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Impact of agriculture extension services on technical efficiency of rural paddy farmers in southwest Bangladesh

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ABSTRACT

Agricultural Extension Services (AES) aim to improve farming knowledge that helps in increasing crop production and the technical efficiency of paddy farmers in Bangladesh. The purposes of this study are to measure the impact of an AES, namely, the Blue Gold programme, on the technical efficiency and production level of the Boro paddy farmers in southwest rural Bangladesh. A total of 122 paddy farmers were interviewed, employing a random sampling method. To analyse the technical efficiency of the farmers, the Cobb-Douglas stochastic frontier model was employed. The findings show that the mean technical efficiency levels of the participants and non-participants are 95% and 82%, producing 162.74 and 136.48 maunds per hectare, respectively. The findings are indispensable for devising strategies for environment-friendly agricultural activities and rural economic development in Bangladesh.

1. Introduction

Agriculture is the most prominent and sustainable livelihood sector in rural Bangladesh. About 60% of the total population lives in rural areas, where most of their livelihoods predominantly depend on agriculture (Haq, 2016). Among the varieties of agricultural products produced year-round, rice is the staple crop in Bangladesh. The demand for rice has been increased with the rapid expansion of the population in Bangladesh (Rahaman et al., 2018). To fulfil the demand, the farmers use fertilizer, pesticide, water, and other tools and technologies extensively and modern inputs use (Parveen, 2010). Actually, a few years after the Liberation War in 1971, the Government of Bangladesh focused on improving agriculture education to enhance economic development (Alam et al., 2009). By adopting modern agricultural technologies, ameliorating the efficiency, and diffusion process, along with improvement of the limited ability of the farmers through the agricultural extension services (AES), productivity has been improved substantially. However, still, the country lacks sustainable agricultural development (Adem and Gebregziabher, 2014), and the farmers possessed low human capital (Asadullah and Rahman, 2009). Thus, it requires agricultural extensions to foster faster production and rural income by accelerating the diffusion process of improved technology (Athukorala, 2017; Birkhaeuser et al., 1991).

In describing the current agricultural situation of the country, Haq (2013) reported that farmers use more chemical fertilizers and irrigation than before. In addition, Rahaman et al. (2018) claimed that insect pests have increased in recent decades, and the farmers usually depend on "pesticides" for improving production. These result in ecological degradation by contaminating pesticides with food, water, soil, and air (Rahaman et al., 2018; Parveen, 2010). Likewise, other significant barriers to production are two folds, like socio-technical and environmental. The socio-technical barriers refer to the inadequate irrigation system, lack of modern technologies, and poor management practices, whereas the environmental barriers are the depletion of soil, the intensity of salinity, drought, and high rainfall. All these together adversely impact the farmers' production level and efficiency in Bangladesh (Wadud and White, 2000; Elias et al., 2014; Miah et al., 2020). Therefore, addressing these social and environmental adversities is the critical challenge for improving the production and technical efficiency of the farmers in Bangladesh (Hasan et al., 2020).

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This study contributes to this field and investigates the farmers' technical efficiency involved in a specific agricultural extension service (AES) programme under the Blue-Gold (BG) program in southwest Bangladesh. BG is a collaboration programme of the Netherlands and Bangladesh Governments. The Ministry of Water Resources implements it through the Department of Agricultural Extension (DAE) and Bangladesh Water Development Board (BWDB), where BWDB is the lead agency. The overall objective of the BG programme is to reduce poverty by ensuring food security through improving water management and diversifying the agricultural products in 22 polders in coastal Bangladesh. Another important goal of the programme is to produce the maximum level of paddy, improving the farm management knowledge of the farmers while creating less pressure on the environment. BG has established the Farmer Field Schools (FFS) linked to the Water Management Groups (WMG) to enhance the productivity of crops, livestock, and aquaculture of coastal polders in Bangladesh. The first intervention of the BG is to increase rice production and enhance the farmers' knowledge by providing information on:

- The cultivation practices regarding cropping systems and technologies, varieties of seeds and time to plant them, quality of seeds, past management systems, fertilizers to use, harvesting techniques, value addition, etc.
- The productivity, market price, and profitability of crops and also the availability and price of the inputs, services, and products,
- The subject of the weather and climate conditions.

Here, in this study, the extension service is defined as the consultation provided by agricultural extension agents to promote productivity (Haile et al., 2018) and agrarian knowledge, ideas, techniques, and utilisation of modern technologies (Uddin, 2008). Technical efficiency refers to the ratio of the observed maximum production level with the given level of production technology and a set of inputs (Asadullah and Rahman, 2009). Accordingly, this study comprises the specific objectives:

(i) To estimate the technical efficiency of the participant and non-participant paddy farmers of BG programme;
(ii) To determine the impact of agricultural extension contact on technical efficiency, and
(iii) To find out the production level of the participants and non-participants of BG programme.

The results of this study will support both the government and non-government organizations (NGOs) to pursue policies and programmes and enhance agricultural production while imposing less pressure on the environment. The following sections outline the literature review, the materials and methods, then results and discussion.

2. Literature review

The impact of agricultural extension is positively associated with technical efficiency, suggesting that agricultural extension services can boost the participants' productivity and livelihood by educating farmers on their proper resource utilization (*i.e.*, inputs and technology) (Athukorala, 2017). Similarly, the effect of agricultural extension services is affirmatively and significantly allied with agricultural productivity in developing countries (Haq, 2013; Owens et al., 2003). On the contrary, in their studies, Adem and Gebregziabher (2014) and Elias et al. (2014) found no significant difference in technical efficiency between the treatment and non-treatment groups. They reported that the technical efficiency of the participant and non-participant farmers in an AES programme in Northern Ethiopia was 57% and 53% and 72% and 71%, respectively. According to Dinar et al. (2007), farmers in Crete (the largest island in Greece) who use private and public extension services achieve higher technical efficiency than those who adopt either public or private and those who do not adopt any. Furthermore, urban farmers are less efficient than rural farmers despite better access to factors of production, especially fertilizers, in Ondo State, Nigeria (Ajibefun et al., 2006). Table 1 shows the relationships between technical efficiency and various indicators of agricultural farms in previous studies.

The enrichment of farmers' wealth in Bangladesh mostly depends on their education, family size, and farming experience (Haq, 2014). Mottaleb et al. (2017) found that in Bangladesh, whether a farm household would be the lead farmer or not in their community significantly depends on their education, availability of credit, and risk-taking attitude. Besides this, Chaity and Rahman (2017) found that agricultural intervention by NGOs enhances new knowledge, access to modern technology and maintains the quantity and quality of female farmers in Bangladesh. Schreinemachers et al. (2016) found a similar effect of training that improves the output, land productivity, profitability and net income of the smallholder by more than 39%, 47%, 50% and 48%, respectively, in the Kharif season[1]. From the estimation of the production function, Ajibefun et al. (2006) perceived that the higher the extension contact between farmers and agents, the higher the farmers' income in Bangladesh. Bio-slurry increases soil fertility, maximising the Boro production with less chemical fertilizers, dry dung-cake, and labour, and reducing CO_2 emission (Kabir et al., 2016). The contact between farmers and agricultural extension agents[2] depends on the size of the farm families, level of education, chemical fertilizers, and the proximity of the village to the Upazila headquarters (Ajibefun et al., 2006). Together with private entrepreneurship, the government policies are the instruments for facilitating the widespread entrance of agricultural machinery (Mottaleb et al., 2017).

According to the definitions of neo-classical theory, the production method is technically efficient only if it is possible to produce maximum level output with the given level of inputs (Elias et al., 2014; Sexton et al., 1993). In their study on assessing farmers' technical efficiency in southwest Bangladesh, Afrin et al. (2017) found that farmers are about to 86% technically efficient. Amongst them, the farmers who are non-credit takers are less efficient than the credit takers. Correspondingly, the credit programmes (both microcredit and traditional banks) help rural families use modern agricultural inputs and technology to improve the linkages of farm/nonfarm activities in Bangladesh (Khandker and Koolwal, 2016). Anik and Salam (2017) identified that agricultural extension services, credit, and rent in the land are positively associated with efficiency, and the level of technical efficiency is sensitive to farming practices, education, ethnicity, and income. Comparatively, Haider et al. (2011) found that the years of farming experience and available credits enhance the efficiency level of the farms. Inefficiency is negatively associated with different factors like age, family size, education level, land ownership, off-farm earning, visits of the agricultural officers in the paddy farm, and communication with the agricultural officers (Athukorala, 2017).

On the contrary, Rahman et al. (2012) found that age, education, and family size are positively related to technical efficiency, but farm size is negatively associated. Correspondingly, to increase rice production and enhance the possible output, primary and secondary education of households should be ensured, as it significantly reduces production inefficiencies (Asadullah and Rahman, 2009). Still, environmental degradation and irrigation infrastructure substantially influence the paddy farmer's efficiency in Bangladesh (Wadud and White, 2000). Also, several studies conducted by Alamgir et al. (2018), Hasan et al. (2018) and Lázár et al. (2015) demonstrated the impact of climate change on farmers' income variation in different regions, food security, and agricultural livelihoods, respectively in coastal Bangladesh. Balcombe et al. (2007) examined the efficiency level between the farms that adopted traditional rice and modern rice varieties. Another study conducted by Islam and Haider (2018) investigated the association between efficiency

[1] Kharif season is one of three cropping seasons starts from mid-March to mid-July. The major crops are Jute, Aus rice, Cotton etc.

[2] The extension agents indicate the mediators who provide agricultural training or extension services.

Table 1
Indicators used in relevant literature in measuring Technical Efficiency (TE) at a glance.

Indicators	Contribution to TE (references)
Financial inclusion from different credit sources	Credit taker farmers were more technically efficient than non-credit taker farmers Afrin et al. (2017).
Drivers of production: land ownership, income, extension service, credit, land fragmentation, land slope, crop diversification	Share of plain land, agricultural income, extension service, and credit are positively and significantly associated with TE. In contrast, land fragmentation, land ownership, and land slope are negatively associated with TE Anik and Salam (2017).
Agricultural extension services	Agricultural officers contributed to increasing TE of farmers, about 13% Athukorala (2017).
Extension system: Participatory Demonstration and Training Extension Systems	The extension had a significant and positive relation with TE; participant farmers of the extension system could contribute more to enhance productivity than non-participants Gebrehiwot (2017).
Agricultural credit	Agricultural credit could increase the TE by 3.8% Abdallah (2016).
Agricultural micro-credit	Micro-credit did not contribute significantly to increase TE Anang et al. (2016).
Application of bio-slurry	Bio-slurry helped to increase Boro production by improving soil fertility and reducing chemical fertilizer use; thus, it contributed to the farm's TE Kabir et al. (2016).
Extension service	TE of participant farmers was found higher than non-participant farmers Adem and Gebregziabher (2014).
Agricultural extension service	Agricultural extension programme participants (72%) and non-participant (71%) farmers had almost the same TE Elias et al. (2014).
Agriculture credit	Mean TE of credit users found 0.90%, whereas, for the non-credit users, that was 0.79% Akram et al. (2013).
Farm size-specific productivity	Large, medium and small farms had an average TE of 0.88, 0.92, and 0.94, but the marginal farms had 0.75 Rahman et al. (2012).
Farming experience and credit availability	Farming experience and credit availability had a positive and significant effect on the TE of the farms Haider et al. (2011).
Education	Educated farmers can boost farm production, mainly the farmers who received education from primary and secondary schooling had increased TE Asadullah and Rahman (2009).
Age, education, and modern tools	Young farmers are more technically efficient than old farmers; educated farmers and mechanized households having tractors were technically efficient Abedullah and Mushtaq (2007).
Public and private extension services	Farms using private and public extension services together had increased TE Dinar et al. (2007).

Source: Authors' illustration 2020.

and poverty and found that there is heterogeneity selling behaviour of the farmers in the southwest coastal region of Bangladesh. Thus, the literature shows that existing studies rarely emphasize assessing the impact of agricultural extension services on the technical efficiency of paddy farmers in southwest Bangladesh.

3. Materials and methods

3.1. A brief overview of the Blue-Gold programme

BG is a collaboration programme of the Netherlands and Bangladesh Governments and is implemented by the Ministry of Water Resources through the Department of Agricultural Extension (DAE) and Bangladesh Water Development Board (BWDB) (Blue Golda, 2021a). The Government of the Netherlands funded this coastal development programme. BG claimed that about 34% of the total coastal population is below the poverty line and faces a higher level of vulnerability in terms of income, drinking water, health, and food scarcity (Blue Goldb, 2021b). Furthermore, the coastal people of Bangladesh suffer from tidal surges and floods, the intrusion of saline water, lack of fresh water in the dry season, and the impact of extreme events like cyclones. This programme intervened in 1,50,000 households living in the southwestern coastal polders (22 out of 139) that covered around 1,15,000ha of land in coastal Bangladesh. It includes eleven polders in Khulna, ten polders in Patuakhali, and one polder in the Satkhira district. However, to eradicate the problems mentioned above and improve coastal livelihoods by ensuring food security, improving water management, and diversifying agricultural products. Some government agencies, such as the Department of Livestock Services (DLS) and Department of Fisheries (DoF), alongside the BWDB and DAE, made contributions to the farmer field schools (FFS) to encourage farmers to cultivate and selecting crops and varieties that are well-suited for the coastal environment. Local governments, mainly the Union Parishads, are partners in polder development planning, maintenance, and coordination. The FFS are linked to the Water Management Groups (WMG's) in the selected polders to provide education and assist male and female farmers in promoting crops, aquaculture, and livestock. The expected outcome reveals that through the improvement of water management and the coordination of WMG's, there is scope to improve productivity (Blue Goldb, 2021).

3.2. Study sites

Two villages, namely Chari Jialtala and Balabunia, located in Shovna Union under Dumuria Upazila in Khulna District of Bangladesh, were selected to conduct this study. There are 14 unions in Dumuria Upazila. The total area of Shovna Union is about 10,972 acres, which consists of 19 villages (2011). The two villages Chari Jialtala and Balabunia, have been selected based on the information of trainers (mainly Blue Gold) and initial visits. In Chari Jialtala and Balabunia villages, the total numbers of households are 218 and 140, respectively, and the total populations are 936 and 547, respectively (2011). The primary source of livelihood is agriculture-related activities, in particular, rice and sweet-water prawn cultivation. Furthermore, many people in this region practice mixed farming in different seasons of the year. To pursue the intended objectives of our study, we selected the Chari Jialtala and Balabunia villages from the same geographical region. The village of Balabunia is four kilometres away from the village of Chari Jialtala and has similar characteristics. Again, all respondent farmers have equal access to the same production technology, but the difference is the efficient utilization (Dinar et al., 2007) in both villages.

Since all paddy farmers of the treatment village did not take agricultural extension training, they might be the followers of the participant farmers. There is an externality effect of schooling observed when educated farmers help to increase the crop productivity of their uneducated neighbours (Weir and Knight, 2007). Therefore, there might be a spillover effect[3]. In this regard, to avoid possible spillover effects, the control group was not selected from the same village (Schreinemachers et al., 2016). Accordingly, this study considered the Chari Jialtala village as the treatment village because the farmers were participants in the environmental-friendly AES of BG. On the other hand, the village of Balabunia has been chosen as the control village. Fig. 1 depicts the location of the study villages.

[3] Here, the spillover effect impels the effect of farming knowledge of the participants that received the BG extension service may be shared with the non-participants.

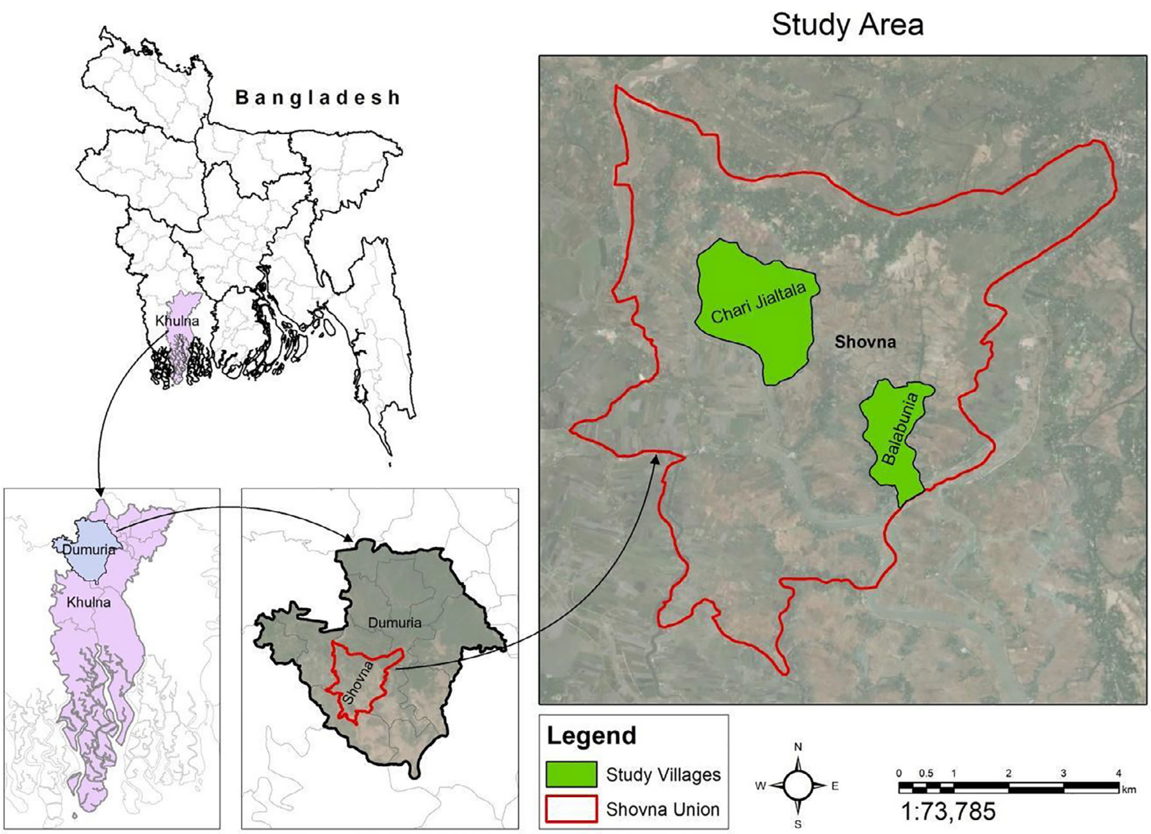

Fig. 1. Study area.

3.3. Data collection

The study employed a structured questionnaire survey to collect information from both participant and non-participant Boro paddy farmers. A random sampling method was applied to select 122 paddy farmers, 55 from the control village and 67 out of 150 trained farmers from the treatment village. The AES training was provided for the randomly selected participants under the BG project. A qualification question (*i.e.*, whether they received BG provided training) was asked to select the respondents in the treatment village. Thus, it also avoids the spillover effect between the farmers.

The structured questionnaire form was designed in KoBoToolbox (Kobo, 2019), an open-source field data collection tool. It allows tablet or mobile as well as computer or paper data for field-level data collection. In this study, it was adopted in an Android system-supported mobile device for collecting data. The trainers of the different NGOs and project officers, especially from the BG project, were interviewed as key informants. The questionnaire consisted of household, farm-related, and environment-related questions. The farmers of Balabunia (the control village) were surveyed from 05 to 15 August 2019, and the farmers of Chari Jialtala (the treatment village) were surveyed from 20 August to 4 September 2019. Each interview took about 25-30 minutes.

3.4. Specification of the model

The efficiency and productivity analysis techniques are broadly categorized into two approaches, parametric and non-parametric (Data Envelopment Analysis) (Jarzębowski, 2013). Again, there are two parametric methods; stochastic and deterministic (Afrin et al., 2017). The model's output varies due to the input changes, technical efficiency/inefficiency, and random shocks such as weather situation, environmental influences, and availability of resources (Mehdi et al., 2016; Kumbhakar and Lovell, 2003; Sesabo, 2007). The Stochastic Frontier approach allows the decomposition of both efficiency and random shock, where the non-parametric DEA does not assume random shocks (Abedullah and Mushtaq, 2007). Again, a homogeneous production function provides a scale factor to compute the return to scale and interpret elasticity coefficients (Afrin et al., 2017).

The stochastic approach is mainly and commonly used for the estimation of technical efficiency. In the technical efficiency analysis, the Translog and Cobb-Douglas production functions are broadly utilized as a functional form of a stochastic approach (Rahman et al., 2012;Haider et al., 2011; Hossain et al., 1970). Moreover, it suffered less severity of multicollinearity as well as from a degree of freedom (Rahman et al., 2012). In order to measure the technical efficiency of the paddy farmers, this study considers the functional form of the stochastic production function in the following Eq. (1) (Afrin et al., 2017; Rahman et al., 2012; Abedullah and Mushtaq, 2007; Battese and Coelli, 1995).

$$Y_i = f\left(X_i;\ \beta\right)e^{\varepsilon} \tag{1}$$

Where, Y_i, X_i and β indicate the amount of output, vectors of inputs, and unknown parameters of the vectors of inputs, respectively.

The logarithm expression of the Cobb-Douglas production function is as follows in Eq. (2):

$$lnY_i = \beta_0 + \sum_{j=1}^{n} \beta_j lnx_{ij} + \varepsilon_i \tag{2}$$

Where, $i = 1, 2, 3 \ldots\ldots\ldots, n$ and $j = 1, 2, 3, \ldots\ldots\ldots, m$ are the number of paddy farmers and vector of inputs, respectively. $Y_i =$ Output (maunds); $X_{ij} =$ vector of factors of production of the $i^{th}ith$ farmer. The symbol β indicates the unknown parameters of the vectors of inputs, and ln indicates the logarithm, respectively. The symbol ε in Eq. (3) represents the composed error term which is the sum or difference of ω_i and u_i (Belotti et al., 2013).

$$\varepsilon_i = \ \omega_i - u_i \tag{3}$$

Where, ω_i is two-sided ($-\infty < \omega_i < +\infty$) customarily distributed random error term or random shocks those reflects are out of the farm control like natural disasters, and weather; and u_i refers to technical inefficiency. This error term is non-negative ($u_i \geq 0$) one-sided random variable effects independent of ω_i. The random shock (ω_i) is assumed to be $N(0, \sigma_\omega^2)$ indicating that the error term is independently and identically normally distributed (Coelli et al., 2002). Similarly, it is assumed that the inefficiency (u_i) is ($U \sim |N(0, \sigma_\omega^2)|$), which indicates the inefficiency effects are independently distributed (Rahman et al., 2012;Baten et al., 2009).

The following Eq. (4) represents the functional form of technical inefficiency as a function of different socio-demographic, socio-economic and farm unique characteristics.

$$U_i = f\left(Z_{ji}\right) \tag{4}$$

Where, $U_i(= 1 - TE_1)$ is the technical inefficiency of the i^{th}ithfarmers and the Z_{ji} is the set of independent variables.

We estimated the parameters of the stochastic frontier model using the Maximum Likelihood Estimation (MLE) procedure using Eq. (2), where the likelihood function is presented in terms of variance parameter in Eq. (5) (Ajibefun et al., 2006; Rahman and Barmon, 2019).

$$\sigma^2 s = \sigma^2 \omega + \sigma^2 u; \gamma = \frac{\sigma^2 u}{\sigma^2 s} \text{and} 0 \ \leq \gamma \geq 1 \tag{5}$$

Where, the $\sigma^2 s$ symbolizes the variation of output due to the changes in random shock and inefficiency. The value of γ lies between 0 and 1, indicating If the value of $\gamma = 1$, there is complete inefficiency, and if $\gamma = 0$, there is no technical inefficiency

3.5. Hypothesis testing and the empirical model

Technical efficiency refers to how the farmers can produce the maximum feasible output with the given inputs (Coelli et al., 2002). Farrell (1957) analysed farm efficiency, using both output and input approaches to increase efficiency and productivity. One concerns how much production can be increased with given inputs, and another considers how much input can be reduced, without changing the production, respectively (Elias et al., 2014). Likewise, the previous study conducted by Rahman and Barmon (2019), as we have used a large number of explanatory variables, firstly chosen the Cobb-Douglas instead of the Translog production function. Kopp and Smith (1980) claimed that there is no significant variation in the efficiency score in the choice of functional form. Notwithstanding, we tested various hypotheses for the selection of production function.

The null hypotheses:

H_0: $\beta_{jk} = 0$. The Translog production function adequately represents the data.

$H_0 : \delta_1 = \delta_2 \ldots\ldots\ldots\ldots \delta_{16} = 0$. The coefficients of the independent variables in the inefficiency model are zero.

H_0: $\gamma = 0$. The inefficiency effects are not present in the model.

The logarithm expression of the Cobb-Douglas production function is as follows in Eq. (6):

$$\begin{aligned} lnY_i = {} & \beta_0 + \beta_1 lnx_{1i} + \beta_2 lnx_{2i} + \beta_3 lnx_{3i} + \beta_4 lnx_{4i} \\ & + \beta_5 lnx_{5i} + \beta_6 lnx_{6i} + \beta_7 lnx_{7i} + \varepsilon_i \end{aligned} \tag{6}$$

Where, Y_i = Output (maunds) of the i^{th}ith paddy farmers; x_1= land size/hectare; x_2 = human labour/man-day; x_3 = seed/kg; x_4 = chemical fertilizer/kg; x_5 = cultivation cost/kg x_6 = pesticide/kg; and x_7 = irrigation cost/BDT. ε_i = composed error term.

To estimate the determinants of the technical efficiency, three categories of variables, namely, socio-demographic characteristics (Z_{1ij}), agricultural extension services characteristics (Z_{2ij}) and farmers' unique characteristics (Z_{3ij}) were incorporated, respectively in Eq. (6) (see Table 2).

The following Eq. (7) estimates the determinants of the farmers' technical inefficiency.

$$U_i = \alpha_0 + \sum_{j=1}^{m} \delta_{1j} Z_{1ij} + \sum_{j=1}^{m} \delta_{2j} Z_{2ij} + \sum_{j=1}^{m} \delta_{3j} Z_{3ij} + e_i \tag{7}$$

Where,

$i = 1, 2, 3 \ldots\ldots\ldots.., n$ and $j = 1, 2, 3, \ldots\ldots.., m$

TE_i = *Technical efficiency*

Z_{1ij} = *Socio-demographic characteristics*

Z_{2ij}= *Agricultural extension characteristics*

Z_{3ij}= *Special characteristics of the paddy farmers*

α_0= *Intercept term*

δ_1, δ_3 *and* δ_2=*Coefficients*

e_i= *Error term*

In Eq. (7), a total of eleven socio-demographic characteristics, *i.e.*, age (Z_{11}), years of education (Z_{12}), household size (Z_{13}), farm size (Z_{14}), ownership of the land (Z_{15}), years of farming experience (Z_{16}), access to credit (Z_{17}), off-farm work (Z_{18}), and the amount of credit (Z_{19}), the amount of off firm income (Z_{110}) and distance of the plot (Z_{111}) from the homestead have been incorporated. On the other hand, four variables under the training and AES, *i.e.*, farmers' adoption of agricultural extension services from the BG extension services (Z_{21}), number of visits of agricultural officers (Z_{22}), receive training from an agricultural training centre (ATC) (Z_{23}), and the dummy variable watch agricultural programme on TV (Z_{24}) were used.

Finally, three particular characteristics of farmers, *i.e.*, irrigation system (Z_{31}), mouse protection system (Z_{32}) and use of dung (Z_{33}) in the paddy farms were incorporated to assess the technical efficiency of the Boro paddy farmers.

Using $\text{STATA}_{14,}$ the maximum likelihood estimates (MLE) of the Cobb-Douglas stochastic frontier and inefficiency model were obtained simultaneously.

Likewise, Elias et al. (2014), this study conducts the overlap hypothesis employing normalized different given by the following Eq. (8)

$$\Delta X = \frac{X_1 - X_0}{\sqrt{\delta_1^2 + \delta_0^2}} \tag{8}$$

Where, δ_1^2 and δ_0^2 are the sample variances. And X_1 and X_0 are the mean value of the different indicators of the participant and non-participant groups, respectively.

4. Results

4.1. Summary statistics of the respondents

The farmers' socio-demographic characteristics, training, AES characteristics, and standard inputs used for paddy cultivation are presented in Table 2. The mean age of the sample respondents is about 45 years, with a minimum of 20 and a maximum of 82 years old. The mean years of education of the farm operators are 7.57, where the minimum and maximum years of education are 0 and 16. Similarly, the mean year of farming experience is 25.12, with the minimum and maximum years of farming experience at 2 and 55, respectively. About 95% of farmers were involved in off-farm work such as driving, business, day labour, and paddy farming, and 14% of farmers took credit for Boro paddy cultivation from different sources.

In total, 55% of the paddy farmers have received agricultural extension services from BG. Furthermore, 12% of the total paddy farmers received short-term training from Dumuria Agricultural Training Centre (ATC) and other sources. On average, the frequency of the agricultural officers' visits to paddy farms is less than two times upon the request of farmers when they consulted regarding the Boro paddy cultivation, and 53% of farmers watched agricultural programmes on TV. Both activities might enhance the farm knowledge as well as the technical efficiency of the paddy farmers.

Table 2
Summary statistics of the rural paddy farmers.

Variables	Mean	Std.	Min.	Max.
Socio-demographic characteristics				
Age (Years)	44.98	13.36	20.00	82.00
Education of the farm operator (Years)	7.57	4.10	0.00	16.00
Experience of farming (Years)	25.12	13.22	2.00	55.00
Household size (Numbers)	5.00	1.65	2.00	12.00
Farm size (Hectares)	0.65	0.48	0.12	3.04
Ownership of the land (Own=1, Lease=0)	0.93	0.26	0.00	1.00
Access to credit (Yes=1, No=0)	0.14	0.35	0.00	1.00
Off-firm work (Yes=1, No=0)	0.95	0.22	0.00	1.00
Amount of credit (BDT)	3360.66	10172.94	0.00	60000.00
Amount of off-firm earning (BDT)	7780.87	5979.73	0.00	41666.00
Distance of plot from home (Km)	0.47	0.50	0.01	3.00
Training and AES service characteristics				
Participation in AES school of BG (Yes=1 No=0)	0.55	0.50	0.00	1.00
Frequency of visits of AO (Numbers)	1.64	2.12	0.00	10.00
Receive training from ATC (Yes=1 No=0)	0.12	0.33	0.00	1.00
Agricultural programme on TV (Yes=1 No=0)	0.53	0.590	0.00	1.00
Farmer's distinctive characteristics:				
Irrigation system (Shallow=1, Otherwise=0)	0.25	0.44	0.00	1.00
Mouse abatement methods (Electricity =1, Otherwise=0)	0.39	0.49	0.00	1.00
Use of organic fertilizers (Yes=1, No=0)	0.51	0.50	0.00	1.00
Commonly used factors of production:				
Land (Ha)	0.65	0.48	0.12	3.04
Labour (Man days/ha)	87.96	18.28	39.51	138.27
Fertilizers (Kg/ha)	475.86	150.72	237.04	908.64
Organic fertilizer (Kg/ha)	268.21	327.30	0.00	1975.31
Seed (Kg/ha)	14.55	7.05	9.88	49.38
Pesticide (g/ha)	293.95	158.02	49.38	987.65
Irrigation cost (BDT/ha)	10273.22	6626.11	987.65	39506.17
Cultivation cost (BDT/ha)	6376.12	1135.55	3459.47	11861.04
Outcome variables:				
Output (Maunds/Ha)	151.12	31.55	39.52	222.30
TE of the paddy farmers (%)	0.89	0.13	0.26	0.98.

N.B.: One maund = 40 Kg; AES = Agricultural extension service; BG = Blue Gold; AO = Agricultural officers; ATC = Agricultural training centres.
Source: Authors' compilation based on the field survey, 2019.

The results demonstrate that the farmers used on average 0.65 hectares of land for Boro paddy. Also, the uses of common factors of production like labour, chemical fertilizer, organic fertilizer, seed, pesticide, and irrigation were on average 87.96 person-days, 475.86 Kg, 268.21 kg, 14.55 kg, 293.95 g, and 10273.22 BDT (120.93 US$) per hectare, respectively. Thirty-nine percent of farmers used electricity in their paddy fields for mouse abatement. It shows that about 51% of farmers used dung as organic fertilizer. In the Boro season, 25 % of farmers cultivate paddy with shallow water, whereas the rest use water from rivers, canals, ponds, and other sources. The result also shows that the Boro paddy farmers' irrigation cost is generally higher for those who use shallow water.

The mean output is more than 151.12 maunds (6044.80 kg) per hectare with a maximum of 222.30 maunds (8892 kg) and a minimum of 39.52 maunds (1580.890 kg) paddy per hectare. The average technical efficiency is 89%, with a maximum of 98 and a minimum of 26, respectively.

4.2. Participants and non-participants of AES under Blue Gold

Table 3 shows the mean comparison of the extension services receivers of the treatment village and non-receivers of the control village. The mean difference between the participant's education level and non-participant farmers of the treatment village and control village is 1.13. The farmers of the treatment village who received agricultural extension services earned off-firm revenues of about 3209.67 more BDT (37.78 US$) on average compared to the non-receivers, which is statistically significant at a 1% level. In contrast, it has been found that the non-participant farmers receive more credit, about 3481.68 BDT (40.95. US$), which is also statistically significant at the 10% level. Furthermore, the normalized differences shown in Table A.1 are minor, indicating that the farmers' demographic, economic, and other training and extension service characteristics are well balanced between the two groups. In the balancing test, Imbens and Wooldridge (Imbens and Wooldridge, 2009) considered a normalized difference more significant than 25.

It has been found that about 33% more farmers from the treatment village who have received extension services from BG use organic fertilizers in their paddy land, which is significant at a 1% level.

In comparison to the standard inputs uses of the rural paddy farmers, it has been calculated that the farmers of the treatment village need more labour days (around 9.1 labour days more per hectare of land). In contrast, they spend less (about 3520.31 BDT or 41.44 US$ per hectare of land) for irrigation purposes shown in Table 3. These results are both statistically significant at a 1% level. The result indicates that the participant farmers use significantly fewer pesticides and fertilizers than the non-participant farmers of the treatment village. Comparison of the results also shows that the farmers of the treatment village use significantly more organic fertilizer. Many farmers from the treatment village reported that they have learned from the AES school of the BG programme that if they use more pesticides and more fertilizers in the paddy fields, it will have adverse impacts on the human body and the environment. Furthermore, most of the paddy farmers of the treatment village reported that they had learned alternative ways to protect from insects to using pesticides.

The average output produced by the participant and non-participant farmers of the treatment and control village is 162.74 maunds/ha (6509.60 kg/ha), and 136.84 maunds/ha (5473.60 kg/ha), respectively. The mean difference between these two groups is 25.91 maunds/ha (1036.40 kg/ha) and is statistically significant at the 1% level.

Table 3
Mean differences between treatment and control village.

Variables	Treatment village (N = 67)		Control village (N = 55)		Mean difference	t-test
	Mean	Std.	Mean	Std.		
Household characteristics						
Age (Years)	45.45	12.45	44.42	14.49	1.03	0.42
Household size (Numbers)	5.24	1.49	4.71	1.79	0.53	1.78*
Education level (Years)	8.07	3.64	6.95	4.55	1.13	1.52
Experience (Years)	24.69	13.18	25.65	13.38	-0.97	-0.40
Off-firm revenue (BDT)	9227.85	6424.94	6018.18	4889.49	3209.67	3.05***
Amount of credit (BDT)	1791.05	6496.01	5272.73	13173.28	-3481.68	- 1.90*
Distance of plot from home (Km)	0.45	0.45	0.49	0.55	-0.04	-0.42
Use of organic fertilizers (Yes = 1, No = 0)	0.66	0.48	0.33	0.47	0.33	3.80***
Traditional inputs						
Land (Hectares)	0.66	0.49	0.63	0.47	0.03	0.38
Labour (Man days/ hectare)	92.06	17.55	82.96	18.07	9.10	2.81***
Seed (Kg/Hectare)	14.45	6.72	14.68	7.50	-0.23	-0.18
Fertilizers (Kg/hectare)	455.52	123.44	500.63	176.47	-45.12	-1.66*
Organic fertilizers (Kg/hectare)	313.03	256.44	213.60	392.60	99.42	1.68*
Pesticide (Grams/hectare)	267.70	143.24	325.93	170.23	-58.23	-2.05**
Irrigation cost (BDT/ hectare)	8686.20	6712.36	12206.51	6031.63	-3520.31	- 3.02***
Cultivation cost (BDT/ hectare)	6461.61	1189.95	6271.97	1067.08	189.64	0.92
Outcomes						
Output (Maunds/hectare)	162.74	25.20	136.84	32.61	25.91	4.95***
Technical efficiency (%)	0.95	0.04	0.82	0.17	0.13	5.99***

N. B.: * t > 1.68, ** t > 1.96, *** t > 2.32.
Source: Authors' compilation based on the field survey, 2019.

4.3. *Maximum-likelihood of the Cobb-Douglas stochastic frontier model*

Various hypotheses testing has been carried out given the Cobb-Douglas production function and inefficiency model in equation-6 and 7. The first hypothesis testing was chosen the functional between Translog and Cobb-Douglas production function. The log-likelihood function of the Cobb-Douglas and Translog production functions are 68.89 and -64.80. The log-likelihood ratio is (LR = -2*(-64.80–68.89 = 267.38), which is excelled the tabulated values obtained from the Kodde and Palm (1986). This complies with rejecting the null hypothesis that the Translog production function is appropriate for the data. Hence, the Cobb-Douglas production function adequately represents the data. Secondly, the null hypothesis $H_0 : \delta_1 = \delta_2 = \ldots \ldots \ldots \delta_{16} = 0$ that states that the coefficients of the independent variables in the inefficiency model are zero must be rejected because there are explanatory variables that significantly impact the inefficacy in the inefficiency model. Finally, the null hypothesis, γ =0 says that the technical inefficiency is absent from the frontier model is rejected. The value of the γ is presented in Table 4 different from zero, indicating the existence of inefficiency. However, based on the results of these hypothesis testing, the Cobb- Douglas production function has been selected as the prescribed model that fits the data better.

The parameters of the Cobb- Douglas production function and the parameters of the jointly estimated model (stochastic frontier and inefficiency model) are shown in the second and last column in Table 4. From the estimation, Cobb-Douglas (OLS) 's production function shows a positive relationship between the land and paddy production of the farmers, which is significant at the 1% level. It indicates that with a 1% increase in land input, the output increases by 0.10.

Cobb-Douglas production function estimates that the chemical and firm cultivation cost are statistically significant at the 1% level, implying that the increase in fertilizers and cultivation costs increases production. On the other hand, pesticides are significantly and negatively associated at a 5% level with the output level. It might be that generally, farmers in the study area use pesticide only when it is needed. Similarly, the jointly estimated SFA model shows that the fertilizer and cultivation costs are significant at 1%. These positive coefficients indicate that a 1% increase in the fertilizer use and the land cultivation cost increase 0.21 and 0.24 in the rice production of the rural farmers. On the other hand, the negative coefficients of the inputs seed and pesticide are adversely associated with the production level. This indicates that in the increase in seed and pesticide by 1%, the production level declined by 0.11 and 0.04, respectively.

The lower panel of the Table 4 demonstrates the determinants of the technical inefficiency of the Boro paddy farmers. All variables were split into three categories to determine the factors that influence the technical efficiency of the rural paddy farmers. These are socio-demographic characteristics (Z_1), training and agricultural extension characteristics (Z_2), and farmer's special characteristics (Z_3).

The significant and negative coefficient of the BG school's agricultural extension service (AES) indicates that the participant farmers are 9.38% more efficient than the non-participant farmers. The inefficiency model, lower panel of Table 4, shows that the age of the farmers and household size are negatively and significantly associated with the farmers' technical inefficiency. A significant and opposite relationship has been predicted between the access to off-farm work and the technical inefficiency of the Boro paddy farmers. This indicates that farmers engaged in off-firm work have a technical efficiency 8.69% higher than those who do not.

The inefficiency model shows that the paddy farmers' years of farming experience and technical inefficiency are positively associated. The number of agricultural officers (AO) visits is negatively and significantly associated with technical inefficiency. On the other hand, the model estimates a significant positive relationship between technical efficiency and watching TV.

4.4. *Distribution of technical efficiency*

The distribution of the technical efficiency of the Boro paddy farmers has been listed in Table 5. In this study, the farmers' technical efficiency results have been classified into seven categories ranging from 26 to 98%. The estimated results indicate that the technical efficiency of the more significant number of participant farmers (more than 64.18%) of the treatment village and non-participant farmers (more than 38.18%) of the control village lies between and 0.95≤ TE 0.85 ≤ TE < 0.95, respectively.

The mean technical efficiency of the agricultural extension service receivers of the treatment village is about 95% for those who received training from the BG extension services. In contrast, the technical effi-

Table 4
OLS and MLE of the Cobb-Douglas stochastic frontier model.

Variables	Symbols	Ordinary Least Squares (OLS)	Maximum Likelihood Estimation (MLE)
Land	(Ln_{x1})	0.10***(0.03)	0.00(0.02)
Labour	(Ln_{x2})	0.01(0.09)	0.07(0.05)
Seed	(Ln_{x3})	0.01(0.06)	-0.11***(0.03)
Chemical fertilizer	(Ln_{x4})	0.23***(0.07)	0.21***(0.04)
Cultivation	(Ln_{x5})	0.42***(0.12)	0.24***(0.07)
Pesticides	(Ln_{x6})	-0.08**(0.04)	-0.04**(0.02)
Irrigation	(Ln_{x7})	-0.03(0.03)	0.02(0.02)
Constant		0.59(1.22)	1.74**(0.73)
Log-Likelihood function		14.21	68.89
		Inefficiency model	
Age	(Z_{11})		-0.28*(0.18)
Education of the farm operator	(Z_{12})		0.00(0.27)
Household size	(Z_{13})		-2.35*(1.33)
Farm size	(Z_{14})		-3.48(3.62)
Land ownership	(Z_{15})		1.59(5.07)
Experiences of farming	(Z_{16})		0.28*(0.17)
Access to credit	(Z_{17})		8.52(5.88)
Off-farm work	(Z_{18})		-8.69*(5.20)
Amount of credit	(Z_{19})		-0.00(0.00)
Amount of off-farm income	(Z_{110})		0.00(0.00)
Distance of plot	(Z_{111})		-1.50(2.08)
Participate in AES school of BG	(Z_{21})		-9.38**(4.81)
Number of visits of AO	(Z_{22})		-2.17*(1.50)
Receive training from ATC	(Z_{23})		-8.86(7.35)
Agricultural programme on TV	(Z_{24})		4.64*(2.84)
Irrigation system	(Z_{31})		3.18(2.80)
Mouse protection system	(Z_{32})		-0.88(2.28)
Uses of the dung	(Z_{33})		-1.09(2.43)
Constant			13.01*(7.92)
γ			0.99**(2.74)

N. B.: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Authors' compilation based on the field survey, 2019.

Table 5
Distribution of the technical efficiency of the rural paddy farmers.

Technical Efficiency (TE)	Treatment village		Control village	
	Participants in AES (N = 67)	(%)	Non-participants in AES (N = 55).	(%)
TE<0.45	0	0	3	5.45
0.45≤TE<0.55	0	0	2	3.64
0.55≤TE<0.65	0	0	1	1.82
0.65≤TE<0.75	0	0	9	16.36
0.75≤TE<0.85	1	1.49	8	14.55
0.85≤TE<0.95	23	34.33	21	38.18
0.95≤TE	43	64.18	11	20.00
Mean		0.95		0.82
Std. Dev.		.035		0.17
Maximum		0.98		0.98
Minimum		0.82		0.26

Source: Authors' compilation based on the field survey, 2019.

ciency of the non-receiver farmers of the control village is approximately 82%, as shown in Table 5. The results presented in Table 5 show that the technical efficiency of 64.18% of farmers of the treatment village is more than 95% (up to 98%). There is no farmer in the treatment village whose technical efficiency is less than 75%. In contrast, there are many farmers (about 27.27%) in the control village whose technical efficiency is less than that. The farmers' technical efficiency variation is very scanty between the land ownership groups and additional income and educational groups in both villages. Whereas Table A.2 reports that the mean technical efficiency significantly varies across the farming with own land and different level of income and educations between the participants and non-participants.

5. Discussion

Rice production plays a vital role in a nation's agricultural sector (Athukorala, 2017). Still, there are high levels of inefficiency in modern rice production due to allocative, technical, and scale inefficiency (Rahman, 2003). In this regard, there is a possibility of increasing productivity by adopting advanced technologies or improving farmers' efficiency, or both (Adem and Gebregziabher, 2014). The central objective of this study was to assess the impact of agricultural extension contact on the technical efficiency of the participant and non-participant farmers of the BG programme.

The agricultural extension service of the BG positively and substantially influences farmers' technical efficiency in southwest coastal Bangladesh, which is also consistent with previous studies (Elias et al., 2014; Dinar et al., 2007; Anik and Salam, 2017). The socio-demographic factors, *i.e.*, age, family size, and off-farm work, are positively and significantly related to technical efficiency. This finding is similar to (Haq (2014) and Mottaleb et al. (2017), where they mentioned that the enhancement of farmers' wealth in Bangladesh mostly depends on their education, family size, and farming experience. Furthermore, Athukorala (2017), Afrin et al. (2017) and Rahman et al. (2012) found that household size is positively and significantly associated with the farmers' technical efficiency.

The number of farm visits of the agricultural officers plays a vital role in enhancing the farmers' technical efficiency; this finding supports the research of Athukorala (2017). The years of farming experience have a negative association with the technical efficiency of the paddy farmers, whereas previous studies conducted by Afrin et al. (2017) and Rahman et al. (2012) found an affirmative association between them.

The positive changes in land surge enhance the production of paddy per hectare. This result is similar to the findings of Afrin et al. (2017), Abdallah (2016) and Duy (2015). In contrast, Haider et al. (2011) found the inverse relationship between crop production and property. The increase of chemical and organic fertilizer usages positively influences paddy production, whereas the increase in pesticide usages adversely affects paddy production.

There is a significant difference between the technical efficiency of the participant (around 89%) and non-participant groups (around 80%). This result is also akin to the previous findings byAdem and Gebregziabher (2014), Elias et al. (2014) and Dinar et al. (2007) which reveals that there is the potentiality to promote technical efficiency of the Boro paddy farmers through the agricultural extension services. The participant farmers of the AES in the treatment village need more labour days per hectare of land but fewer irrigation costs. Gebrehiwot (2017) found a similar significant result for the input variable 'labour days'. There is a significant difference in the production level between the participants (162.74 Maunds/hectare) and non-participants (136.84 Maunds/hectare), which is consistent with the previous findings of Birkhaeuser et al. (1991), Haq (2013), Owens et al. (2003), Gebrehiwot (2017) and Haider et al. (2011). In the mean comparison results, it has been found that the farmers from the treatment village use less chemical fertilizers and pesticides than the farmers of the control village in the Boro season. Again, to increase the productivity of paddy farms, a significant number of farmers from the treatment village use more organic fertilizers than the farmers from the control village. It also implies that the farmers of the treatment villages practise environment-friendly activities for paddy production.

Therefore, the findings postulate that the agricultural extension services of the BG programme help enhance the technical efficiency of the paddy farmers and increase environment-friendly agriculture-related knowledge. In this regard, the findings of this study are crucial for illiterate rural farmers to yield paddy efficiently and productively, creating less pressure on the environment. Furthermore, this study would help to promote environmentally sustainable farming strategies and increase rural economic development through policy implications. This study recommends developing agricultural extension services methods and the inclusion of more farmers under such training programs to enhance the technical efficacy and production level of rural paddy farmers.

Declaration of Competing Interest

The authors have declared that no competing interests exist. Also the authors received no specific funding for this work.

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Supplementary materials

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