Double Transplanting: Economic Assessment of an Indigenous Technology for Submergence Avoidance in the Flood-prone Rice Environment in Bangladesh

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I: Introduction

Rice is the dominant staple food and source of energy intake of the 140 million people of Bangladesh. Rice occupies about 75% of the total cropped area, contributes to over 50% of the agricultural value added, and continues to be the main source of livelihood in rural Bangladesh (BBS, 2004). Aman rice (monsoon-season rice) is the traditional rice crop grown during the months of July to December in 5.5 million ha of land and contributes to 45% of the total rice production (BBS, 2005). In the greater Rangpur region (the northern part of Bangladesh), a large proportion land is medium and low-lying which are subjected to the risk of flooding from heavy rains during the month of August and September (Figures 2). So farmers have to go for transplanting tall and aged seedling for the Aman plant to tolerate this climatic stress. Most farmers practice a double transplanting system of crop establishment; transfer about 30 days' old seedlings from the seedbed to a relatively high level field with dense transplanting, and then transfer to the main field about 60 days' old seedlings when the seedlings are tall and the risk of flooding is over. This method of crop establishment is locally known as the *Bolon* system. It is an indigenous technology developed by farmers to manage the risk of submergence.

The objective of this paper is to assess the profitability and economic efficiency of the *Bolon* system compared to the single transplanting system (locally called *Naicha*) commonly practiced elsewhere in Bangladesh and Eastern India for *Aman* rice. As a background to the analysis the *Bolon* system is explained in section II. The method of data collection and the analytical procedures are explained in Section III. The findings of the survey on costs and returns and comparative technical efficiency are discussed in section IV. Section V draws implication for crop improvement research on *Bolon* for further refining the system.

II: The *Bolon* System

Bolon is a crop establishment system for rice cultivation where farmers transplant Aman rice seedlings twice, first on a piece of high land, and then in the main field after the recession of heavy rains (Fig.1). The seedlings are prepared in a seed bed for about a month. The seedlings are first transplanted in a plot called as "*Bolon bari*". Farmers transplant seedlings in the *Bolon* plot with closer spacing and large number of seedling per hill. They take care of this plot like a main rice field and apply chemical fertilizers, and insecticide to nurture the seedlings. After another 25-30 days these aged seedlings are again transplanted to the main field with broader spacing and less number of seedlings per hill. The seedlings grown in one decimal area of the seedbed (*Bechan bari*) would occupy three decimals of land in the "*Bolon bari*", and are sufficient for transplanting about 24 decimals of land in the main rice field (*Dhan bari*). At the time of final transplanting the seedbed and the *Bolon Bari* are also covered with sparse transplanting, so no land is wasted.

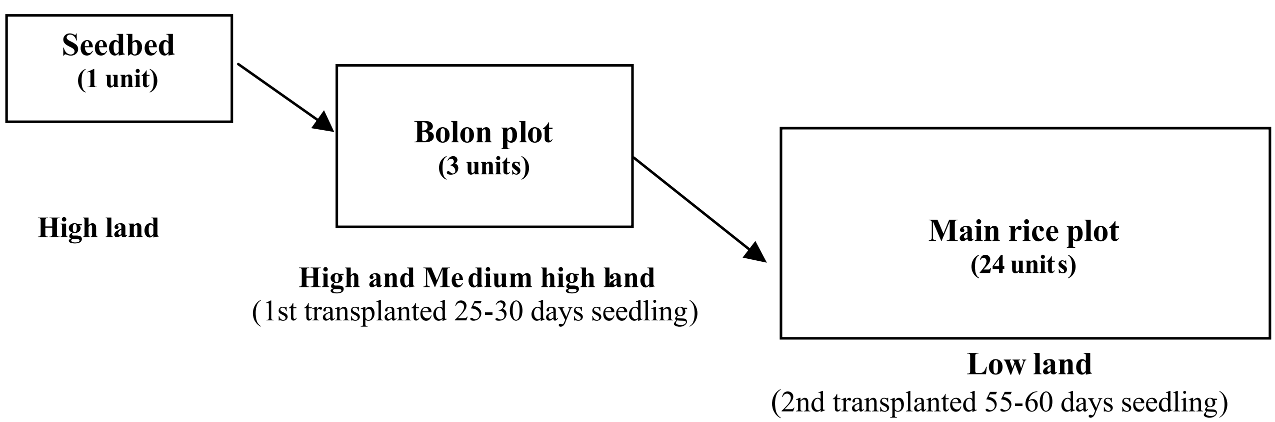

Fig 1. Aman rice cultivation under the Bolon system

The *Bolon* system permits a flexible late transplanting during the rainy season, which is its prime advantage. The rice growers can transplant rice in their main plot/field at an advantageous time with regard to seasonal pattern of rainfall (Figure 2). The medium to low lying parcels of rice land is generally submerged during the months of August to mid-September if there are consecutive days of heavy rainfall. So, this type of land is not suitable for transplanting young seedlings directly from the seedbed to main plot as the seedling height is not tall enough and there is a risk of submergence. Under *Bolon* system, aged tall seedlings are transplanted to the low-lying rice fields from the *Bolon* plot late in the season when there the probability of occurrence of consecutive days of heavy rains is less, and even if it occurs the tall seedlings would not be submerged. Thus, this method of crop establishment helps avoid submergence of rice plant from the uneven distribution of rainfall during the peak of the monsoon season.

For medium to high lands where there is little risk of submergence from heavy rains farmers follow the single transplanting system early in the season (July to mid-August) with young seedlings directly pulled from the seed bed. This method is locally known as *Naicha* and is practiced elsewhere in Bangladesh is lands of shallow flooding depth.

The Biological Scientists engaged in rice research in Bangladesh argue that the double transplanting system is an inefficient method of rice establishment compared to the single transplanting system. They argue that the aged seedlings would have less time to produce tillers in the field compared to the young seedlings, and hence the crop stand would less dense in the double transplanted field, resulting in lower crop yield. Also the cost of rice production would be higher in the double transplanted systems due to the additional cost of labor for transplanting in the *Bolon* field, which can be avoided under the single transplanting system. Thus, the profitability of rice farming would be less under the double transplanting system.

In a focus group meeting on the *Bolon* system that we organized before conducting the survey, the farmers refuted the argument of inefficiency of the double transplanting system compared to single transplanting method. The farmers' experience is that the plants under the double transplanted plots are usually healthy, have longer panicles and more filled grains than the plants on the single transplanted parcels. They adjust the spacing at the time of transplanting (aged seedlings are transplanted more densely than younger seedlings) to ensure uniform crop stand under both systems. Through weeding and the pesticide use in the *Bolon* plot (one-eight in size than the main field) they avoid the need for further crop care in the main field, and thereby reduce the cost of inter-cultural operations. According to the farmers, diseases and insect infestation is comparatively lower under this system than under single transplanting system. On the other hand, due to staggering of the time of transplantation (single transplanting on high land early in the season and double transplanting on low-land late in the season), farmers can avoid labor scarcity if all of them transplant rice at the same time after the onset of the heavy rains that allows puddling of the main field. It helps utilizing family labor for longer periods and reduces the demand for hired labor and putting pressure on the labor market. Therefore, the *Bolon* system appears to an appropriate technology invented by the farmers themselves to address this unfavorable (heavy rainfall) environment.

Since the *Bolon* system involves additional cost for the second transplanting, it would be useful to estimate the magnitude of the cost and the associated benefits in terms the impact on yield and on other management practices. The main purpose of the research is to generate data from sample survey of the rice growers to study the economics of the *Bolon* system compared to *Naicha* which is the commonly practiced crop establishment method for Aman rice throughout Bangladesh.

III: Methodology

To generate primary data, a farm household survey was conducted from a cross-section of farmers from five villages belonging to three northern districts- Rangpur, Lalmonirhat and Nilphamari. The villages were purposively selected on the basis of prior knowledge of the upazila officials of the Department of Agricultural Extension (DAE) regarding the land type and the existence of the *Bolon* system. The villages were selected such that they have a large proportion of area under flooding depth of 50 to 100 cm during the peak of the monsoon season, while some other areas under shallow flooding depth so the farmers also practice the single transplanting system. For each of the selected villages, a list of farm households was drawn through a census of all households in the village and information on the method of establishment of the Aman crop. Then 40 farmers were selected randomly from the list of those farm households who practiced both the double transplanting and the single transplanting system for the parcels operated by the farm. Thus the sample consists of 200 farmers, 40 each from five villages scattered throughout three districts.

Data were collected by administering a structured questionnaire which contained questions on the socioeconomic background of the farmers and the details of the costs and returns of Aman rice cultivation of two parcels; one for which the farmer practiced the *Bolon* system and the other, the *Naicha* system. The questionnaire was pre-tested by the first author to assess their relevance for the local conditions, and to avoid any lead questions and was revised. Three local investigators were hired and trained by the first author for administering the survey. The first author supervised the data collection and he was involved in checking the filled-in questionnaires, and editing and processing of data.

The pared t-test was performed to test the significance in mean differences of inputs and outputs of rice production between two systems for the same household.

Several researchers (Aigner, Lovell and Shemidt (1977); Meeusen and Van den Broeck (1977); Aly *et al.* (1987); Battese (1992); Battese and Coelli (1995); Fan *et al.* (1997)) have used the Cobb-Douglas production function model to measure technical efficiency for industries and farms. They propose the estimation of a stochastic frontier production function, where noise is accounted for by adding a symmetric error term (u_i) to the non negative term to provide,

$$\mathrm{Ln}(Y_i) = f(X_i; \beta) + \varepsilon_i ; \qquad \text{Where, } \varepsilon i = v_i - u_i ; \qquad i = 1, \ldots\ldots\ldots, N$$

Where Y_i denotes the output quantity of the ith farm, X_i is a vector of the input quantities used by the farm, β is a vector of parameters to be estimated and ε_i is the error term composed of v and u. v_i

is independently and identically distributed random errors N (0, σv^2). These are the factors outside the control of the firm. u_i is a non-negative random variable which is independently and identically distributed as N (0, σu^2) i.e. the distribution of u_i is half normal. $| u_i | > 0$ reflects the technical efficiency relative to the frontier. $| u_i | = 0$ for a firm whose production lies on the frontier and $| u_i | < 0$ for a firm whose production lies below the frontier.

According to Battese and Coelli (1995), technical inefficiency effects are defined by;

$u_i = z_i \delta + w_i, \qquad i = 1,\ldots\ldots, N$

z_i is a vector of explanatory variables associated with the technical inefficiency effects and δ is a vector of unknown parameter to be estimated. w_i is an unobservable random variable, which is assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2, such that u_i is non-negative. According to Battese and Corra (1977), the variance ratio parameter γ which relates the variability of ui to total variability (σ^2) can be calculated in the following manner;

$\gamma = \sigma u^2/\sigma^2, \qquad$ Where $\sigma^2 = \sigma u^2 + \sigma v^2; \qquad$ so that $0 \leq \gamma \leq 1$

If the value of γ equals zero the difference between farmers yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency (Coelli, 1995).

The stochastic frontier production function can be estimated using either the maximum likelihood method or using a variant of the COLS (corrected ordinary least squares) method suggested by Richmond (1974). For this study we have used the maximum likelihood method because the availability of software, the Frontier Programme (Coelli, 1994) has automated the maximum likelihood method.

The following frontier production function model specifications were used in the study analysis.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 D_1 + \beta_5 D_2 + \beta_6 D_3 + v_i - u_i$$

Where Ln denotes logarithms to base e

Y = Yield of rice (ton/ha)

X_1 = Seed (Kg/ha)

X_2 = Fertilizer (Kg/ha)

X_3 = Human labor (man-days/ha)

D_1 = Dummy crop establishment method (1 = *Bolon,* 0 = *Naicha*)

D_2 = Dummy low land (1 = low land, 0 = otherwise)

D_3 = Dummy high land (1 = high land, 0 = otherwise)

$v_i - u_i$ = Decomposed error term as specified in Battese and Coelli (1995)

The technical inefficiency model can be expressed as,

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + W_i$$

Z_1 = Age of farmer (years)

Z_2 = Education (years of schooling)

Z_3 = Dummy farm size (1= farm size is greater than 1 hectare, 0 = otherwise)

Z_4 = Tenancy ratio

Z_5 = Dummy location (1= farmer resides in Rangpur, 0 = otherwise)

Wi = unobservable random variables

IV: Results and Discussion

Land type and the rate of adoption of the *Bolon* system

Farmers were asked to report the depth of flooding during the peak of the monsoon season for each parcel of land in their land portfolio. The high land was defined as those parcels which are flooded up to a depth of 20 cm, medium level land as those flooded up to 50 cm and the low lands as those flooded at over 50 cm depth. The estimate from the survey shows that about 23% of the parcels operated by the sample farmers were high land, 52% were medium land the remaining 25% were low lands. The double transplanting system was adopted in about 71% of the total Aman rice crop;

80% for the low land, 73% for the medium land and 42% for the high land. The low lands in which the *Bolon* system is not used are flooded at more than one meter depth where the traditional tall and low-yielding deep water rice varies are grown. There varieties are direct seeded in the month of March and April, maintained as an upland crop for about 8 to 10 weeks and then grown along with the rising flood water with the onset of flooding beginning of July. The farmers reported that the *Bolon* system was previously used mainly for the medium and low land, but recently the practice is spreading in the high land also.

Crop management aspects of *Bolon* and *Naicha* systems

Farmers practice a closer line spacing (6 x 10 cm) and higher number of seedling per hill (9-16) for transplanting 25-34 days aged seedlings in the *Bolon* plot (Table 1). During the period of July 15 to August 05, the farmer uproots the tall seedlings from the *Bolon* plots and transplant 60-65 days aged seedlings to the main fields. Farmers who practice the *Naicha* use different age of seedlings (35-45 days) depending the type of land i.e., aged seedlings for low land and younger seedlings for medium and high land (Table 1). However, the average crop duration of *Bolon* is reported at 120 days, 10 days shorter compared to the *Naicha* system.

Input use and costs of production

Farmers require less amount of seed under the *Bolon* system. Due to transplanting in another field (the *Bolon* plot) the plants go for tillering and hence the number of healthy seedlings increases. The survey data show that farmers use 43 kg of seed her ha under the *Bolon* system compared to 68 kg seeds for *Naicha* system. The savings on account of seed, land preparation, transplantation and chemical fertilizers is estimated from the survey at US$ 19.25 per ha under the *Bolon* system compared to the *Naicha* system. Regarding the use of labor, farmers require an additional 14 man-days/hectare for transplanting seedlings to the second transplanting that could be saved under the

Naicha system. Results also reveal that weed and pest infestation is comparatively low in the rice field cultivated under the *Bolon* system.

Economics of rice cultivation under *Bolon* and *Naicha* systems

The productivity of Aman rice was comparatively higher under *Bolon* system than that of *Naicha* for all types of land. The average yield of rice grown in low land under *Bolon system* was 4.04 t/ha, about 8% higher than that of *Naicha* (Table 2). Besides, the yield of rice was 4.10 and 3.82 t/ha under *Bolon* and *Naicha* systems, respectively for medium land. Results of paired t-test indicate that yield difference between *Bolon* and *Naicha* systems was significant at 1% level (Table 3). Farmers earned almost 8% higher gross returns from both low and medium rice land following *Bolon* over *Naicha* system. The study shows, per hectare cost of rice cultivation (US$ 208) under *Bolon* system is marginally higher than that of *Naicha* (US$ 204), but the difference is not statistically significant (Table 3). Although the cost of labor under the *Bolon* system was significantly higher than that of *Naicha*, but other cost such as pesticide was significantly lower under this system (Table 3). On balance, the total cost of cultivation is not significantly different between the two systems.

Since the *Bolon* system gives higher yield where as the cost difference is marginal, the profitability in rice cultivation under the system compared to that for *Naicha*. The net return from Aman rice cultivation under the *Bolon* system was US$ 255/ha for the low lands, about 14% higher than that for *Naicha*. The net return was 7% higher for the medium land. For all land types the profitability gain was 10% for the *Bolon* system than that of *Naicha*, which is statistically significant (Table 3).

Technical inefficiency: results from Stochastic Frontier model

The maximum likelihood (ML) estimates of the estimated stochastic frontier model are presented in Table 4. The estimated ML coefficients of human labor and fertilizer were 0.125 and 0.058 respectively, which were statistically significantly different from zero. This indicates that increment of the inputs, human labor and fertilizer by one percent will increase output by 0.12 and 0.06 percent, respectively. The significant coefficient of the dummy for crop establishment method indicates that the rice yield under *Bolon* system was significantly higher than that of *Naicha*. The coefficients of dummy variables for both high and low land are negative and statistically significant. The results indicate that the technical efficiency in rice production is the highest for the medium level land.

The estimated coefficients in the inefficiency model are presented in Table 5. The technical inefficiency is positively related with the age of the farmer which indicates older farmers are less efficient than younger ones. The negative and significant coefficient for education shows that the educated farmers were more efficient than the non-educated farmers. The technical inefficiency is positively related with farm size, indicating that smaller farmers are more efficient than the larger ones. The coefficient of tenancy variable is negative and statistically significant, indicating that tenant farmers are more efficient than owner farmers.

The mean technical efficiency of the rice farms under is found at 89% for the *Bolon* system and 83% for the *Naicha* system (Table 6). The estimates show fairly high levels of efficiency in Aman rice cultivation in Bangladesh. As the technical efficiency of *Bolon* farms is higher than that of *Naicha*, it can be concluded that the *Bolon* system is technically more efficient than the *Naicha system*.

Farmers' perceptions

The qualitative response obtained from the farmers indicated the following merits and demerits of the *Bolon* system.

Advantages:

- Farmers can transplant Aman rice in the field at a time when the risk of consecutive days of heavy rains is less

- The aged and tall *Bolon* seedlings can be transplanted to the rice field with stagnant water
- Healthy seedlings produce longer and uniform panicles resulting in less unfilled grains, higher grain weight and higher therefore higher productivity compared to single transplanting system
- Helps saves seed, and pesticides and weeding labor
- Greater opportunity for using family labours through phasing of planting dates for lands of different elevation, and hence reduce dependence on hired labor
- Ease labor scarcity and avoid high wage rate during transplanting

Disadvantages:

- Additional cost involved in land preparation and transplanting of seedlings at the *Bolon* plot
- Bold rice straw produced from *Bolon* cultivation system is not good as cattle feed
- This system is not convenient for the big farmers because many plots need to be transplanted two times.

V: Conclusions

The findings of the study indicate that Aman rice cultivation in the low lying areas through *Bolon* system is an appropriate technology to avoid submergence problem in the flood-prone rice ecosystem. Higher productivity as well as significant net return from rice cultivation using *Bolon* system indicates that farmers indeed gain by adopting this method of crop establishment. The stochastic frontier model also proved rice farming under *Bolon* system is more efficient than that of *Naicha*. Due to the higher productivity and efficiency the *Bolon* system are spreading even on the medium and high level land where there is little risk of submergence from heavy rains. So, instead of discarding the system, rice researchers must work on refining the system through developing appropriate varieties and other crop management practices for the system.

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Table 1. Variation in agronomic parameters practiced in *Bolon* and *Naicha* systems

Agronomic parameters	*Bolon system*		*Naicha system*
	Bolon plot	***Main plot***	
Age of seedlings for transplanting in the rice field (days)	25-34	60-65	35-45
Seedlings per hill	9-16	3-4	4-6
Line spacing (cm) Line to line Plant to plant	 10 6	 15 15	 20 15
Crop duration (days)	120		130

Table 2. Economics of Aman rice cultivation under *Bolon* and *Naicha* systems at northern districts of Bangladesh

Particulars	Low land		Medium land		High land	
	Bolon	*Naicha*	*Bolon*	*Naicha*	*Bolon*	*Naicha*
Rice yield (ton/ha)	4.04	3.75	4.10	3.82	3.68	3.57
Gross return (US$/ha)	459	424	468	435	419	407
Gross cost (US$/ha)	204	202	218	203	218	210
Net return (US$/ha)	255	223	250	233	201	197

Table 3. Difference in yield and other production parameters between *Bolon* and *Naicha* systems

Parameters	Bolon	Naicha	Percent difference	t- value	Significance level
Yield (ton/ha)	4.00	3.79	5.5	2.66	0.010
Labor cost (US$/ha)	107	104	3.2	2.08	0.041
Pesticide cost (US$/ha)	5.5	7.3	-24.7	-2.77	0.007
Gross cost (US$/ha)	208	204	1.9	1.57	0.121
Net return (US$/ha)	237	216	9.4	2.55	0.013

Table 4. Maximum likelihood estimates of the stochastic frontier production function

Variables	Parameter	Coefficients	Standard error	t-ratio
Constant	β_0	7.2860	0.6141	11.86***
Seed	β_1	0.0244	0.1407	0.173
Fertilizer	β_2	0.0578	0.0275	2.101**
Human labor	β_3	0.1247	0.0437	2.852***
Crop establishment method (dummy)	β_4	0.1127	0.0666	1.693*
Dummy low land	β_5	-0.0348	0.0247	-1.410*
Dummy high land	β_6	-0.0956	0.0358	-2.667***
	σ^2	0.0938	0.0325	2.882***
	γ	0.7883	0.0851	9.265***
	Log Likelihood	90.41		

*** Significant at 1% probability level,
** Significant at 5% probability level,
*Significant at 10% probability level

Table 5. Determinants of technical inefficiency model

Variables	Parameters	Coefficients	Standard-error	t-ratio
Constant	δ_0	-1.442	0.9993	-1.443*
Age of farmer	δ_1	0.012	0.0085	1.443*
Education	δ_2	-0.083	0.0598	-1.393*
Farm size (dummy)	δ_3	0.110	0.0718	1.531*
Tenancy ratio	δ_4	-0.440	0.3253	-1.354*
Location (dummy)	δ_5	0.322	0.3254	0.9895

Table 6. Technical efficiency estimates of the rice farms under *Bolon* and *Naicha* system

Crop establishment system	Technical efficiency score	
	Mean	***Standard deviation***
Bolon	0.90	0.021
Naicha	0.84	0.066

Fig 2. Daily Average Rainfall Data, 1992-2003