Towards Sustainable Enhanced Rice Production for Meeting Food Grain Self-Sufficiency: A Strategic Food Outlooks of Bangladesh By 2030 and 2050

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Abstract

The present study forecasted the demand and supply of food grains in Bangladesh by 2030 and 2050, by using Box and Jenkin's ARIMA model. It is the 8th most populous country in the world. Cereals provide a major part of the calorie intake in Bangladesh, but their share in the total calorie supply is predicted to be decreased over the years, while it is from non-cereal items will have an increasing trend from 2030 to 2050. The total crop demand for rice is projected to be 39.1 MMTs in 2030 and 42.6 MMTs in 2050. The Business as Usual Scenario predicted that there will have a marginal surplus of rice in 2030 and 2050 but the pessimistic scenario projected that there could be a deficit of 3.62 MMTs in 2030 and 1.93 MMTs in 2050 due to climatic shocks. Although the country has achieved self-sufficiency in rice, the projections reflected that its food security could be threatened due to natural calamities. Supportive government policy with increased investment in research and extension is needed for generating climate resilient high yielding rice varieties with production technology and as well requiring establishment of a strategic rice grain reserve for the country to meet emergency food crisis during natural xalamities.

Keywords: Demand for and supply of food grain, climate change, food security, and government policy,

1. BACKGROUND OF BANGLADESH AGRICULTURE

Bangladesh is a densely populated country with an area of about 50,000 square miles of which about 9.03 million ha is cultivated land. Agriculture plays a dominant role in the growth and stability of the economy of Bangladesh. During the recent decade, the overall Gross Domestic Product (GDP) of Bangladesh has shown a remarkable progressive increasing trend. The average growth rate of the GDP from 2011 to 2021 was 6.4%. In 2020, the GDP growth rate declined to 3.45% due to the Covid-19 pandemic. But beyond 2020, GDP growth rate again revived with an increasing trend. On the other hand, the growth in agricultural GDP slightly declined, from 4.46% in 2011 to 3.17% in 2021 with an average growth rate of 3.30% per annum

There has been a structural change in the Bangladesh economy with the declining share of agriculture to GDP over the years while it for the industry and service sector gradually increased which is a sign of a developing economy. It is evident from the fact that after independence in 1975, the GDP share of agriculture, industry and service sectors were 62%, 23.2% and 26.4%, respectively. Over the years the share of agriculture to GDP sharply declined while it increased for the industry and, service sectors and, stood at 11.63%, 33.32% and 51.3%, respectively, in 2021. As a result, the country moved towards a developing economy. The per capita income of the country increased from US $380 to US $2824 during 2008-2022. (BBS, 2021).

The agriculture sector of Bangladesh is playing important role in employment generation and poverty reduction. Bangladesh has a total population of about 165 million people out of which the labour force covers about 83 million workers. The Agricultural sector in 2021 accounted for almost half of the labour force is employed in Agriculture. During 1981-90, the share of employment in the agriculture sector was 60% of the labour force. The share of the economy as well as the share of employment in the agricultural sector has been decreasing with the expansion of the industrial and service sectors.

The emerging pattern of growth in poverty reduction in Bangladesh is encouraging. Bangladesh experienced substantial poverty reduction during the last 20 years (2000-2021). During this period, the average annual rate of poverty reduction was 1.4%. During this period GDP per worker both in agriculture and non-agriculture increased substantially and contributed to poverty reduction in Bangladesh. It was found that GDP growth had a higher impact on poverty in Bangladesh than that of all South Asian countries in the region, although Vietnam, China, and Thailand had higher GDP growth rates than Bangladesh and had a lower reduction rate in poverty (Islam, *et a*l, 2017).

There found to have a negative relationship between poverty rates and growth in GDP per worker from the agriculture and non-agriculture sector in Bangladesh Islam *et al* (2017). They found that for 1% increase in income of agriculture GDP per worker would reduce poverty by 0.39% while it was 0.11% for non-agriculture GDP. Such result was found to be consistent and confirms the findings of a study by Cervantes-Godoy and Dewbre (2010) conducted in 25 countries of Asia and Africa. Further, the agriculture sector is the center of the economy ensuring food security. However, with the growing population, going from 147.6 million in 2010 to 164.7 million in 2020, with the outbreak of the Covid -19 pandemic and climate change, the sector has continued to be resilient and vibrant in terms of productivity and feeding its population. Over the last 30 years, rice production tripled from approximately 10 million metric tons in the mid-1970s to almost 37.33 MMTs in 2021. Such productivity improvement came through the cultivation of high-yielding varieties under irrigation with the use of chemical fertilizers and irrigation. It enabled Bangladesh to increase food availability to meet the demands of a rapidly growing population. An increase in food production and attaining self-sufficiency in Bangladesh requires sustainable growth of the agricultural sector in order to supply adequate food for its increasing population.

The recent Eighth Five Year Plan of Bangladesh prioritized the importance of research and extension for generation and dissemination of technology to boost agricultural production through promoting intensification, diversification and resilience to climate change. The National Agricultural Research System (NARS) institutes developed a large number of HYV crop varieties. Technologies developed by the NARS institutes were disseminated successfully to the farmers through the Department of Extension and NGOs.

Current climate change issues are considerably affecting the food security of the millions of people of Bangladesh; it is now one of the most vulnerable countries to climate risks in the world. In Bangladesh, damage caused by natural disasters like floods, cyclones, river bank erosion, and droughts are the main sources of crisis for poor households damaging crops, disrupting markets and affecting household food security.

Rice is the main staple food grain of Bangladesh and it dominates agriculture, with almost 75 percent of the total cropped area under rice cultivation. Rice production has shown a steady increase in Bangladesh Availability of staple food has been increased largely and Bangladesh has become self-sufficient in rice staple food Since independence of 1971 rice production has been tripled in 2020 while population has increased by 2.6 times.

With an expanding population, planning for future food production and demand is crucial to meeting the food security challenges in Bangladesh. To facilitate this planning, projections of future supply and demand for food are important. Another important issue needs to consider in connection with the food supply is that agricultural land is decreasing due to industrialization, urbanization and, other factors. Despite the fact that agricultural growth has been higher than the rate of population growth concerns have been raised about whether the land mass of Bangladesh is actually capable of supporting its expanding population by 2030 and 2050.

Food security is a priority concern of many developing countries. There is a growing body of literature of concern on the projection of demand for and supply of food in the world. The world food system is facing pressure due to increased population and the adverse impact of climate change which will intensify in the next decades. Increased food production will require more land, water and energy. Many countries will suffer due to the scarcity of water and the completion of resources will intensify (Islam and Karim, 2019, Foresight, 2011, To and Grafton, 2015; UNEP, 2014). Agricultural sector is dynamic, changing with the demand of people and the availability of technology. In search of the answer to the question: Could the future growth of the supply of food in a country match its increased demand for food as a result of population pressure and rising income? A number of studies have been conducted in this context to project the demand for and supply of key food items in various countries and assessed the possibility of deficits (Grafton et al., 2015; Ahmad and Kiresur, 2016; Nilesh et al., 2014; Kumar et al., 2016; Valin et al., 2014; Zhou and Staatz, 2016; Ray et al., 2013, Islam and Talukdar, 2017a and 2017b, Samal *et al*, 2022).

The present study is an attempt to carry out future projections with a view to assessing the likely gap between the supply of and demand for cereal in Bangladesh and the implications on food security. It will be useful for the researchers and the policymakers for the development of new crop varieties, generation of new technology, and policy briefs in the context of 2030 and 2050 scenarios. Section 2 of this article presents a description of the methodology used and sources of data, key results and discussions are presented in Section 3 and conclusions are provided in Section 4.

2. METHODOLOGY

2.1 The ARIMA Model for forecasting

Substantial efforts have been made in modeling for forecasting the supply and demand for food in a country typically using global agricultural models (Islam and Karim, 2019). Among these models, the Box and Jenkins ARIMA (Autoregressive Integrated Moving Average) model is widely used in the world for forecasting purposes because of its very low forecast error and reliability of estimates (Box and Jenkins 1976). There is growing body of literature on the use of the ARIMA model for projections of demand for and supply of food **(**Islam and Talukdar, 2017a and 2017b, Ganesh-Kumar, et al, 2012, Amarasinghe, *et al* 2014, Mishra *et al*, 2021, Halliyavar, *et al* 2020, Sankar 2022, Samal *et al* 2022). The present study also used **the** Box-Jenkins ARIMA time-series methodology for modeling and forecasting.

The framework of the ARIMA model consists of five steps as discussed below:

Step 1. Prediction of the calorie intake of different crop commodities: The ARIMA time series model was used to forecast the per capita calorie intake to 2030 and 2050 (Box and Jenkins 1976). The ARIMA (p, d, q) model has p and q autoregressive and moving average terms of the stationary time series of order d; it takes the form:

$$(Y_t - \alpha_1 Y_{t-1} - \alpha_2 Y_{t-2} - \ldots . - \alpha_p Y_{t-p}) = \beta_0 + (u_t - \beta_1 U_{t-1} - \beta_2 U_{t-2} - \ldots . - \beta_q U_{t-q}) \qquad (1)$$

Where: Y_t is the d^{th} difference of the original time series, and *u* is a random noise. Differencing of the original variable gives a stationary time series *t.*

Step 1. **Estimation of food calorie demand**: We used the ARIMA models to forecast the calorie demand of selected cereal crops. The total calorie demand is the product of per capita calorie demand and population projections. We used the population projection of Bangladesh Bureau of Statistics, Ministry of Planning of the Government of Bangladesh. The projected population of Bangladesh in 2030 is 188.12 million and in 2050 is 205.02 million (BBS, 2015).

Step 2. Estimation of the food demand: It is estimated as the product of calorie demand for a cereal crop and the food- to- calorie conversion ratio. The food- to- calorie conversion ratio (in terms of grams/kcal) is the quantity of food required to provide one kcal of nutrition. For rice, it is about 0.28 grams/kcal. Calorie content data of selected cereal crops were collected from the Institute of Nutrition and Food Science of the University of Dhaka

Step 3. Estimation of the feed demand: It is the product of calorie demand from animal products and the feed- to- calorie conversion ratio. The feed- to- calorie conversion ratio of a crop is the ratio of the total quantity of crops/products used as feed to the calorie demand from animal products. The feed demand for cereals increases with the increasing demand for animal products (Bradford 1999; Bhalla and Hazell 1997).

Step 4. Estimation of the total crop demand: We estimated it as the sum of the demand for food, feed, seed, and other uses and waste.

Step 5. Estimation of the food supply: The ARIMA models predict the area and yield of rice, whea,t and maize. Food supply was estimated as the product crop area and yield.

The procedures used in Box and Jenkins ARIMA Method are illustrated in Figure I as follows.

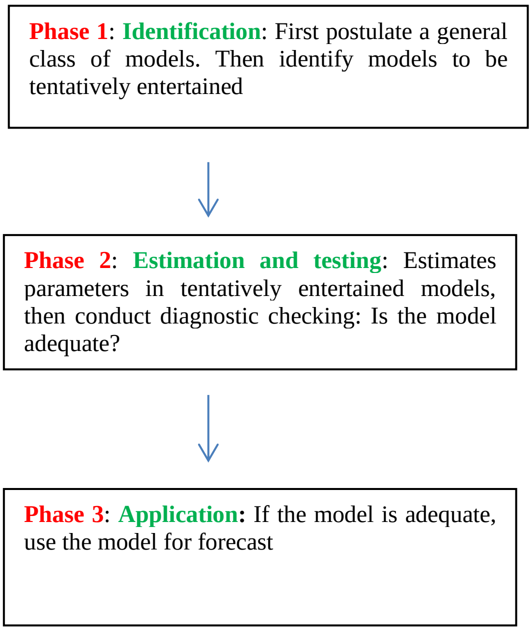

Figure I. Illustration of ARIMA Method

We have used statistical software known as NCSS (version 12) for the estimation of ARIMA models and forecasts. We used the software for identifying the most parsimonious ARIMA model. An ARIMA analysis uses stationary time series, i.e., those series without trends. At first, the time series data is made stationery through differencing. Then, the order of the ARIMA called p and q is determined by generating and plotting ACF and PACF curves as shown in the graph (Figure 2).

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

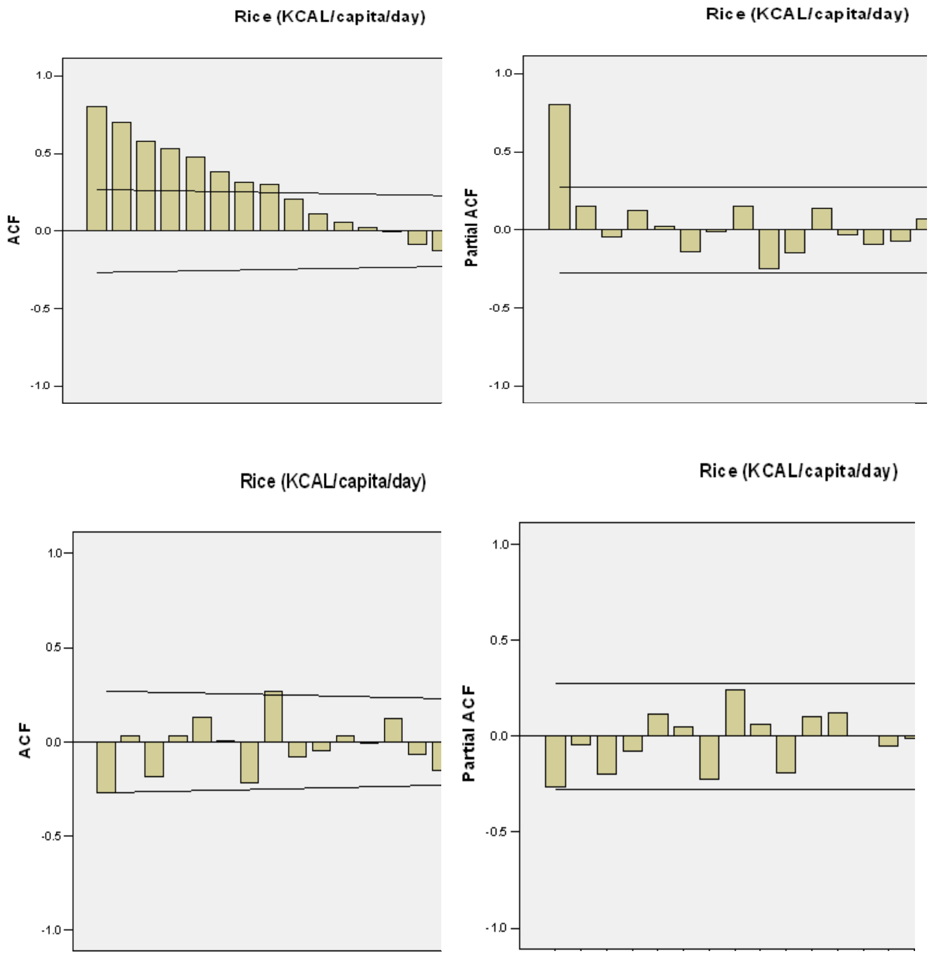

Figure 2. Identification of p and q

2.2. Sources of data

The ARIMA models were estimated using time series data from 1971 to 2021. The secondary time series data were used from the Bangladesh Bureau of Statistics (BBS), the Department of Agricultural Extension of Bangladesh (DAE), and on-line data from the Food and Agriculture Organization known as FAOSTAT. Also, secondary data were used from National Agricultural Research Institutes, Reports, Journals, and relevant studies. The time series data of calorie intakes for ARIMA modeling have been taken from the Food Balance Sheets of the FAOSTAT database (FAO 2013a). These include per capita calorie supply of cereals: rice, wheat, and maize. The time series data for ARIMA modeling of the crop areas, production and yields have been taken from BBS and DAE for the period 1971 to 2021. Also, primary data were collected for the validation of models through regional workshops, and consultations with scientists, extension experts, farmers, and various stakeholders.

3. RESULTS AND DISCUSSION

3.1. Projections of calorie consumption demand of cereals

The estimated coefficients of the ARIMA models of rice, wheat and maize have been presented in Table 1. Most of the estimates were found to be significant as indicated by standard errors of the estimates, t-values and all the models were adequate as judged by Portmanteau Test statistics. We have validated the forecast models by comparing our forecast results in 2021 with actual data for 2021 and found that ARIMA models have very insignificant forecast errors.

Table 1. Parameter estimates of ARIMA model of calorie intake of cereals

Crops	Model	Parameter	Standard error	t-value	Portmanteau Test value	Portmanteau Test decision
Rice	ARIMA (0,1,1)	0.320**	0.125	2.63	32.08	Adequate model
Wheat	ARIMA (1,2,0)	-0.660**	0.099	-6.62	48.03	Adequate model
Maize	ARIMA (0,1,1)	0.401**	0.121	3.31	36.67	Adequate model

Source: Author's estimation from ARIMA model, Note: ** p < 0.01, * p < 0.05

3.2 Composition of calorie intake

It is revealed from the time series data that the food consumption patterns in the Bangladeshi diet is slowly diversifying over the years. Cereals still provide a major part of the calorie intake, but their share in the total calorie supply has decreased from 89.6% in 1990 to 80.5% in 2021. ARIMA projections showed that it will further decrease to 79.6% in 2030 and 77.5% in 2050 (Figure 3). The contribution to calorie intake from potatoes, vegetables, and animal products gradually increased from 1990 to 2021 and will continue to increase from 2030 to 2050.

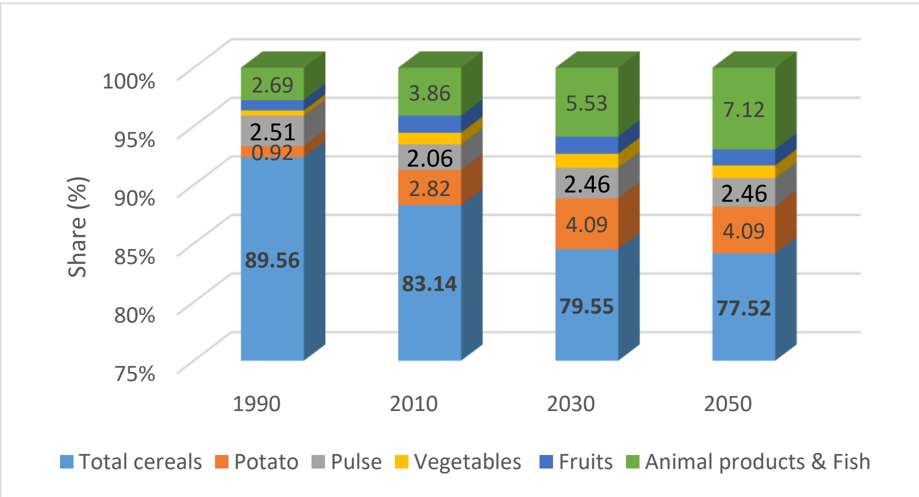

Figure 3. Share of major food items in total calorie intake per capita

Source: Author's estimation

3.3 Demand for cereals

Rice, wheat and maize are the three staple cereals food of Bangladesh. It is revealed from the estimates of ARIMA models that daily per capita per day calorie demand for rice is 1777 Kcal and the estimate of rice consumption per person per year is 180 kg. This is consistent with the estimates of FAO. According to FAO estimated results published in The Food Outlook: of FAO, per capita rice consumption in the country was 181.3 kg per year in 2021. The average per capita rice consumption in Bangladesh was second highest in Asia during 2016- 2019 and it was the highest in Asia by 2020-21 (FAO, 2022).

In order to validate rice consumption estimates we have reviewed the results of relevant studies. We have compared the results with HIES (Household Income and Expenditure) Survey of BBS in 2016, IFPRI's Bangladesh Integrated Household Survey (BIHS) of 2017 and a survey conducted by the Bangladesh Institute of Development Studies (BIDS) in 2012. According to the results of HIES 2016 the per capita consumption of rice declined sharply from 459 grams in 2000 to 440 grams in 2005 and further to 416 grams in 2010; since then to 367 grams in 2016. These estimates imply that the per capita rice consumption has declined by about 1 percent per annum between 2000 and 2010; and by more than 2 percent per annum `in the next six years. However, the estimates have been argued to be biased downward due to the failure to account for the changes in consumer behavior. Besides, BBS' coverage of food items made of rice and wheat consumed outside the home does not seem to be comprehensive. Consequently, the parsimonious inclusion of items made of food grains at the home and less than an adequate emphasis on consumption of items made of food grains outside the home may introduce an inherent downward bias in the estimates of per capita consumption. The survey results of BIDS implied that per capita consumption of rice decreases over the years both in rural and urban areas, a bit marginally. The per capita consumption of rice is projected to decline from 469 grams in 2012 to 459 grams in 2016. This translates to an annual decline in per capita rice consumption by about half a percentage point during 2012-2016 (Hossain and Yunus 2016). The BIHS estimates of IFPRI implied a decline in per capita daily rice consumption from 467 grams to 426 grams during the same period.

The HIES 2016 estimate of 386 grams of per capita rice consumption appears to be an underestimate and not plausible, as it leads to about 6 million metric tons of surplus. In 2017 April, there was a flash flood in the northeastern part of Bangladesh that caused a loss of about 1 million metric tons of rice production. If HIES estimates were right there could be a surplus of rice of over to million metric tons. But it did not happen and the country faced a food shortage and had to import rice from India. If HIES estimates is right the country would not have to import such a big volume of rice in 2017. The estimates of the BIHS 2016 and IFPRI's validation survey 2018 generated a positive net balance of 2.4 and 3.5 million metric tons (MMT), respectively. These are clearly plausible estimates, as households always hold precautionary stocks. Our projection of total demand for rice in 2030 based on the ARIMA model is 39.1 MMT which is consistent with the results of the BIHS survey of the IFPRI and survey of the BIDS and also close to the projection of Amarasinghe *et al* (2014). Amarasinghe projected that the total demand for rice in 2030 will be 37.8 MMTs.

Based on estimates of the ARIMA model total food demand for rice in 2021 was 30.5 MMT and including feed, seed, other uses, and wastage it was 35.2 MMT. This is also found to be consistent with the estimates of USDA and FAO. According to the USDA, milled rice production is expected to rise by 1.3% to 36.3 MMT in 2022-23 due to increased harvesting. With the prospect of a bumper Boro harvest during the current harvesting season.

The total food demands of rice, wheat, and maize have been estimated for the periods 2030, 2035, 2040, 2045 and 2050. There found to have an increasing trend in the total consumption of these cereals (Table 2). The total food demand of rice for consumption in 2030 will be 33.9 MMTs, which is an 11% increase from the 2021 level and it will further rise to 36.9 MMT in 2050. The food demand for wheat will be 3.3

MMT in 2030 which is an increase of 0.4 MMTs from the 2021 consumption level (13.7% higher) and will rise to 3.8 million in 2050. On the other hand, the food demand for maize will be 0.13 MMTs in 2030 which is 8.3% higher than the 2021 level and will slightly rise to 015 MMTs. Overall, the forecasted total cereal demand for food in 2030 will be 37.34 MMTs which is an increase of 3.82 MMTs between 2021 and 2030 and will reach to 40.85 MMTs.

The total crop demand for rice was 35.2 MMTs in 2021. Its demand is projected to be 39.1 MMTs in 2030 and 42.6 MMTs in 2050. Total crop demand for wheat and maize were 5.4 MMTs and 6.5 MMT,, respectively in 2021. The total quantity of wheat and maize imported in 2021 were 7.2 MMT and 2.4 MMT, respectively and productions were 1.03 MMT of wheat and 4.21 MMT of maize (according to BBS data) and 5.64 MMT (according to DAE data). There remains a-year ending stock of wheat and maize in Bangladesh every year ranging from 0.5 MMTs to 2.0 MMTs. Demand for wheat has been trending upward over the last decade due to increased exports of wheat-based goods. According to the Export Promotion Bureau (EPB) export of wheat- based products from Bangladesh in 2021 was around 270 million US dollars. Total crop demand of wheat and maize projected to be 6.39 MMTs and 8.43 MMTs in 2030, and 8.09 MMTs and 16.99 MMTs in 2050, respectively (Table 2). Demand for maize has been trending upward over the last decade due to increased growth in livestock and fisheries production and increased industrial uses in Bangladesh.

Table 2.Projections of demand for cereals during 2030-2050 (Based on estimates of ARIMA model)

Year and demand	Quantity in MMT/year			
	Rice	**Wheat**	**Maize**	**Total cereal**
Food demand				
2021	30.5	2.9	0.12	33.52
2030	33.9	3.3	0.13	37.34
2035	34.9	3.5	0.14	38.54
2040	35.8	3.6	0.14	39.54
2045	36.5	3.7	0.15	40.35
2050	36.9	3.8	0.15	40.85
Total crop demand (food+ seed + feed +wastage)				
2021	35.2	5.4	6.5	47.1
2030	39.1	6.39	8.43	53.92
2035	40.2	6.82	9.67	56.69
2040	41.3	7.21	12.09	60.6
2045	42.1	7.66	13.64	63.4
2050	42.6	8.09	16.99	67.68

Source: Author's estimation from ARIMA model

3.4 Supply of rice

3.4.1. Projections of crop areas and yields

The estimated coefficients of the ARIMA models of areas of cereal crops have been presented in Table 3. All the models were found to be valid with significant parameters as indicated by standard errors of the estimates, t-values, and Portmanteau test results.

Table 3. Parameter estimates of ARIMA models of areas of rice crops

Crops	Model	Parameter	Standard error	t-value	Portmanteau Test value	Portmanteau Test decision
Aman Rice	ARIMA (0,1,2)	0.484**	0.126	3.815	42.26	Adequate model
		0.488**	0.126	3.854		
Boro Rice	ARIMA (0,1,1)	-0.151	0.142	-1.063	51.76	Adequate model
Aus Rice	ARIMA (0,1,2)	0.003	0.137	-0.023	39.58	Adequate model
		-0.319**	0.138	-2.294		

Source: Author's estimation, Note: ** $p < 0.01$, * $p < 0.05$

3.4.2. Projection of areas of rice crops

Rice as the major cereal crop of Bangladesh covered nearly 80% of the gross cropped area (GCA) in 2021. Aus rice area decreased from 3.0 million ha to 1.1 million ha during the period 1972 to 2015, Thereafter it slightly increased to 1.3 MMT in 2021 (Figure IV). ARIMA model of Aus rice predicts that Aus rice area will further slightly increase to 1.35 million ha in 2030 and thereafter it will stabilize at 1.35 million ha still 2050. Aman area in 1972 was 5.4 million ha and in 2021 it was 5.6 million ha. It is projected that the Aman area will reach 5.68 million in 2030 and thereafter it will stabilize at 5.5 million ha still 2050. Boro rice area in Bangladesh significantly increased from 0.8 million ha to 4.78 million ha during 1972-2021. ARIMA model predicts that the Boro rice area will slightly increase to 4.79 million ha in 2030 and thereafter it will stabilize at 4.79 million ha in 2050.

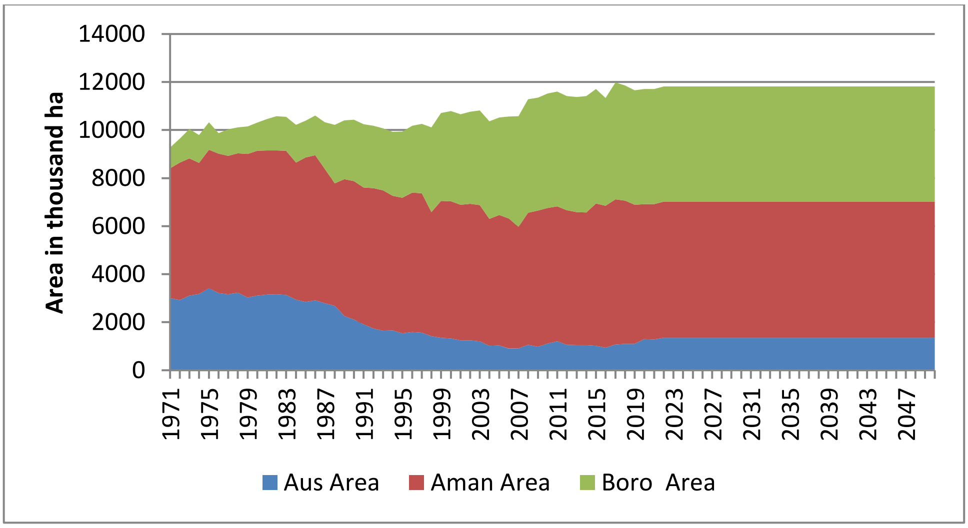

Figure 4. Projections of three rice areas of Bangladesh
Source: Author's estimation, Data source: BBS

3.4.3. Projections of yields of rice crops

The ARIMA model predicted that yield of all rice will increase by 1.7% annually between 2021 and 2030 and will reach 3.7 tons/ha in 2030. It will further increase by 1.4 % annually between 2030 and 2050 and will reach to 4.7 tons/ha by 2050 (Figure 5). Figure VII show that three rice crops predicted to have increasing trend in yield during 2030-2050. For instance, the yield of Aman rice will increase from 3.0 tons/ha in 2030 to 3.9 tons/ha in 2050. The yield of Boro rice is predicted to increase from 4.7 tons/ha in 2030 to 5.9 ton/ha in 2050.

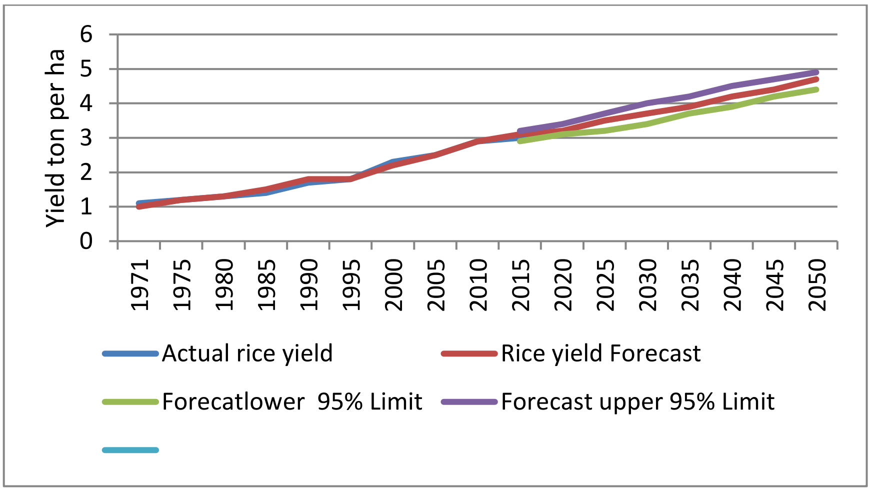

Figure 5. Projections of rice yield during 2030-2050.

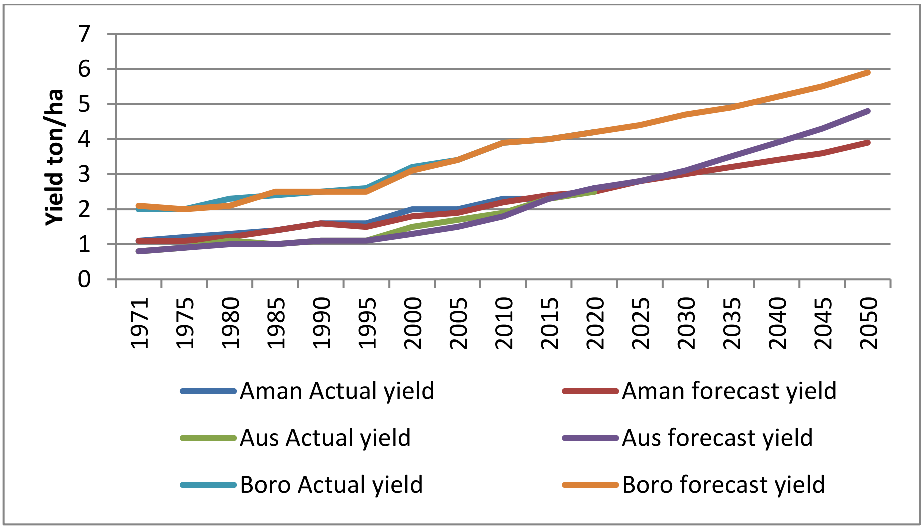

Figure 6I. Projections of yields of Aman, Aus and Boro rice during 2030 to 2050.

3.4.4 Projection of supply of rice

In order to validate our projections of rice supply we have reviewed relevant studies and compared the results. There might have a bias in rice production estimates of concerned government agencies (DAE and BBS) as evident from the consultations with the experts and stakeholders in the field. Usually, there is a tendency to overestimate rice production data in the country. So, we allowed a crop cut error adjustment of 5% production deflation in the adjusted BAU forecast to make it a plausible result. We have considered different alternative scenarios for comparison of projections of the supply of key crop-rice:

- BAU scenario: Projections of ARIMA model with business as usual(BAU) case,
- Adjusted BAU scenario for reducing crop cut bias
- Pessimistic scenario (PS): Projections of the ARIMA model at a lower limit with a 95% confidence level to reflect the effect of natural calamities and degraded conditions like flood, drought and insect/pest, soil degradation, etc.

The results of the above three alternative sceneries are presented in Table 4. When compared with the actual rice production of 37.33 MMT in 2021 it was found that the ARIMA model gave very close estimates of the actual production under three alternative scenarios. The projections had insignificant errors. It is revealed that under the adjusted BAU scenario total supply of rice could be 41.04 million metric tons (MMT) in 2030 and 52.13 MMT in 2050 against 43.20 MMT and 54.97 MMT under the BAU scenario, respectively. According to the pessimistic scenario total supply of rice could be 35.47 MMT in 2030 and 40.68 MMT in 2050. Our projection of rice production in 2030 is compared with the projection of Ganesh *et al*, (2013) and Amarasinghe *et al* (2014.). Ganesh projected that rice production in 2030 will be 38.8 MMT under BAU scenario. Projection of Amarasinghe shows that production of rice in 2030 will be 49 MMT under BAU scenario (Table 6). The projection of Amarasinghe is found to be overestimation due to the fact that he assumed an increasing trend in the Boro rice area up to the year 2030 which is not feasible because under the context of increasing population pressure and urbanization on land resources and the gradual decline of cultivable land over time in Bangladesh..

Under the BAU scenario total rice production could be higher than the adjusted BAU scenarios. Adjusted BAU scenario seems to be more plausible than BAU scenarios. BAU scenario is not feasible in that with this projected level of production there will have a rice surplus of around 2.3 MMT in 2021 and 4.2 million in 2030. But the reality is that Bangladesh had a food deficit and imported about 0.6 MMT of rice in 2021. In the next decades Bangladesh will have to face problems of climate change, soil degradation, increased soil salinity, scarcity of irrigation water, etc. The PS scenario reflects rice production under degraded conditions. In the long term new rice technology will be available and will be adopted. However, with the adoption of new rice technology, the total production could be most likely in between PS and adjusted BAU scenario.

Table 4. Projections of production (supply) of rice during 2030-2050 in MMTs

	Rice supply under alternative scenarios		
Year	BAU scenario	BAU with crop cut adjustment scenario	Pessimistic scenario
2021	37.54	35.66	34.59
2030	43.20	41.04	35.47
2035	45.43	43.16	36.52
2040	48.28	45.86	38.18
2045	51.12	48.56	39.49
2050	54.87	52.13	40.68

Source: Author's estimation from ARIMA model

3.4.6 Projection of surplus and deficit of rice supply

Projections of surplus and deficit of supply of rice by 2030 and 2050 is presented in Table 5. It is already discussed above that the BAU scenario is not plausible. Based on estimates of the adjusted BAU scenario there will have a marginal surplus of rice of 1.95 MMT in 2030 and it will gradually reach to 4.60 MMT in 2040 and further to 9.53 MMT in 2050. But the pessimistic scenario predicts that there could be a deficit of 3.62 MMT in 2030, 3.08 MMT in 2040 and a deficit of 1.93 MMT in 2050. According to the pessimistic scenario rice deficit in 2021 was 0.61 MMT due to the flood which is more plausible than the adjusted BAU scenario due to the fact that the quantity of rice imported in Bangladesh was 0.6 MMT in 2021.

Table 5. Projections of surplus and deficit of supply of rice by 2030 and 2050 (Quantity in MMT)

Year	Demand	Supply			Surplus/deficit		
		BAU	Adjusted BAU	Pessimistic	BAU	Adjusted BAU	Pessimistic
2021	35.20	37.54	35.66	34.59	2.34	0.46	-0.61
2030	39.09	43.20	41.04	35.47	4.11	1.95	-3.62
2035	40.23	45.43	43.16	36.52	5.20	2.93	-3.72
2040	41.26	48.28	45.86	38.18	7.02	4.60	-3.08
2045	42.07	51.12	48.56	39.49	9.05	6.49	-2.57
2050	42.60	54.87	52.13	40.68	12.27	9.53	-1.93

Source: Author's estimation from ARIMA model

4 CONCLUSIONS

The present study used the ARIMA model for projections of the demand and supply of cereals in 2030 and 2050. The ARIMA model gave plausible results when compared with the actual result with predicted results in 2021. We compared our projections with those of other authors and found that our projections were quite plausible from a realistic point of view.

The total food demand of rice for consumption in 2030 is projected to be 33.9 MMT, which is an 11% increase from the 2021 level. The total crop demand for rice was 35.2 MMT in 2021 and it is projected to be 39.1 MMT in 2030 and 42.6 MMT in 2050. The food demand for wheat will be 3.3 MMT in 2030 which is an increase by 0.4 MMT from the 2021 consumption level (13.7% higher). The food demand for maize will be 0.13 MMT in 2030 which is 8.3% higher than the 2021 level. The total crop demand for wheat and maize projected to be 6.39 MMT and 8.43 MMT in 2030, and 8.09 MMT and 16.99 MMT in 2050, respectively. Demand for wheat and maize has been increasing upward over the last decade. Wheat demand has an increasing trend mainly due to increased exports of wheat-based goods. Also, demand for maize has been increasing trend due to increased growth in livestock and fisheries production and increased industrial uses in Bangladesh.

It is revealed from projections of the supply of rice that according to the adjusted Business As Usual Scenario there will have a marginal surplus of rice of 1.95 MMT in 2030 and 9.53 MMT in 2050. But pessimistic scenario predicted that there could be a deficit of 3.62 MMT in 2030 and 1.93 MMT in 2050. Bangladesh will face negative impacts of climate change, soil degradation, increased soil salinity, scarcity of irrigation water, etc. in the coming decades. It is already observed due to climate change flash floods and cyclones are already frequently attacking Bangladesh agriculture and damaging its rice crops. Although Bangladesh has achieved self-sufficiency in rice, it is facing a deficit of rice due to natural calamities. The projections reflected that Bangladesh's food security could be threatened due to floods and cyclones. The pessimistic scenario reflects rice production under natural calamities. In the long term, new climate-smart rice technology will be available and will be adopted. However, with the adoption of new technology, the total production could be most likely in between a pessimistic scenario and an adjusted Business as Usual Scenario.

Supportive government policies with increased investment in research and extension is needed for promoting climate-resilient natural resource management, technology generation, adoption of climate-smart technology and enhancing rice productivity through generating new rice varieties to eliminate rice deficit during the 2030s and 2050s to feed the future population of Bangladesh. It is necessary to prepare a long- term plan for technology development and transformation of Bangladesh's agriculture in the 2030s and 2050s. The government of Bangladesh should develop a strategic rice grain reserve of a minimum 1.5 million to maximum of 2.5 MMTs in public warehouses of the Ministry of Food to address the vulnerability in rice supply due to various natural shocks.

ACKNOWLEDGMENTS

This research was funded by the Ministry of Agriculture, Government of Peoples Republic of Bangladesh under the Proje**ct, "**Projections of supply and demand for selected food crops in Bangladesh by 2030 and 2050"

Feedbacks provided by the various stockholders from the regional and national workshops hight acknowledged

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