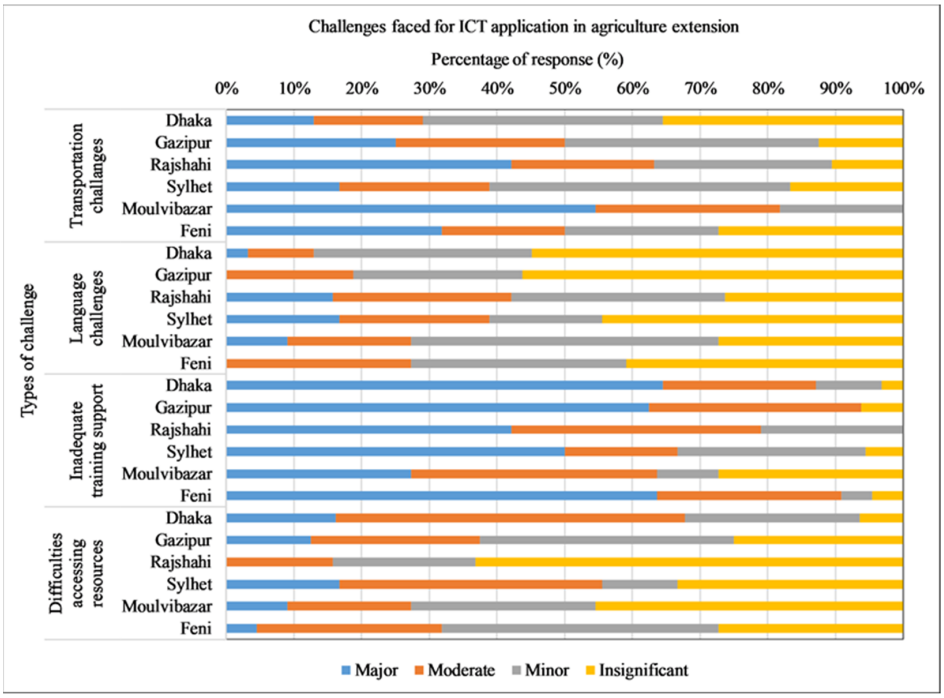

Figure 12. Distribution of the four-point Likert scale response types, expressed as percentages, for the questions on challenges faced in ICT application.

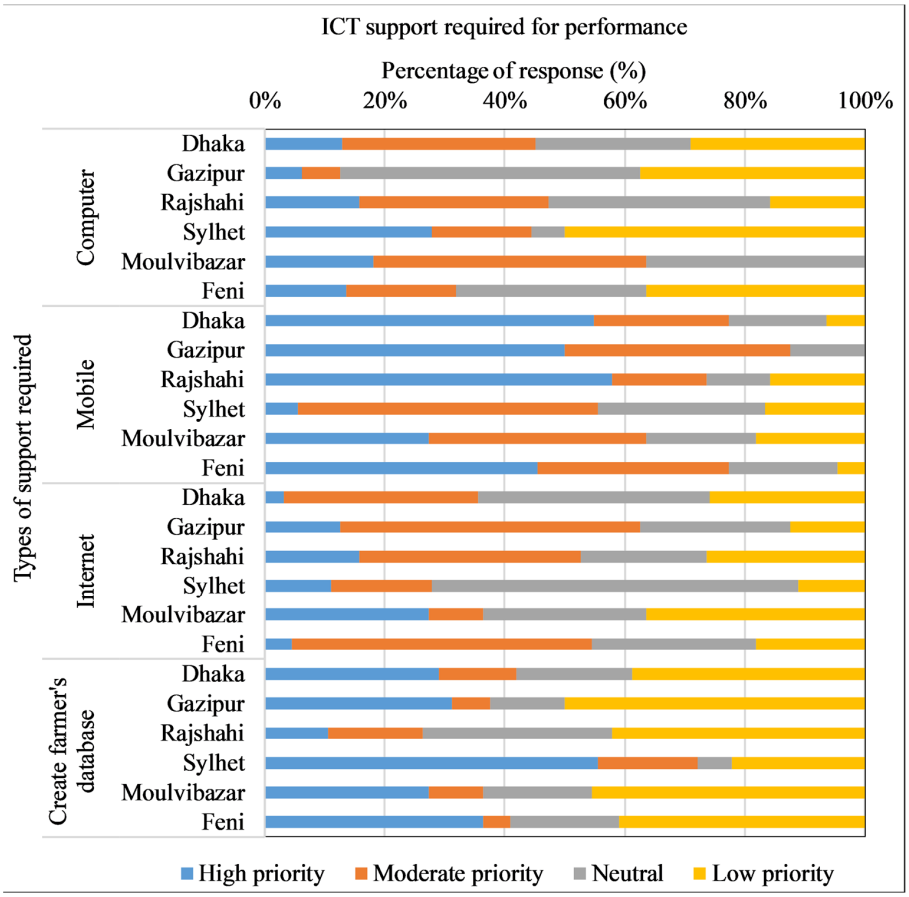

Figure 13. Distribution of the four-point Likert scale response types, expressed as percentages, for the questions on support required for performance.

3.11. Issues to Overcome for Strengthening ICT Usage in Agriculture

We extracted the barriers faced by respondents during their delivery of agriculture information to farmers in the surveyed districts from open-ended questions; the results are listed in Table 3.

Table 3. List of barriers and factors mentioned in different districts that need to be considered to strengthen ICT usage in agriculture.

Issues to Overcome in ICT in Agriculture	Concern Reported in District
A. Barriers faced for ICT usage	
Unavailability of internet connection	Gazipur, Feni, Rajshahi, Sylhet, Moulvibazar
Transportation barriers	Rajshahi, Sylhet, Moulvibazar
Internet expenses	Sylhet, Moulvibazar
Political interference	Sylhet
Farmer's ignorance	Sylhet
Insufficient internet speed	Dhaka, Gazipur, Sylhet
ICT knowledge gap	Dhaka
Lack of research content	Dhaka
B. Factors limiting to use ICT applications	
ICT Training	Dhaka, Gazipur, Feni, Rajshahi, Sylhet, Moulvibazar
Insufficient ICT-related equipment	Dhaka, Gazipur, Feni, Rajshahi, Sylhet, Moulvibazar
Not enough funding	Feni
Irregular updating of agricultural applications	Gazipur
C. Factors hindering new ICT technologies	
Gap between research work and field requirement	Dhaka

Barriers faced for ICT usage: Although the respondents were willing to use ICT during their extension work, some major obstacles made it difficult for them to use. The availability of internet connectivity was the most common barrier to using the applications in all surveyed districts except Dhaka. Moreover, they also identified the transportation barriers to visiting each farmer in Rajshahi district, Sylhet district, and Moulvibazar district because they caused trouble with respect to the diffusion of agricultural information from one community to another. Apart from these, the cost of internet expenses (Sylhet district and Moulvibazar district), the knowledge gap (Dhaka district), and insufficient internet speed (Dhaka district, Gazipur district, and Sylhet district) were also mentioned as barriers.

Factors limiting the ability to use ICT applications: According to the current situation, a lack of training and insufficient equipment hamper SAAO's ability to work, as was described in all districts. Moreover, the irregular updating of agriculture apps and limited funding for skill development were mentioned in Gazipur district and Feni district, which reduced the growth and use of ICT applications.

Factors hindering new ICT technologies: A gap between research activities and need in the field was recognized in Dhaka district as a barrier because research usually took place in separate areas that were strictly monitored by the researcher; thus, in many cases, it could not fulfill needs at the grassroots level and became unusable for the respondents.

3.12. Barriers and Suggestions for ICT Enhancement from Stakeholders

To obtain more elaborate and detailed information, we conducted focused group discussions with researchers, experts, and professionals from different government and private

stakeholders. During this research, we visited these organizations and recorded barriers and suggestions for improving ICT usage in agriculture extension with the required permission from the respective organizations. In addition, we learned that the overall categories of agricultural information collected included soil, weather, crop cultivation, pesticides, fisheries, disease, market information, irrigation, livestock, and production technologies.

As shown in Table 4, professionals from public organizations determined ICT-based barriers in Bangladesh that involved limited manpower and resources in regional offices, a lack of new policies, a lack of databases about farmers, and universities (public) mostly offering theoretical courses and less field-oriented research. Furthermore, specialists from private organizations acknowledged that their scope of work only included a small group of people. We also found that ICT-based courses at private universities are limited to the classroom. Nevertheless, it is necessary for SAAOs to increase their skills and competence for better performance. The experts contributed several suggestions, including a linkage between research institutes and field-level extension, sufficient training, enough equipment support for workstations, the development of a synchronized agricultural web and mobile platform, and public–private partnership.

Table 4. Summary of barriers and needs illustrated by agriculture extension-related stakeholders for ICT enhancement in agriculture extension.

Stakeholders	Organizations	Barriers	Suggestions
Government	*Agriculture Extension Service provider:* Agriculture Information Services (AIS) National Agricultural Technology Program (NATP) A2i (Access to Information) *University:* Sher-e-Bangla Agriculture University (SAU) *Research Institutes:* Bangladesh Rice Research Institute (BRRI) Bangladesh Agriculture Research Institute (BARI)	➢ Limited manpower and resources in regional offices ➢ Lack of information dissemination ➢ Lack of adjustment and new policies ➢ Lack of database information about farmers ➢ Lack of logistic support ➢ University mostly offers extension-related theoretical courses and research	➢ Make a linkage between research institutes and field-level extension ➢ Need to purchase equipment for smart agriculture at workstations ➢ Requirement of training in ICT for smallholder farmers to increase the productivity of diversified crops ➢ Need to develop only one agriculture-related online/mobile application/platform ➢ Necessity and importance of advanced ICT in rice cultivation in the unique ecological zone of Bangladesh
Private	mPower (NGO) East West University (EWU)	➢ Only works with a small group of farmers in a small area ➢ ICT study is limited to the classroom only	➢ Cooperation between government and private organizations for advanced agriculture technology innovation and adoption ➢ Need practical knowledge from fieldwork

3.13. Logit Estimation for ICT Adoption

The results shown in Table 5 revealed that the estimated probit model was statistically significant at the 1% level. The results of this model confirmed that knowledge, ICT usage, and farmers' need positively and significantly influenced interest in ICT adoption among the respondents. However, gender and mobile type had a positive and age had a negative effect, although all were non-significant. The marginal effect of age indicated that the likelihood of adoption decreased by 0.2% for every one-year increase in their age. Although mobile type had a positive relation with ICT adoption that was non-significant, the marginal effect showed that the addition of smartphones could increase adoption by 4% compared to basic phone users.

Table 5. Logit model analysis for the adoption of ICT.

Variable	Coef	St.Err.	Marginal Effect
Gender (1 = male, 0 = female)	0.830	2.503	0.013
Age	−0.115	0.096	−0.002
Knowledge (yes = 1, no = 0)	3.744 **	1.689	0.060
Use of ICT (yes = 1, no = 0)	4.552 *	2.696	0.073
Farmers need (yes = 1, no = 0)	3.528 **	1.556	0.057
Mobile Type (smartphone = 1, basic mobile = 0)	2.507	1.786	0.040
Constant	−3.318	5.461	
Pseudo r-squared	0.889		
Chi-square	116.515		
Akaike crit. (AIC)	28.519		
Number of obs	117		
Prob > chi2	0.000		

** significant at 5%, * significant at 10%.

There was a significant and positive link between adoption and respondents' knowledge, indicating a higher likelihood of seeking an understanding and know-how of ICT; the marginal effect of knowledge indicated that the likelihood of adoption increased by 6% for every unit of ICT knowledge increase among the respondents.

The use of ICT significantly positively influenced the likelihood of adopting it. The marginal effect analysis also showed that a unit increase in ICT usage increased the probability of adopting technology by 7.3 percent compared to those less likely to use ICT.

The positive and significant effect of satisfying farmers' needs can be explained by those who had better knowledge and higher usage. The marginal effect also showed that respondents could increase their fulfillment of farmers' needs for agricultural information by 5.7% with an increase in each unit of adoption.

4. Discussion

A mind map was created to reflect the associated design methodology of this research work (inputs) and the results of this study (outputs), including the barriers, challenges, factors, and needs obtained from the survey of sub-assistant agricultural officers as well as the barriers and suggestions received from the focus group discussion, which can be used to accelerate their functions in disseminating agriculture information to farmers (Figure 14).

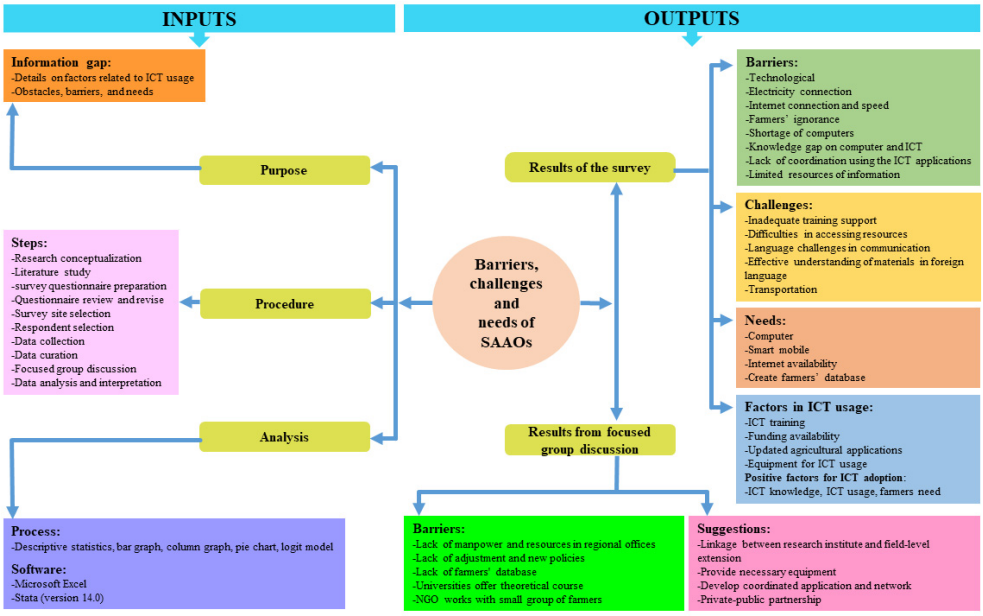

Figure 14. Mind map of research methodology and outcomes.

Due to movement limitations and social distancing guidelines during the pandemic caused by COVID-19, the implementation and use of ICTs has resulted in a feasible solution for both extension agents and farmers who have faced challenges with regular access to agricultural extension and advisory services as well as the timely exchange of updated information [62–64]. To achieve sustainable agriculture, ICTs in the agricultural sector must be effectively integrated through the progressive processing of agricultural data, which can provide useful information for extension agents to provide to farmers for decision-making processes [65–67].

In the present study, the respondents' ages ranged from 35 to 50 years, which was found to be similar to previous research conducted to determine SAAO attitudes toward using ICT in agriculture extension [29]. They reported performing field visits and training for farm families at regular intervals as an effective tool for disseminating agricultural information, which is in consensus with the findings of Maulu et al. [38]; however, in emergencies, they have failed to reach farmers due to transportation challenges. Additionally, we revealed that the respondents used mobile phones to facilitate the flow of information by connecting farmers. Other reports were also discovered regarding the utility of electronic devices (mobile) for extension staff to communicate with farmers and provide climate-resilient farming supports [68–71], particularly when they were unable to visit offline [45].

In terms of satisfaction, training and workshops were the best methods used to obtain knowledge on agricultural technologies according to our survey. As shown in Figure 7, both mass media and online social media were listed as potential resources for communication and channels for information exchange. Facebook was the most suitable platform in this study to connect with other SAAOs, experts, and even farmers to share and exchange updated information among themselves. Moreover, we determined that YouTube facilitated access to valuable content and global resources. It is now widely expected that online platforms, especially social media, will provide an open space for direct communication between different stakeholders with embedded links to agricultural advisory services and production technologies for accurate information and the connection of farming communities [6,72,73]. Meanwhile, we observed that radio and TV played effective roles in educating, exhibiting evidence, and motivating SAAOs by providing innovative approaches from national and global agricultural extension programs. Thus, it made them aware of their duties and responsibilities [74,75].

Our open-ended queries also identified that every sub-district had inadequate equipment and limited training facilities to help them acquire ICT-related knowledge for extension, which was categorized as an organizational barrier [76]. Furthermore, in Bangladesh the usual academic qualification of SAAOs is a 4-year diploma in agriculture, which must be followed by technical education beginning after their secondary school certificate (SSC, 10 years of schooling) and ending after their higher secondary certificate (HSC, 12 years of schooling) [77]. Our study revealed that SAAOs need knowledge and training on ICT for better performance in delivering agricultural advisory and rural services. In addition, we revealed that an unavailable internet connection, internet expenses, insufficient internet speed, and irregular updates of applications were considered as technological barriers.

Interestingly, hands-on knowledge was obtained from training and workshops, and SAAOs needed to use similar strategies during field visits as a suitable tool for the dissemination of information to farmers, which is consistent with previous findings about field visits in hydride rice technology dissemination [78]. Mobile users were high in Gazipur district and Rajshahi district; thus, it can easily be explained why social media was found to be a suitable source of information in these same districts. In Sylhet district and Moulvibazar district, respondents reported handbooks as satisfactory information sources. Interestingly, in the same districts, their choice of approach for disseminating information was FFS. This preference for FFS may be due to the unavailable internet connection in these two districts, where they can use handbooks instead. Moreover, in the same districts, we identified farmers' ignorance as a barrier to strengthening these applications. This is easily explained

by a lack of internet access and knowledge of ICT among farmers [79]. Because of the unavailable internet connection in Moulvibazar district, Sylhet district, Gazipur district, Feni district, and Rajshahi district, SAAOs spent less time on the computer and revealed they lacked related information. In Dhaka district, they faced unavailable information and a lack of coordination when using ICT applications, which caused difficulties in using the ICT tools. Inadequate training support was a concern with ICT usage because it generated information and knowledge gaps in the Dhaka and Rajshahi districts and reduced the SAAO's skills and work efficiency in extension services. In response, the majority of participants mentioned smartphones as a required technical support that could help them collect information and deliver it to farmers, which is in harmony with the results presented by Fabregas et al. [80]. Moreover, broadcast media such as TV and radio could help reduce language barriers, especially in Rajshahi district. In Sylhet district, Gazipur district, Feni district, Dhaka district, and Moulvibazar district, the officers stated that creating databases would support them in overcoming the difficulties associated with disseminating agricultural information.

Under the above circumstances, to overcome these challenges and difficulties, vital and significant suggestions were provided from consultations with related experts and professionals (focus groups) that were found to be similar to the support requested by key respondents (Figure 14). These can be used to generate solutions for developing capacity and skills in officers using ICT tools for agriculture extension. However, the factors associated with agricultural information collection and delivery are solely determined by ecological zones and crop diversity in different regions. As a result, seeing these challenges and barriers, as well as the necessary actions required to adopt ICT-based development based on agroecological zones, is concerning.

ICT adoption for enhancing sustainability in agriculture

Sub-assistant agricultural officers are working as a key information hub in the agricultural sector to connect directly with farmers. As they are a liaison between experts and farmers, it is important for extension staff to be more skilled, knowledgeable, and prompt with their service [81]. In terms of ICT adoption, knowledge, ICT usage, and farmers' needs were found to play significant roles in the adoption of ICT technologies for improved production, farm management income, and livelihoods, which is similar to the result of a study in Mali [82].

ICT-based transformation for sustainable agricultural and food systems

Certainly, the benefits of integrating ICTs in agriculture are well known as the "digital revolution" or "e-agriculture" in developing countries, which target small-scale farmers' decision making during crop production and marketing. The risks, barriers, and challenges in this sector need to be properly considered through policy and guideline frameworks with adequate infrastructure and ethical concerns to attain sustainability in agricultural production [83–85]. However, countries in the Global South have struggled to overcome barriers, including limited technical resources, inefficient extension systems, high management costs, and less coordinated food supply chains [86].

Customized ICT-based mobile applications could also help farmers and extension agents access targeted information, including climate and weather data, expected yield, local information, monetary data, data-driven decisions and recommendations, and product price estimates, especially during the pandemic caused by COVID-19 [87–90]. Although smartphone-based digital extension services are limited, a precision application model and mobile-based advisory services have influenced farmers' adoption of sustainable agricultural technologies, and their utilization in decision making should be promoted in developing countries [91–93]. Collaborations between different stakeholders and linkages from the bottom up through the design and usage of ICT have shown positive outcomes for climate adaptation in Bangladesh and resilience farming in India [94–96]. Sensors, remote sensing technologies, and software applications have undergone trials or field testing with small farmers, but their usage is limited for large-scale country-wide services, except for a few government web-based platforms [97–99]. Such technology-based development

and linkage decision systems between researchers and extension agents could empower rural farmer communities toward a digital ecosystem for future sustainability in the food systems of developing countries, including Bangladesh [100–104].

Thus, the present work also enlightens policies toward ICT-based ecosystems for agriculture extension services in Bangladesh through empowering SAAOs, which could help farmer communities achieve sustainable agricultural production and attain the smooth management of the national agri-food system [31]. Such a transformation in extension services can bring about change in the whole rural advisory system, which could play a role in boosting sustainable agricultural production for food and nutritional security in Bangladesh [105–107].

The limitations of this research have broadened the scope of future comprehensive studies on ICT technologies in agriculture extension. These may include the following concepts: (i) precision agriculture is rarely implemented at the grass-roots level in the country, resulting in a knowledge gap and a lack of response during our survey; (ii) studies in other ecological zones could investigate new barriers and challenges; (iii) gender bias between SAAOs and farmers during the dissemination and collection of agricultural information; (iv) the behaviors and preferences of both SAAOs and farmers for applications and individual ICT tools and their usage; (v) the performance of service delivery based on tools; (vi) tailored-tools for specific crops and risk management; (vii) an information management system as a big-data approach; (viii) the mechanisms of knowledge and the adoption of specific technology; (ix) how the interface of a coordinated platform works; and (x) the mechanism of a better partnership among different stakeholders and research on ICT innovation systems.

5. Conclusions

The majority of respondents in our study admitted the importance of ICT in delivering agricultural information to farmers, and most of them were trying to embrace the techniques that were essential for their fieldwork and better service satisfaction. Throughout this study, we sought detailed data on their use of ICT and knowledge, obstacles, and needs for distributing agriculture information among the farmers.

Among the surveyed SAAOs, the majority had basic ICT knowledge and agreed that it was useful for their service delivery. In Sylhet district, most of them were well-served according to the needs of the farmers. Field visits were the most effective tool in all districts, whereas training and workshops for farmers were frequently used as an extension approach to deliver information to farmers in Dhaka district, Moulvibazar district, and Rajshahi district. However, farmer field school was prominent in Sylhet district, Gazipur district, and Feni district. In terms of satisfaction, when SAAOs sought agricultural information, training and workshops for themselves were considered as the best sources. In addition, online social media were also used to communicate and seek knowledge about information and technologies. They agreed that using social media is advantageous as a tool for acquiring information and connecting with farmers and experts. Afterward, we found that television had gained popularity for collecting information in Dhaka district, Rajshahi district, and Feni district. While delivering agricultural information, SAAOs encountered difficulties that included technical obstacles (Gazipur district, Rajshahi district, Sylhet district, and Dhaka district) and internet connectivity (Moulvibazar district and Sylhet district). Additionally, they also specified equipment shortages, knowledge gaps, a lack of awareness about new tools, and the unavailability of the required information when asked about their difficulties in using the ICT tools. Inadequate training support in Dhaka district and difficulties in accessing information resources in Sylhet district were the two major challenges faced by SAAOs during their services to farmers. For improved performance, mobile phones in Rajshahi district and creating a farmers' database in Sylhet district were their major requirements, through which they could easily access farmers' information online rather than manually. To strengthen ICT usage among SAAOs, there are some issues that need to be overcome, including farmers' ignorance, the knowledge

gap, a lack of research content, inadequate training, insufficient ICT-related equipment, the irregular updating of agricultural applications, and the gap between research work and field experiments. Finally, based on a focus group discussion, some recommendations for ICT enhancements were also suggested, such as the linkage between research institutes and field-level extension, synchronized agricultural web and mobile platforms, and public–private partnerships.

Taken together, our results show that to overcome the barriers faced by these extension officers in using ICTs for the dissemination of agriculture information to farmers, possible solutions and their needs and requirements should be prioritized during decision making and implementation by the government as well as private research organizations, universities, and other stakeholders. On the other hand, strengthening ICT infrastructure along with the linkages between research experiments, implementation, and field extension could enhance the facilities for SAAOs to develop their skills and knowledge. Notably, the improvement of ICT usage in agriculture extension through redesigning the policy and future development lies in the better integration and reconstruction of tools and the improvement of the skills of experts as well as SAAOs. The significant development of ICT-based services can revolutionize agriculture advisory services for a digital transformation in Bangladesh, which will play a major role in reaching the goals of becoming an upper middle-income country by 2030 and a high-income country around 2041 without poverty [108].

Author Contributions: Conceptualization, W.W., G.L. and M.B.A.; methodology, W.W., G.L., F.M.S.A., S.J.R. and M.B.A.; formal analysis, F.M.S.A., M.B.A. and S.J.R.; investigation, G.L, F.M.S.A., A.K. and M.B.A.; resources, B.X., G.L., F.M.S.A., A.K. and M.B.A.; data curation, M.B.A.; writing—original draft preparation, M.B.A., F.M.S.A. and S.J.R.; writing—review and editing, W.W., G.L., B.X., M.B.A., S.J.R., A.K. and F.M.S.A.; supervision, W.W. and G.L.; funding acquisition, W.W. and G.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Key R&D Program of China, grant number 2021ZD0110901.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Acknowledgments: We are grateful to the experts, officials, researchers, scientists, and professionals from the Department of Agricultural Extension (DAE), National Agricultural Technology Program (NATP)-Phase II, Agriculture Information Services (AIS), Bangladesh Rice Research Institute (BRRI), and Bangladesh Agriculture Research Institute (BARI) under the Ministry of Agriculture, Government of the People's Republic of Bangladesh for their coordination, cooperation and collaboration during the survey. We are also grateful to the professors and researchers of Sher-e-Bangla Agricultural University (SAU), East West University (EWU), and mPower for their immense support and providing technical cooperation in our study. We highly appreciate the sub-assistant agriculture officers (SAAOs) of the DAE from the surveyed districts who participated in the survey.

Conflicts of Interest: The authors declare no conflict of interest.

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