第 9 回 CSAT 会議

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Agricultural Modernization and Sustainability of Rice Production in Bangladesh: Technological Issues

Muhammad SALIM

Abstract

At the beginning of Green Revolution in the late 1960s, modern varieties of rice were introduced in a number of developing countries that were struggling to overcome food deficits, including Bangladesh. The area under rice production in Bangladesh since independence/liberation in 1971 has been, to date, almost static while production has been increasing over the four decades. Rice production more than tripled but progress has been slowing down. The yield plateau of rice must be overcome by revamping agricultural research through the development of a wide number of technologies such as development of suitable varieties in different Agro-ecological zones, fertilizer management technology, water saving technology and System of Rice Intensification (SRI) etc. Globally, the orientation of the development of agricultural is shifting from productivity to sustainability, stability and safety. However, these issues have not been studied properly in Bangladesh. This study focuses on technological issues and the sustainability of rice production in Bangladesh.

INTRODUCTION

Bangladesh is a deltaic country located in South Asia, with a relatively small land area (147,570 km^2) but with the 8^{th} largest world population (161 million) and high population density (1252 km^{-2}). Bangladesh also suffers from periodic natural calamities such as drought, flooding and cyclones. Due to its location in a delta, climate change and associated sea level rise is expected to increase risk of flooding and salinization of agricultural lands, especially near the southern coast (Hossain and Silva, 2013; MOA-FAO,2012).

With this given condition, rice is the life in Bangladesh. It is the staple for food for the people, the largest component of the country's agricultural sector, and is the main stay of the rural economy (Chowdhury, 2015):

- Rice contributes 51% of the agricultural sector's portion of the national gross domestic product (GDP); by itself, rice contributes 17% to the national GDP.
- Rice supplies 71% of the total calories and 51% of the protein in a typical Bangladeshi diet.
- About 75% of the total cropped area and more than 80% of the total irrigated area are planted to rice.
- Rice accounts for about 40% of all employment: the rural and urban poor spend up to 60% of their income on rice.

Agricultural Modernization and cultivation or rice in Bangladesh

At beginning of Green Revolution in the late 1960s, modern varieties (MV) of rice were introduced in a number of developing countries that were struggling to overcome food deficit, including Bangladesh. If we look into the time frame of 1971 (since liberation of Bangladesh) to date, we really see that the birth of Bangladesh was with chronic hunger. The production of rice in the country was 9.8 million tons from 9.2 million hectares of land in 1971-72 to feed 75 million people. There was 3 million tons of food deficit and widespread poverty, starvation and malnutrition. Around 70% people were below poverty level. As the adoption of MV rice steadily increased along with government's initiatives and subsidy of modern inputs, the scenario started to change rapidly. The rice production in 2015-16 was 35million tons from 11.3 million hectares of land (Table 1, Fig. Slide 10). Thus, over the four decades the rice production in the country has been increased by 3.6 folds. The country has achieved self-sufficiency in rice production to feed its 161 million people.

Among the three growing seasons (viz. Aus, Aman and Boro), the rice production is the highest in Boro season. The contribution of Boro, Aman and Aus rice to total rice production (33.91 million tons) in 2015-16 were 54.19%, 38.77 and 7.04%, respectively. Area, production and yield of boro rice showed increasing trend while those of aus rice showed decreasing trend over the decades which for aman rice remained more or less constant (Fig. Slide 11-14). The area under rice is almost static while the production is increasing over the four decades (Fig. Slide 10). This yield increase has been attributed to the use of modern varieties and improved technologies as well as increase of area under boro rice (Table 1). Thus the food security largely depends on performance of boro rice production in particular.

Can Bangladesh produce enough rice to meet future demand?

Ways to improve future food sufficiency

- **Increase crop yields**
- **Increase crop intensity (i.e., growing more crops per year); already approx.. 200% at present**
- **Increase in rice imports**

BEST OPTION SEEMS TO BE TO INCREASE CROP YIELD

Recent findings show that most of the land suitable for cropping in the country is already under cultivation and arable land area is even decreasing by 1.0% per annum due to increasing demand for residential and industrial use, while the population is being increasing by 1.58% (Rahman *et al*., 2013). According to the medium variant UN projection (UN, 2015), Bangladesh’ population will further increase to 186 and 202 million by the years 2030 and 2050, respectively. Our estimates indicate that current yields in Bangladesh are not sufficient to meet future rice demand due to combination of expected cropland area reduction and expected grain demand increases. Therefore, rice production needs to be increased to a great extent to maintain the food security in the country. Though rice production more than tripled since liberation, but the progress is slowing down recently (Fig. Slide 16). The yield plateau of rice must be overcome by revamping agricultural research with development of wide number of modern rice growing technologies (Fig. Slide 17)

Technology

Development of suitable variety in different AEZs

(Fig. AEZ of Bangladesh, Slide 18)

Though Bangladesh occupies 4th position among the rice producing countries of the world but yield per hectare is 4.5 tons only which is much lower than China, Japan and Korea where yield ranges 6-6.5 ton per hectare. But while China, Japan and Korea produces only one rice crop per year, Bangladesh produces three rice crops from the same field in a year. In this regard the yield of rice in Bangladesh is not meager. However, to keep pace with the food demand, rice production should be increased by adopting suitable modern variety and sustainable technology.

IR 8 was introduced as first modern rice variety to cultivate in Bangladesh in 1968 from IRRI. With the inception of Bangladesh Rice Research Institute (BRRI), it developed so far about 70 modern rice variety suitable for cultivating in different agro ecological regions of Bangladesh. BRRI, Bangladesh Institute of Nuclear Agriculture (BINA) and Bangladesh Agricultural University (BAU) developed MV rice varieties cover about 80% rice area which accounts 91% of the total rice production in Bangladesh. Rest 20% of the rice area is covered by local rice varieties and by imported hybrid rice.

Fertilizer management technology

Use of balanced fertilization is a must to obtain good yield in rice. In applying fertilizer two things need to be given due consideration. First, fertilizer dose should be determined by considering weather, soil fertility, variety under cultivation, life duration etc. Second, to increase fertilizer efficiency, it should be applied based on cropping pattern instead of applying for a single crop. Following two technologies will ensure farmer to obtain economic benefit from fertilizer management.

1) Use of Leaf-color Chart (LCC) for nitrogenous fertilizer management particularly urea : LCC is a color chart or scale made by plastic body having four colors in it (Fig. Slide 19). By using LCC right amount of urea fertilizer can be top-dressed to rice plant in right time. Consequently, the amount and cost of urea can be minimized and the efficiency of urea becomes more. Results show that by using LCC 20-25% urea can be saved. BRRI (2017) has formulated the time and dose of urea to be applied through LCC for the modern rice varieties in Bangladesh.

2) Use of Urea Super Granule (*Gooti* urea) (Fig. Slide 20)
Urea Super Granule is granular urea made from pilled urea with a special device developed by IFDC in Bangladesh. Two types of granules are available, 1.7g granule^{-1} and 2.7g granule^{-1}. The smaller granules are recommended for aus and aman rice while bigger granules are recommended for boro rice cultivation. Granules are applied in the rice field within 7-15 days after transplanting rice seedling. Good result can be obtained if 2-3cm water can be kept in the field continuously. By using Urea Super Granule 80-100 kg urea ha^{-1}can be saved by which farmers become economically benefitted.

Water saving technology and Direct seeding

Water saving technology with Alternate Wetting and Drying (AWD) irrigation technology: Rice is a semi aquatic plant which is generally grown by transplanting requiring 1000-5000 litres of water for producing one kilogram of rice (Bouman and Tuong, 2000). It involves about 1/3rd of the total cost of cultivation of boro rice. AWD technology has already been introduced in the country to sustain Boro rice production at the expense of less (30%) irrigation water (Fig. Slide 21-22).

In AWD system, the field is irrigated with enough water to flood the paddy field for 3-5 days, and, as the water soaks into the soil, the surface is then allowed to dry for 2-4 days before getting re-flooded. A PVC pipe (20cm in diameter and 40 cm in length) with holes (5 mm in diameter spaced at 2 cm) is installed in the rice field (15 cm above and

25 cm below the soil surface) after transplanting seedling to monitor groundwater. AWD is started at 10 days after transplanting and the field is allowed to dry out. The field is re-flooded to a standing water layer of 5 cm when the ground water is 15-20 cm below the soil surface. AWD cycles are continued up to one week before flowering (50-60 days after transplanting), and a standing water layer of 5 cm is kept at flowering until harvest.

Direct seeding

Several experiments conducted at Bangladesh Rice Research Institute clearly demonstrated that irrespective of rice varieties, direct seeding using Drum Seeder has out yielded the conventional transplanted rice by 15-20% both the Aman and Boro seasons (Hossain, 2005) (Fig. Slide 23) Islam (2008) stated that direct seeding in rice reduced 8-12 days growth duration, gave 88% higher number of panicles m^{-2} and 10% higher grain yield than transplanted rice. However, poor crop establishment, heavy weed infestation and termite problems are the barriers to the adoption of this technology.

System of Rice Intensification

The system of rice intensification (SRI) is an integrated approach of all management practices to increase the yield of rice. SRI, originated in Madagascar and was first synthesized by Fr. Henry de Laulanie, S.J., who between 1961 and 1995 worked with Malagasy farmers and colleagues to improve the possibilities of rice production in that country. It is a system of plant, soil, water and nutrient management for irrigated rice, developed in Madagascar has been yielding 5, 10, even more t ha^{-1}on farmers' field where previous yields averaged around 2 t ha^{-1}. This was achieved using whatever variety of rice the farmers were already using. This system shows that alternative management practices, creating optimal growing conditions for plants, can bring out previously untapped genetic potential (Uphoff, 1999). Under SRI methods, less than 15 day old infant seedlings are transplanted gently within 30 minutes of uprooting with single seedling $hill^{-1}$ and having spacing of not less than 25 x 25 sq. cm even up to 50 x50 sq. cm in a square method of planting. The seedlings are transplanted so that their roots remain in ‘L’ shape instead of usual ‘J’ shape. The field should be kept moist, no standing water would be allowed until reproductive stage. During the reproductive stage, the rice plants should be given a thin layer of water (1-2 cm) on the surface of the soil. During the growing period, occasionally, even once a week, the soil is allowed to dry out, at least to develop hairy crack on the surface. Minimum 3 to 4 weeding should be done before the plants complete their growth and begin flowering. Soil need to be enriched by addition of nutrients, preferably through addition of compost and manure. It shows great promise to the substernal increase of irrigated rice yield, its average yield is around 8.0 t ha^{-1} which is twice more than world average 3.6 t ha^{-1} (Uphoff et al., 2002) (Fig. Slide 24).

There are some positive and negative aspects of SRI technology as mentioned by Gupta (2000). Very recently SRI has been introduced in Bangladesh but this system received limited success.

Conclusion

Bangladesh agriculture has achieved significant structural changes over past three and half decades. Technological change with market forces greatly influenced Bangladesh agriculture in mid-sixties and seventies. From a relatively stagnant sector in the pre-green revolution period, Bangladesh agriculture emerged as a dynamic sector in the green revolution period. There was a significant growth in agriculture infrastructure as well as a shift towards liberalization from government control. Total rice production total in 1971 was 9.8 million tons; in 2015-16 it was 35 million tons. The net result is that the country has gone from a situation of chronic deficit to self-sufficiency. Cropping intensity increased to about 194% in 2015-2016. Long-term trend of rice production shows that the dominant factor in growth is rice yield, stimulated by modern variety, fertilizer and irrigation technology. Technological progress of in rice research, as evidenced by release of about 80 modern rice variety by BRRI, BINA and BAU is commendable. Extension too played a role to disseminate know how of modern rice cultivation to the farmers. Chemical fertilizer and pesticide use became popular across all groups of farmers from 1971. Integration of variety-fertilizer-irrigation development was a major factor behind spread of modern variety of rice and consequent yield increase. Other concurrent developments include increasing mechanization of agricultural operations particularly two wheel tractors (Power Tiller). Government is pursuing efforts to promote more and more rice production technologies to boost up rice yield and production in the country.

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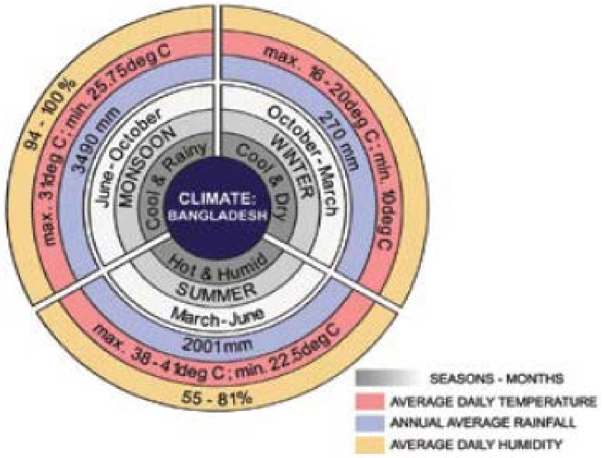
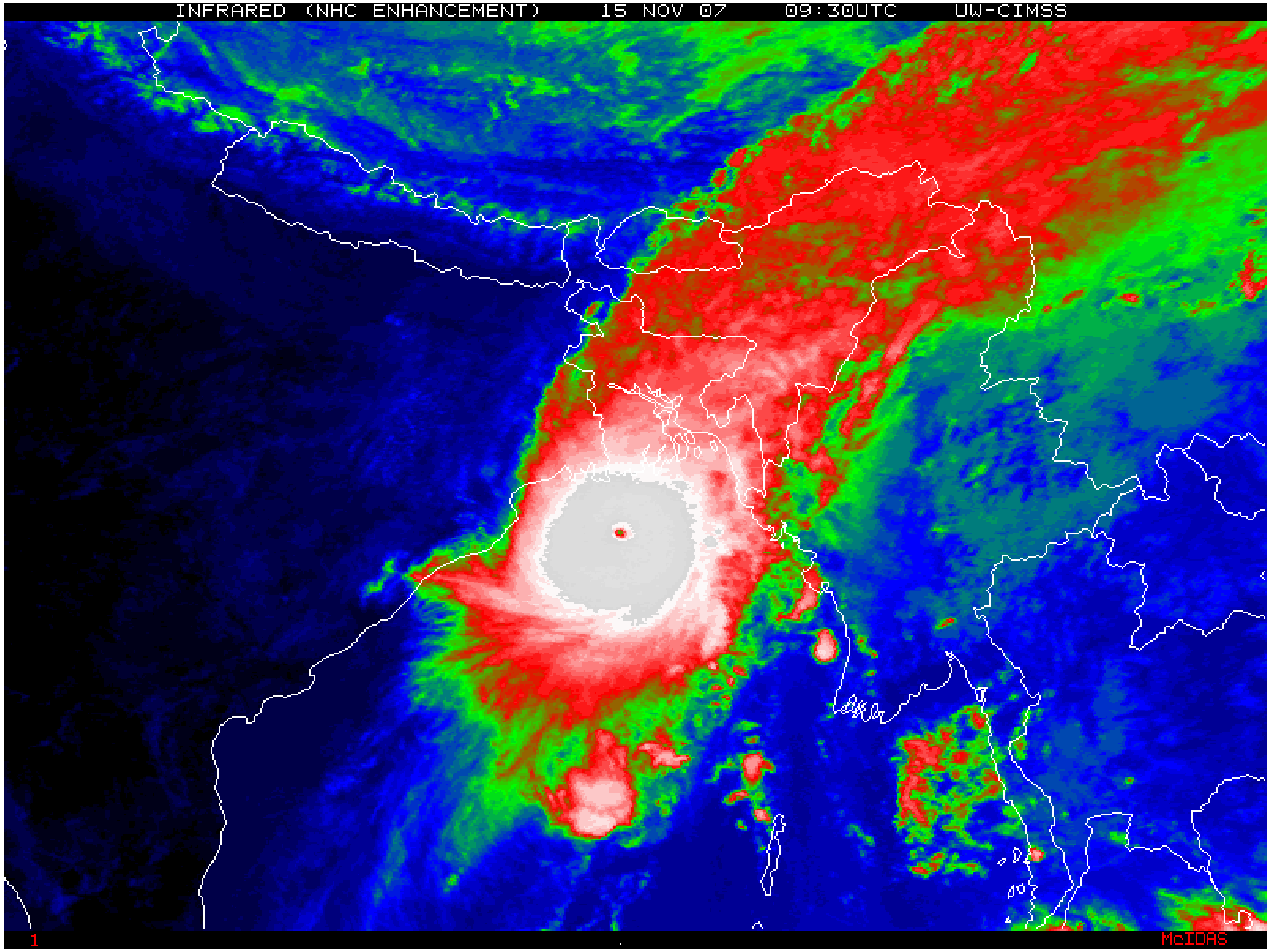
Recurrent Natural Calamities

- Cyclones - 1970, 1991, 2007(Sidr), 2009(Ayla)
- Floods - 1988, 2000, 2004, 2007
- Erratic rainfall (e.g. late rainfall Aug/’09)
- Severe drought
- Heat and cold waves
- Declining water table



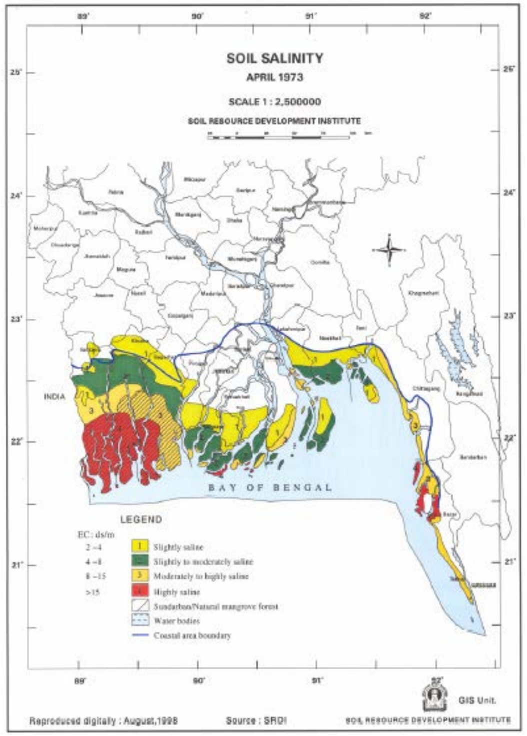
Climate of Bangladesh

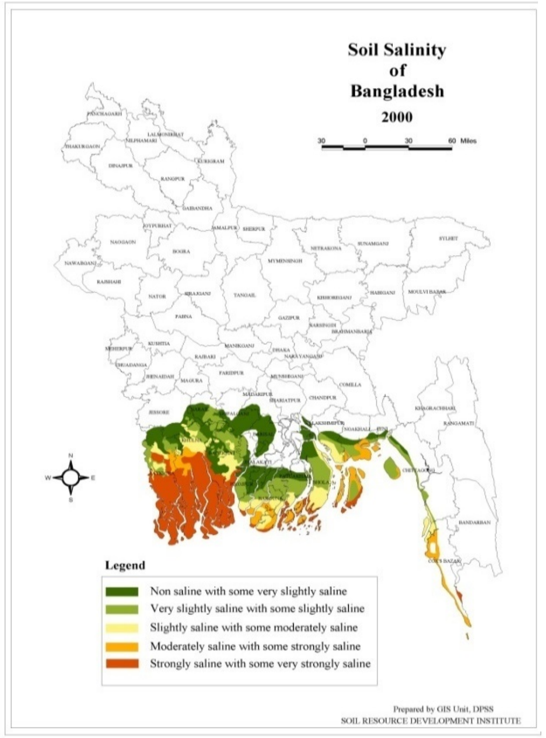


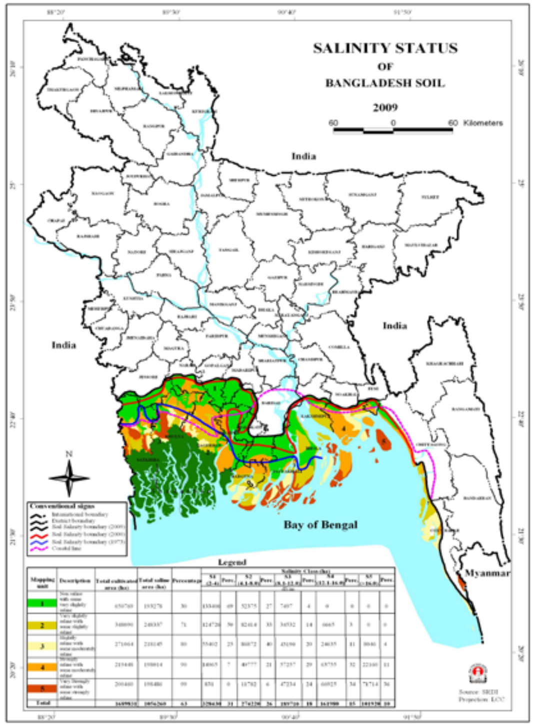
The S-W coast of Bangladesh was hit by ‘Sidr’ in Nov. 2007 which damaged 2.3 million households. ‘Aila’ hit the south coast in May 2009 which affected about 5 million people.

Saline area is increasing with time

26.7 % area increased over 4 decades





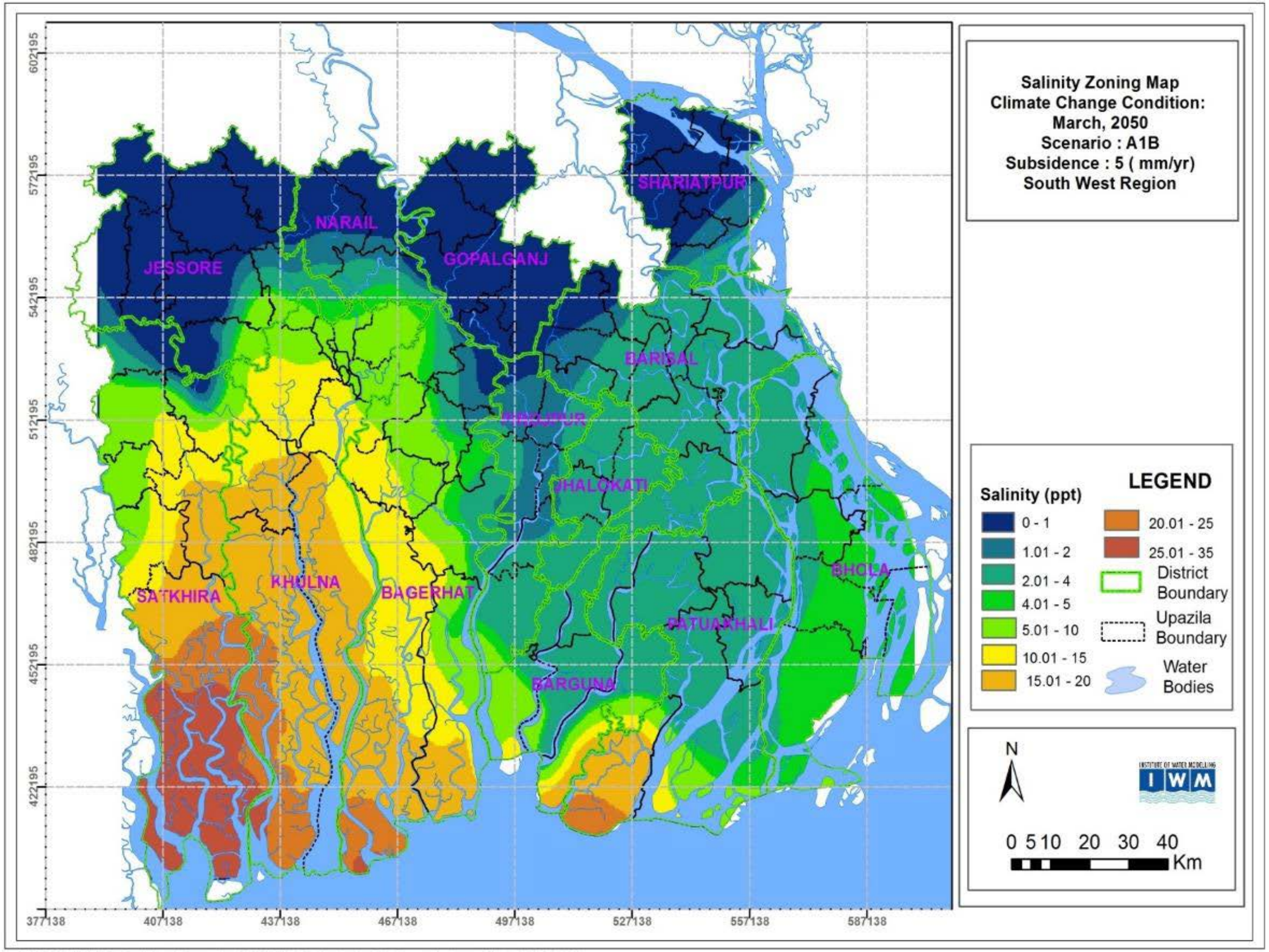


1973	2000	2010
0.83 mha	1.02 mha	1.06 mha

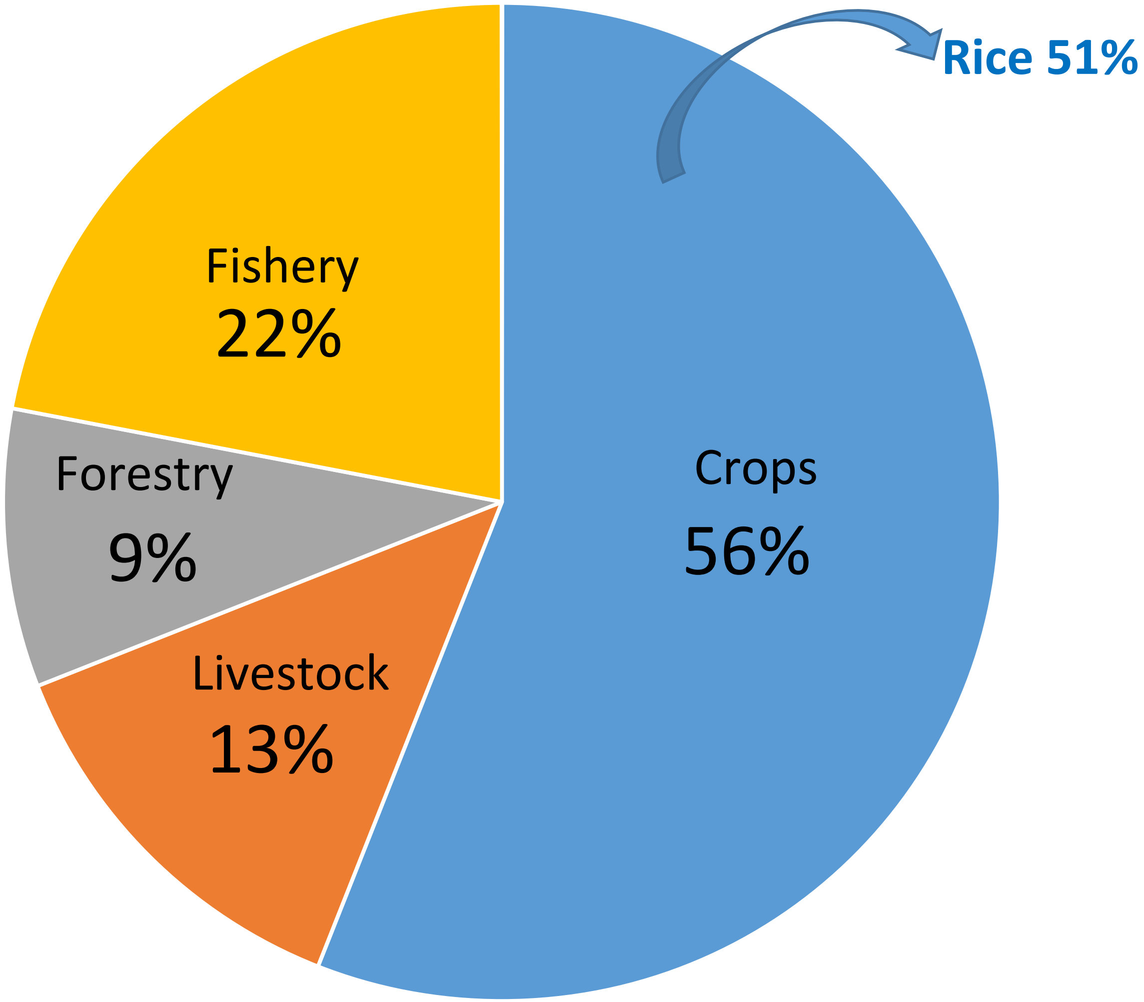
Source: SRDI

Map: Effect of Sea Level on 2ppt Salinity contour (A1B, 2050)

Source: IWM



Contribution of Agriculture to GDP



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- Rice contributes 51% of the agricultural sector's portion of the national gross domestic product (GDP); by itself, rice contributes 17% to the national GDP.
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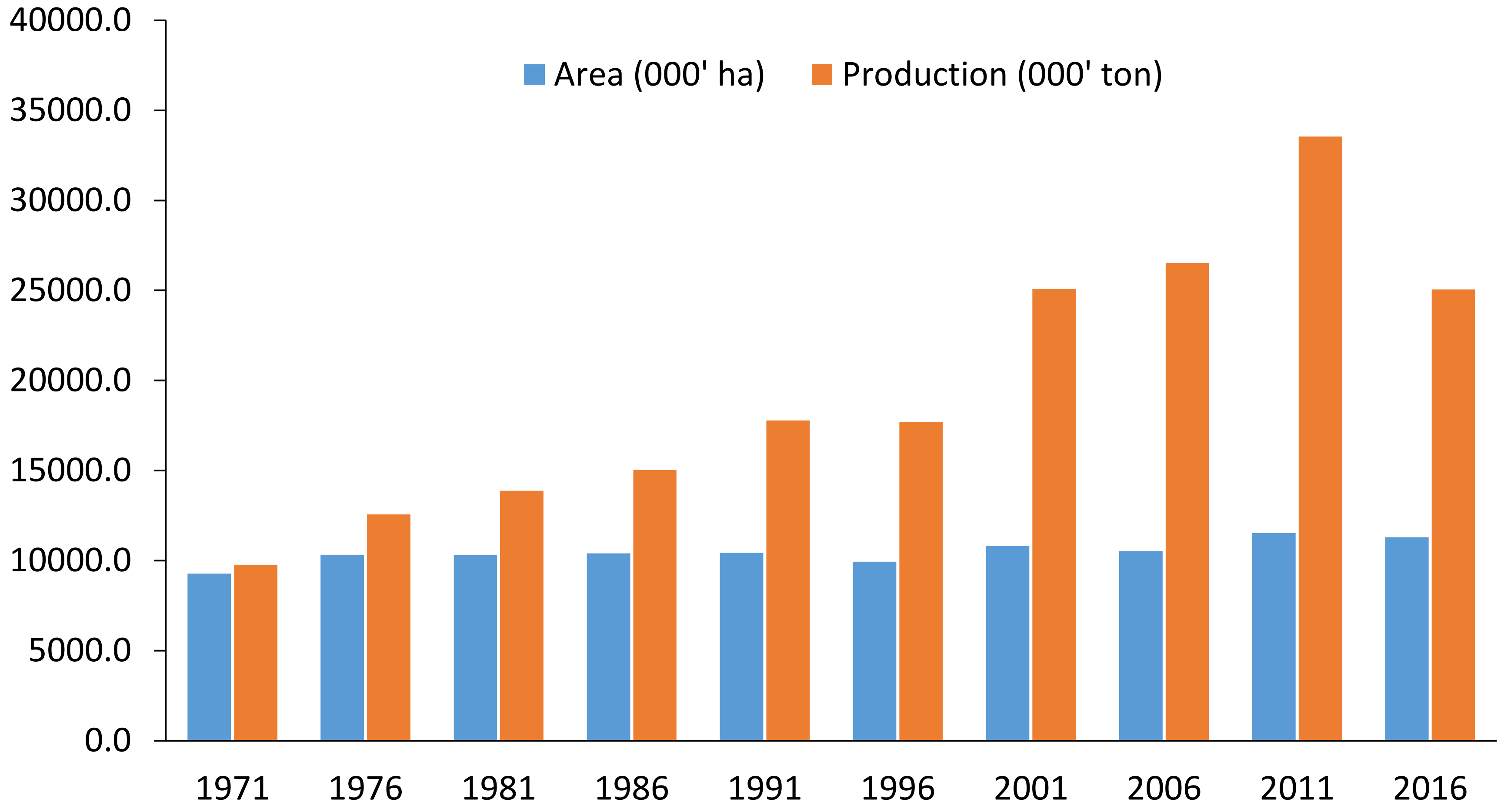
- Rice accounts for about 40% of all employment: the rural and urban poor spend up to 60% of their income on rice.

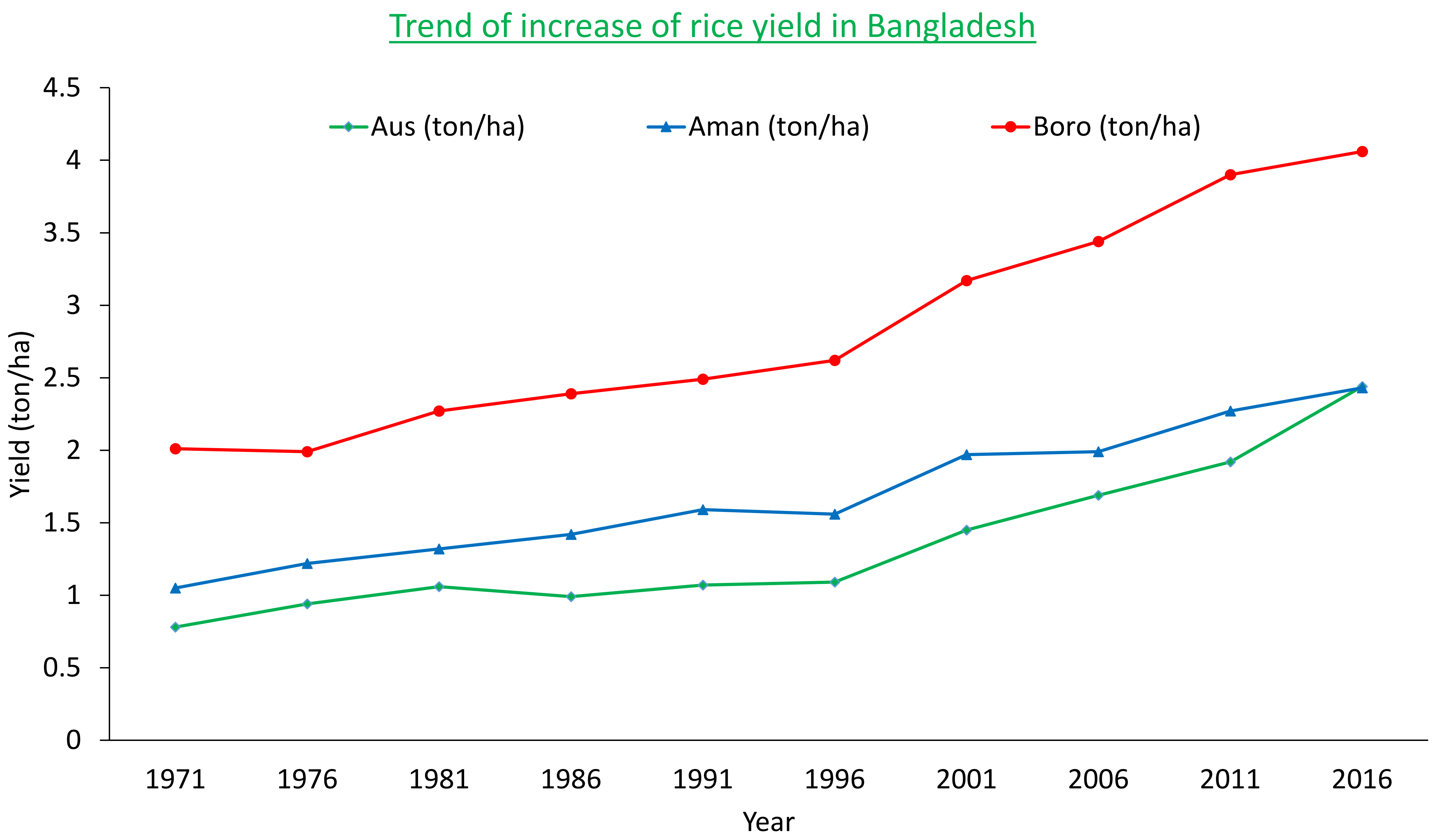
Birth of Bangladesh with Chronic Hunger (1971)

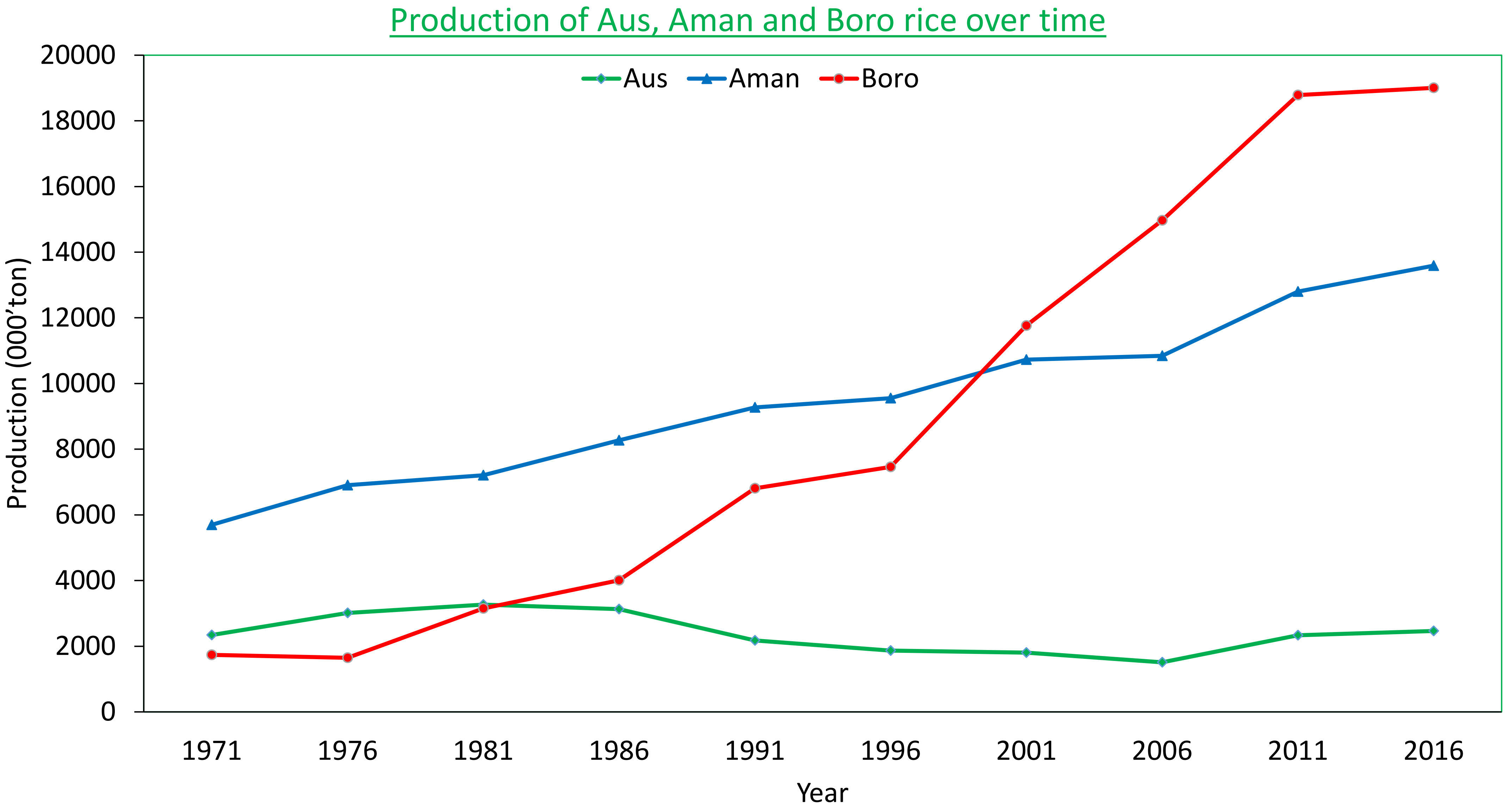
- Nation used to produce about 11 million tons of food grain and had to feed more than 75 million people.
- About 3 million tons of food deficit and widespread poverty, starvation and malnutrition.
- Around 70% people were below poverty level
- Malnutrition was acute problem



Total area and production of rice in Bangladesh over 4 decades

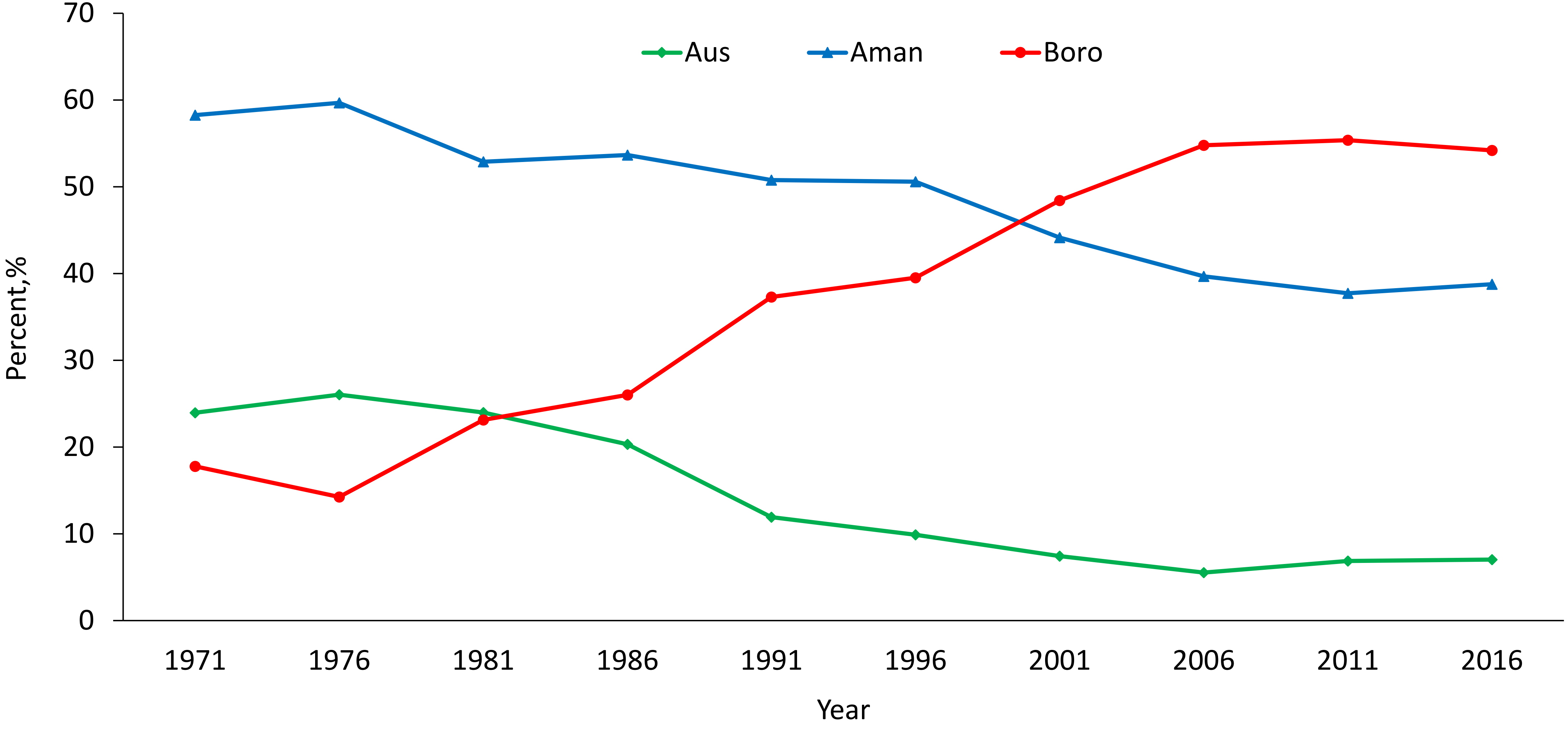
The area under rice is almost static while the production is increasing over the four decades


Trend of increase of rice yield in Bangladesh
Aus (ton/ha)
Aman (ton/ha)
Boro (ton/ha)
Yield (ton/ha)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
Year



Production of Aus, Aman and Boro rice over time
Aus
Aman
Boro
Production (000’ton)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
Year

Contribution of Aus, Aman and Boro rice to total rice production in Bangladesh



Area of Aus, Aman and Boro rice over time

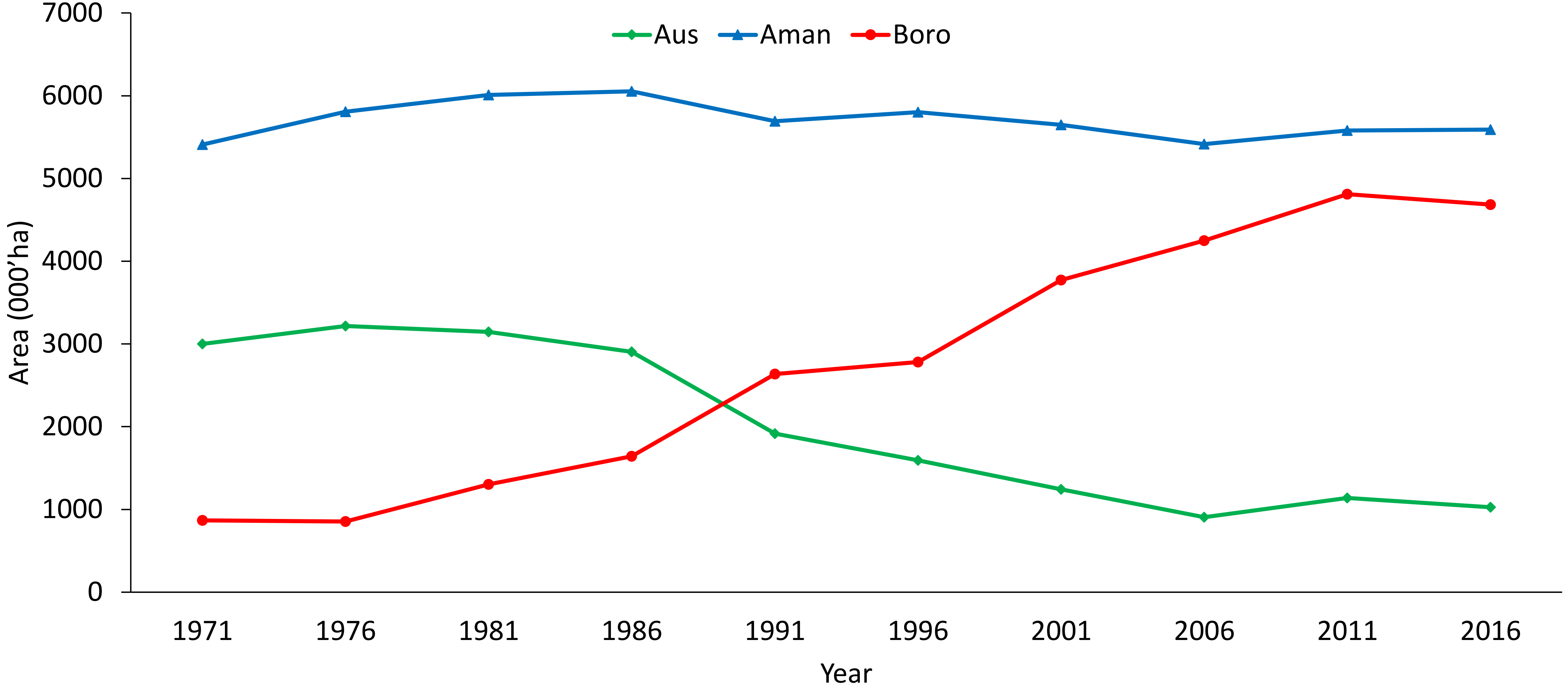
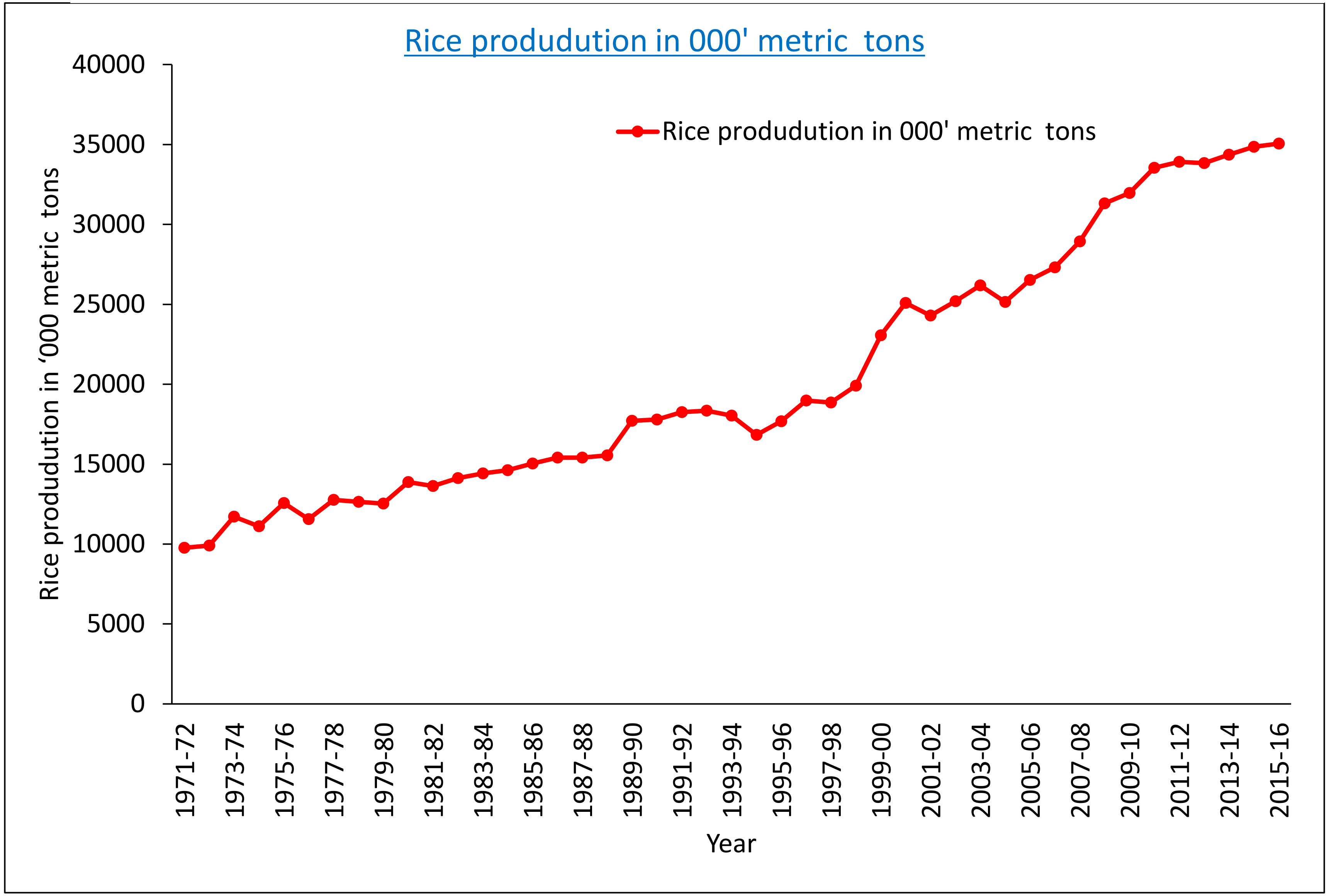


Table 1: Total Rice (Aus, Aman and Boro) Area (000'ha), Production (000'ton) and Yield (ton/ha) of Bangladesh

	Area (000'ha)			Production (000'ton)			Yield (ton/ha)		
Year	Aus	Aman	Boro	Aus	Aman	Boro	Aus	Aman	Boro
1971-72	3001.60	5410.70	866.40	2341.00	5695.00	1738.00	0.78	1.05	2.01
1972-73	2930.00	5713.80	1002.60	2243.00	5587.00	2071.00	0.77	0.98	2.07
1973-74	3107.90	5718.70	1222.70	2801.00	6699.00	2220.00	0.90	1.17	1.82
1974-75	3179.10	5449.90	1161.20	2859.00	6000.00	2250.00	0.90	1.10	1.94
1975-76	3419.90	5759.90	1147.90	3229.00	7045.00	2286.00	0.94	1.22	1.99
1976-77	3217.10	5806.40	854.20	3014.00	6905.00	1650.00	0.94	1.19	1.93
1977-78	3161.70	5771.20	1093.70	3103.00	7422.00	2239.00	0.98	1.29	2.05
1978-79	3234.60	5805.10	1071.80	3287.00	7429.00	1929.00	1.02	1.28	1.80
1979-80	3036.30	5972.70	1148.40	2809.00	7303.00	2427.00	0.93	1.22	2.11
1980-81	3111.20	6035.80	1160.00	3289.00	7964.00	2630.00	1.06	1.32	2.27
1981-82	3145.60	6010.30	1301.70	3270.00	7209.00	3152.00	1.04	1.20	2.42
1982-83	3158.10	5993.00	1432.80	3065.00	7516.00	3548.00	0.97	1.25	2.48
1983-84	3138.70	6006.70	1401.20	3222.00	7843.00	3350.00	1.03	1.31	2.39
1984-85	2937.60	5710.20	1574.40	2783.00	7930.00	3909.00	0.95	1.39	2.48
1985-86	2844.90	6018.90	1533.20	2828.00	8542.00	3671.00	0.99	1.42	2.39
1986-87	2903.60	6052.40	1651.70	3130.00	8267.00	4010.00	1.08	1.37	2.43
1987-88	2788.30	5590.40	1942.60	2993.00	7690.00	4731.00	1.07	1.38	2.44
1988-89	2683.46	5100.80	2438.30	2856.00	6857.00	5831.00	1.06	1.34	2.39
1989-90	2255.00	5702.50	2453.60	2475.00	9202.00	6033.00	1.10	1.61	2.46
1990-91	2107.30	5775.30	2547.90	2261.00	9167.00	6357.00	1.07	1.59	2.49
1991-92	1915.90	5692.30	2634.90	2179.00	9269.00	6807.00	1.14	1.63	2.58
1992-93	1735.10	5843.70	2598.90	2075.00	9680.00	6586.00	1.20	1.66	2.53
1993-94	1649.40	5843.30	2580.80	1850.20	9419.20	6772.20	1.12	1.61	2.62
1994-95	1663.75	5594.17	2663.54	1790.70	8504.00	6538.70	1.08	1.52	2.45
1995-96	1541.85	5646.40	2753.57	1676.00	8790.00	7220.60	1.09	1.56	2.62
1996-97	1592.29	5802.49	2782.59	1870.00	9551.00	7460.00	1.17	1.65	2.68
1997-98	1565.88	5808.45	2888.56	1874.60	8849.80	8137.30	1.20	1.52	2.82
1998-99	1424.26	5165.50	3526.67	1616.90	7735.80	10551.90	1.14	1.50	2.99
1999-00	1351.32	5704.87	3651.89	1734.00	10306.00	11027.00	1.28	1.81	3.02
2000-01	1325.23	5709.96	3761.84	1916.00	11249.00	11920.50	1.45	1.97	3.17
2001-02	1242.18	5647.22	3771.34	1808.00	10726.00	11766.00	1.46	1.90	3.12
2002-03	1243.72	5682.11	3844.84	1850.70	11118.40	12222.20	1.49	1.96	3.18
2003-04	1202.58	5677.61	3943.50	1831.80	11520.50	12837.10	1.52	2.03	3.26
2004-05	1024.68	5279.92	4063.79	1500.00	9819.00	13837.10	1.46	1.86	3.40
2005-06	1034.27	5429.01	4065.81	1745.00	10810.00	13975.30	1.69	1.99	3.44
2006-07	905.71	5415.62	4250.10	1512.00	10841.00	14965.00	1.67	2.00	3.52
2007-08	918.66	5048.16	4607.85	1507.00	9662.00	17762.00	1.64	1.91	3.85
2008-09	1065.56	5497.77	4716.31	1895.00	11613.00	17809.00	1.78	2.11	3.78
2009-10	984.22	5662.89	4706.60	1709.00	12207.00	18059.00	1.74	2.16	3.84
2010-11	1112.87	5645.64	4770.00	2132.82	12791.00	18616.00	1.92	2.27	3.90
2011-12	1138.00	5580.00	4810.00	2333.00	12798.00	18783.00	2.50	2.29	3.90
2012-13	1053.00	5610.00	4760.00	2158.00	12897.00	18778.00	2.05	2.30	3.95
2013-14	1051.00	5530.20	4790.00	2326.00	13023.30	19007.00	2.21	2.36	3.97
2014-15	1045.00	5530.00	4846.00	2328.00	13190.20	19343.00	2.23	2.38	3.99
2015-16	1025.00	5590.40	4685.10	2468.00	13591.40	19001.10	2.44	2.43	4.06

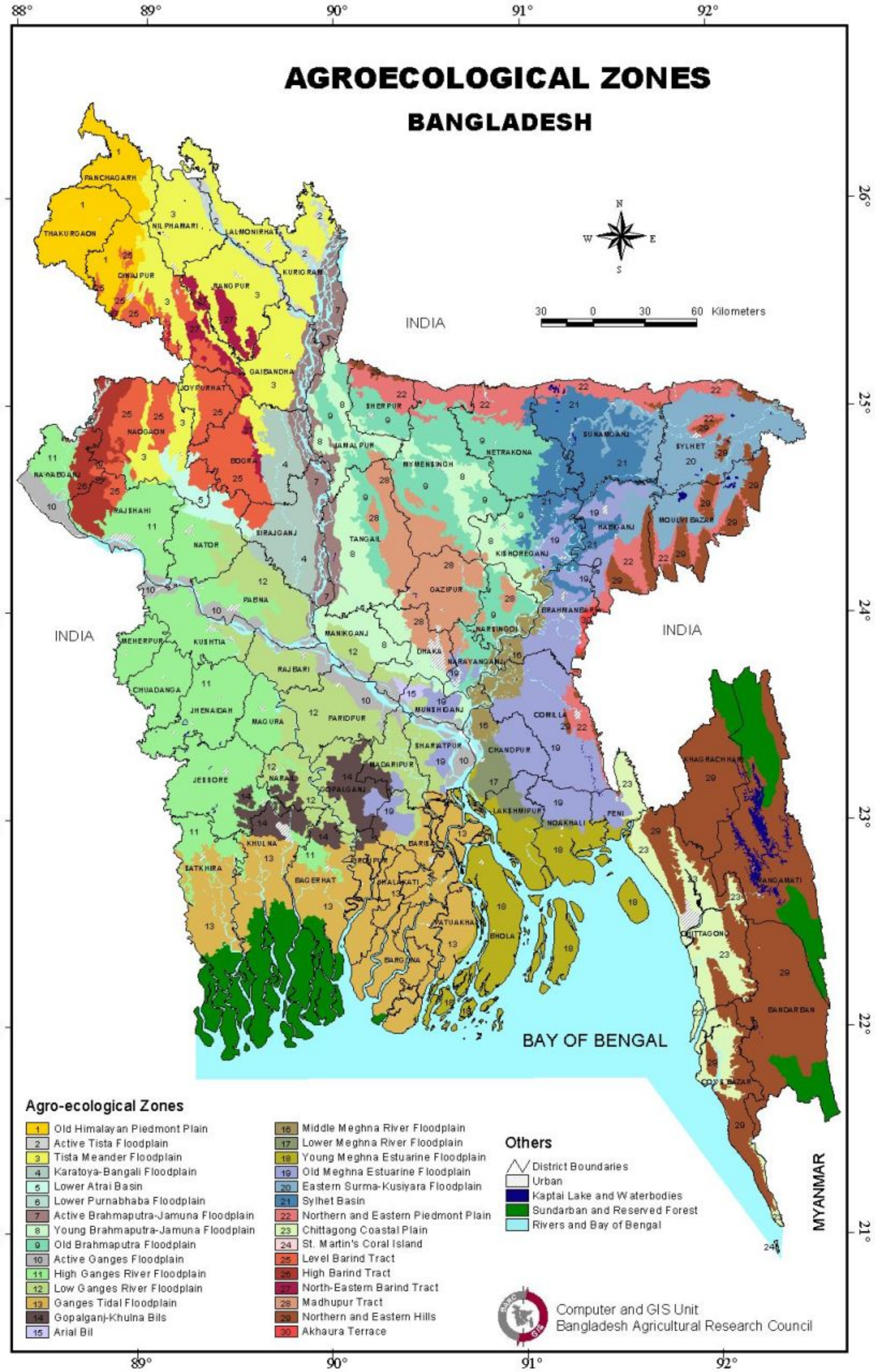
Source: BBS and DAE

Rice production more than tripled since liberation, but the progress is slowing down



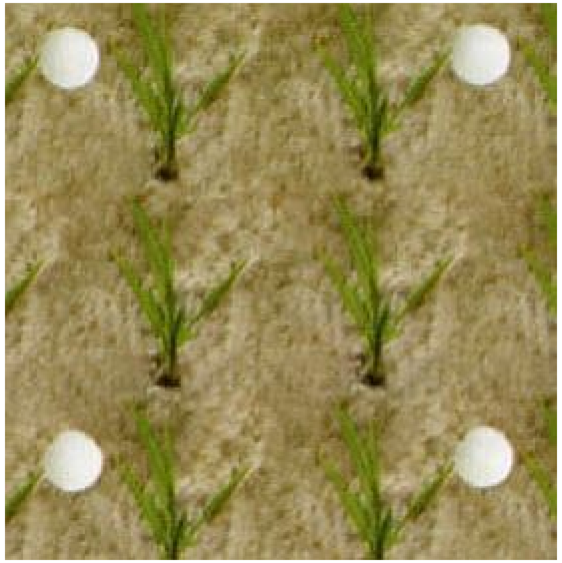
Modern technologies for rice productions

- Development of suitable variety in different AEZs
- Fertilizer management technology (USG/*Gooti* urea,LCC)
- Water saving technology (AWD, Direct seeding)
- System of Rice intensification (SRI)

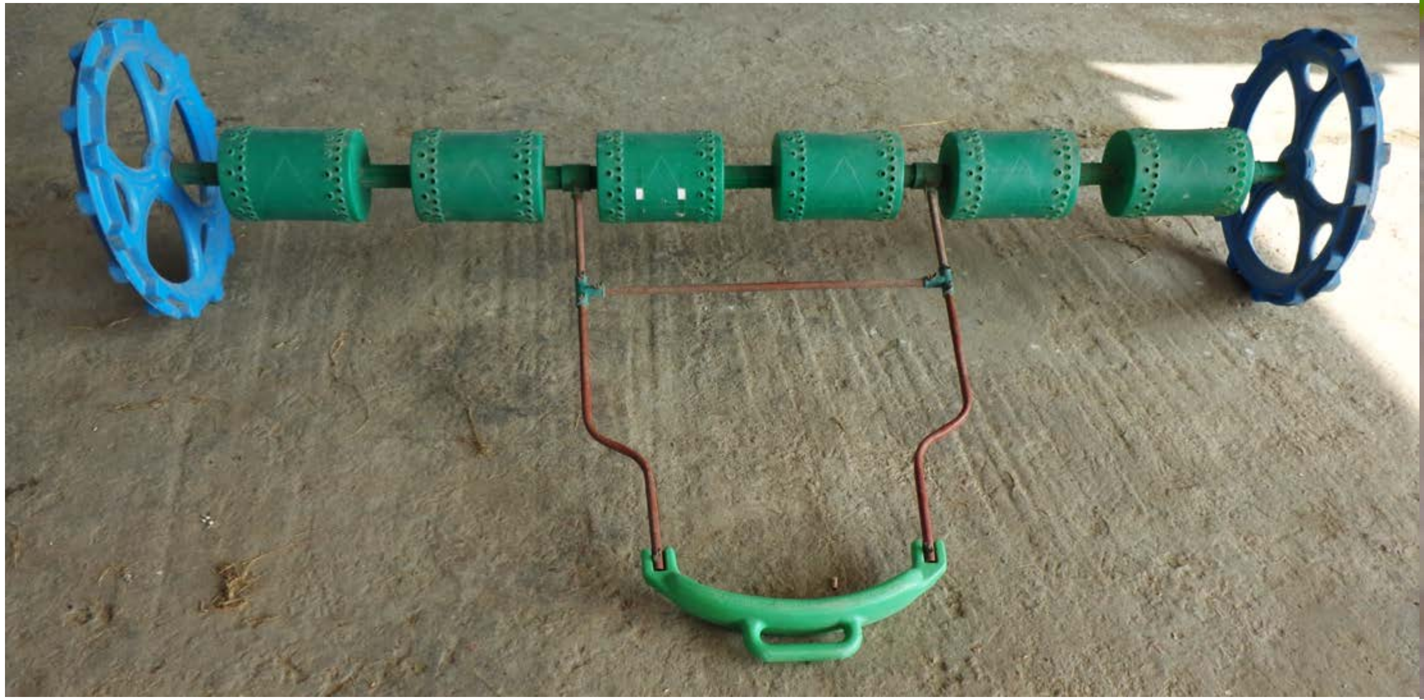

AGROECOLOGICAL ZONES
BANGLADESH
INDIA
INDIA
INDIA
BAY OF BENGAL
MYANMAR
30 0 30 60 Kilometers
N
S
E
W
Agro-ecological Zones
1 Old Himalayan Piedmont Plain
2 Active Tista Floodplain
3 Tista Meander Floodplain
4 Karatoya-Bangali Floodplain
5 Lower Atrai Basin
6 Lower Purnabhaba Floodplain
7 Active Brahmaputra-Jamuna Floodplain
8 Young Brahmaputra-Jamuna Floodplain
9 Old Brahmaputra Floodplain
10 Active Ganges Floodplain
11 High Ganges River Floodplain
12 Low Ganges River Floodplain
13 Ganges Tidal Floodplain
14 Gopalganj-Khulna Bils
15 Arial Bil
16 Middle Meghna River Floodplain
17 Lower Meghna River Floodplain
18 Young Meghna Estuarine Floodplain
19 Old Meghna Estuarine Floodplain
20 Eastern Surma-Kusiyara Floodplain
21 Sylhet Basin
22 Northern and Eastern Piedmont Plain
23 Chittagong Coastal Plain
24 St. Martin's Coral Island
25 Level Barind Tract
26 High Barind Tract
27 North-Eastern Barind Tract
28 Madhupur Tract
29 Northern and Eastern Hills
30 Akhaura Terrace
Others
District Boundaries
Urban
Kaptai Lake and Waterbodies
Sundarban and Reserved Forest
Rivers and Bay of Bengal
Computer and GIS Unit
Bangladesh Agricultural Research Council

Leaf Color Chart (LCC)

Urea Super Granule



Drum seeder



AWD

AWD

SRI system