Asian Journal of Agricultural Extension, Economics & Sociology

39(3): 1-14, 2021; Article no.AJAEES.67653
ISSN: 2320-7027

Production and Acreage Growth and Seasonality in Rice in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MKIS designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SGK and MJA managed and supervised the statistical analysis and reviewed the draft. Authors M. M. Hoque and M. M. Hassan managed the literature searches and helped in data analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2021/v39i330540
Editor(s):
(1) Dr. Zhao Chen, University of Maryland, USA.
Reviewers:
(1) Saw Min, Palacky University, Czech Republic.
(2) Arpita Panda, University of Delhi, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/67653

Original Research Article

Received 06 February 2021
Accepted 12 April 2021
Published 16 April 2021

ABSTRACT

Bangladesh is facing noticeable risks to self-reliance in rice production, considering the population and its future demand, land scarcity, intensity of natural disaster, soil degradation, global warming. In Bangladesh, rice is cultivated in three seasons which are known as Aus, Aman, and Boro. Considering the year from 1971 to 2015, the area of cultivation growth rate of Aus, Aman, and Boro were -3.4 percent, -0.01 percent, and 4.29 percent, respectively. The yearly yield growth rate of Aus, Aman and Boro were 2.13 percent, 2.48 percent, and 1.8 percent, respectively and production growth rate of Aus, Aman, and Boro were -1.3 percent, 2.45 percent, and 6.9 percent, respectively.

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During the period, overall rice cultivation area increased at the rate of 1.23 percent, the yield capacity increased at 3.42 percent. The total production increased at the rate of 4.19 percent. The yearly cultivated area growth of rice was 0.31 percent, yield growth was 2.9 percent, and production growth was 3.27 percent. The study found that Boro season rice contributed 2.29 times higher production compared to Aus, and 2.24 times to Aman.

Keywords: Production; acreage; yield; growth; seasonality; rice; Bangladesh.

1. INTRODUCTION

Bangladesh is one of the high densely populated countries in the world. According to the estimates from the Bangladesh Bureau of Statistics, the population density is 1,070 persons per square kilometer in the year 2014 [1]. Presently, more than 160 million people are getting food from merely 8.75 million hectares of agricultural land [2]. From the ancient time, this land is famous for rice and jute cultivation. The total rice cultivated area in Bangladesh is about 11.8 million hectares and production is about 34.55 million metric tons in the year 2015/16 [3]. Bangladesh is one of the largest rice producers in Asia. About 81 percent rice is produced by the seven rice producing countries of Asia are China, India, Indonesia, Bangladesh, Viet Nam, Thailand, and Myanmar [4]. It is projected that in the year 2050 the population of Bangladesh will be around 215.4 million. Presently, consumption of rice is 148 kg per person per year and it will decrease to 133 kg per person per year as the rice consumption is decreasing by 0.7 percent per year due to change of food habit [2]. Every year, the large area of agricultural land submerged by the rainwater during the monsoon. On an average, annual flood inundates 20.5 percent area and during severe flood it reaches up to 70 percent of the country [5]. Although flood increases the fertility of soil by scattering silt, it also damages mainly Aman rice. Flood and disaster are one of the main reasons of the deficiency of rice production with the increasing population. Now the demography is gradually changing. The population is increasing but the growth rate is gradually decreasing. In the late 1970's it was higher, but from 1980 the rate (2.85 percent) is decreasing and it stands 1.22 percent in the year 2014 [6]. So, it is a big challenge for Bangladesh to feed the future increased population facing the shortage of agricultural land, flood, the natural disaster with the increasing demand of land for industry and service sector as these two sectors are expanding significantly.

The findings of this study will benefit the policy maker for initiating long-term planning for ensuring food security. Presently, Bangladesh is self-reliant in rice other than crop loss due to the natural disaster. In future, the population will be increased, so the demand for food will also be increased. In that situation, the finding will help the policy makers for land and disaster management policy development and its implementation for ensuring cereal safety and agricultural land development. For the researchers, the study will help to uncover critical areas in the field of rice production.

Given the above backdrop the objectives of the study are to estimate the acreage, yield and overall production growth of rice in Bangladesh and to determine the impact of seasonal cultivation area of Aus, Aman and Boro on total production of rice. Section 1 presents the introduction which is followed by the literature review in section 2. Section 3 presents the materials and methods used. Section 4 presents the findings and discussions. Finally, section 5 concludes.

1.1 Review of Literature

Rice is the most important food crop globally. Presently more than half of the global population are consuming rice. Global annual production of rice is about 703.8 million metric tons in 159 million hectares of land, which covers 11 percent of cultivated area. About 91 percent of global rice grown in Asia. Global population is projected to be 9.7 billion in the year 2050 and demand for rice will increase but the production of rice will be decreased due to global warming, scarcity of water, salinity, deterioration of soil structure, labor shortage, wage rate increase [7].

Rice is one of the main sources of calories and protein in Asia. The average annual consumption of rice in south-east Asia per person per year is 131 kg and provides 49 precent of the calories and 39 percent of the protein. The financial benefits of rice vary from region to region considering international market price and production cost considering soil structure, climate, water availability, and technology. Farmers of Philippines, Indonesia, Vietnam gained from rice production on an average $88 per hectare from 1985 to 2007. The average price of rice was US$400, but in the year 2009, the export price became more than double. There was a severe flood in Bangladesh in the year of 2009 and Bangladesh imported about 5 million tons of rice in the following year. Crop failure due to a natural disaster is one of the determinants of rising international rice market price [8].

Rice production increased about 130 percent from 257 million tons to 600 million tons in 1966 and, 2000 due to green revolution. The population also increased about 90 percent between the year 1966 and 2000. Mainly high yield variety, fertilizer, irrigation, pesticides, and mechanization were the driving force to increase rice productivity [9].

Rice production needs to be increased to fulfill the demand of increasing population in Asia. Sustainable rice production needs quality water and irrigated rice-based production system. Due to drought and scarcity of water, hampers the growth of rice production. Considering the global warming and water shortage, without sacrificing yield of rice, water saving technologies are experimented by IRRI. That may reduce the demand for water, but the quality of soil may deteriorate, and soil productivity may decrease, the greenhouse gas emissions may reduce [10].

It appears from the long-term land use data of China that with the movement of the labor force from rural to urban area, the pattern of cultivable land and the location of crop also changed due to the scarcity of labor. The yield per unit chemical fertilizer use decreased in the long run after saturation of fertilizer into the soil. Too much use of fertilizer deteriorates the quality of soil and water and occurs the environmental degradation. Eventually, food security hampered, import dependency increase and generate adverse effects on sustainable development [11].

Groundwater plays the central role in rice production. Due to climate change and global warming, the intensity of drought, cold and precipitation are changing. For sustainable use of groundwater possible opportunities and challenges of climate change should be taken care of and climate adaptation strategies need to follow [12].

Favorable climate and abundant water the Indo-Gangetic plain (IGP; including regions of Pakistan, India, Nepal, and Bangladesh) is generally characterized by fertile soil. The demand for food and non-agricultural purposes the demand for land resources increases highly as the people are suffering from poverty. The high densely populated area is the reason of land deterioration of agriculture-environments and water resources. Consequently, this affects the food systems of the region. Adaptation strategies are required with the climate change and sustainable development. Natural resource management needs to be developed with flexible policy [13].

The people of Bangladesh prefer parboiled rice. Parboiled rice has some advantages such as high milling yield, nutritional value, and storability, but it requires higher labor and energy for boiling, drying. During boiling about 2.5-9.6 million tons of CO_2 emission occurred every year in Bangladesh. Most of the energy comes from biomass. There are three seasons of rice Aus, Aman and Boro. Boro is irrigated rice and Aus and Aman are rain feed. Irrigations are done by shallow tube-well, which depth is 20-70 meter. Due to irrigation, the groundwater level goes down every year and the intensity of arsenic in water has been increasing. Boro rice containing 14 percent moisture carries 1.5 times higher concentration of arsenic compared to Aman rice. Arsenic concentration for the Boro and Aman season rice were 183 and 117 mg/kg [14].

Fragmentation of land, ownership of resources (land labor and draft power), tenant farming, have different productivity. Output reduces 0.05 percent if fragmentation increases 1 percent, ownership of resources and mechanization provide higher technical efficiency [15].

In Bangladesh Aman season rice grows in the winter season and Boro is growing in the summer season. Temperature and rainfall have a significant impact on rice production. Higher temperature has a positive impact and lower temperature has a negative impact on Aman rice production. On the other hand, higher temperature has a negative impact. Rainfall has a positive impact on Aman production [16].

The effect of climate change on the yield of two varieties of Boro rice such as BR3 and BR14 for the years 2008, 2030, 2050 and 2070 have been simulated for 12 locations (districts) of Bangladesh. Assuming the characteristics of soil, hydrologic and typical crop management practices for Boro rice were used in the simulations. Using the regional climate model PRECIS, it is predicted that significant reduction in yield of both varieties of Boro rice due to climate change; average yield reductions of over 20 percent and 50 percent for the years 2050 and 2070, respectively in addition to reducing yield, climate change may also make rice yield more vulnerable to transplanting date [17].

Bangladesh is a deltaic country that is why most of the lands are consists of alluvial sediments deposited by the rivers Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. Terraces cover about 8 percent, the coastal region covers almost about 20 percent of the country. The coastal areas cover more than 30 percent of the cultivable lands and about 53 percent of the coastal areas are affected by salinity. The dominant Aman crop is grown in the saline areas with low yields (Haque [18]).

A simulation study was conducted to assess the vulnerability of rice production in Bangladesh considering potential climate change. Simulation were made for high-yield varieties of rice for Aus (March-August), Aman (July-November), and Boro (February-July). The CERES-Rice model runs for three scenarios (baseline, Canadian Climate Centre Model, and Geophysical Fluid Dynamics Laboratory) and sensitivity analyses for temperature increases of 2 and 4°C at three levels of $CO2$ (330, 580, and 660 ppm) were used. It is found that the yield will increase with the increase of $CO2$ but yield decreases about 35 percent if the temperature increases 4°C [19].

Nourishment security will be the national necessity for Bangladesh since its autonomy over 1971. Bangladesh is confronting the atmosphere change, fast populace growth, declining accessibility of cultivable land, furthermore insufficient water in the dry season. Those generally effect environmental change on the preparation of sustenance grains clinched alongside Bangladesh. Obviously, it appears to be very little because of treatment what's more power for $CO2$, yet the seriousness from claiming climate for example, rainfall, flood, saltiness and dry season makes insecurity of rice production. Those negative effects for environmental change in 2050, can be observable and production of rice might drop by 8 percent. Similarly as groundwater will make rare and the caliber about water will bring a chance to be poor. Moreover, the interest in watering system water will be higher especially in the dry season. Those lack of water could influence not just crop as well as human, and fish [20].

Those force from claiming catastrophe is incremented on a considerable folds because of environmental change. People would be getting to be more powerless because of reduction for life, crop disappointment. Improvement approach and catastrophe management will be required to maintain e crop handling. Ensuring grounds water utilization, ought to kick more amazing weight on improvement of methodologies, furthermore sustenance security [21].

2. MATERIALS AND METHODS

The paper used the secondary data source. The secondary data such as area, production and yield data were collected from the Food Planning and Monitoring Unit of the Ministry of Food.

To analyse the growth, the paper employed compound growth model. The compound growth analysis was used for determining the acreage, yield and production growth trends of three seasonal varieties of rice such as Aus, Aman, and Boro.

The paper has used the exponential function to estimate the compound growth rate of acreage, yield and production of rice of different seasons in Bangladesh during 1971-72 to 2015/16. The estimated equation was as follows:

$$log_e(\hat{Y}) = \alpha + \beta X$$

Where independent variable X is used for the year and dependent variable Y is used for acreage, yield, and production. So, the study used the following equations to estimate the compound growth rate.

$$log_e(\hat{Y}) = \alpha + \beta X$$
$$e^{log_e(\hat{Y}) = e^{(\alpha+\beta X)}}$$

$$\widehat{Y} = e^{\alpha} e^{\beta X}$$
$$\widehat{Y} = A e^{\beta X}$$

Later, the paper used simple OLS method to find the impact of different seasons on rice production in Bangladesh. The estimated equation was as follows:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \mu$$

Where:

Y = production of rice
X1= Aus area; X2= Aman area; and X3= Boro area
β_o = Intercept and β_1, β_2, and β_3 are the estimated coefficients and
μ = the regression residual

For testing autocorrection problem, the study used Durbin – Watson value, which was found to be less than 2, indicating that there is no auto correlation among the explanatory variables.

3. RESULTS AND DISCUSSION

3.1 Yearly Area of Cultivation Growth for Aus, Aman and Boro Rice

Rice cultivation area increases very slowly as the land is scarce. Presently Boro occupies the top position, second Aman, and third Aus. In the year 1971-72 the cultivated area for Aus, Aman, and Boro were 7414, 13364 and 2140 thousand acres[1]. That indicates 32 percent, 58 percent, and 9 percent area were cultivated for Aus, Aman, and Boro, respectively. The early stage of independence, in the year 1971-72 the Aus rice was the second largest in terms of area compared to Aman and Boro. Aman was cultivated the highest area and Boro was the lowest among the three-rice seasons. In 2015-16 the area of cultivation of Aus, Aman, and Boro was 2516, 13814, 11789 thousand acres, in terms of percentage it was 9, 49 and 42, respectively. It is also observed that Aus area decreased from 32 percent to 9 percent, Aman area decreased from 58 percent to 49 percent and Boro area increased from 9 percent to 42 percent. After introducing the high yielding variety, Aus area gradually decreased and the Boro area increased as these two are competing one another for land. . Overall, the cultivated area of Aus has decreased and on the other hand, Boro area has increased and Aman cultivated area increased a little.

The total area of rice cultivation increases very slowly as the scarcity of land and high density of population. In 1971-72, total rice cultivation area was 22918 thousand acres and in 2015-16 it increased to 28119 thousand acres.

Fig. 1 shows that the Aus area decreased very steeper way, Aman area slowly and Boro area increased sharply and upwards. Form the exponential equation we found for Aus, Aman, and Boro acreage growth of cultivation which are as follows:

Y = 9899.5e-0.034x (i)

Y = 14464e-0.001x (ii)

Y = 2208.9e0.0429x (iii)

Where,

Y = area of cultivation and X= year
-0.034 =yearly growth of acreage for Aus
-0.001 =yearly growth of acreage for Aman
0.0429 =yearly growth of acreage for Boro

From the estimated equations, it is observed that the yearly acreage growth rate for Aus, Aman, and Boro are -3.4 percent, -0.01 percent and 4.29 percent, respectively. Aus and Aman showed negative growth rate and Boro showed positive growth rate. The growth rate showed that the yearly acreage growth for Aman is minimum. It indicates that there is no meaningful change of Aman cultivation area.

3.2 Yearly Yield Growth for Aus, Aman and Boro Rice

It is observed from the above Fig. 1 and data table (Appendix) that the per acre yield capacity for Aus, Aman, and Boro were 0.316, 0.303 and 0.812 in the year 1971-72 and in the year 2015-16, these were 0.91, 0.97 and 1.606, respectively. The yield capacity increases for all the rice crops Aus, Aman, and Boro over the period. It is observed that Aus yield capacity increased but it was the lowest among three seasons. On other hand Aman, area increased higher compared to Aus. The Boro maintains top all the way from the year 1971-72 to 2015-16.

[1] 1 hectare=2.47 acres

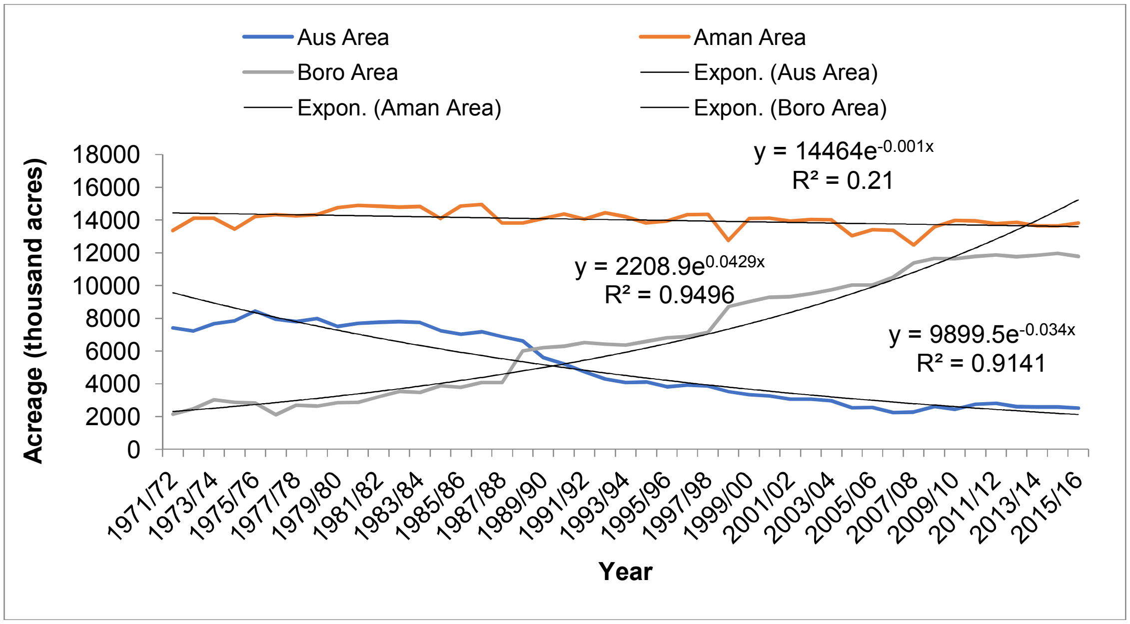

Fig. 1. Cultivation area growth of Aus, Aman and Boro

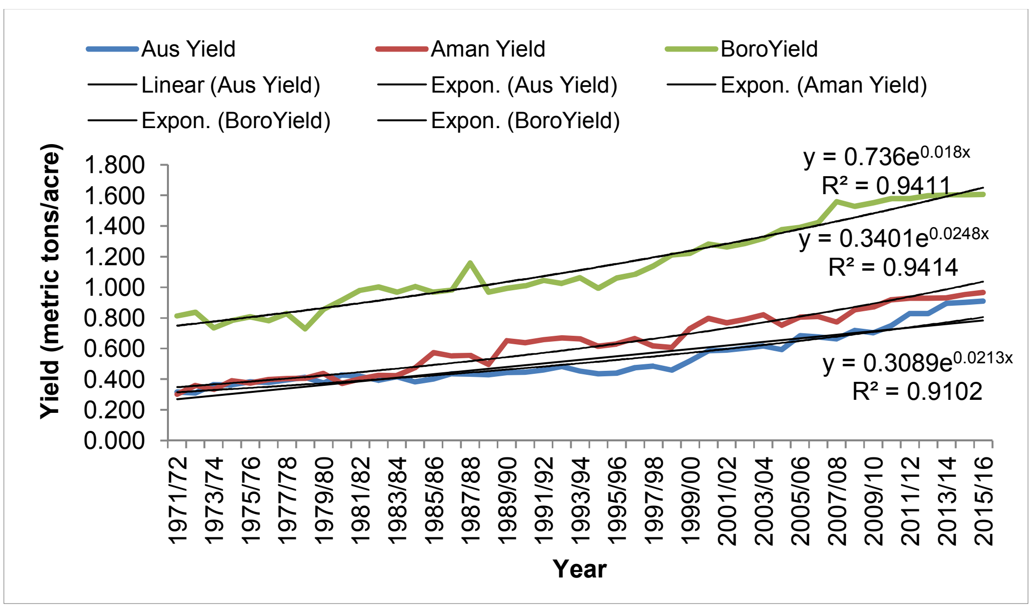

Fig. 2. Yield growth of Aus, Aman, and Boro

Fig. 2 shows that Aus, Aman, and Boro yield increased gradually. The estimated exponential functions for Aus, Aman, and Boro, respectively as follows:

Y = 0.3089e0.0213x (iv)
y = 0.3401e0.0248x (v)
y = 0.736e0.018x (vi)
Y = yield capacity; X = year

0.0213 =yearly growth of yield for Aus; 0.0248 =yearly growth of yield for Aman and 0.018 =yearly growth of yield for Boro

From the equations, it is observed that the yearly yield growth rate of Aus, Aman, and Boro were 2.13 percent, 2.48 percent, and 1.8 percent, respectively during the period from 1971-72 to 2015-16. Aus, Aman, and Boro, all are showing positive growth rate. The growth rate of yield for Boro is minimum among the three-seasonal rice. In case of Aman rice, growth of yield is the highest although the yield capacity is in between the Aus and Boro rice yield. Surprisingly, it is observed from the analysis that Boro growth rate of yield is the lowest although the yield capacity is the highest among the three rice seasons.

The exponential equations for Aus, Aman, and Boro showed that the intercepts were 0.308, 0.340 and 0.736, respectively. The values indicate that the level of yield capacity for the three seasons. The yield capacity of Aus season shows the lowest. The yield capacity of Boro season occupies the middle and Boro shows the highest capacity of yield among the three seasons of rice.

3.3 Yearly Production Growth Trend of Aus, Aman and Boro Rice

In terms of production growth, Aus at the bottom, Aman at the middle, and Boro at the highest among the three seasons of rice. In the year 1971-72, the production of Aus, Aman, and Boro was 2341, 4188, and 1738 thousand tons, respectively. In the year 2015-16, it was 2289, 13483 and 18938 thousand tons, respectively. It is observed that the production of Aus decreased, but the Aman increased at 3.22 times and Boro increased at 10.89 times.

Fig. 3 shows that the production growth of Aus is negative, but the growths of Aman and Boro are positive. The estimated production growth for Aus, Aman, and Boro are as follows:

$$y = 3054.8e{-}0.013x \quad \text{(vii)}$$
$$y = 4758.7e0.0245x \quad \text{(viii)}$$

$$y = 1625.6e0.0609x \quad \text{(ix)}$$

Y = Production of rice
X = Year

-0.013 = yearly growth rate of production for Aus
0.0245 =yearly growth rate of production for Aman
0.0609 =yearly growth rate of production for Boro

From the equations, it is observed that the yearly production growth rate for Aus, Aman, and Boro are -1.3 percent, 2.45 percent and 6.9 percent, respectively. Aus shows negative production growth rate, on the other hand, Aman and Boro shows positive. The growth rate shows that yearly production growth rate for Boro is higher than Aman. The intercepts of exponential equations

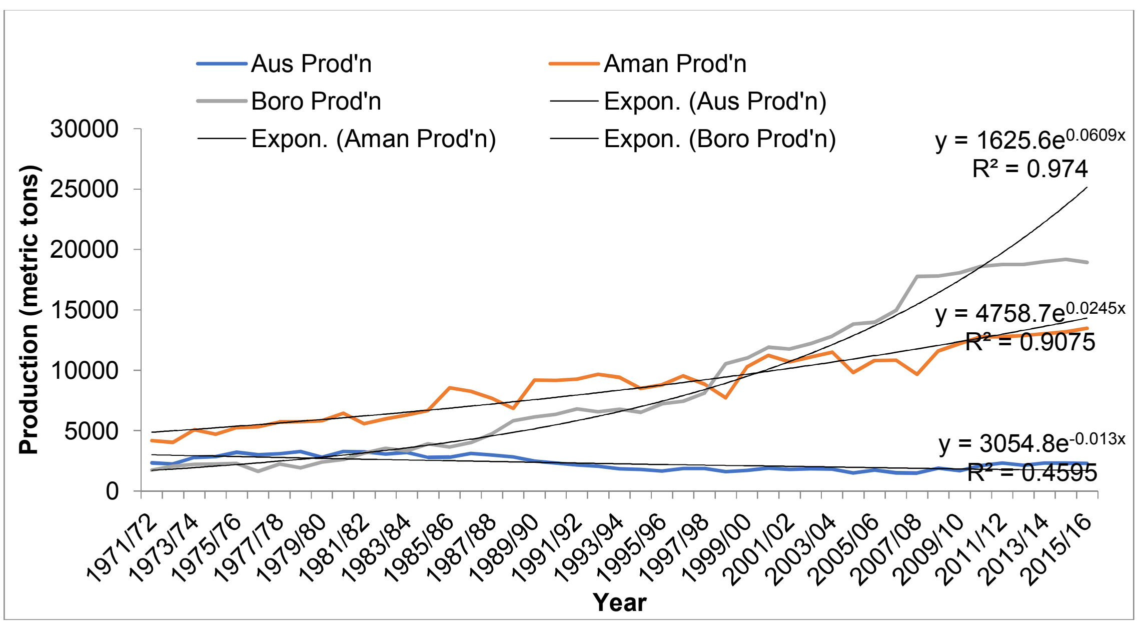

Fig. 3. Production growth of Aus, Aman, and Boro

are 3054.8, 4758.7 and 1625.6 for Aus, Aman, and Boro, respectively. The Boro rice is the top choice of the farmers as it provides the highest yield among the three seasons of rice. The Aman rice is at the middle position and the Aus at the lowest position in terms of production.

3.4 Overall Rice Production

The total production of rice in Bangladesh considering the three-seasonal rice (Aus, Aman, and Boro) shows that the area, yield and production increased. The area of rice production was 22918 thousand acres in the year 1971-72 and was 28119 thousand acres in the year 2015-16. Which indicates that the area of rice cultivation increases 1.23 percent. In case of the yield of rice, it was 0.361 ton per acre in the year 1971-72 and 1.234 tons per acre in the year 2015-16. It reveals from the data that the yield capacity increases 3.42 percent. The total production of rice was 8267 thousand ton in the year 1971-72 and 34709 thousand tons in the year 2015-16. It reveals that the rice production increases 4.19 percent in Bangladesh.

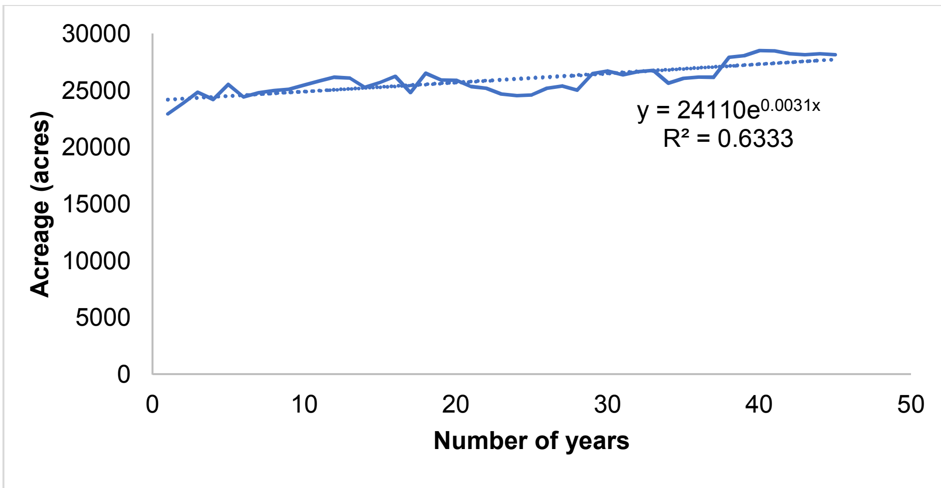

Fig. 4. Overall rice cultivation area growth

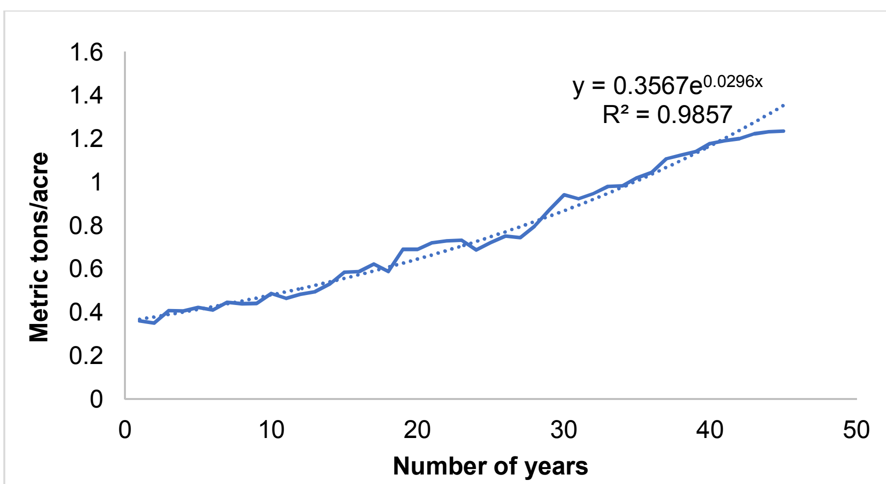

Fig. 5. Overall rice yield growth

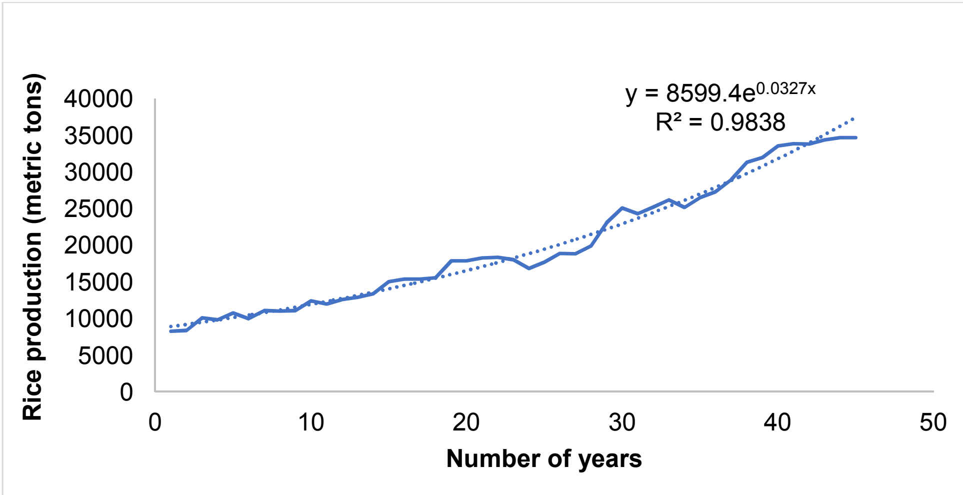

Fig. 6. Overall rice production growth

Figs. 4, 5 and 6 show that the cultivated area growth, the yield growth, and the production growth of rice, respectively. It is observed that the production growth trends are positive. The estimated exponential equation shows the growth of cultivation area, yield, and production of rice in Bangladesh from 1971-72 to 2015-16.

$$y = 24110e^{0.0031x} \quad (x)$$

Where Y = area of cultivation

$$y = 0.3567e^{0.0296x} \quad (xi)$$

Where Y = yield capacity

$$y = 8599.4e^{0.0327x} \quad (xii)$$

Y = production of rice and X = year
0.0031 = yearly cultivated area growth of rice
0.0296 = yearly yield growth of rice
0.0327 = yearly production growth of rice

From the equation (x), (xi) and (xii) it is observed that the yearly cultivated area growth of rice is 0.31 percent, yield growth is 2.9 percent, and production growth is 3.27 percent. It is observed that the growth of cultivation is very poor although the demand for rice is increasing with the increased number of populations. This is the most alarming issue for Bangladesh and the reflects scarcity of cultivable land. The yield growth (2.9 percent) of rice is substantial which implies the research and development effort for the improvement of rice yield are going well. The production growth rate is also substantial, which is consistent with the global trend. With the economic emancipation, the consumption level of cereals, vegetables, fruits and horticultural flowers are also increasing in the country. To fulfill the demand of other foods and to maintain the fertility of soil-crop, diversification is needed. Moreover, due to increases of wage rate and low price of paddy and rice, farmers are migrating from rice production to vegetables, spices and fruit production. In those circumstances, the yield may increase but not significant increase of cultivable land. The production growth of rice may not be sustainable without land reclamation and protecting land from salinity, flood, and disaster. Moreover, due to increasing number of populations the demand for settlements, roads, industries are also increasing in an increasing rate.

3.5 Impact of Seasonal Cultivation Area of Aus, Aman and Boro on the Rice Production

From the equation, we can conclude that the production of rice significantly depends on the cultivated area of three seasons of rice. The Aus season rice crop is planted during March-April and harvested during June-July. The Aman season rice is planted in June-July and harvested during November-December. The Boro season rice is planted in December-January and harvested during May-June. From the analysis, it is observed that total production of rice varies by season.

It reveals from the coefficient of multiple regression, among the three rice seasons, Boro

Table 1. OLS results

Variables	Coefficients	T values	Significant
Constant	-32306.085	-5.298	0.000
Aus area	1.490***	5.139	0.000
Aman area	1.523***	3.805	0.000
Boro area	3.405***	18.499	0.000
F	714.403***		0.000
R^2	0.981		
Durbin Watson	1.359		
Area of cultivation (in thousands of acres)			

$$Y = -32306.085 + 1.49 X_1 + 1.523 X_2 + 3.405 X_3$$

season rice contributes 2.29 times higher production compared to Aus, and 2.24 times higher compared to Aman. Comparing between Aus and Aman season rice, Aman rice production is higher than Aus rice.

Total rice production =- 32306.08 +1.49 Aus area +1.523 Aman area + 3.405 Boro area

According to `t` statistics, all coefficients including intercept are significant at 0 percent level of significance. The value of F is 714.403, which is significant at 0 percent level of significance. The value of R^2 is 0.981 indicates that the 98 percent of total variation are explained by these explanatory variables. The value of Durbin-Watson is 1.359, which indicates there is no autocorrelation among the explanatory variables.

For Boro rice area, with the increase of one thousand acres of cultivated land, the production of Boro will increase 3.405 thousand tons. Boro is the largest rice crop in Bangladesh in terms of acreage and production. The yield capacity also the highest among Aus and Aman, but the yield growth is the lowest. Althought the acreage is the highest due to replacement of Aus area, as both Aus and Aman are produced in the same season. The total area of cultivation for overall rice production in terms of acreage for Aus, Aman, and Boro is not increasing considering the demand of rice in Bangladesh. The acreage growth for rice production is 0.31 percent which is the lowest compared to yield and production growth. That indicates the cultivable land for rice is almost exhausted, but the impact of Boro production on self-reliance in rice is highly significant. This implies that Boro is still lucrative to the farmers considering its higher yield, but the farmer cannot go for larger production due to scarcity of land.

Boro is cultivated in the dry season, so its irrigation highly depends on groundwater. As it is growing in the largest area, so, every year the groundwater level goes down and it is not fulfilled further. Normally shallow tube-well (STW) is used for Boro irrigation. The depth of STW is around 20-70 ft. Due to withdrawing huge amount of groundwater in the Boro season for irrigation, the arsenic concentration in water is increasing and eventually the Boro rice is affected by arsenic. Gradually the level of concentration of arsenic is increasing in rice and it becomes beyond the level of consumption for human.

Due to the global warming, the intensity of disaster such as flash flood, flood, drought, cyclone, tidal surge, salinity is increasing in many folds in Bangladesh. For that reason, every year mass area of rice becomes damaged. Moreover, Boro shows negative impact from higher temperature. Due to global warming, the future of Boro production is under risk as the temperature is increasing quickly compared to past.

Salinity is the other problem in the coastal belt of Bangladesh. The land is plain, and its status is not high compared to sea level. Mass area of coastal belt already affected by saline water, for that reason rice is not growing that areas as rice gives low yield.

Chemical fertilizer is highly used for fulfilling the soil nutrition in Boro rice production. Gradually soil loses its quality with the high consumption of nutrients by rice crop. Moreover, farmers are cultivating rice crop every year in the same land. As a result, soil loses its quality. To fulfill the deficiency of nutrition, farmers are increasing the higher amount to urea and other fertilizers. Due to degradation of soil, the sustainable rice production is under risk.

For sustainable Boro rice production, surface water preservation and its use, compost fertilizer development, protection of Boro area from flash flood and salinity are highly required. Moreover, Boro area is also competing with other crops as farmers are seeing other crops are less risk-prone in terms of management and profit.

In the case of Aman rice area, with the increase of one thousand acres of land, the production of Aman will increase 1.523 thousand tons. Aman rice is the second largest rice crop in Bangladesh. Its area of production is stable but yield growth is high as a result the production growth is high. It is growing in the rainy season so there is no need for irrigation. It is harvested in the winter season. The chilly weather has a negative impact on its yield, on the other hand, a bit higher temperature has a positive impact on its yield. The limitation of the Aman rice is the availability of land as land height is one of the determinants of Aman production. Aman rice is highly affected by natural disaster mainly flood and cyclone. There is no other way to compensate Aman rice production if it is affected by natural disaster as it is growing in the rainy season. Self-sufficiency in rice mainly depends on safe harvesting of rice in Bangladesh. When Aman rice fails, Bangladesh becomes the rice import-dependent country.

The Aus area coefficient found to be 1.490, which indicates that the production of rice increased at the rate of 1.490 thousand tons with the increase of one thousand acres of land. Aus rice is no more attractive to the farmers considering its low yield capacity.

International rice market is not such a position to supply a huge amount of rice to compensate the deficit production of rice of a country due to the natural disaster. In the year 2009-2010, the international rice market jumped about double as Bangladesh`s rice production affected by severe flood in 2009 and needed to import about five million tons of rice. So, sustainability of rice production and maintaining food security in Bangladesh are becoming more delicate.

4. CONCLUSION

In Bangladesh, the total area of rice cultivation does not increase significantly, considering the increased population. Among the Aus, Aman, and Boro rice seasons, the Aus season rice are replaced by the Boro rice. Aman cultivation area remains same. The yield capacity of Aus, Aman, and Boro increased around double due to research and development over the past decades. Among the three seasons of rice, the yield capacity of Boro rice is the highest, then Aman and Aus although the yield growth trend of Aman is higher compared to Aus and Boro. The overall growth of production trend of Aus is negative as it is gradually replaced by Boro rice. The Boro rice contributes the highest in the overall production of rice, then contributes Aman and Aus. Boro yield capacity and the area of cultivation is the highest, but due to land scarcity, the scope of increasing the cultivable area is very limited. So, more attention is required in Aman production in terms of area and yield. Moreover, adequate measures are required to protect Aman crop from disasters to maintain self-reliance in rice production. Among the three rice seasons, Boro season rice contributes 2.29 times higher production compared to Aus, and 2.24 times higher compared to Aman. Between Aus and Aman season rice, Aman contributes higher than Aus in self-reliance of food. Considering the population and its future demand, land scarcity, intensity of natural disaster, soil degradation, global warming are noticeable risks to self-reliance in rice production in Bangladesh.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ACKNOWLEDGEMENTS

The authors would like to acknowledge to the Korea International Cooperation Agency (KOICA), for the financial support to the first author for pursuing Master of Agricultural Science at the Department of Food Security and Agricultural Development, Kyungpook National University, South Korea.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1. Data table

Years	Area				Production				Yield		
	Aus	Aman	Boro	Total	Aus	Aman	Boro	Total	Aus	Aman	Boro
1971/72	7414	13364	2140	22918	2341	4188	1738	8267	0.316	0.303	0.812
1972/73	7237	14113	2476	23827	2243	4045	2071	8359	0.310	0.360	0.836
1973/74	7677	14125	3020	24822	2801	5084	2220	10105	0.365	0.333	0.735
1974/75	7852	13461	2868	24182	2859	4706	2250	9815	0.364	0.390	0.784
1975/76	8447	14227	2835	25509	3229	5252	2286	10767	0.382	0.375	0.806
1976/77	7946	14342	2110	24398	3014	5328	1650	9992	0.379	0.399	0.782
1977/78	7809	14255	2701	24766	3103	5723	2239	11065	0.397	0.404	0.829
1978/79	7989	14339	2647	24975	3287	5764	1929	10980	0.411	0.407	0.729
1979/80	7500	14753	2837	25089	2809	5829	2427	11065	0.375	0.438	0.856
1980/81	7685	14908	2865	25458	3289	6465	2630	12384	0.428	0.374	0.918
1981/82	7770	14845	3215	25830	3270	5574	3152	11996	0.421	0.402	0.980
1982/83	7801	14803	3539	26142	3065	5974	3548	12587	0.393	0.426	1.003
1983/84	7753	14837	3461	26050	3222	6304	3350	12876	0.416	0.425	0.968
1984/85	7256	14104	3889	25249	2783	6692	3909	13384	0.384	0.474	1.005
1985/86	7030	14876	3789	25695	2828	8540	3670	15038	0.402	0.574	0.969
1986/87	7175	14958	4082	26215	3129	8267	4010	15406	0.436	0.553	0.982
1987/88	6891	13817	4082	24790	2993	7689	4731	15413	0.434	0.556	1.159
1988/89	6633	13815	6026	26474	2856	6857	5831	15544	0.431	0.496	0.968
1989/90	5593	14093	6205	25891	2487	9202	6167	17856	0.445	0.653	0.994
1990/91	5216	14373	6297	25886	2328	9167	6357	17852	0.446	0.638	1.010
1991/92	4735	14068	6511	25314	2179	9269	6804	18252	0.460	0.659	1.045
1992/93	4287	14441	6423	25151	2075	9680	6586	18341	0.484	0.670	1.025
1993/94	4076	14209	6378	24663	1850	9419	6772	18041	0.454	0.663	1.062
1994/95	4111	13824	6582	24517	1791	8504	6538	16833	0.436	0.615	0.993
1995/96	3810	13953	6804	24567	1676	8790	7221	17687	0.440	0.630	1.061
1996/97	3935	14339	6876	25150	1870	9552	7460	18882	0.475	0.666	1.085
1997/98	3868	14353	7138	25359	1875	8850	8137	18862	0.485	0.617	1.140
1998/99	3519	12762	8715	24996	1617	7736	10552	19905	0.460	0.606	1.211
1999/00	3339	14097	9024	26460	1734	10306	11027	23067	0.519	0.731	1.222
2000/01	3275	14110	9296	26681	1916	11249	11921	25086	0.585	0.797	1.282
2001/02	3070	13955	9319	26344	1808	10726	11766	24300	0.589	0.769	1.263

Years	Area				Production				Yield		
	Aus	Aman	Boro	Total	Aus	Aman	Boro	Total	Aus	Aman	Boro
2002/03	3073	14041	9501	26615	1851	11115	12222	25188	0.602	0.792	1.286
2003/04	2972	14030	9745	26747	1832	11521	12837	26190	0.616	0.821	1.317
2004/05	2532	13047	10042	25621	1500	9820	13837	25157	0.592	0.753	1.378
2005/06	2556	13416	10047	26019	1745	10810	13975	26530	0.683	0.806	1.391
2006/07	2239	13382	10522	26143	1512	10841	14965	27318	0.675	0.810	1.422
2007/08	2270	12474	11386	26130	1507	9662	17762	28931	0.664	0.775	1.560
2008/09	2633	13585	11654	27872	1895	11613	17809	31317	0.720	0.855	1.528
2009/10	2432	13993	11631	28056	1709	12207	18059	31975	0.703	0.872	1.553
2010/11	2750	13951	11788	28489	2133	12792	18617	33541	0.75	0.92	1.579
2011/12	2811	13783	11881	28474	2332	12798	18759	33889	0.83	0.93	1.579
2012/13	2601	13857	11757	28215	2158	12897	18778	33833	0.83	0.93	1.597
2013/14	2596	13666	11859	28121	2326	13023	19007	34356	0.90	0.93	1.603
2014/15	2581	13659	11961	28201	2328	13190	19192	34710	0.90	0.95	1.605
2015/16	2516	13814.29	11789	28118.793	2289	13483	18938	34710	0.91	0.97	1.606

Notes: Production in 000 m tons, area in 000 acres and yield in ton/acre

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