Rice in Bangladesh

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Abstract

Bangladesh is located in South Asia, between 20° 35′ N to 26° 75′ N latitude and 88° 03′ E to 92° 75′ E longitude. Total area of the country is 14.4 million ha of which 62% consists of arable land. Eighty percent of the arable land is devoted to rice. Bangladesh is one of the most densely populated countries of the world. Ninety percent of the people depend on rice and derive 70% of their calories from it. Agriculture employs 70% of the labour force and accounts for 40% of the GDP, of which 20% is contributed by rice.

Bangladesh ranks third in total rice area, fourth in production but sixteenth in yield. It is characterized by the diversity of land, soil, rainfall, temperature, solar radiation and day length which accounts for the varieral diversity of the landraces of rice. Rice is grown in 3 overlapping seasons with 4 ecotypes, such as, Boro which is mostly irrigated, tolerant to cool temperatures and insensitive to photoperiod; Aus which is usually direct-seeded and sensitive to cold and insensitive to photoperiod; transplanted Aman sensitive to photoperiod which grows in rainfed lowlands, and broadcast Aman or deepwater rice which is photoperiod-sensitive and planted in lowlying flooded areas. Newly developed modern rice varieties are cultivated over 50% of the land and the changes in the rice cropping pattern induce the genetic erosion of landraces. Out of estimated 4,000 landraces 3,000 have been collected and conserved. Three wild species have been identified. Future collection will involve rice varieties from the hilly and tribal areas, including wild and weed races of rice.

Geography and historical aspects of Bangladesh

Bangladesh a part of the Bengal basin was originally a part of British India. During independence in 1947 from the British, the Indian subcontinent was partitioned into India and Pakistan and it became a part of Pakistan and was known as East Pakistan (1947-1971). Later in 1971 East Pakistan became independent and sovereign again and was named Bangladesh. It is bordered by the Bay of Bengal of the Indian ocean in the South, India in the West, India, Nepal and the Himalayan mountains in the North, India and Burma in the east. It is situated between 20° 35 to 26° 75 N latitudes and 88° 03 to 92° 75 E longitudes (Fig. 1).

Bangladesh as a part of South Asia, is a transition zone between Southwest and Southeast Asia. Arabian, Iranian and Turkish influences are noticeable in architecture, art, food, clothing and in many words of Bengali vocabulary. On the other hand in common with Southeast asia, rice and fish are the common diet. As Bangladesh is one of the most densely populated rural areas in the world, 45% of the farmers are landless (people with land holding less than 0.5 acre are designated as landless). Bangladesh has 20 soil types and 30 agroecological regions (Fig. 4). As a part of the Bengal basin, it has 65,000m² of delta of the Gandes and Brahmaputra river system in the foothills of the Himalaya. Except for some parts of the northern and the eastern parts where there are some small hills, most of the country is formed by the alluvial deposits from the sediments carried from the hills and mountains in the northern and eastern sides. Some alluvial deposits date back to the pleistocene era and some are as old as 10,000 years mostly in tidal

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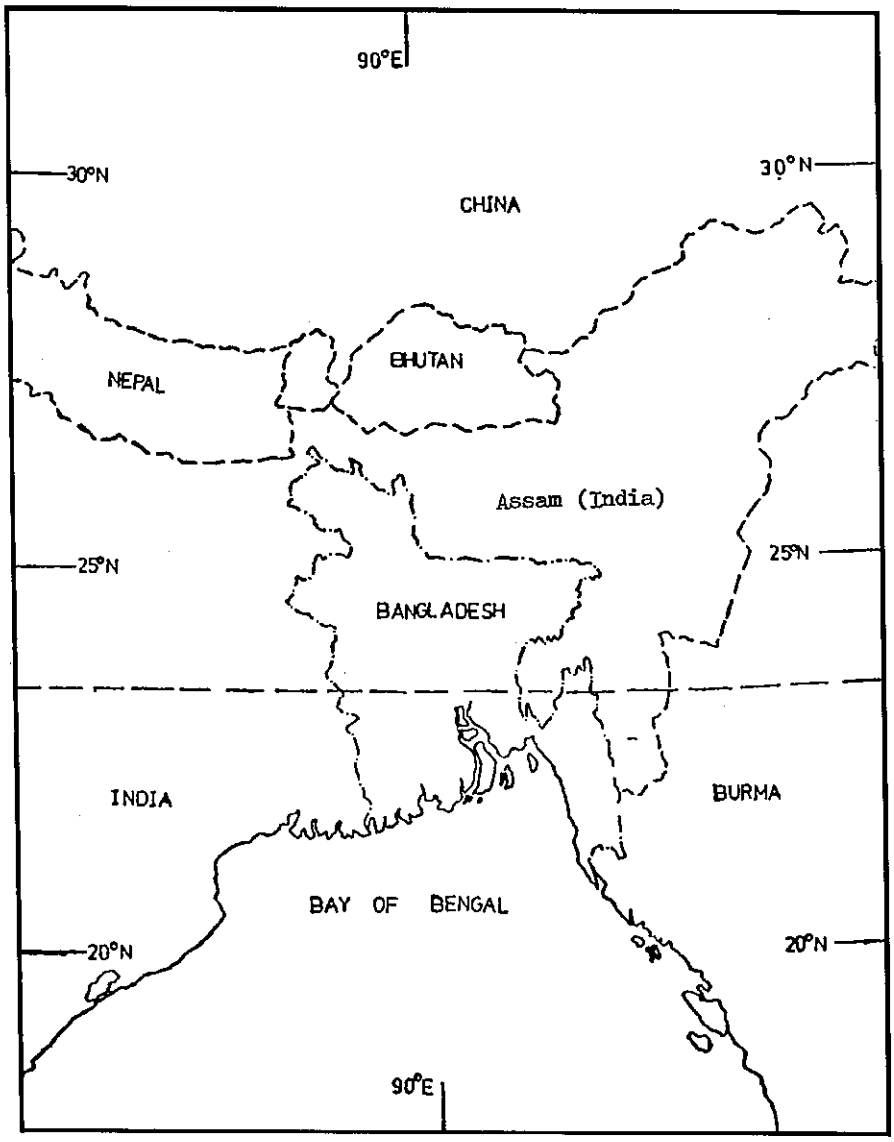

Fig. 1 Geographic location of Bangladesh in South Asia

wetlands in the southern part of the coast. Elevation of the country ranges between 2 to 1,200 m high from the mean sea level. The country has large networks of rivers, canals, streams which total about 24,000 km (Fig. 2). The Ganges, Brahmaputra and Meghna river system annually carries about 2.4 billion tons of sediments to the sea.

Soils and climate

From the physiographic point, three broad soil divisions are found; hill soils of (10.8%) tertiary rocks and pleistocene sediments, old alluvial soils (7.1%) of two tracts of Pleistocene (Bramner *et al.*, 1988) terraces and recent alluvial deposits (67.1) of several rivers. The pH of the soil varies from 4.0 to 10.0.
The N, P, K and CaO contents of the soils are 0.10, 0.10, 1.03 and 1.16%, respectively.
The organic matter content is 0.2% (Brammer *et al.*, 1988; Haroun, 1977).

The climate of Bangladesh is characterized by high rainfall and temperatures and marked by seasonal variation of solar radiation and daylength (Table 1). The mean higher temperatures range from 31 °C in Cox's Bazar to 36°C in Rajshahi The mean minimum of 8.3°C is in Sylhet, 9.4°C in the northern part. Highest temperature is recorded during March to September and the lowest during the last week of De-

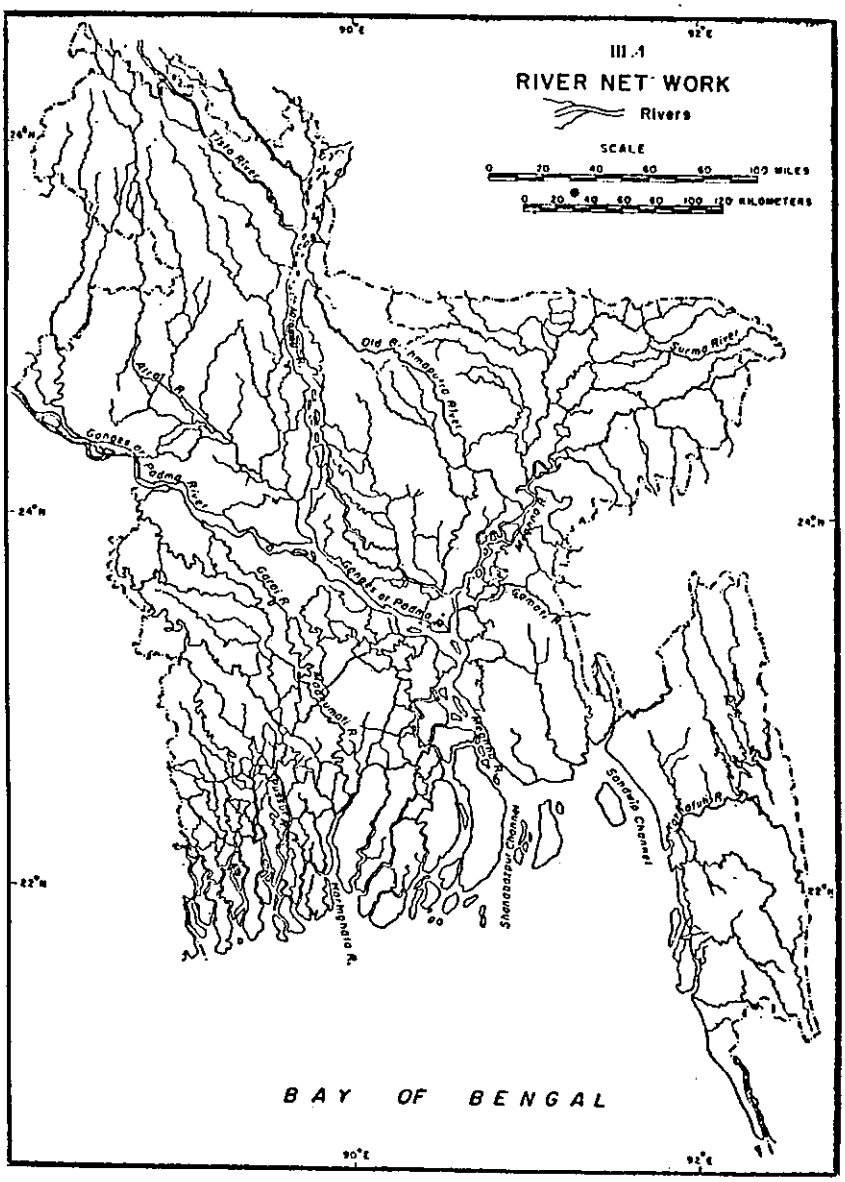

Fig. 2 Rivers and Canals networks of Bangladesh

cember and first week of January. In summer, the temperature may rise up to 40.5°C. The solar radiation is the lowest during July to August and daylength varies from 10.7 to 13.6 (Table 1). The monsoon starts in June and ends in October. This period accounts for 80% of the rainfall. The average annual rainfall varies from 119 to 345 cm, maximum in the East and Southeast and minimum in the Northwest (Fig. 3). Monthly rainfall fluctuates over the seasons and years causing drought at the beginning and end of the monsoon.

Based on seasonal flooding, five land types are identified in Bangladesh, as follows: highland (29%) above normal inundation, medium highland (35%) which is again divided into two, land inundated up to 30 cm and land inundated up to 30-90 cm, medium lowland (12%) inundated up to 90-180 cm, lowland (8%) inundated up to 180-300 cm and very lowland (1%) inundated by more than 300 cm (Brammer *et al.* 1988).

Rice and agriculture in the economy of Bangladesh

Agriculture dominates the economy of Bangladesh, accounting for an estimated 40% of the GDP, of which about 20% is contributed by rice alone. It employs 70% of the labor force and earns 40% of the

Table 1 Mean rainfall, temperature, bright sunshine hours and day length in Bangladesh (Agro-climatic survey of Bangladesh-Manalo)

	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall (mm)	13.0	19.4	45.5	113.4	255.1	426.3	434.4	399.1	290.0	161.0	33.1	14.6
Temperature (°C) Max:	25.5	27.9	32.2	34.0	33.2	31.6	30.9	31.2	31.4	30.9	28.8	26.3
Min:	12.0	14.2	18.8	22.8	24.4	25.2	25.6	25.6	25.4	23.3	17.7	13.4
Bright sunshine (hours)	8.9	9.1	8.6	8.5	8.2	4.2	4.6	4.7	5.8	7.3	9.1	8.8
Day length (hours)	10.8	11.4	12.0	12.7	13.3	13.6	13.5	13.0	12.3	11.6	11.0	10.7

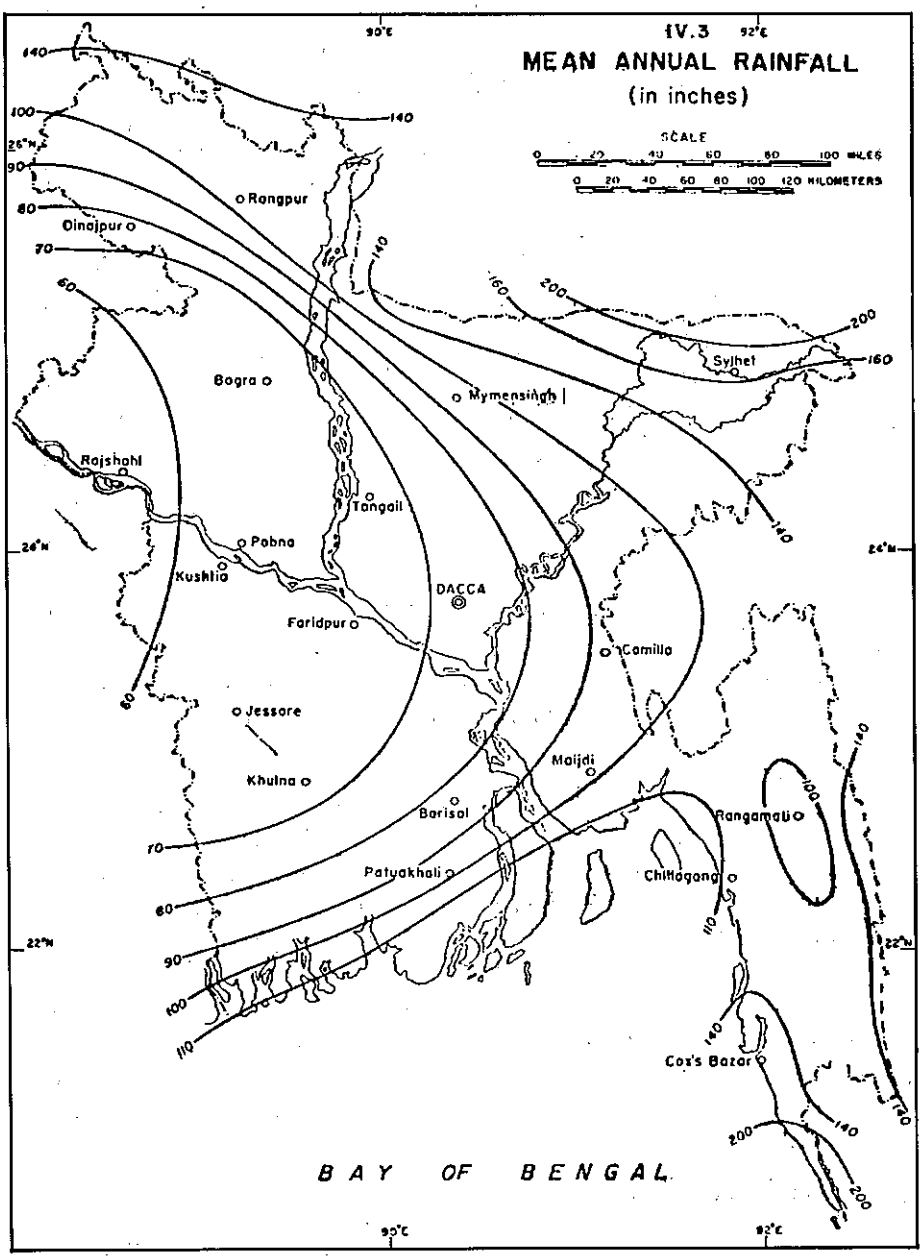

Fig. 3 Variation of mean anmual rainfall over locations in Bangladesh

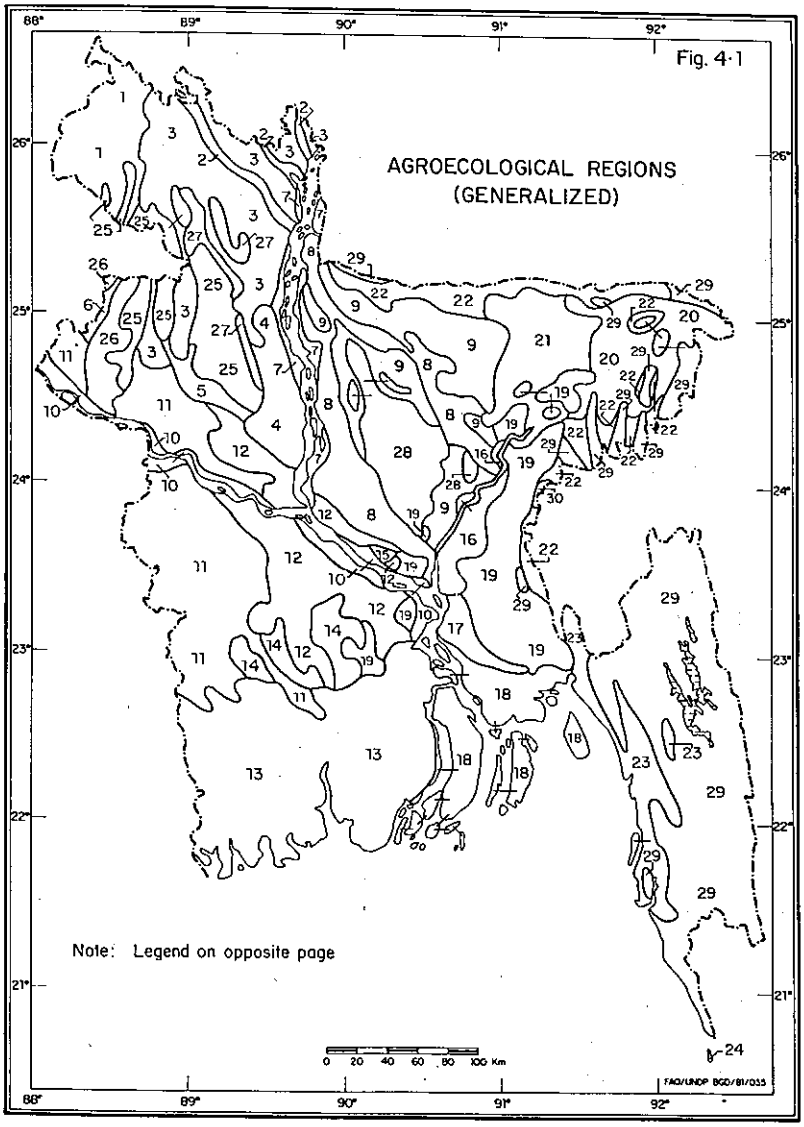

Fig. 4 Thirty agroecological regions of Bangladesh

Agroecological Regions

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 and Jamuna Floodplains
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 Plains
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

foreign exchange (including items manufactured from jute). The total area of Bangladesh is 14.4 million ha of which about 62% is arable or cultivable. Out of this arable land, 80% is devoted to rice. The present area under rice lovers 10.7 million ha (Table 2). The cropping intensity of rice is 150. Rice accounts for 95% of the food grain production and more than 90% of the people depend on rice for their daily diets and derive 70% of their calorie uptake, though, there was a decrease in the consumption of rice from 147 kg in 1960 to 130kg in 1985 (Huke, 1990). Bangladesh ranks third in total rice area but fourth in total production and sixteenth in yield out of 26 leading rice-producing countries of the world (Huke, 1990). Population in Bangladesh increases at the rate of 2.5%, nearly at the same rate as that of food grain production, leading to a constant deficit of 1.5 to 2.0 million tons of food grains per year. Per capita land available in Bangladesh is only 0.1 ha (0.25 acre). The present population of 115 million will reach 145 and 223 million by the years 2000 and 2030 respectively, if the population increases at the present rate. This population will require 25 to 48 million tons of food grains by the years 2000 and 2030, respectively. Food production has to be doubled over the next thirty to forty years. Future land available for cultivation will be rather reduced due to the increases of the population from 764 persons/ km^2 to 1,652 persons/ km^2 by the year 2030. The alternative to this massive problem is to increase the yield per unit area, and increase the cropping intensity.

Antiquity of rice in Bangladesh

The earliest references to the areas in Bangladesh are mythological rather than historical. Bangladesh is situated in the lower course of the river Ganges and historical evidences are available from the first quarter of the fourth century B.C. The earliest known people in this area were negritoes, followed by the proto-Australoid, who presumably came from western Asia. They might have introduced agriculture. From the dawn of agriculture and crop husbandry, rice was probably the most important crop that could be found based on various and distinctive names of rice and diversity of seasons and varietal names. The people of Bangladesh can be divided into four ethnic groups, the Dravidian group from South India, Proto-Australoid (Santals and Khasias), the mongoloid (Koch, Garo, Hajong, Chakma, Moghs, Monipuri) and the non-tribal, the largest group of people known as Bengali, after the language they speak. These "Bengali" people consist of a heterogeneous mixture of proto-Australoid, Mongoloid and caucasoid strains. From excavations at Pundra Nagar, a ruined city, 10 km from the town of Bogra of present Bangladesh, written evidences indicate that the king of Pundranagar by the third to second century B.C. ordered the distribution of rice from the store to the "distressed" people, though the nature of "distress" is not clear. This was the earliest written evidence so far available for the antiquity of rice in Bangladesh. There are reports of 81 varietal names in scripture of Buddhist era, Government reports in 1910 showed the names of 451 rice varieties. The Bengali name of unhusked rice or paddy is 'dhan' which is 'dhanya', 'shali' 'breehi' and for wild rice 'treena dhanya' and 'neebara' in ancient sanskrit languages in India. The

Table 2 Area, trend of production and yield of paddy in Bangladesh (1960-1992)

Year	Area (million ha)	Production (million tons)	Yield (t/ha)		Area under MV (%)
			Total	MV	
1960	8.55	12.91	1.51	—	—
1965	9.21	16.20	1.76	—	—
1970	10.30	21.73	2.11	5.08	2.5
1975	9.79	18.79	1.92	3.58	14.5
1980	9.99	21.27	2.13	3.43	20.0
1985	10.23	23.73	2.32	3.33	27.8
1989	10.10	23.73	2.35	3.10	37.8
1992	10.74	25.82	2.40	3.42	53.4

Source: Nasir Uddin, Md. 1993. MV=Modern rice variety

husked rice is called 'chal' or 'chawl' and cooked rice is 'bhat' in Bengali. The distinctive names of rice under different processes indicate its diversity. The knowledge of rice perhaps existed before the knowledge of cultivation (Haroun, 1977 ; Chatterjee, 1950).

Rice groups and seasons

Due to the variation in climate, soils and land types, three distinct seasonal rice groups are found with four ecotypes. These are "Boro", "Aus" and "Aman". The aman is divided into transplanted aman and broadcast aman or deep water/floating rice (Table 3). Seasonal and varietal characteristics of four ecotypes are described below (Alim *et al*., 1962).

1 Boro

The meaning of boro is not clear. This rice crop is usually irrigated. The season varies from December to May. Land types for the traditional varieties are low to very lowlands in the haor, baor and beel areas of the country but due to the introduction of modern rice varieties and expansion of irrigation facilities, medium high and medium lowlands are included. The present area under this season covers around 2.31 million ha. Due to favorable temperature and solar radiation (Table 1) the yield is the highest in this season and the area under the season is increasing gradually (Table 4). The characteristics of traditional land races in this season are lack of sensitivity to photoperiod, tolerance to cool temperature and lack of seed dormancy.

2 Aus

The term aus might have been derived from the Bengali word "Ashu" meaning early. The land races in this season have a short growth duration of 90-110 days. Land races are broad-seeded in dry land at the beginning of the monsoon in March. But the modern rice varieties are both direct-seeded and transplanted. The land types for this rice are highlands, medium high, medium lowlands of the country. The season usually starts in March and ends in August. Due to high temperature and low solar radiation (Table 1) and high pressure of diseases and pests, the yield is low in this season. Area under traditional va-

Table 3 Seasons, ecotypes, area and yield of rice in Bangladesh (Area and yield are for the year 1989)

Seasons and time	Eco- or Cultural types	Area (million ha)	Yield (t/ha)	MV area (%)
A Boro (December-May)	1) Irrigated rice	2.37	3.80	87
B Aus (March-August)	2) Direct-seeded aus (upland rice)	2.26	1.70	—
(May-August)	3) Transplant aus (rainfed lowland)	0.41	2.76	15
	4) Tiday wetland (boro-aus, saline)	0.80	—	—
C Aman (June-December)	5) Transplanted aman (rainfed lowland)	3.20	2.14	27
(Transplant Aman)	6) Tidal wetland (Non-saline)	1.65	3.0	—
(March-November)	7) Broadcasted aman (deepwater rice)	1.00	1.6	—

Source : Nasir Uddin Md, 1993

Table 4 Changes in area for the four rice seasons, paddy production and yield and future trend in Bangladesh

Year	Area (million ha)				Total area (mha)	Total production (mmt)	Yield (t/ha)
	Boro	Aus	DWR	T. Aman			
1960	0.37	2.40	1.80	4.0	8.55	12.51	1.51
1970	0.88	3.40	1.87	4.13	10.30	21.73	2.11
1980	1.14	3.15	1.58	4.42	10.21	21.27	2.05
1990	2.62	2.09	0.83	4.95	10.48	28.00	2.60
2000	3.25	2.0	0.5	5.0	10.75	32.25	3.00
2010	4.00	2.0	0.5	5.0	11.50	37.37	3.25
2020	4.50	2.0	0.5	5.0	12.00	42.00	3.50
2030	4.50	2.0	0.5	5.0	12.00	48.00	4.00

Source: Nasir Uddin M. 1993.

Hypothetical trend in change of area, yield and production of rice in Bangladesh (2000-2030).

rieties is decreasing (Table 4) while the area under modern varieties is increasing.

Characteristics of landraces of this group are short growth duration, adaptation to direct seeding under upland conditions, lack of sensitivity to photoperiod, sensitivity to cold and lack of seed dormancy.

Transplanted aman

The term aman may have been derived from the Arabic word 'Aman' meaning safety. The crop is seeded in July and harvested in the safe period from mid-October to mid-December at the end of the monsoon. Another name given to transplanted aman rice is "shali or sail dhan" means 'rice' in sanskrit language. Actually this is the main rice season (Table 4). Ancient literature deals with rice of this season. Highest varietal diversity is found in the landraces of this rice crop. The varietal characters are photoperiod sensitivity, seed dormancy and adaptation to cool temperature. The land includes usually the medium high and medium lowlands in the country. The growth duration is usually 135 to 150 days for the landraces.

Broadcast aman or deepwater rice

This type of rice is grown in the medium low and lowlands where the water depth varies from 100-300 cm depth during June to September. The crop is rainfed and direct-seeded and sometimes transplanted if direct seeding fails. This type of rice is also grown as mixed crop with 'aus' in one-third of the deepwater area in the proportion of one-third deepwater and two-thirds Aus. The aus, the short duration rice is harvested in May-June leaving behind the deepwater at the vegetative stage of growth.

The yield is the lowest and the area under this type of rice is decreasing year by year and converted to safer irrigated modern rice varieties (Table 4). The varietal characters for the rice are the same as those of transplanted aman i.e. photoperiod sensitivity, seed dormancy and in addition peculiar characteristics of internode elongation capacity during the rise of flood water. The height of deep water rice usually varies from 3 to 5 meter. There is a varietal diversity in this group which is adapted to different flooding conditions of the land. The early group known as "Bhadoia" and "Aswina" is harvested in September-October, respectively. The common deepwater rice is harvested from mid-October to mid-November. Another deepwater rice which is adapted to the very lowland conditions and is grown in mixture with 'boro' rice is known as "Rayada". This type of rice has all the characteristics of deepwater rice except that it lacks see dormancy and has a low seed viability. As after harvest in November, it is mixed-sown again with boro rice, Rayada rice becomes a 12-month crop.

Pest research on rice, production trends and future strategies

Research on rice started in 1910 at the Dhaka station near the present capital of Bangladesh, being the first rice research station in the Indian subcontinent. Studies on rice went through several phases, the British period (1910-1946), Pakistan period (1947-1971) and the period of rice breeding based on the concept of modern plant type (1966-). During this long period of 1910 to 1966 rice varietal improvement also experienced several stages. First stage involved the collection of local germplasm, purification through mass and pureline selection (1910-1933). In the second stage (1936-1947) hybridization among tall indica rice varieties was undertaken.

The third stage corresponds to the period of hybridization between indica and japonica types (1947-1965) and introduction of high-yielding modern plant types. The fourth stage corresponds to the period of introduction of IR 8 and improvement through hybridization based on modern plant type concept (1966-).

The first three stages involved the development of varieties of traditional plant types through mass, pureline selection and hybridization. During this period, a total of 63 varieties were developed. Out of these, 11 varieties in four ecotypes, 2 each in aus, deepwater rice, boro and 5 in transplanted aman were developed through hybridization. The other 52 varieties, 6 in boro, 16 in aus, 21 in transplanted aman and 9 in deep water rice were developed through either mass or pureline selection. Besides, cultural practices, pest management studies were also conducted during this period.

New era of rice research was ushered with the concept of modern plant type for the tropics and rice improvement in this line started in Bangladesh from 1966. An autonomous Rice Research Institute started functioning from October 1970 and rice research adopted a new direction under the Bangladesh Rice Research Institute from 1971. To date, 25 modern rice varieties were developed, of which 15 for irrigated rice, 3 for direct seeding, 11 for transplanted aus and 8 for transplanted aman. Modern rice varieties (mv) cover 50% of the area and contribute 70% of the total rice production in the country. Economically, it was estimated that 1 taka investment in rice research gives a benefit of 36 taka.

Rice area, production, yield and area under mv rice and trend of production are shown in Tables 2 and 4. It is clear that the production and yield have almost doubled over the last 30 years. But as the area under mv increased, the yield of mv decreased (Table 2). The decline of yield of mv rice is a matter of concern for policy makers, administrators and researchers and raises the question of sustainability and stability of Bangladesh production system. The decrease of yield of mv rice is attributed to the range of varieties with varied yield potential, expansion of mv areas from favorable to less favorable areas, decrease of intensity of management practices, increase of biotic pressures and degradation of soil resources. It is estimated that for the next thirty years, Bangladesh will require 42 million tons of rice which in turn will require to increase the yield from the present 2.4 t/ ha to 3.5 t/ ha (Nasir Uddin, 1993). This will be a challenge for rice researchers. As there is little possibility of increase of the area under rice, it is likely that the area under rice may even decline.

Recently three rice seasons of Bangladesh have been divided into 7 ecotypes (Table 3) to sharpen the focus and direct research to all regions and environments of Bangladesh, which may contribute to minimize the gaps in research that existd in the past (Table 3). Future research strategies should focus on the break of the present yield ceiling of mv rice and the development of stable, input-efficient higher-yielding rice varieties, increase of the rice cropping intensity, sustainable soil management, maintenance of an ecological balance and effective technology transfer mechanisms. To break the present yield ceiling of mv rice several options are available as follows: to change the present plant architecture with low tillering, heavy panicles with 150-200 grains, increase of harvest index. Physiological approach to break the yield ceiling consists of the partitioning of dry matter production and energy utilization by the rice plant, especially by increasing pre-heading starch storage. The third possibility is the adaption of hybrid rice, though complicated and expensive (Nasir Uddin, 1993).

Genetic resources, wild and weed races of rice in Bangladesh

Bangladesh as a part of the Indian gene center is considered to be one of the centers of origin of cultivated rice (Chatterjee,1950). It has a rich varietal diversity of landraces and wild rices. Bangladesh has

three distinct rice seasons and four rice ecotypes. These seasonal rice groups are distinct in terms of physio-ecological requirements as stated earlier. No country in the world has such distinct rice seasons and ecotypes. In each ecotype, there is a diversity in landraces with their distinct names and characteristics. Besides, there are ethnic or tribal people living in Bangladesh who have also their special rice for their own purpose, e.g. wine-making, etc. Tribal rices could be considered primitive or obsolete types.

Recently, three species of wild and weed races have been identified (Morishima,*et al.*, 1991; Nasir Uddin, 1993; Vaughan, 1988). The wild rices consist of annual (*O. nivara* type), perennial (*O. rufipogon*) and two samples of *O. officinalis* types collected in 1992 from the coastal region of the country by the author and his colleagues. Existence of wild rice in this part of the subcontinent was reported by Prain in 1903 in his book on Bengal plants. There were sporadic reports on the occurrence of wild rices in Bangladesh but no effort was made in the past for collection, conservation and characterization of wild and weed races of rice. Collections by the author and Vaughan identified great variations in the wild rices as regards their morphology among the annuals and perennials. About 70 samples of wild and weed races were collected, conserved and future collection will continue. Out of estimated 4,000 landraces, 3,000 have been collected and conserved. Future collection of rice germplasm will involve tribal rices, rice from the remote and difficult areas, wild and weed rices (Nasir Uddin, 1983). David Prain reported in 1903 five species of wild rice in Bengal, as follows: *O. sativa* var. *fatua, O. latifolia, O. granulata, O. sativa* var *plena* and *O. coarctata. O. coarctata* has recently been excluded from the genus and named *Porteresia coarctata.* We collected a few samples of *P. coarctata* from the coastal region of the country (Nasir Uddin *et al.*, 1993). The species displays saline and tidal submergence tolerance.

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Discussion

Nakagahara, M. (Japan): What is the present situation of preservation of floating rice germplasm in your country and what are the results of collections of landraces of the floating type of *O. sativa*?

Answer: About 80% of floating or deep water rice has been collected and some of the materials have been sent to IRRI for long-term storage. There are sill remote area where such materials could be found. Also wild rice which is very close to floating rice has been collected. All the floating types belong to *O. sativa*. The floating rice area is decreasing as it is converted for the cultivation of irrigated modern rice varieties.

Kikuchi, F. (Japan): 1. You mentioned that out of the estimated 4,000 landraces, 3,000 have been collected. Do you plan to collect the rest? 2. Do the modern varieties mostly belong to the boro type?

Answer: 1. We plan to continue the collection of the rest of landraces. 2. Modern varieties belong to all the three season types, boro, aman and aus. In the boro season, boro varieties account for the largest proportion (87%).