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Article

Economic Consequences of Land Fragmentation on Farm Production: Empirical Evidences from Bangladesh

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ABSTRACT

This study examines the impact of land fragmentation on farm productivity in northern Bangladesh. To achieve that objective, primary data were collected from 193 farm households through a direct interview method from Mymensingh and Dinajpur districts. A combination of analytical tools was employed like perception index, fragmentation index, Simpson index and multiple linear regression model. Most of the farm lands in the study area were severely fragmented. The decreasing rate of average farm size was more prevalent for those farmers whose lands were less fragmented. Moreover, farmers, having more fragmented land, incurred more costs in farm production. Regression results revealed that the number of parcels, average plot size and average distance from plots to homestead were found to have significant negative impact on rice production. Policy implications include developing effective land consolidations program by the spread of commercialization of farming by public or private authority and spread of mechanization through machine service providers at the local level and creating employment opportunities to release pressure on the land.

Keywords: Simpson index, fragmentation index, perception index, productivity, average plot size.

1. Introduction

The agriculture sector of Bangladesh contributes about 14.23% to the country's gross domestic product and provides employment of about 40.62% to the total labour force which makes it important in the overall economic development of the country (BBS, 2020). Rice is considered as the most important crop to millions of farmers accounting for about 75% of total agricultural land use and 45% of the total labour force (BBS, 2020). For being always a vulnerable and highly sensitive sector, now a days agriculture is in hindrance due to high population growth in almost all developing countries of the world. The ever-growing population results in fragmented land and it has become a challenging job to feed the increasing population. The possibility of expanding cultivable land to meet the increasing demand for food is very limited as the agriculture sector has been operating at the cutting edge of land (Hossain & Rahman, 2012).

Several literatures have defined land fragmentation as the situation in which a single farm is consistent of a number of spatially separated parcels (King & Burton, 1982; McPherson, 1982; Van, 2003). The demographic pressure along with inheritance laws, according to which the land is equally divided amongst all brothers and half of brothers' share to sisters (occasionally), is augmenting the land fragmentation process (Khan, 2004). The persistence of land fragmentation could be explained by numerous supply-side and demand-side arguments. Several exogenous supply side forces like inheritance laws, population pressure and scarcity of land put pressure on farmers to opt for fragmented land (McPherson, 1982; Bentley, 1987). This is the case particularly in South Asia where land is serving as the main source of livelihood and wealth and also a means of social security, status and identity. As such, the declining size of individual landholdings is observed in this region, while at the same time the number of landholdings is increasing (FAO, 2001). The fragmentation of almost all cultivated holdings is one of the major problems of Bangladesh agriculture.

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Land fragmentation has been studied in many countries and regions throughout the world (Tan *et al.,* 2008; Niroula *et al.,* 2007; Van *et al.,*2007; Shuhao, 2005; Yaslioglu *et al.,* 2009; Kjelland *et al.,* 2007; Sengupta 2006). It was evidenced that the annual household income, per capita arable land, size of land rented in and rented out by household, labour force, family size, education level, land ownership, number of crops planted by household were the significant factors that influenced land fragmentation (Obayelu *et al.,* 2019; Kalantari & Abdollahzadeh, 2008). Al-Amin *et al.* (2016) showed a positive effect of the number of plots on technical inefficiency of rice production in Bangladesh. Shafiqul (2014) pointed that land fragmentation is leading increased uses of chemicals followed by decreased vegetable and grain production. Ben-Chendo *et al.* (2014) explored that small landholding size discourages the practice of rice framing in Nigeria. Kawasaki (2010) showed that the parcel number increase cost inefficiency in Japan. In Bulgaria, fragmentation was found to reduce farm profitability (Di Falco *et al.,* 2010). Similar result was found by Rahman & Rahman (2009). Similarly, land fragmentation was restraining increasing productivity in Nepal, India, and other nearby regions (Blaikie & Sadeque, 2000).

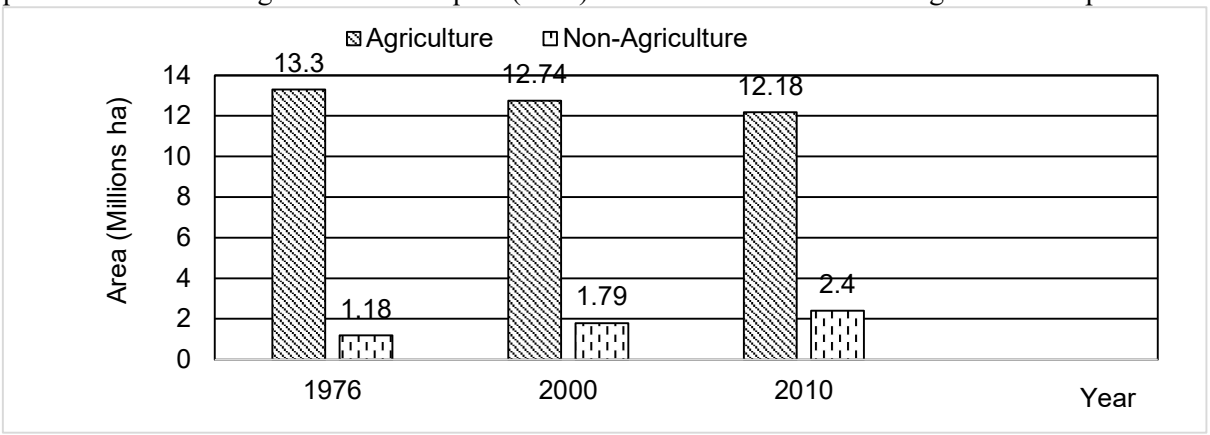

Figure 1: Agricultural and non-agricultural land-use change in Bangladesh between 1976 and 2010

Source: Hasan et al. *(2013)*

A fall in total agricultural land (including cropland, forest, mangrove, river, lake, beel and haor, aquaculture, tea estates, and saltpans) by 1.12 million ha is visible from Figure 1. On the other hand, non-agricultural land had increased by 1.22 million ha in Bangladesh between 1976 and 2010. National statistics revealed that the country had almost 67.38% of agricultural land in 1976. Since then, the agricultural land contraction rate was 0.13-1 per cent per year till 2010 (Reddy *et al.*, 2016). Rural societies across the globe have a common phenomenon of land fragmentation affecting farm productivity. As such, it is worthy to estimate farm productivity under fragmented farm conditions in Bangladesh context. The present study tries to fill the knowledge gap and provide a scientific understanding about land fragmentation and their impact on farm productivity and input using pattern. The findings of the study would be very useful to the researchers and policy makers in taking appropriate decision with respect to land fragmentation and encouraging the new researchers in conducting more comprehensive and detailed investigation in these issues. The research will try to answer some questions, such as, (a) how do farmers perceive the existing land fragmentation which affect their farm production? (b) what is the input use pattern at farm level due to land fragmentation? and (c) which factors have influence on production in a fragmented farm? These questions will be helpful in clarifying the following specific objectives:

i. To explore farmer's perception about land fragmentation;

ii. To assess the changing pattern of input use due to land fragmentation; and

iii. To measure the impact of land fragmentation on-farm production.

2. Methodology

The study area comprises Mymensingh and Dinajpur districts as these two regions are the highest rice-producing districts in Bangladesh. The research preferred multistage purposive

sampling for cost and feasibility reasons. Five sub-districts (Upazilas) were chosen purposively with the consultation of the Deputy Directors (DD) of agriculture and Upazila Agricultural Officer (UAO) from the respective districts. A farm-level survey was conducted in 12 villages of 11 Upazilas from the above mentioned districts. As land fragmentation is prevalent all over the country, concentration of rice cultivation was considered while selecting the samples.

Data were collected for the production year 2018-2019 from 193 farm households in March 2019. After that, necessary classification, tabulation and analysis were done for achieving the objectives set for the study. Perception index was calculated to explore farmer's perceptions about land fragmentation. To that aid, a Likert scale questionnaire was developed with which each respondent was asked to assign points based on how much they agree with a specific statement regarding land fragmentation (Elia *et al.*, 2015). To assess the changing pattern of input use due to land fragmentation, different descriptive statistics like mean, standard deviation, per centages, graphical analysis, etc. were used.

Simpson index was used to measure the extent of land fragmentation. This index is an average of the number of plots per farm. Simmons (1964) proposed a land fragmentation index that took into account the number of parcels in a holding and the relative size of each parcel. The formula for Simmons' land fragmentation index is as follows:

$$FI=\frac{\sum_{i=1}^{n} a_i^2}{A^2} \quad (1)$$

$$SI=1-\frac{\sum_{i=1}^{n} a_i^2}{A^2} \quad (2)$$

Where, FI = Fragmentation index; SI = Simpson index; n = Number of parcels belonging to a holding; a = Size of a parcel; and A = Total holding size. An FI value of 1 means that a holding consists of only one parcel and value closer to zero mean higher fragmentation. The Simmons index becomes the Simpson index if it is subtracted from 1 (Shuhao, 2005). When the value of Simpson index is zero, it indicates a holding consists of only one parcel and a value closer to one means higher land fragmentation. Multiple regression analysis was used to measure the impacts of land fragmentation on farm production. The implicit form of the model is as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + \varepsilon_i \quad (3)$$

Where, Y_i = Annual crop yield ($Y_t - Y_{t-1}$); β_0 = Constant term; X_{1i-ki} = Independent variables; β_{1-k} = Regression coefficients; and ε_i = Stochastic disturbance term. Dependent variable Y_i is the annual crop yield and independent variables are the crop-specific land fragmentized variables.

3. Results

3.1 Farmer's perception about land fragmentation

For calculating perception index, a Likert scale questionnaire is followed and the scale is used to measure the perception regarding different aspects of land fragmentation including its advantages and disadvantages. The research includes 5 statements related to the disadvantages of land fragmentation and 4 statements related to the advantages of land fragmentation. The 5 points of Likert scale and their scoring are (i) Strongly agree (+2); (ii) Agree - (+1); (iii) Undecided (0); (iv) Disagree (-1); and (v) Strongly disagree (-2). The mean score for each statement was calculated. The perception index was found to vary from 243 to -93 for sampled farmers. Table 1 reveals the perception index score and the ranking of the statements based on the score.

3.2. Land fragmentation status in study regions

Fragmentation status of operating lands in the study regions has been explored by using the fragmentation index (FI). The study revealed that about 35 per cent and 58 per cent of farmers in Mymensingh and Dinajpur, respectively have fragmentation index below 0.3. That means, land is more fragmented in Dinajpur region. On average, almost half of the sample farmers are facing a severe fragmentation problem having FI value of less than 0.3. Overall, only about six per cent of farmers have fragmentation index above 0.7. Simpson index is used to describe the changing pattern of average farm size and average plot size.

Table 2 shows the land fragmentation status within different farm categories in the study region. Among the total sample, around 19 per cent were marginal farmers, 71 per cent were small farmers, 10 per cent were medium farmers and only about 1 per cent were large farmers.

Table 1: Farmers' perception of land fragmentation

	Sl. No	Statement	Nature of opinion					Perception index	Rank
			Strongly agree	Agree	Undecided	Disagree	Strongly disagree		
Disadvantages	1	High travel time and cost	2	126	20	42	0	88	4
	2	Parcels at a greater distance are cultivated less intensively	3	84	73	30	0	60	5
	3	Land wastage because some portion remain uncultivated at the margin of parcels	10	130	40	10	0	140	3
	4	Use of modern machinery is difficult or may be impossible	84	79	23	4	0	243	1
	5	Require more labours	44	138	5	3	0	223	2
Advantages	1	Minimize risk by producing variety of crops	6	84	61	39	0	57	2
	2	Minimize risk from climatic and natural disaster	21	100	41	23	5	109	1
	3	Adjust the labour because crops ripe at different times	0	32	92	65	1	-35	3
	4	Parcels will be distributed easily to their inheritors	0	14	80	85	11	-93	4

Source: Author's calculation based on field survey, 2019.

About 69 per cent of marginal farmers, having below 0.25 ha of land, fall into the Simpson index of 0.5 to 0.7 which means that most of the marginal farmer's land were fragmented. About 42 per cent of small farmers belonged to SI of 0.5 to 0.7 and about 53 per cent of small farmers

belonged to SI over 0.7. Surprisingly, all of the medium and large farmers had Simpson index over 0.7. High level of land fragmentation was revealed among these two groups of farmers. The table also represents that the increasing farm size is positively related with the high level of land fragmentation. This finding was obtained for the sample farmers in terms of number of parcels.

Table 3 shows that average farm size and average plot size are decreasing over the years. The decreasing rate of average farm size (45 per cent) was more common for those farmers who belonged to SI value of less than 0.5. This indicates that the decreasing rate of average farm size was prevalent for those farmers who are less fragmented. On the other hand, the decreasing rate of average plot size was lower (8 per cent) for the Simpson index value of less than 0.5 and higher (17 per cent) for the Simpson index value of 0.5 to 0.7, respectively. It means the decreasing rate of average plot size was prevalent for those farmers who are more fragmented. Moreover, farmers who had two, three or four parcels of land ten years ago in both regions, are having an increasing rate of fragmentation at present. Survey also revealed that the majority of the farmers (27 per cent) had more than six parcels of land.

3.3 Changes in input use pattern due to land fragmentation

Table 4 explains the variation in the input costs due to land fragmentation in the study area. The Input costs are presented for both rice seasons: aman (rainfed season) and boro (dry and irrigated season). Most of the farmers used purchased seeds from markets. The cost of seed was determined based on market prices. The amount and cost of seeds are both increasing with increasing value of Simpson index which implied that fragmentation had increased seed costs in farm production. The similar results were observed for all input costs. The respondents mainly used five types of fertilisers namely urea, Tripple Super Phosphate (TSP), Muriate of Potash (MoP), D Di-Ammonium Phosphate (DAP) and Gypsum. The cost of fertilizer was calculated by the prevailing market rate which was paid by the farmers. The average total cost of fertiliser per hectare found Tk. 4826, Tk. 5362 and Tk. 5520 in Aman season and Tk. 9595, Tk. 9680 and Tk. 10158 in Boro season for the farmers having Simpson index below 0.5, 0.5 to 0.7, and above 0.7, respectively. Farmers having higher value of Simpson index incurred higher cost for insecticide and labour also. Irrigation is mainly needed for boro season because the aman season mostly depends on natural rain. Highest irrigation cost was found for farmers having Simpson index value of 0.5 to 0.7.

Table 2: Land fragmentation status within different farm categories

Categories	Land (ha)	Farmers (%)	Simpson index (SI)		
			0.0 - 0.5	0.5 - 0.7	Over 0.7
Marginal	Below 0.25	18.45	31.25%	68.75%	0%
Small	0.25-1.00	70.86	5.04%	42.36%	52.60%
Medium	1.00-3.00	9.77	0%	0%	100.00%
Large	Above 3.00	1.08	0%	0%	100.00%

Source: Author's calculation based on field survey, 2019.

Table 3: Changing pattern of farm size and plot size due to land fragmentation

Simpson index	Particulars	At present (Decimal)	10 years ago (Decimal)	Change (%)
Below 0.5	Average farm size	49.11	89.06	- 44.94
	Average plot size	30.215	32.90	- 7.85
0.5 to 0.7	Average farm size	80.12	133.04	- 39.54
	Average plot size	26.62	32.16	- 17.04
Above 0.7	Average farm size	214.75	240.51	- 10.16
	Average plot size	28.08	34.79	- 16.86

Source: Author's calculation based on field survey, 2019.

Table 4: Input cost variation due to land fragmentation

Inputs		Aman Simpson index			Boro Simpson index		
		Below 0.5	0.5-0.7	Above 0.7	Below 0.5	0.5-0.7	Above 0.7
Seed	Kg/ha	43.68	45.47	46.64	51.77	54.90	51.81
	Tk./ha	1673.73	1741.08	1782.73	1962.50	2081.96	1974.06
Fertiliser (Kg/ha)	Urea	109.12	117.25	121.55	210.97	216.00	231.27
	TSP	48.90	55.61	59.46	111.66	115.20	120.55
	MoP	60.13	66.85	66.78	102.06	106.67	108.45
	Gypsum	12.04	12.42	12.70	22.84	23.83	25.53
Fertiliser cost Tk./ha)		4825.87	5362.04	5520.34	9594.88	9680.37	10157.96
Irrigation cost Tk./ha)		126.24	205.98	90.71	11719.32	12066.54	11952.75
Insecticide cost (Tk./ha)		1634.75	1766.53	2086.27	1919.59	2239.39	2696.00
Labour cost	Person-days/ha	82.23	84.47	85.84	81.37	80.17	85.11
	Tk./ha	32945.03	33780.33	34147.17	36676.78	36072.34	38282.81

Source: Author's calculation based on field survey, 2019.

Table 5: Land fragmentation impact on input technology over time (%)

Particulars	Using technology	Simpson index Below 0.5		0.5-0.7		Above 0.7	
		At present	10 years ago	At present	10 years ago	At present	10 years ago
Land preparation	Tractor	47.35	0	38.98	0	42.38	0
	Power tiller	52.66	100	61.03	93.33	57.63	91.88
	Manual	0	0	0	6.67	0	8.12
Irrigation	Pump	26.19	0	31.93	2.57	32.19	7.81
	STW	71.54	90.46	60.45	84.75	59.07	82.03
	Canal/River	2.27	9.55	7.63	12.69	8.75	10.17
Pesticides apply	Sprayer	67.86	53.03	70.13	49.75	79.67	52.32
	Manual	32.15	46.97	29.87	50.26	20.34	47.69
Harvesting	CHV	0	0	2.59	0	0	0
	Manual	100	100	97.41	100	100	100

Source: Author's calculation based on field survey, 2019.

Table 5 shows the impact of land fragmentation on input using technology over the time. For land preparation, tractor or harrow and power tiller are used while it was completely dependent on power tiller and manual system 10 years ago. The proportion of farmers using tractor for preparing land is higher (47 per cent) for lower Simpson index value (below 0.5). That means, the less the land is fragmented, the more farmers can use big machineries in their fields. Although farmers use improved technology but the rate is still very low. For irrigation purposes, farmers mainly depend on motor pump or Low Lift Pumps (LLP) and Shallow Tube Wells (STW). The results from field survey indicated that farmers with more fragmented land used motor pumps for irrigation while farmers (almost 72 percent) with less fragmented lands (with a lower Simpson index value of below 0.5) used STW. However, this may not represent any direct relationship between fragmentation of land and irrigation technology. The choice of irrigation device in the country is primarily conditioned by the proximity of the plots to the surface water irrespective of the extent of land fragmentation.

3.4 Impact of land fragmentation on farm production

In regression analysis, rice productivity per hectare was considered as a dependent variable. Six different parameters are generally used to measure the degree of land fragmentation: farm size, number of plots, plot size, plot shape, the spatial distribution of plots and the size distribution of the plots (Obayelu *et al.*, 2019; Al-Amin *et al.,* 2016; Rahman & Rahman, 2009; Kalantari & Abdollahzadeh, 2008; Bentley, 1987). The study considered four socioeconomic variables namely labour intensity, age of household, education, farming experience and three land fragmentation related variables namely, the average distance from plots to homestead, cultivated parcel number, the average area of cultivated parcels as explanatory variables.

The old farmers are more experienced to take farming decisions than young and the young farmers are more enthusiastic and risk-taker in the farming decision. So, the age of the household head is assumed to influence productivity either positively or negatively. Education level is measured through the number of years attended in an educational institution. Increasing years of schooling enriches the farmers' knowledge of agriculture and helps them to optimally use inputs to produce more. This variable is hypothesized to appear with positive sign in the estimated model. The farming experience of a farmer determines his managerial ability on the farm. More experienced farmers can make more economic decisions regarding the optimum combination of inputs to get better outputs. Modern improved technology is mostly impossible to introduce where land is fragmented and the parcels are in different positions from each other. The expected sign of this variable is negative (Table 6).

Summary statistics of the explanatory variables show that the average labour use for rice farming is 139.54 person-days per farm (Table 6). The mean value of the age of household head, his education and farming experiences are 47.57, 5.35 and 18.04 years, respectively. The average distance from plots to homestead area is 270.16 meters. The average number and area of cultivated parcels are 5.01 and 0.12 hectare, respectively in the study regions.

The ordinary least square (OLS) method provided the regression results which are presented in Table 7. All land fragmentation related variables turn out significant. The number of cultivated parcels owned affected farm productivity significantly but negatively. This has the implication that the farmers could have optimal return from the land holding with fewer plots. Similar results had been found by Biziman *et al.* (2004) and Gashaw *et al.* (2017) although Al-Amin *et al.* (2016), Tan *et al.* (2010), Sherlund *et al.* (2002) reported positive impact of number of plots on farmer's technical efficiencies.

The average area of cultivated parcels (ha) positively and significantly affected farm productivity. Similarly, Singh (1975), Gavian & Fampchaps (1996) and Jha *et al.* (2005) found that farm size affected yield positively and significantly. However, an insignificant relationship between the farm size and productivity was reported by Gashaw *et al.* (2017) while Maqbool *et al.* (2012) found a negative relationship between the two. The distant parcels from homestead give significantly less return than the closer ones. Among socioeconomic variables, education of farmers

Table 6: Measurement, expected signs and summary statistics of explanatory variables in the regression model

Variables	Nature and unit of measurement	Expected signs	Mean	Standard Deviation
Age of household head	Quantitative: Years	±	270.16	260.48
Education of household head	Quantitative: Years	+	5.01	3.78
Experiences in farm production	Quantitative: Years	±	0.12	0.07
Labour use	Quantitative: Person-days	±	139.54	52.99
Number of plots	Quantitative: Numbers	-	47.58	13.12
Average plot (parcel) size	Quantitative: Hectare	-	5.35	7.13
Average distance from plots to homestead	Quantitative: Meters	-	18.04	8.29

Source: Author's calculation based on field survey, 2019.

and labour usage were significant.

Table 7: Regression results showing the impact of land fragmentation on farm productivity

Explanatory variables	Estimated values of coefficient		
	Coefficient	Standard error	*P*-value
Constant	1502.59	1089.02	16.694
Labour use (person-days)	7.80**	2.036	0.041
Age of household head (years)	-3.32	4.753	4.211
Education of household head (years)	8.21**	3.025	0.036
Farming experience of household head (years)	7.63	6.473	3.331
Average distance of parcels from homestead (meters)	-15.49**	6.129	0.011
Cultivated parcel number	-12.01**	3.343	0.021
Average area of cultivated parcels (Ha)	11.51*	4.114	0.078
R^2		0.804	
Adjusted R square		0.765	
F- ratio		16.255**	
Observation		188	

Source: Author's estimation based on field survey, 2019.

Note: *, ** and, *** indicate significance level for respective variables at <0.01, <0.05 and <0.001 per cent level of significance.

The coefficient of multiple determination was 0.084 which suggested that about 80% variation of dependent variable can be explained by the independent variables included in the model. The significant F-value imply that all the explanatory variables were important for explaining the variation in farm productivity.

4. Discussion

The research includes five statements related to the disadvantages of land fragmentation and four statements related to the advantages of land fragmentation. In case of disadvantages of land fragmentation, the highest score (243) is found for the fourth statement. That means most of the farmers agree that the use of modern machinery is difficult and sometimes impossible in their farm due to fragmented land size. The second highest perception index (223) is observed for the statement that 'more labour is required' while the statement 'land wastage because some portion remain uncultivated at the margin of the parcels' got third rank with PI of 140. That means a major number of farmers think that more labours are required in fragmented land and some portion of fragmented land remain uncultivated at the margin of the parcels which results in land wastage. Moreover, farmers agree that they need more time to go from one piece of land to another. As such, the travel time between their pieces of land increases which also raise their cost. Findings from several research support this statements. Cholo *et al.* (2020) showed that land fragmentation could significantly result in higher workloads and longer working hours for farmers. Women farmers work longer hours and lose time that otherwise be allocated to rest and leisure (Bardasi & Wodon, 2006; Kes & Swaminathan, 2006; Doss, 2001). However, a considerable number of farmers were undecided about the statement that 'parcels at a greater distance are cultivated less intensively' which got fifth rank with the PI score 60.

Land fragmentation could have some advantages too. Among them, the highest score (109) is found for second statement. That means, most of the farmers agree that they can minimize risk from climatic and natural disasters when the land is fragmented. Farmers also agree that they can minimize risk by producing a variety of crops. This statement got the second rank with the PI score of 57. However, majority of farmers were undecided and many farmers disagree that they can adjust labour as crops ripe at different times and parcels can be distributed easily to their inheritors if the land is fragmented. Likewise, Bui *et al.* (2020) mentioned that land

fragmentation could bring some positive outcomes too.

Land fragmentation made it difficult to adopt and use modern machineries in the fragmented land of farmers. The use of big machineries for land preparation, has been declined over the period of last ten years in the study regions. Land fragmentation could be one of the reasons behind this. Harvesting technology is mostly manual in the study area. It is difficult to generalize any relationship between land fragmentation and technology usage for irrigation. Now a days, with the spread of custom hire service market for irrigation, tillage or harvesting practices in Bangladesh, fragmentation of land has very little to do with the adoption of irrigation technologies. Rahman & Rahman (2009) reported that land fragmentation was one of the main reasons behind the hindrance of adopting modern technologies which ultimately hampered farm productivity. This has also been perceived by majority of sample farmers as can be seen from Table 1.

A linear production function was employed to analyse the impact of land fragmentation on productivity by considering all possible variables. King & Burton (1982) cite six relevant factors to measure the land fragmentation which were holding size, number of parcels belonging to the holding, size of each parcel, the shape of each parcel, the spatial distribution of parcels and the size distribution of parcels. Simmons (1964) calculated a land fragmentation index by utilizing two variables namely, the number of parcels in a holding and the relative size of each parcel. . In another study, fragmentation was computed by measuring the distance of parcels from the homestead for which a farmer would have to travel to reach each of the parcels (Dovring, 1965).

Average distance of parcels from homestead (meters) significantly affects farm productivity. Distance increases the travel time of labour between homesteads and parcels. It hinders the transportation of inputs from homestead to parcels, makes it difficult to supervise and to protect the land and creates loss of working hours. Most importantly, it becomes uneconomic to transport and use agricultural implements which induces the diseconomies of scale in the production system. Gashaw *et al.* (2017) found rice productivity to be negatively affected by the distance of parcels from homestead (minutes) at a significant level. Moreover, King & Burton (1982) and Gavian & Fafchamps (1996) concluded that by extensively increasing the production costs, long distances between parcels reduced the crop productivity.

Al-Amin *et al.* (2016) also reported a negative influence of average distance on technical efficiencies of rice production. The significance of average size of parcels variable implied that it would be optimal for the farmers to have greater farm sizes on average. Small size of land brought less yield.

Besides land fragmentation parameters, different socioeconomic variables (Age, education and farm experiences) are included in the regression model. From Table 7, it can be seen that age and farming experiences showed insignificant impact on productivity although Backman *et al.* (2011) stated a significant negative impact of farming experience on farm production. Education was significant and affected farm productivity positively as expected. Labour use has positive effect on productivity which was also significant at 5% probability level. Obayelu *et al.* (2019) reported similar significant impacts of education and labour use on farm productivity. On the other hand, Gashaw *et al.* (2017) found that labour use intensity did not significantly influence rice productivity even though rice farming is labour intensive. This might be because of the presence of abundant labour and where fragmentation does not reduce working time of farm activities. The overall findings of this research indicated that land fragmentation could hamper farm productivity as it leads to small and uneconomic size of operational holdings which may cause mismanagement in operations. However, one should be very careful in generalizing these causal effects as rice productivity in Bangladesh keeps on increasing in spite of decreasing farm size and increasing land fragmentation. It may be concluded that the increasing rate of productivity could be enhanced by keeping the land fragmentation process at minimum.

5. Conclusion

The study provides the empirical evidence on the negative impact of land fragmentation on rice productivity in Bangladesh. Primary data were collected from two districts namely, Dinajpur and Mymensingh by interviewing a total of 193 farm households. Most of the farmers perceive that the use of modern machinery was difficult in

fragmented lands. Many farmers also agree that fragmented land help them to minimize risk from climatic and natural disaster. Though, the management and operation in multiple parcels of land is little bit difficult with the modern technology, but it safeguards the loss of crops due to disease attack or any other kind of natural hazards. Land fragmentation was found to have increased the input cost for the farmers. But it could reduce the market/price risk as well. Modern technology usage was reduced over last ten years in the study areas due to fragmentation. Multiple linear regression model summarizes that education and average plot sizes had significant positive impacts on farm productivity while number of plots, labour use intensity and distance of plots from household showed significant negative impacts on farm productivity.

Based on findings of the study, it can be concluded that land fragmentation was one of the significant factors in explaining the variation in rice productivity holding the rice variety, quality of seeds and inputs, irrigation application, agronomic practices, etc. as constant but their effect is not overlooked. Appropriate measures should be taken into consideration to minimize the effects of fragmented plots, their parcel size and distance within the parcels on farm productivity. Thus, realizing the adverse effects of land fragmentation, policies should be geared towards modification of the law of inheritance by gender such as the right to produce the number of parcels of land by one or appropriate farmer, laws and regulations to give the individual titleship to land and private rights to use land and creation of employment opportunities for promoting non-farm income and releasing pressure on land. Consolidation of small and fragmented landholdings for farming through commercializing by private or public authority could be considered an effective policy tool. To that end, recent government move towards 'synchronized cultivation' should be continuously analyzed for its success throughout the country. Government policies should be taken towards developing an effective strategy that promotes land consolidations program by the spread of commercialization, spread of mechanization through machine service providers at the local level for the upcoming future generations.

Conflict of interest

Authors declared no conflict of interest.

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