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Formation Factors of High Rice Productivity in Bangladesh: A Case Study in the Alunja Village, Rajshahi Division

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Abstract A case study was carried out in Alunja village of Bogra region (pre-1982 administrative district) to identify the factors affecting high rice productivity in Bangladesh. Results of the study revealed that a suitable natural environment and modern technology (HYV, fertilizer and irrigation) have played vital roles for increasing rice productivity in Alunja village. Consequently, Alunja village has achieved high rice productivity.

Key Words: Bangladesh, Factor, High productivity, Rice, Technology adoption.

I. Introduction

In our previous study a significant difference in rice productivity in Bangladesh was observed when comparisons were made on a regional basis.[1)] Rice productivity in different regions is a widely discussed phenomena. There are many studies on important issues of Bangladesh agriculture relating to farm size and productivity, relative productivity efficiency of different tenure classes. However, there is no empirical study on regional variation of rice productivity. Therefore, our study is focusing into rice productivity variation by regional basis. In the study, it was clearly identified that among all the divisions of the country, Rajshahi achieved the highest productivity. It is generally believed that seed, fertilizer and irrigation are important technologies which vehicles for increasing area, production and productivity. However, growth in rice productivity is not only a technological phenomena, it primarily depends on natural environmental factors, and those factors are relatively less favourable in the less developed areas.[2)]

With view of the above discussion, a vital question arises as to what are the most important vehicles －new technology or natural environment or both－ for increasing rice productivity. Thus the current study aims (1) to identify the factors affecting rice productivity, which was cited as insufficient in the previous study and (2) to recommend possible policy options for agricultural development. Specifically, the study will discuss technological adoption, natural condition and farm income viability, as they affect overall rice productivity. The findings are expected to be helpful to planners and policy makers concerned with agricultural development.

The paper is divided into four sections. Following the introduction, in section II, we explain the data collection and analysis. It also provides background information on the survey village. Section III, the Results and Discussion identifies the factors-technological, natural and analyze production for identifying factors causing higher rice productivity in Bogra and in the Rajshahi division. Finally, in section IV, we draw conclusions.

II. Materials and Methods

1. Data Collection and Analysis

The study was based on data from statistical publications by the Bangladesh Bureau of Statistics (BBS), Ministry of Planning, and a field survey conducted by our research team at Alunja village of Bogra region, Rajshahi division. Alunja village (Referred as Alunja) is situated in Khetlal Thana, Bogra region (former district). The village is situated in the Eastern Barind Tract in the north-western part of Bangladesh. The soil is poorly drained, loamy clay with moderate fertility. It has achieved a sustainable ecological equilibrium, similar to well-farmed agricultural land in other parts of the country.[3)] The land level, soil fertility, natural and environmental conditions of Alunja are the same as in Eastern Barind Tract. The data was collected on the production year of 1998, from 24 sam-

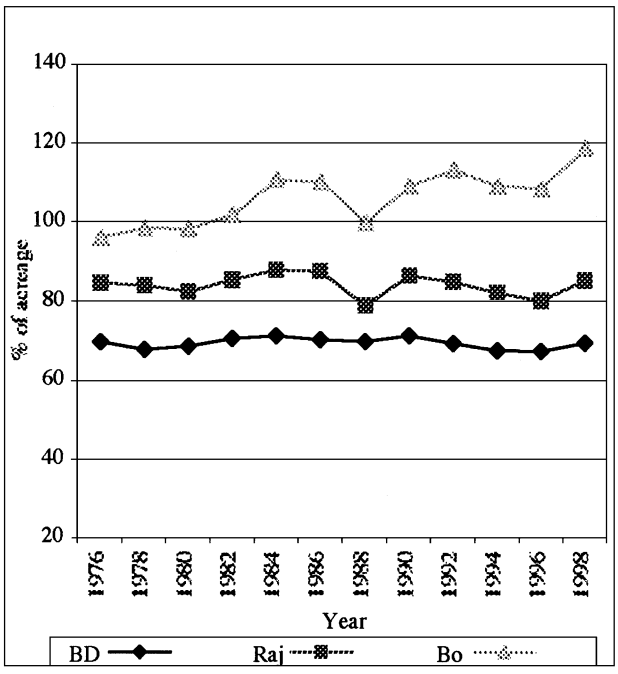
ple farm families during the period 15th to 31st March, 1999. The data were analyzed simply and the results presented in tabular form. Frequency, arithmetic mean, percentage and ratio were the major statistical attributes employed to show results in a comprehensible manner.

The major terms used in the analyze are defined below. Acreage of operated land defined by total acres of owned land minus acres rented out plus acres rented in during the year of investigation. In this study farm size groups (small or large) are defined by the average farm size. Level of rice productivity and level of technology adoption are distinctively defined by the average level of rice productivity and average level of technology adoption, for this makes easy the comparison of different farms and different productivity groups. The percentage of HYV (High Yielding Variety) rice acreage, irrigated rice acreage and the chemical fertilizer use per acre are referred to as the level of adoption of the respective technology. The natural condition is measured as the annual rainfall, temperature level and fertility condition of soil under adoption of modern technology. Income viability of individual farm household is measured by the total household income. The annual of income of farm household represents the total household income in cash obtained from both agricultural and nonagricultural sources. It indicates the purchasing power of goods and services as well as the ability for savings and investments.

2. Background Information-Comparative Productivity Level of the Survey Village

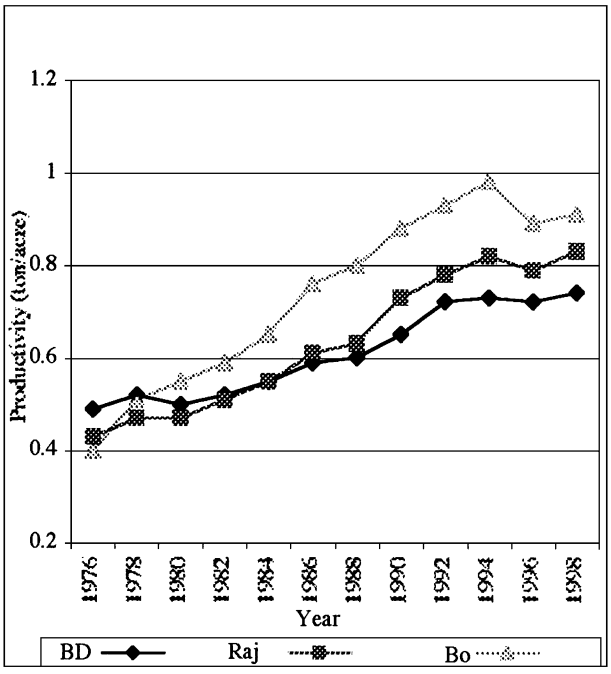
Traditionally, most of the Barind Tract produces a single crop of transplanted (T) Aman per year. During the last three decades the eastern half of the Barind has become double cropped with T. Aus followed by T. Aman under rainfed conditions. However, after the introduction of ground water irrigation in the middle seventies, a substantial area was brought under HYV Boro cultivation followed by T. Aman. [4)]

As stated previously, Rajshahi division has achieved the highest rice productivity in Bangladesh. However, rice productivity among different regions in Rajshahi division showed a significant variation. Among all the regions in Rajshahi division, Bogra region achieved the highest level of rice productivity, about 0.91 ton per acre. This is significant because two and half decades ago, Bogra region was one of the regions with the lowest rice productivity in Bangladesh. [5)]



Note: BD=Bangladesh, Raj=Rajshahi, Bo=Bogra
Source: Bangladesh Bureau of Statistics(BBS) 1985 and 2000.

Figure 1: Comparative trends of rice acreage, during 1976 to 1998.



Note: BD=Bangladesh, Raj=Rajshahi, Bo=Bogra
Source: Same as figure 1.

Figure 2: Comparative trends of rice productivity during 1976 to 1998.

Figure 1 shows the trend of percentage of rice acreage in the Bogra region compared with the trend of percentage of rice acreage in the Rajshahi division and Bangladesh during the period of 1976-1998. The figure reveals that the percentage of rice acreage in Rajshahi is about 85.2 and in Bangladesh it is about 69.2 percent. However, the percentage of total rice acreage in Bogra is about 118.7. This indicates that most of the land areas here been brought under rice cultivation and that has lead to higher rice production. Figure 2 shows the comparative trends of rice productivity in the Bogra, Rajshahi and Bangladesh. In 1976, per acre rice productivity was high in Bangladesh (0.50 ton/acre) and the Rajshahi division (0.44 ton/acre) and low in Bogra (0.43 ton/acre). However, during the period of 1980 to 1998, a significant growth in rice productivity occurred in Bogra. As a result, Bogra achieved high rate of rice productivity 0.91 ton/acre during 1998.

Table 1 shows average rice productivity, the percentage of HYV rice acreage, irrigated rice acreage and chemical fertilizer use per acre. These figures compare the Alunja village with Bogra region, Rajshahi division and the country average. The table reveals that Alunja village achieved high productivity (about 1.39 ton/acre) which is significant when compared to the average productivity in Bogra region (0.91 tons/acre), Rajshahi division (0.84 tons/acre), and the country average (0.74 tons/acre). Rice productivity in Alunja village is approximately double than average of the country. This productivity differential is most probably due to the difference in adoption rates of HYV, irrigation and chemical fertilizer use among the different areas.

Table 1: Rice productivity, HYV acreage, irrigated acreage, fertilizer use in Alunja village, Bogra region, Rajshahi division and Bangladesh.

	Productivity (ton/acre)	% of HYV acreage	% of irrigated acreage	Fertilizer use (kg/acre)
Alunja	1.38	80.5	100.0	148.7
Bogra*	0.91	77.9	50.0	n.a
Rajshahi*	0.84	64.4	37.4	n.a
Bangladesh*	0.74	51.9	31.1	107.8

Note: n.a-not available.
Source: Survey data, 1999; *BBS, 1998.

The information in the table shows the HYV adoption rate in Alunja compared with Bogra region, Rajshahi division and the country average. The adoption rate of HYV in Alunja is significantly higher than average percentage for the country. The adoption rate of HYV 80.5% in Alunja represents a higher percentage of acreage used for HYV rice cultivation when compared with 77.9% in Bogra region, 64.4% in Rajshahi division and 51.9% in the country average.

Irrigation is apparently one of the most important reasons for the difference observed in HYV adoption. For example, in Alunja 100% of the cultivable land is brought under modern irrigation. During the end of seventies, a deep tube well was sunk in this village. Owing to this deep tubewell with two additional shallow tubewells, all of the rice lands were brought under irrigation, which made it possible to grow HYV rice on all of the rice land of this village. However, irrigated rice acreage is only 31.1% in the national average, 37.4% in Rajshahi and about 50% in Bogra region. Utilizing modern methods of irrigation such as shallow tubewell and deep tubewell have made possible the exploitation of ground water for higher irrigation in Alunja.

Overall fertilizer use is low throughout Bangladesh. It is 107.8 kilogram/acre (kg/acre), compared with 148.7kg/acre in Alunja which is approximately double than the national average. Fertilizer use is coupled with HYV adoption. Higher chemical fertilizer use in Alunja corresponds directly to higher acreage of HYV production. The above discussion indicates that modern technology (HYV, irrigation, fertilizer) adoption resulted in higher rice productivity which was one of the reasons behind the selection in Alunja for the field survey.

III. Results and Discussion

1. Natural Environment Factors Affecting Rice Productivity

Adoption of new technology and growth of rice productivity may be dependent on environmental conditions and characteristics of modern technology. Plain land, clayey loam or clayey soil with moderate fertility, somewhat extreme temperature in summer and moderate rainfall are major characteristics of the Barind Tract. Most of the land in this area is high land and medium land (above normal flood level). The lands shallowly flooded by rainwater within field bunds in the rainy season.[6] Mean annual rainfall is the lowest in the Barind Tract, with 1250mm in the west and 2000mm in the north-east. The highest amount of rainfall are in the northern, eastern and southern parts of Bangladesh at about 2500mm annually; it exceeds 5000mm in the extreme north-east of Sylhet. Monsoons bring

rainfall for five months from the end of May to about mid-October. However, a few days delay in the arrival of the monsoon, or any shortage of rainfall, can have a drastic impact on productivity.[7)]

Temperatures in the Barind Tract are somewhat extreme from the northeastern and the southeastern parts of Bangladesh. It is common that for several days in summer the highest temperatures exceed 40℃ and the lowest temperatures are less than 5℃ in winter. Most of the local varieties of rice are photosensitive-extreme temperature or day length influence the crop growth. It is not possible to grow photoperiod sensitive local varieties during any time of the year due to the fixed period of flowering time, but this is not the case for modern variety (HYV). Modern varieties are weakly sensitive or non-photosensitive. For this reason, it is possible to grow HYV rice in different agro-ecological condition at any time during the year.

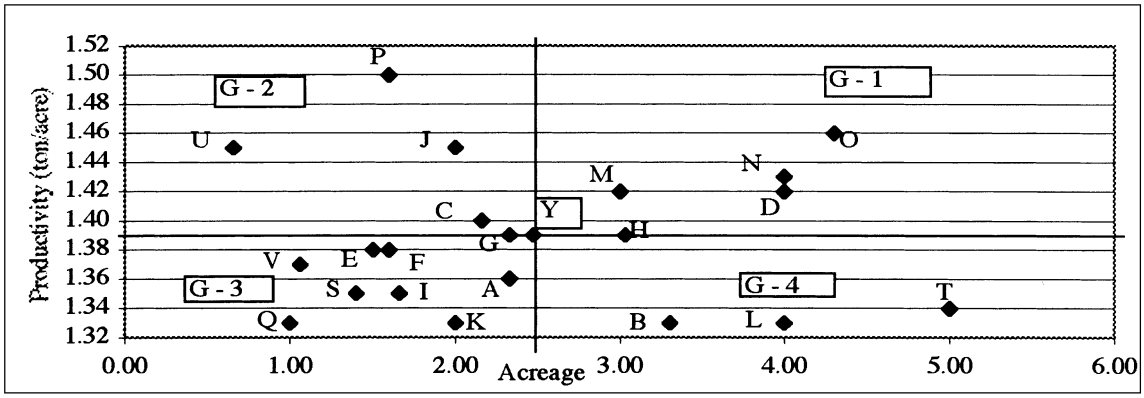
Next we discuss the adoption of new technology by individual farms within the Alunja and the resulting affects on rice productivity.

2. Factors for Adoption of Modern Technology Affecting Rice Productivity

Figure 3 shows the farm size and per acre rice productivity among different farms in Alunja. The information in the figure reveals that farms in Group 1 achieved higher rice productivity and farms in Group 3 achieved low rice productivity. Farms in Group 2 achieved higher rice productivity and farms in Group 4 achieved low rice productivity. It indicates that large or small farm those who used higher modern inputs such as HYV seeds, chemical fertilizers etc., achieved high rice productivity. Therefore, it may be observed that a more important factor in achieving higher rice productivity lies in the adoption rate of modern technology.

Table 2 presents rice acreage by variety and season in Alunja compared with the country average. The figures of the table reveals that in Aman season (late kharif) local (L) Aman rice acreage was lower in Alunja (19%) than in the country average (31.8%). The productivity of L. Aman rice was higher in Alunja (0.77 ton/acre) than in the country average (0.45 ton/acre). The percentage of HYV Aman rice acreage was higher in Alunja (32.2%) than in the country average (24.8%). The productivity of HYV Aman rice was also higher in Alunja (1.20 ton/acre) compared with the country average (0.83 ton/acre). In Boro season (rabi season), 48.8% of the total cultivated acreage was in HYV Boro rice in Alunja against 26% in the country average.

In the Boro season, L. Boro rice was not produced in Alunja, but L. Boro rice was produced only 2.1% of the Boro rice acreage in the country average, where the productivity of L. Boro rice was 0.63 ton/acre. However the productivity of HYV Boro rice was 1.75 ton/acre in Alunja and 1.18 ton/acre in the country average. The productivity of HYV Boro rice was much higher in Alunja than in the country. During the Aus season (early kharif), Aus rice was not produced in Alunja, because Aus rice (both local and HYV) was replaced by HYV



Note: Farm size groups (small or large) are defined by average farm size and level of rice productivity (high or low) are defined by average rice productivity. Farms in Group 1 large farm of high productivity, farms in Group 2 small farms of high productivity, farms in Group 3 small farm of low productivity and farms in Group 4 large farm of low productivity.
Source: Survey data.

Figure 3: Farm size and rice productivity in different farms in Alunja

Table 2: Rice productivity percentage of rice acreage and production in different rice season in different farms in Alunja comparatively with Bangladesh.

Farms group*	Farm	Rice productivity (ton/acre)	Net cultivated land (acre)	Acreage (%) Aman Local	Aman HYV	Boro HYV	HYV percentage of total rice acreage	Total cultivated land (acre)	Total prodution (kg)
G - 1	O	1.46	2.20	8.50	42.70	48.80	91.50	8.20	11960
	N	1.43	3.80	18.40	31.60	50.00	81.60	7.60	10840
	D	1.42	3.84	20.40	31.90	47.70	79.60	7.34	10392
	M	1.42	2.80	14.10	31.30	54.70	86.00	6.40	9070
	J	1.45	1.90	13.20	36.80	50.00	86.80	3.80	5500
	C	1.40	2.00	13.80	36.30	50.00	86.30	4.00	5580
G - 2	P	1.50	0.50	0.00	50.00	50.00	100.00	3.00	4500
	H	1.39	1.34	22.20	31.60	46.20	77.80	5.63	7816
	U	1.45	0.00	0.00	50.00	50.00	100.00	1.00	1450
	G	1.39	0.48	28.50	21.50	50.00	71.50	4.66	6458
G - 3	E	1.38	1.35	16.70	33.30	50.00	83.30	2.70	3735
	F	1.38	1.50	33.30	16.70	50.00	66.70	3.00	4150
	V	1.37	0.90	16.70	33.30	50.00	83.30	1.80	2460
	A	1.36	1.17	31.30	20.50	48.20	68.70	4.15	5660
	I	1.35	1.50	20.00	30.00	50.00	80.00	3.00	4050
	S	1.35	0.40	14.30	35.70	50.00	85.70	2.80	3780
	T	1.34	1.00	20.00	30.00	50.00	80.00	10.00	13400
	Q	1.33	0.90	33.30	16.70	50.00	66.70	1.80	2400
G - 4	K	1.33	1.90	23.70	26.30	50.00	76.30	3.80	5060
	L	1.33	3.70	25.30	37.70	38.00	75.70	7.90	10480
	B	1.33	3.14	18.20	31.80	50.00	81.80	6.28	8336
Average		1.39	1.73	19.10	32.20	48.80	81.10	4.71	6527

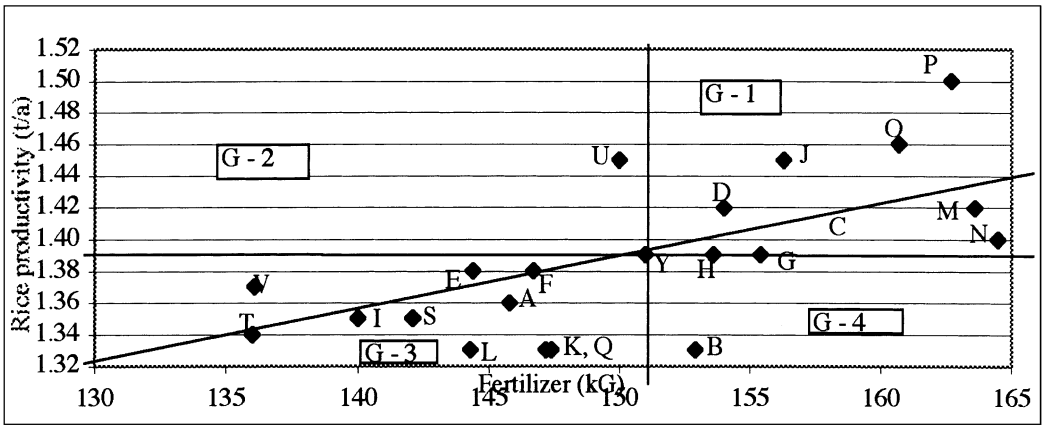
Season/ variety	Alunja Acreage (%)	Alunja Production (%)	Alunja Productivity (ton/acre)	Bangladesh Acreage (%)	Bangladesh Production (%)	Bangladesh Productivity (ton/acre)
Aus — Local	0	0	0.0	10.5	5.3	0.37
HYV	0	0	0.0	4.8	4.6	0.72
Total/average	0	0	0.0	15.3	9.9	0.48
Aman — Local	19.0	10.7	0.77	31.8	19.3	0.45
HYV	32.2	27.8	1.20	24.8	27.6	0.83
Total/average	51.2	38.5	1.04	56.8	46.9	0.62
Boro — Local	0.0	0	0.0	2.1	1.8	0.63
HYV	48.8	61.5	1.75	26.0	41.3	1.18
Total/average	48.8	61.5	1.75	28.2	43.1	1.14
Grand total/average	1000	100	1.39	100	100	0.74

Note: *Definition of farm size groups are the same as figure 3.
Source: Survey data and BBS, 2000.

Boro rice. In the Aus season, 10.5% of the total cultivated acreage was in L. Aus rice and 4.8% of the total cultivated acreage was in HYV Aus rice in the country average. The average productivity of L. Aus rice was 0.37 ton/acre and HYV Aus rice was 0.72 ton/acre.

The percentage of HYV rice acreage of the total rice acreage in different rice season was much higher in Alunja (Aman 32.2%, Boro 48.8%) compared with the country average (respectively 24.8% and 26%). The percentage of L. rice acreage of the total rice acreage was much lower in Alunja (only Aman 19.0%) compared with the country (Aus 10.5%, Aman 31.8% and Boro 2.1%). The productivity of all the varieties of rice were much higher in Alunja (L. Aman 0.77, HYV Aman 1.20, HYV Boro 1.75) than the country average (L. Aman 0.45, HYV Aman 0.83, L. Boro 0.63, HYV Boro 1.18, L. Aus 0.37 and HYV Aus 0.72). It suggests that a higher percentage of HYV rice acreage and a higher level of rice productivity caused higher overall rice productivity in Alunja compared with the country average.

Table 2 also gives average productivity, acreage and production of rice in different farms by variety and season. Farms in Group 1 achieved higher productivity and farms in Group 3 achieved lower productivity. With farms in Group 1, a higher percent of HYV rice acreage caused higher productivity. Farms



Note: Definition of groups (fertilizer use groups-high or low) are same sa figure 3.
Source: Survey data.

Figure 4: Fertilizer use per acre in Alunja village (kg)

in Group 2 achieved higher productivity and farms in Group 4 achieved lower productivity. This was apparently due to the percentage of HYV acreage and Chemical fertilizer use (Figure 4).

The productivity differential among different farm groups was not reflected by HYV rice production only, it was also due to different rates of chemical fertilizer use. Figure 4 shows chemical fertilizer use among different farms in Alunja. The figure reveals that those farms which used large amounts of fertilizer per acre correspondingly achieved high rice productivity.

During the dry season, HYV rice was grown on 100% of the cultivated land among the all farms in Alunja. However, in Aman season some of the farms grow a local variety of T. Aman because of its good taste. Besides, the market price of the fine quality rice always remains high than that of the medium to coarse quality HYV rice.[8)] In both cases the percentage of HYV rice acreage and fertilizer use per acre for farms in Group 1 and farms in Group 2 achieved was higher, and resulted in higher productivity. Therefore, it was identified that the factor for adoption of modern technology is one of the main reasons for achieving high rice productivity among farms in the Alunja.

3. Factors affecting rice productivity

In order to determine the functional relationship between input use and rice productivity, a technique is used to quantitative analysis of the study village in the framework of production function model. To explain the factors affecting rice productivity, it is thus necessary to do a multiple analysis of the factors that determine the behavior and the importance of these factors. This is attempted here through the use of the multiple regression technique. The following model was estimated by using the OLS method in the presence of heteroscedasticity of Newey-West estimator with truncation lag = 2, to identify the factors that affect rice productivity.

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10})$$

Where, Y = rice productivity in kg/acre,

X_1 = labor use per farm in man-days,

X_2 = chemical fertilizer use in kg/acre,

X_3 = irrigated rice area as percentage of total rice area,

X_4 = HYV rice area as percentage of total rice area,

X_5 = age of farm household head,

X_6 = squire Age of farm household head (experience),

X_7 = literature of farm household head,

X_8 = rice area (acre) per farm,

X_9 = squire rice area (acre) per farm,

X_{10} = bank loan (taka) per acre per farm,

Other independent variables which may affect rice productivity such as land level, soil fertility, seed were assumed to be subsumed in the error term of estimated regression function.

The estimated results of the coefficient and related statistics of the multiple regression are presented in table 3. The adjusted value of multiple regression coefficient, R^2 is 0.81, indicates that most of the factors have strong positive impact on productivity. The value of F-statistics is significant at 1percent level of probability, express fitness of the model.

The coefficient of HYV is highly significant at 1 percent level of significance implies that due to adoption of HYV rice productivity increased significantly. The coefficient of irrigation is negative and significant at 1% level of significance, indicates that cost of irrigation is high. That means most of the small farmers used hired water for irrigation by a high payment. The coefficients of chemical fertilizer is positive and significant at 1% level of significance, indicates that strong impact on increasing productivity.

Table 3: Estimated value of multiple regression coefficients of different inputs used for rice production in Alunja village.

Variables	Coefficient	t-Statistic
Intercept (constant)	875.561	20.668**
Labor	0.005	0.377
Chemi. Fertilizer (per acre	0.201	3.806**
Irrigation+others	−0.046	−3.601**
HYV	3.660	6.431**
Age−10	8.865	2.453*
$(Age-10)^2$	−0.206	−3.042**
Literature	24.537	2.753**
Area (acre)	−27.421	−2.234*
$(Area)^2$	3.251	2.483*
Loan (per acre)	0.002	1.000
R^2	0.905	
Adjusted R^2	0.811	
F value	9.556*	
Observations	21	

Note: * and ** indicate significant at 5% and 1% level of significance respectively.
Source: Survey data.

There are some socio-economic factors such age, literature, farm size and bank loan also reflect in the production function. The coefficient of age is positive and highly significant (5%), implies that younger farmer may take risk for adoption of modern technology which affect on increasing rice productivity. But square value of age is negative and highly significant (1%), indicates that experience or extension activity impact on increasing productivity. The coefficient of literature is positive and highly significant at 1% level of significance indicates that empirical know-how about modern technology and better management affect on increasing rice productivity. The coefficients of labour and bank loan are positive but insignificant, imply that underemployment and miss use the inputs respectively. The coefficients of farm size is positive but insignificant, indicates neutrality of farm size, that means those farm who use higher modern inputs achieved higher productivity.

Therefore, the results of regression analysis suggest that except for a few variables, all the variables positively effect on rice productivity in Alunja.

IV. Conclusions

This study investigated the factors affecting high rice productivity in the Rajshahi division of Bangladesh. It was found that suitable natural environmental and higher adoption of modern technology contributed to increase per acre rice productivity. Suitable land and natural environments have played vital roles in the higher concentration of modern technology. Out of all technological and socio-economic factors considered 'HYV and fertilizer' and 'farmer age and literature' come out to be important factors for increased rice productivity. Therefore, to increase the per acre productivity and total rice production in Bangladesh, it is necessary more to use modern technology and give more education to the farmer.

Notes:

1). See Islam et al. [1, 350-351].
2). Adoption of improve maize seed...but also in the socioeconomic environment. See Nkonya, et al. [2, p. 1-12].
3). See Brammer [3, p. 129].
4). "Natural environmental condition and cropping patterns" described in figure 1.3, page 14 and "the environment" See Brammer [3, p. 14 and p. 126-129].
5). See Islam et al. [1, 350-351].
6). See Rahman, et al. [6, Vol. 2, p. 46].
7). See S. Huq, et al. [7, p. 3].
8). See Talukdar [8, p. 155].

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