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Impact of Environmental Factors on Efficiency of Rice Production in Bangladesh

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Abstract: This study uses environment variables in Data Envelopment Analysis (DEA) and examines the influence of environmental factors on efficiency of rice production in Bangladesh. Data was collected from Bangladesh Bureau of Statistics (BBS) and Bangladesh Meteorology Department Efficiency with and without environmental factors of three type of rice production (AUS, AMAN and BORO) are measured using data envelopment analysis. Efficiency of rice production which measured without environmental factors is explained by the environmental factors (Rainfall, Temperature and Humidity) using Tobit regression to weigh up the impact of these factors on rice production. Efficiency of BORO production with environmental factors is almost similar to the efficiency of production without environmental factors. Production efficiency of AUS and AMAN employing environmental factors is higher than that of without environmental factors. Humidity has a positive and significant effect on all types of rice production. Temperature has a negative impact on production efficiency, implying that global warming could be a cause for a decrease in efficiency of rice production. Rainfall has a positive impact only on BORO production.

Key words: Data envelopment analysis, tobit model, environmental factors, efficiency, Bangladesh

INTRODUCTION

Agricultural productivity depends on environmental, behavioural and policy dimension (Clapham, 1980). Favourable conditions of environmental factors increase the production of rice. When environmental factors are unfavourable, farmers allocate more input for production (Sherlund *et al*., 2002). Environmental factors affect productivity and efficiency of agricultural production (Long and Yabe, 2011). Bangladesh produces three different types of rice such as AUS, AMAN and BORO. AUS and AMAN are rain-fed crops. Thirty to 70% of Bangladesh experience flood every year (Agrawala *et al*., 2003), therefore rice production is largely affected by factors such as rainfall, humidity and temperature (Islam *et al*., 2011a). For policy making, it is necessary to know the impact of environmental factors on efficiency of rice production.

Most of research conducted on efficiency of rice production in Bangladesh did not consider the effect of environmental factors. Sarker *et al*. (2012a) explored the relationship between climate changes (Rainfall, Temperature change) and rice yield using time series analysis. Basak *et al*. (2010) showed the impact of climate change on BORO production using Decision Support System for Agro-technology Transfer (DSSAT). Hossain *et al*. (2012a,b) showed the influence of environmental constraints on efficiency of rice using Tobit regression analysis. Coelli *et al*. (2002) find out the efficiencies of farms and then explained the efficiencies with socio demographic variables and environmental factors using Tobit regression. On the other hand, Wadud and White (2000), Haider *et al*. (2011), Sharif and Dar (1996), Banik (1994) and Hossain (1989) focused only on efficiency. Wadud and White (2000) compared the efficiency of household rice farm using Stochastic Frontier Analysis and Data Envelopment Analysis. The efficiency of rice farms of Northern and Southern part of Bangladesh were measured by Backman *et al*. (2011) and Haider *et al*. (2011) using SFA. Backman *et al*. (2011) also determined the socio-economic factors that affecting the efficiency. Islam *et al*. (2011b) determined the technical efficiency of microfinance borrowers and non-borrowers of rice farming household using SFA. They explained technical efficiency using demographic and socio-economic variables.

An improved understanding of these relationships can help the farmers to allocate scarce resources more efficiently and may assist policy makers to design and formulate agricultural policy to increase agricultural production in Bangladesh. A few number of research consider the three types of rice separately such as

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Hossain *et al.* (2012a,b) and Sarker *et al.* (2012a, b) etc. but as far as our knowledge is concerned no research has been conducted to assess the impact of environmental factors of these three type of rice separately. This study extends the efficiency studies in by comparing AUS, AMAN and BORO rice production performance in the presence of environmental factors. In this article, year-wise efficiency for each type of rice production without environmental factors and with environmental factors is measured using Data Envelopment Analysis. The impact of environmental factors on the efficiency of production is evaluated using Tobit regression.

RICE IN BANGLADESH: CONTRIBUTION AND CULTIVATION

Rice is central to Bangladesh's economy and it is the staple food for the people. About 18% of national Gross Domestic Product (GDP) and half of agricultural GDP are contributed by rice sector. Three quarter of the total cultivated area are used for rice to produce 94% of total crops production. Figure 1 and 2 represent the production of rice and area used for production, respectively. Production of AUS and used of area is almost same for the study year from 1989-2008. Production area for AMAN slightly decreased from 1989-2008 but its production increased between the year. In the earlier year, the BORO production was lower than AMAN but after 1997, it changed. In the recent year area used for AMAN and BORO is almost similar but BORO production is higher than AMAN production.

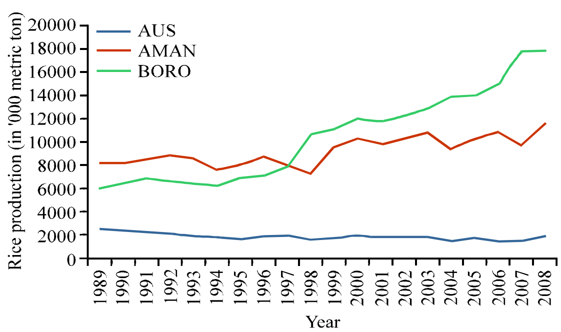

Fig. 1: Production of different type of rice

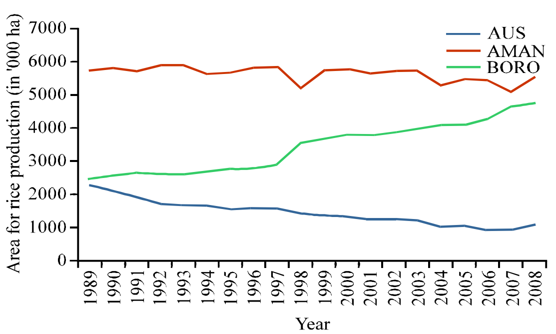

Fig. 2: Area used for different type of rice

In Bangladesh, three types of rice are grown in overlapping seasons. The monsoon rice, AMAN, is sowed from mid-May to mid-August and harvested from November to mid-December. Seed of AMAN is broadcasted in low lands then transplanted in the medium-low to medium-high elevations. The early monsoon rice is known as AUS. A dry direct seed of AUS is sowed in mid-March when mild rains moisten the soil. The plant survives under mild drought conditions until mid-May, grows up with the early monsoon rains and is harvested in mid June to mid August. This low-yielding crop is grown in relatively high lands where cultivation of the rain-fed transplanted AMAN crop is not possible. The dry season irrigated rice is BORO. It is used to be grown in extreme low-lying lands in depressed basins. BORO is transplanted in knee-deep water from middle of November to end of January when the floods recede and is harvested from middle of April to middle of May. Rice production is affected by climate and land type. In highland, it is difficult to keep water from rain as well as low land is flooded easily with rain. Eastern part of Bangladesh has lowland is known as "Hoar". In Hoar area people can cultivate once a year because of environmental factors effect. Northern part of Bangladesh is near to Himalayas. In winter, because of low temperature rice production is effected in this area. Figure 3 shows the calendar of rice in Bangladesh.

Bangladesh is a low lying country situated in South Asia located at 21-26° north of the equator. It experiences six seasons in a year. The country receives over 2000 mm of rainfall in all part of it. About 80% of total rainfall happens during June to September. Bangladesh is one of the wettest places in the world. The highest temperature is usually recorded in April and May, almost 35-38°C. The lowest temperature is in December and January. Temperature in the cool months is varies from 15-20°C.

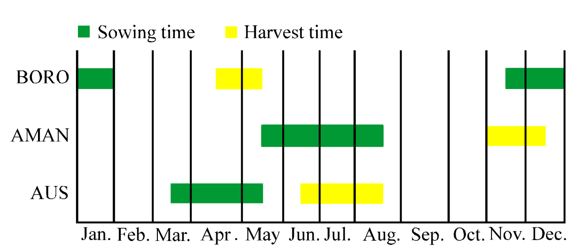

Fig. 3: Rice calendar of Bangladesh

METHODOLOGY

Analytical framework of CRS-DEA: Let us consider that pth farm used s inputs to produce t outputs. In order to measure production efficiency in Constant Return to Scale (CSR), DEA model (Charnes *et al*., 1978) can be defined as follows:

$$\underset{\theta,\lambda}{\text{Max}} \quad \theta_p$$

Subject to:

$$x_{pi} \geq \sum_{p=1}^{n} \lambda_p x_{pi} \quad i = 1, 2, ..., s \tag{1}$$

And:

$$\theta_p y_{pj} \leq \sum_{p=1}^{n} \lambda_p y_{pj} \quad j = 1, 2, ..., t$$

where, $x_{pi} \geq 0$ is the i-th input and $y_{pj} \geq 0$ is the j-th output for pth firm. $\lambda_p \geq 0$ is represent intensity of variable. And this problem has to be solve n times because number of farm is n.

Analytical framework of VRS-DEA: Again, for production efficiency according to variable return to scale the BCC model (Banker *et al*., 1984) could be used. BCC model has an extra constraint:

$$\sum_{p=1}^{n} \lambda_i = 1$$

with the CCR model:

$$\underset{\theta,\lambda}{\text{Max}} \quad \theta_p$$

Subject to:

$$x_{pi} \geq \sum_{p=1}^{n} \lambda_p x_{pi} \quad i = 1, 2, ..., s \tag{2}$$

And:

$$\theta_p y_{pj} \leq \sum_{p=1}^{n} \lambda_p y_{pj} \quad j = 1, 2, ..., t$$

$$\sum_{p=1}^{n} \lambda_p = 1$$

Analytical framework of CRS-DEA with environmental variables: Let us consider that pth farm used 's' inputs to produce 't' outputs in presence of 'r' environmental factors then the CCR model would be:

$$\underset{\theta,\lambda}{\text{Max}} \quad \theta_p$$

Subject to:

$$z_{pk} \geq \sum_{p=1}^{n} \lambda_p z_{pk} \tag{3}$$

And:

$$\theta_p y_{pj} \leq \sum_{p=1}^{n} \lambda_p y_{pj}$$

where, z_k is the (s+r) factors in which first s factors are inputs and following r factors are environmental factors. After including a constraint:

$$\sum_{p=1}^{n} \lambda_p = 1$$

in CRS-DEA with environmental factors it will be analytical framework of BCC-DEA with environmental factors.

Tobit regression model: After measure the relative efficiencies, the determinants of the DEA efficiency scores can be investigated. The dependent variable "Efficiency" is a limited dependent variable because the DEA score lies in the interval 0 and 1. Therefore, it is appropriate to use the Tobit regression which is a censored regression model. The Tobit model may be defined as:

$$\theta_p = \begin{cases} \theta_p^*; & 0 \leq \theta_p^* \leq 1 \\ 0; & \theta_p^* < 0 \\ 1 & \theta_p^* > 1 \end{cases}$$

$$\theta_p^* = \beta_m w_{pm} + \varepsilon_p; \ \varepsilon_p \sim N(0, \sigma^2)$$

Where:

θ_p = DEA efficiency score of pth farm
θ^*_p = Unobserved efficiency of pth farm
β = Parameter to determines the relationship between independent and dependent variable
w_{pm} = m-th environmental factor of pth farm

Data: Information about three types of rice (AUS, AMAN and BORO) was collected from "The Yearbook of Agricultural Statistics, Bangladesh". Variables used in this analysis are production of rice, area used for production, amount of seed and amount of fertilizer. Data for analysis is in between year 1989 and year 2008.

Output variable

Production: Production of rice has been estimated in thousand metric tons. Estimation of BORO production includes varieties such as the local BORO and the hybrid

BORO. Similarly, production of AUS and AMAN has been classified into local AUS and hybrid AUS, broadcast AMAN, local transplant AMAN and HYV AMAN.

Input variables

Area: The total area for AUS, AMAN and BORO production is measured in thousand hectares. Land under each type of rice is considered as Area for that rice.

Seed: The amount of seed is measured in thousand metric tons.

Fertilizer: Urea (nitrogen), Muriate of Potash (MOP) and Triple Supper Phosphate (TSP) are the major fertilizers which are applied in various proportions for rice production in Bangladesh. Amount of different type of fertilizer depends on the type of rice.

Environmental factors: Data of Environmental Factors were collected from Bangladesh Meteorological Department (BMD). Amount of rainfall, humidity and temperature differ from season to season as well as area to area in Bangladesh. These environmental factors play vital role in production of rice.

Rainfall: Rainfall is calculated by millimetre (mm). The annual rainfall is about 1600 mm. Most of the rainfalls occur during the rainy season (June-Sept) and in winter (Nov-Feb) very few amount of rainfall happened in Bangladesh. Rainfall was the aggregate rain in the months of cultivation of AUS, AMAN and BORO.

Humidity: Humidity is an influential factor for production of rice. In Bangladesh, humidity is highest in rainy season and lowest in winter. It is measured in percentage.

Temperature: Temperature is measured in Celsius Temperature in summer varies from 30-40°C. Average temperature is highest in April, almost 35°C. January is the coldest month; average temperature is about 15°C.

For Data Envelopment analysis "DEAP 2.1" version software and Tobit regression from "Project R" was used.

RESULTS AND DISCUSSION

Year wise efficiency of AUS, AMAN and BORO production are presented into Table 1-3, respectively. All types of rice are showing more efficient, when efficiency is measuring with environmental factors rainfall, temperature and humidity than that of without environmental factors. AUS, AMAN and BORO production are showing mean efficiency without environmental factors 0.945, 0.934 and 0.941 whereas mean efficiency with environmental factors are 0.950, 0.941 and 0.943, respectively according to constant return to scale. This indicates that efficiency with environmental factors is greater than efficiency without environmental factors. This result is similar with Sherlund *et al.* (2002). Efficiency of BORO production with environmental factors and without environmental factors is almost similar perhaps due to mostly irrigate area are well control. AUS is efficient in 11 years according to Variable Return to Scale (VRS) whereas efficient in 6 years according to Constant

Table 1: Year wise technical efficiency of AUS

	Without environmental factors				With environmental factors			
	TE				TE			
Year	CRS	VRS	SE	Indicator of VRS	CRS	VRS	SE	Indicator of VRS
1989	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1990	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1991	0.975	0.995	0.979	drs	0.996	0.997	0.999	drs
1992	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1993	0.961	1.000	0.961	irs	0.961	1.000	0.961	irs
1994	0.898	0.933	0.963	irs	0.898	1.000	0.898	irs
1995	0.840	0.846	0.993	irs	0.865	1.000	0.865	irs
1996	0.982	1.000	0.982	irs	0.982	1.000	0.982	irs
1997	0.938	1.000	0.938	irs	0.938	1.000	0.938	irs
1998	0.855	1.000	0.855	irs	0.855	1.000	0.855	irs
1999	0.894	0.896	0.998	irs	0.895	0.903	0.991	irs
2000	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2001	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2002	0.965	0.969	0.996	drs	0.969	0.969	1.000	-
2003	0.954	0.960	0.993	drs	1.000	1.000	1.000	-
2004	0.823	0.849	0.970	irs	0.833	1.000	0.833	irs
2005	0.949	0.959	0.990	irs	0.949	0.991	0.958	irs
2006	0.939	1.000	0.939	irs	0.939	1.000	0.939	irs
2007	0.923	0.983	0.938	irs	0.923	1.000	0.923	irs
2008	1.000	1.000	1.000	-	1.000	1.000	1.000	-
Average	0.945	0.970	0.975		0.950	0.993	0.957	

TE: Technical efficiency, SE: Scale efficiency, CRS: Constant return to scale, VRS: Variable return to scale

Table 2: Year-wise technical efficiency of AMAN

	Without environmental factors				With environmental factors			
	TE				TE			
Year	CRS	VRS	SE	Indicator of VRS	CRS	VRS	SE	Indicator of VRS
1989	0.996	1.000	0.996	irs	0.998	1.000	0.998	irs
1990	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1991	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1992	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1993	0.967	0.968	0.999	drs	0.968	0.968	1.000	-
1994	0.875	0.923	0.948	irs	0.981	1.000	0.981	irs
1995	0.810	0.827	0.979	irs	0.822	1.000	0.822	irs
1996	0.839	0.845	0.993	drs	0.847	0.857	0.988	irs
1997	0.827	0.835	0.991	drs	0.837	0.839	0.997	irs
1998	0.776	1.000	0.776	irs	0.776	1.000	0.776	irs
1999	0.904	0.906	0.997	drs	0.906	0.906	0.999	drs
2000	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2001	0.952	0.970	0.982	irs	0.954	0.971	0.982	irs
2002	0.966	0.967	0.999	drs	0.970	0.972	0.998	irs
2003	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2004	0.901	1.000	0.901	irs	0.901	1.000	0.901	irs
2005	0.961	1.000	0.961	irs	0.961	1.000	0.961	irs
2006	0.992	1.000	0.992	irs	1.000	1.000	1.000	-
2007	0.906	1.000	0.906	irs	0.906	1.000	0.906	irs
2008	1.000	1.000	1.000	-	1.000	1.000	1.000	-
Average	0.934	0.962	0.97			0.941	0.976	0.965

TE: Technical efficiency, SE: Scale efficiency, CRS: Constant return to scale, VRS: Variable return to scale

Table 3: Year-wise technical efficiency of BORO

	Without environmental factors				With environmental factors			
	TE				TE			
Year	CRS	VRS	SE	Indicator of VRS	CRS	VRS	SE	Indicator of VRS
1989	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1990	0.983	1.000	0.983	irs	0.983	1.000	0.983	irs
1991	0.954	0.991	0.963	irs	0.954	0.995	0.959	irs
1992	0.770	0.965	0.798	irs	0.770	1.000	0.770	irs
1993	0.977	1.000	0.977	irs	0.977	1.000	0.977	irs
1994	0.808	0.894	0.904	irs	0.808	1.000	0.808	irs
1995	0.816	0.908	0.899	irs	0.816	1.000	0.816	irs
1996	0.899	0.943	0.953	irs	0.899	0.943	0.953	irs
1997	0.893	0.980	0.911	irs	0.893	1.000	0.893	irs
1998	1.000	1.000	1.000	-	1.000	1.000	1.000	-
1999	0.955	0.963	0.991	irs	0.969	1.000	0.969	irs
2000	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2001	0.956	0.963	0.993	irs	0.956	0.993	0.963	irs
2002	0.999	1.000	0.999	drs	1.000	1.000	1.000	-
2003	0.979	0.979	1.000	-	0.983	1.000	0.983	irs
2004	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2005	0.913	0.944	0.968	irs	0.932	0.966	0.964	irs
2006	0.921	0.948	0.972	irs	0.921	0.948	0.972	irs
2007	1.000	1.000	1.000	-	1.000	1.000	1.000	-
2008	1.000	1.000	1.000	-	1.000	1.000	1.000	-
Average	0.941	0.974	0.966		0.943	0.992	0.951	

TE: Technical efficiency, SE: Scale efficiency, CRS: Constant return to scale, VRS: Variable return to scale

Return to Scale (CRS) out of 20 years in without environmental factors model. Scale efficiency is 1 for 7 years that is in these 7 years CRS and VRS efficiencies are same. VRS has two kinds (a) Increasing return to scale and (b) Decreasing return to scale. Efficiency of 12 years from VRS is indicating increasing return to scale. AMAN production is efficient in 12 years according to VRS whereas according to CRS, in 6 years out of 20 years. Scale efficiency is 1 for 6 years that is in these 6 years CRS and VRS efficiencies are same. Production efficiency of 9 years from VRS is indicating increasing return to scale. BORO is efficient in 9 years according to VRS whereas according to CRS, efficient in 6 years according to CRS out of 20 years. Scale efficiency is 1 for 7 years that is in these 6 years CRS and VRS efficiencies are same. Efficiency of

9 years from VRS is indicating increasing return to scale. Mean efficiency of production without consider environmental factors from VRS is showing maximum for BORO and minimum for AMAN among the three type of rice. This order of efficiency is supported using Stochastic Frontier Analysis (SFA) by Hossain *et al*. (2012a,b). Mean efficiency without environmental factors in CRS and with environmental factors in CRS and VRS are showing that AUS is the most efficient among the rice. In the both model (including environmental factors or not), the mean efficiency of BORO is greater than that of AMAN. This result is same as Khan *et al*. (2010).

Table 4 shows the minimum efficiencies of AUS, AMAN and BORO in the study period. AMAN production has minimum efficiency in all cases. Without environmental factors, the minimum efficiency of AUS, AMAM was 0.810 and 0.840 from CRS as well as 0.827 and 0.846 from VRS in year 1995. With environmental factors, the minimum efficiency of same rice production is showing in different year for VRS and CRS, such as for AUS in CRS and VRS, it was in year 2004 and year 1999, respectively.

Efficiency of rice production is regressed by the environmental factors (rainfall, humidity and temperature). These efficiencies are the efficiencies from model not include environmental factors. Table 5-6 present the Tobit regression result for CRS and VRS, respectively. Rainfall and Temperature has a negative but not significant impact on the efficiency of AUS production. Rainfall has a negative effect on AUS production is supported by Sarker *et al*. (2012b). Humidity has a positive significant (at 5% level of significance) on efficiency of AUS production. Both CRS and VRS for AUS production is showing same results. On efficiency of AMAN production, humidity has a positive and significant (at 1% and 10% level) impact from CRS and VRS. But it is negatively influenced by rainfall and temperature. In CRS, these influences are significant at 1 and 10%, respectively but in VRS, these are insignificant. Efficiency of BORO production is positively influenced by rainfall and humidity. Rainfall is not significant since it grows under completely irrigated conditions. This finding of an insignificant effect of rainfall on BORO production is consistent with the results obtained by Rimi *et al*. (2009). Humidity is positive on efficiency of BORO production and significant at 5% and 1% level of significance in CRS and VRS, respectively. Temperature has a negative insignificant effect on efficiency of BORO. This study has similar result with Karim *et al*. (1996) but conflict with Sarker *et al*. (2012a). Increasing temperature is a cause to reduce production of AUS, AMAN and BORO. This result is supported by Rahman (2011) but conflict with Salam (2004). Result of humidity on efficiency of rice production from this study contradictory with Banaszek and Siebenmorgen (1990).

Table 4: Minimum efficiency of rice

	Without environmental factors		With environmental factors	
Rice	CRS	VRS	CRS	VRS
AUS	0.840	0.846	0.833	0.903
AMAN	0.810	0.827	0.776	0.839
BORO	0.770	0.894	0.770	0.943

CRS: Constant return to scale, VRS: Variable return to scale

Table 5: Impact of environmental factors on efficiency in CRS using tobit regression

	AUS		AMAN		BORO	
	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
Rainfall	-0.00127	0.00078	-0.00224***	0.00085	0.00035	0.00079
Humidity	0.02343**	0.01146	0.04180***	0.01440	0.01811**	0.00903
Temperature	-0.02000	0.02615	-0.07157*	0.03730	-0.01663	0.02209
Scale	0.06893***	0.20184	0.07709***	0.19805	0.08017***	0.20336

***** and * is the indicator of significance at 1, 5 and 10% level, respectively

Table 6: Impact of environmental factors on efficiency in VRS using tobit regression

	AUS		AMAN		BORO	
	Estimate	Std. error	Estimate	Std. error	Estimate	Std. error
Rainfall	-0.00122	0.00100	-0.00066	0.00128	0.00005	0.00039
Humidity	0.03777**	0.01503	0.03881*	0.02054	0.01817***	0.00453
Temperature	-0.05587	0.03429	-0.06983	0.05321	-0.01436	0.01116
Scale	0.07651***	0.25936	0.10580***	0.28540	0.03784***	0.23400

***** and * is the indicator of significance at 1, 5 and 10% level, respectively

CONCLUSION

This study presents an extension of the efficiency studies in the context of CRS and VRS of Data Envelopment Analysis with environmental variables. It examines the influence of environmental factors on efficiency of rice in Bangladesh. Efficiency of BORO production with environmental factors and without environmental factors is almost same but it varies for AUS and AMAN. BORO has shown more efficiency than others because of environmental favourable during production. Increasing temperature cause for less efficiency and humidity shows inverse effect on production of all kinds of rice. This may conclude as global warming will have negative impact on rice production. Rainfall has a negative impact on AUS and AMAN but it increases BORO production efficiency. Humidity has a positive influence on efficiency of all rice. Overall rice production of Bangladesh will be increased if policy makers paid more attention on improving efficiency of AUS.

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