The Bangladesh Journal of Agricultural Economics, 41(1): 35-45, 2020

EFFICIENT USE OF AGRICULTURAL LAND IN BANGLADESH: STRATEGIES FOR OPTIMIZATION

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ABSTRACT

Bangladesh is an agrarian country trying to feed an increasing population with gradually diminishing cultivable land. Majority of the population in Bangladesh depends directly or indirectly on agriculture. The agriculture of Bangladesh is capable of producing different types of crops all around the year. However, crop-wise nutritional value is different from crop to crop. As the amount of cultivable land is a major issue for crop cultivation, required domestic production is very much dependent on the optimum use of these lands. Every year, Bangladesh is to import and export various agricultural products to respond to additional demand and surplus production. The presence of strategies to maintain optimum use of land for each crop based on the domestic demand and export-import policies would stabilize the production system in Bangladesh. Cost of production and fair farm gate price of agricultural produce are two most important aspects related to the smooth marketing of the agricultural products, which also have significant impact on the production of a certain crop in successive years. As there is no alternative technique other than placing pressure on the scarce arable land of Bangladesh to ensure food security for its 168.96 million people, only a better planning for agricultural lands by expected crops may help solve the problem. The main objective of this research is to optimize the amount of land for each type of crop, especially for the *rabi* season, in order to maximize the farm-gate price and minimize the cost of production to help policy makers for devising better policy to ensure food security of the country. With the help of sophisticated statistical techniques this research suggests some alternative scenarios of optimum use of arable land by crops in *rabi* season that will enable the government to device appropriate strategies and incentive plans.

Keywords: Optimization, agricultural land, Bangladesh

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I. INTRODUCTION

Bangladesh is an agrarian country with gradually diminishing cultivable land and increasing population. Two-third of the population in Bangladesh depends directly or indirectly on agriculture. The sector employs 42.7% of the total labor force and comprises 14.2% of the country's GDP (The World Fact book, 2020; BBS, 2019). The performance of this sector has an overwhelming impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security (Rahman and Islam, 2014; Titumir and Rahman, 2011). Agriculture impacts human nutrition in many ways. As a source of food, agriculture provides vital macro- and micronutrients, as well as dietary diversity, to smallholder households. As a source of income for approximately half of the people of Bangladesh that depend on it for their livelihoods, of which two-third are women, agriculture allows those same producers to purchase foods that supplement their own production (Islam *et al.*, 2015). In a subsistence economy which is mostly based on agriculture, the domestic food production has an important role to play in the quest for food security in Bangladesh. The productivity in the agricultural sector is critically important if agricultural production is to increase at a sufficiently rapid rate to meet escalating demands for food (Begum and D'Haese, 2010; Hayami and Ruttan, 1985; Mellor, 1976). The agriculture of Bangladesh is capable of producing different types of crops all around the year. However, crop-wise nutritional value is different. Hence, national demand should have to be fulfilled from varieties of crops grown in different seasons. So far, Bangladesh has been successful in maintaining most of its food demand for the existence of the fertile soils on the few vast floodplains that are annually refilled by siltation during the annual flood (Rahman and Islam, 2014), though there are considerable imports of some agricultural commodities. As the demand for different crops are different and there is an issue of foreign trade (export-import) the country has to produce each crop according to the required quantity so that the balance between demand and supply for each crop is maintained. Also stabilization of market price as well as ensuring a good return for producers is an important issue. As the amount of cultivable land is a major issue for crop cultivation, required domestic production is very much dependent on the optimum use of these lands. Every year, Bangladesh imports (government commercial import, import under food aid and private import) food grains, the figure is gradually increasing to meet the additional requirements in general and to stabilize the food market as well as to take precautions to address the unforeseen incidents in particular (Ahmed *et al.*, 2009). The country also exports many crops based on the additional domestic production and other government policies. The presence of strategies to maintain optimum use of land for each crop based on the domestic demand and export-import policies would stabilize the production system in Bangladesh. This will result in the crop-wise export-import decisions more precise and reasonable.

The gross cultivable area of Bangladesh is about 19,774,000 acres (BBS, 2019). Using this limited area of land, the country grows a wide variety of crops in different seasons (Summer [April-September], locally known as *kharif* season, and Winter [November-March], locally known as *rabi* season) in different types of lands. The yield rate, the cost of production, and the contribution are functions of soil characteristics (fertility, etc.), region, the crop being produced, cropping pattern and method (crops being produced and their sequence, irrigation, non-irrigation, etc.). For a single-cropped land there are a number of alternative crops from which the crop to be cultivated in a year may be chosen. Similarly, there are many different combinations of crops for double- cropped and triple-cropped lands. Different alternatives or combinations give different outputs. The utilization of land for necessary/appropriate crops is the key problem for crop planning in Bangladesh (Sarker *et al*., 1997). Cost of production and fair price of agricultural produce are two most important topics related to the smooth marketing of the agricultural products, which also have significant impact on the production of a certain crop in successive years. Farmers always try to maximize their farm-gate price with minimum cost of production. This controversial situation also affects the cultivation procedure as well as the overall production of agricultural products. Small and marginal farmers in the remote rural areas remain ignorant about the current price of their products in the market, their trends, demand and supply which create obstacles for the farmers in getting fair price of their products. Consequently, the situation discourages the farmers from production of the agricultural products. FAO (2020) data shows that the worldwide food production is enough to meet the current population demand, however nearly one eighth of global population still do not have enough food to fulfill their minimum daily dietary requirements. Moreover, South Asia is considered as the habitation for poor and mal-nourished people in the world (FAO, 2005). Bangladesh is one of the densely populated South Asian countries with malnourished people (UNICEF, 2014). Bangladesh is yet to achieve self-sufficiency in all sectors of food products. Along with various other factors responsible for low agricultural output, such as unscientific methods of cropping, natural calamities and the absence of a proper nationwide crop-planning program have been identified as significant factors (Sarker *et al*., 1997). Bangladesh can reasonably desire to become a middle-income country by 2021, which require a sustained 7.5% annual gross domestic product (GDP) growth or above (GED, 2015). To achieve this, Bangladesh will need a series of structural changes to ensure a more rapid, sustained and employment-generating growth. Bangladesh is also one of the most vulnerable countries to weather variability and natural disasters (World Bank, 2007). As there is no alternative technique other than placing pressure on the scarce arable land of Bangladesh to ensure food security for its 162.7 million people (BBS, 2018), only a better planning for agricultural lands by expected crops may help solve the problem. The main objective of this research is to optimize the amount of land for each type of crop, especially for the *rabi* season, in order to maximize the total production, farm-gate price and minimize the cost of production to help policy makers for devising better policy to ensure food security of the country.

II. METHODOLOGY

This paper focuses on the optimum use of limited cultivable land in Bangladesh. In general, there are three types of cropping seasons prevailing in Bangladesh: *kharif*-1, *kharif*- 2 and *rabi* season. Because of its tropical location, Bangladesh is able to plant several crops on the same land each year. This practice may provide farmers with opportunities for harvesting diverse crops from the same land, increasing total land productivity, and maintaining or improving soil fertility. Most common *rabi* or winter crops are boro rice, wheat, maize, mustard, groundnut, sesame, tobacco, potato, sweet potato etc. To conduct this analysis, we gathered the data on consumption, production, area, yield rate, farm gate price and cost of production of *rabi* crops for the year 2015-16. The data were collected from Bangladesh Bureau of Statistics (BBS) and Department of Agricultural Marketing (DAM).

Weighted Yield Rate

The data on production, area and yield rate were collected from the agriculture wing of BBS which is one of the predominant sources of data as we consider some specific season-wise crops. Seven types of crop varieties, namely, major cereals (boro rice and wheat), cereals-minor (*rabi* maize, barley, *rabi* jower, cheena & kaon, and other *rabi* cereals), other food crops (potato and sweet potato), pulses, oil seeds, spices & condiments and winter vegetables are identified according to the cultivated *rabi* crops in Bangladesh. In each variety, we have many combinations of crops and hence come the necessity of using weighted yield rate. For instance, boro rice and wheat crop combinations were selected for major cereals and from the above consideration, the following formulation was used-

$$\text{Weighted Yield Rate (Major Cereals)}$$
$$= \frac{\text{per acre yield for boro rice} \times \text{area of boro rice} + \text{per acre yield for wheat} \times \text{area of wheat}}{\text{Total area of boro rice and wheat}}$$

Food Grain Consumption

The consumption data for the year 2015-2016 were unavailable (due to a much delay in releasing the HIES 2016 data considering the study period), whereas the Household Income and Expenditure Survey (HIES) 2010 provided us the data on average per capita per day food intake. As the food habit does not change frequently, we converted the HIES 2010 consumption rates (HIES, 2010) and used the same rates for the period 2015-2016 by using the current population 162.7 million (BBS, 2018) in Bangladesh. To calculate the food grain consumption of the country per day the following formula was used:

$$\text{Food Grain Consumption (Kg.)}$$
$$= \frac{\text{population } (2016-2017) \times \text{ gram per capita per day intake}}{1000}$$

Finally, the accurate yearly demand to be covered by the crops of *rabi* season was developed by considering the specific days expected to support by every crop. However, for major cereals (boro rice and wheat) we have kept the current area as demanded area. The reason behind this is that the country is self-sufficient in rice and no significant export is evident for rice. Again, wheat acts as a substitute of rice, so together they are fulfilling the demand of cereals of the country. It should also be mentioned that this study did not use the HIES 2010 data to calculate demanded area for boro rice and wheat as the figures were inconsistent with the current area produced by BBS.

Farmgate Price

We collected the data on monthly average farmgate price (taka/quintal) of *rabi* crops from DAM. Here we converted the data of 2016-2017 of farm gate price (taka /acre) to make the unit similar to the weighted yield rate of these crops.

Cost of Production

Since 2008-2009 to 2015, Agriculture Wing, BBS had been disseminating the reports on cost of production for some specific crops. As the latest cost of production is not available for all of our required crops, we adjusted the price values to achieve present prices using the Consumer Price Index (CPI) considering survey year as the base year for all the crops. We collected the CPI value from the report on “Consumer Price Index (CPI), Inflation Rate and Wage Rate Index (WRI) in Bangladesh” of BBS. Finally, cost of production per acre for each variety of crop were calculated.

Optimization Methods

Optimization techniques are widely used in many developing countries to solve the problems of industry and industrialization (Datta and Bandyopadhyay, 1994; Bhat *et al.*, 2015). These techniques have proven its effect in manufacturing sector, marketing sector. Also, it has great potential to use effectively in health care management (Bhat *et al.*, 2015). The optimization techniques are very useful for model-based land use allocation and management. This approach allows the decision-makers to explore a large number of land use combinations (Memmah *et al.*, 2015). However, the use of optimization in agricultural land use is a very hard and complex task as it involves many stakeholders and decision-makers, many spatial factors, attributes and constraints, and multiple conflicting objectives (Liu *et al.*, 2013). Though optimization strategy has been being used in many sectors like business, industries, food management and forestry it’s use is almost absent in agricultural planning (for example, Darmon *et al.*, 2002; Briend and Darmon, 2000; Buscher *et al.*, 2001; Ohman and Eriksson, 2002). This paper attempted to provide a solution to the problem by using optimization strategy.

Simplex method of optimization, which is a general procedure for solving linear programming of operation research, was applied in this study. Simplex method is an algebraic iteration procedure which solves a linear programming problem in a

finite number of steps (Hiller and Lieberman, 1990). Here the analysis was undertaken by three different approaches (Scenario I, II) of formulating the linear programming model and optimizing the cultivable area in *rabi* season.
Let X_j be the decision variables on areas of the crops of our study. Then the appropriate measure of performance is expressed as the objective function:

$$\text{Optimize } Z = \sum_{j=1}^{n} C_j X_j \ ; \ j = 1, 2, 3, \dots n.$$

Subject to the constraints $a_{ij}X_j \geq b_i$; i = 1,2,3,...,m.

$$\sum_{j=1}^{n} X_j = Total\ cultivable\ land\ and\ X_j \geq 0.$$

Where X_j (*j*=1, 2, …, n) are decision variables (area for a particular crop j). Besides, b_i (for *i= 1, 2, …, m*) is referred as the expected consumption in the i^{th} restrictions and a_{ij} (for *j =1, 2, …, n*) is referred as the amount of weighted yield rate of varieties j. Another constraint mentions the restriction of being the sum of the area of all ***rabi*** crops within the total cultivable land in Bangladesh. Moreover, $X_j \geq 0$ restrictions are called non-negativity conditions.

In our particular problem, X_1(major cereal-boro rice), X_2(major cereal- wheat), X_3 (cereals- minor), X_4 (other food crops), X_5 (pulses), X_6 (oil seeds), X_7 (spices & condiments) and X_8 (winter vegetables) are the cultivable land of these varieties. We also set values of $a_{ij'}$=0 ($j' \neq j$) in the i^{th} restriction for j^{th} variety. Hence, our restrictions were crop specific.

Scenario I:
Maximization of the Farm Gate Price
In this case, we approached to maximize the total farmgate price (*Z*) and the parameter, C_j (for *j = 1, 2, …, n*) in *Z* are farm gate price (taka/acre) for the variety *j*. The other constraints are same as before.

Scenario II:
Minimization of the Cost of Production
In this case, we attempted to minimize the total cost of production (*Z*) and the parameter, C_j (for *j = 1, 2, …, n*) in *Z* are cost of production (taka/acre) for the variety j. The other constraints are same as before.
In our study, the two scenarios were analyzed considering with and without export-import of the crops under study. In presence of export-import, if a commodity is more likely to be imported the condition for optimum area was set to produce at best the equal amount of demanded crop area so that national demand may be fulfilled by own production. However, for the regularly exported commodity the optimum area was set to be greater or equal to the demanded area to maximize

export. In absence of export-import all the optimum areas were set to be greater or equal to the demanded areas irrespective of crop items. Note that as cereals (major and minor) are politically sensitive crops we kept the optimum area greater than the current area. From Yearbook of Agricultural Statistics 2015 (BBS, 2015), we came to an indication of exports for major and minor cereals whereas imports for other varieties (e.g. other food crops, pulses, oil seeds, spices and condiments and vegetables). For this reason, when considering the export- import cases, the restrictions for major and minor cereals kept greater or equal to the demand and less or equal for all other varieties. Again, without considering export- import issues, we kept the coefficients of area greater or equal to the demand for all varieties. The linear programming analysis was solved using MS EXCEL.

It is to be noted here that the results obtained in this research will show the ways to optimize the land use pattern in terms of maximization of farmgate price or minimization of cost of production in a collective way keeping all possible crops in mind under different expected scenarios (restrictions). Farmers' behavior or market response on individual crop may not be reflected always due to different conditions imposed (with or without export-import and others). Also, results should be comprehended along with current import-export situation. These results merely give the guidelines to the policy planners for national crop planning (subsidies and incentives distribution) for an ideal consumption pattern, which will differ much from the real situation as many factors are responsible for farmers' decision to cultivate a particular crop. However, there is a potential of getting benefit from such analysis in terms of motivating farmers using different government agencies.

III. RESULTS

The whole cultivable area (21,155,000 acres during the study period) of the country is not currently used in the *rabi* season (BBS 2015). The assumed area (national consumption/weighted yield) for each crop sector (major cereal, minor cereal, other food, pulses, oil seeds, spices, vegetables) is given in the Table-1 against current cultivated area (about 18,267,427acre). From 2 different scenarios (considering with [column A] and without [column B] import and export) we have found different possibilities using total cultivable area of the country.

Scenario-I (Maximization of the Farmgate Price): The results suggest that if we open export-import (column A) increasing boro rice area would be promising. Also, slight increase in area for spices and oil seeds cultivation will also be beneficial. On the other hand, if export-import is closed (column B) we should not increase the area for boro rice. Instead we should increase the area for spices and oil seeds. Obviously, to maintain the total cultivable land we have to reduce areas for other crops, for example minor cereals, other food crops (potato and sweet potato), pulses and vegetables.

Scenario-II (Minimization of the Cost of Production): When export-import will be open (column A), increasing area for boro rice will be promising. At the same time, little increase in the areas for spices and oil seeds may also be fruitful. In the contrary, if the export-import is closed (column B), like Scenario-I area for boro rice should not be increased. The potential areas to be increased are pulses, spices and oil seeds. The necessary potential decreases in the areas for several other crops are suggested too. These are minor cereals, other food crops (potato and sweet potato), vegetables and pulses (for with export-import condition).

Table 1. Results of the analysis for two scenarios considering with and without import and export

		Optimized Area (acre)			
		Scenario I (Farm Gate Price)		Scenario II (Cost of Production)	
Crops Sectors	Current Area (acre)	(With Export-Import)	(Without Export-Import)	(With Export-Import)	(Without Export-Import)
Boro rice	11,793,512	15,218,875	11,793,512	15,218,875	11,793,512
Wheat	1,099,158	1,099,158	1,099,158	1,099,158	1,099,158
Minor cereal	702,645	227,418	227,418	227,418	227,418
Other food	1,236,448	514,854	514,854	514,854	514,854
Pulses	916,594	705,726	705,726	705,726	4131089
Oil seeds	998,971	1,339,838	1,339,838	1,339,838	1,339,838
Spices	934,497	1,529,048	4,954,410	1,529,048	1,529,048
Vegetables	585,602	520,083	520,083	520,083	520,083
Total Area	18,267,427	21,155,000	21,155,000	21,155,000	21,155,000

For both the scenarios the suggestions of increase or decrease of areas should be viewed with conditions on import-export. For example, when export-import is closed in scenario-I potential area for spices cultivation is shown to increase substantially. Currently, internal demand for spices is supplemented by import. As farmgate price is reasonably good, increase in internal production by allowing more areas under cultivation is very much feasible. Similarly, in scenario-II for closed economy potential areas for pulses cultivation is suggested to increase significantly. The reason is the same as mentioned in scenario-I for spices. Cost of production for pulses is reasonable and to meet the internal demand an increase in the cultivation areas is a good option. Potentials for export for other crops in terms of increasing the areas has not been reflected as we have set restrictions for rice not to reduce from the current level due to political reasons (see methodology section). Lifting the restriction will allow proper reflection on export potential of other crops. However, for almost all the crops, except rice, we are not yet self-sufficient. Hence, option for export may not be a feasible idea at the moment as we are far away from keeping international standard in quality. However, there have been sporadic attempts (not sustainable yet) to export several agricultural produces for better profit ignoring fulfillment of the internal demand.

IV. DISCUSSION AND CONCLUSION

Bangladesh is an agriculture centered country. The agriculture sector contributes almost 16% in the Gross Domestic Product (GDP) of the country (BBS, 2019). Government has been putting all out efforts to make further progress in this sector by introducing new varieties, advocating for crop diversification, increasing crop intensity, adopting new technologies, extending subsidy and extension services to the farmers. The common threat to the agriculture is the natural calamities for which many mitigation strategies are in place. However, price volatility is one of the important drivers of agricultural practices in recent years. Agricultural production of a commodity in one season is largely dependent on the outcome of the previous year except for rice, which is the staple food in Bangladesh. At the same time since most of the farmers in the country are small and marginal farmers' lack of coordinated effort to fulfill country's aggregate demand of a particular crop in most of the times is ignored. Also, it is pitiful that much of the arable land in Bangladesh is uncultivated (BBS, 2019). This is not at all favorable to the countries effort to achieve food security. Here lies the necessity of a centralized planning of the cropping strategy and calendar.

The outcome of the optimization exercise reveals that spices and oil seeds have potentials to optimize the land use in terms of maximizing farm gate price both in open and closed economy. In case of minimizing cost of production pulses, spices and oil seeds have more potentials when import export is closed. These crops have internal demands and their market price does not fluctuate heavily. For closed economy both the scenario suggested not to increase the area for boro cultivation. This is very much in line with our current experience. Since we have achieved self-sufficiency in grains, any additional production will impact the farmgate price. In the recent years rice producers are suffering from this problem and they are not getting appropriate price for their produces. However, for open economy both the scenarios suggested to increase the area under boro cultivation meaning that it will open the export opportunities. Both the scenarios suggested that area under cultivation of potato (termed as other food crops in Table 1) should be reduced. This reflects the recent anomalies in the production, storage and pricing of potato in Bangladesh. Bangladesh has achieved near self-sufficiency in cereal production with steady growth in agriculture along with a strong emphasis on rice production. The major threats that the 7th Five Year Plan identifies are reducing loss of cultivable land; minimizing yield gap; maintaining food security, safety and quality. The government is committed to maintain its policy to incentivize and motivate farmers to diversify agricultural production toward increased production of cash crops (GED, 2015). Strategies proposed in this research may be adopted by the government for broad sense agricultural planning to identify the potential sectors for subsidies and incentives. This research is the very first attempt of optimization of agricultural land in Bangladesh. More can be achieved with incorporation of some more dimensions in the analysis, e.g., value addition of agricultural produces, international market price, real time data on export and imports etc., which are still outside of the access of the researchers. It is well understood that to strictly follow the outcomes of such approach will be difficult and government has to balance between expectations (of farmers, consumers, businessmen). Agricultural farming in Bangladesh is dominated mainly by small and marginal farmers. If countrywide potential areas under each crop can be projected considering different agro-ecological zones (AEZ), Ministry of Agriculture with its workforce (facilitating technology transfer, incentives, training and awareness building) at small administrative levels may guide the farmers for the best option for their land. We may also maintain a balance between production and demand. Optimization practices will at least help minimize the risk and guide efficient utilization of limited resources.

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