

Impact of Irrigation on Food Security in Bangladesh for the Past Three Decades

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Abstract

Bangladesh has made impressive progress in agriculture sector in the last three decades and has almost become self-sufficient in food grain production. This is a tremendous achievement owing to its small territory and huge population and this was achieved through agricultural mechanization and modernization. Irrigation is one of the leading inputs has direct influence to increase yield, food grains production and plays vital role for ensuring food security in Bangladesh. The present study examined the growth of irrigated area and its impact on food grain production during last three decades. Time series data were used for the study. Different statistical methods such as mean, percentage, linear and exponential growth model were applied for getting meaningful findings. Various technologies have been used for irrigating crops which have contributed to rapid expansion of irrigated area. The conventional irrigation methods (Low Lift Pump, Dhona, Swing Basket, Treadle Pump etc.) were replaced by modern methods (i.e Deep Tube Well and Shallow Tube Well). In addition, surface water irrigation also sharply declined, losing its importance due to lack of new surface irrigation project and the ineffectiveness of earlier project. Groundwater covered 77 percent of total irrigated area and major (62%) extractions occurred through Shallow Tube Wells (STWs). The rapid expansion of ground water irrigation in respect to STWs irrigation was due to government's withdrawal on restrictions on tube well setting rule, encouraging private sector and the cost effectiveness of Chinese engine which have been affordable to the small and medium farmers. Irrigated area thus, increased by about three times and cropping intensity also increased from 154 to 176 percent. *Boro rice*, an irrigated crop, consumed 73 percent of the total crop irrigation and contributed to a greater extent in total rice production in Bangladesh. *Boro rice* alone contributed to 55 percent of total food grain and was also highest (3.44 MT per hectare) compared to *aus rice* (1.66 MT per hectare) and *aman rice* (1.99 MT per hectare) per unit production. Consequently, the cultivated area of *boro rice* increased by 1168 to 4068 thousand hectares. The higher productivity of *boro rice* has almost helped the nation to meet her food requirements (about 24 Million MT). *Boro rice* production was highly correlated ($r = .978$) with irrigated area. Expansion of one hectare of irrigated area added 3.22 MT of *boro rice* in Bangladesh. Finally, the study suggested for expansion of irrigated areas (ground water and surface water), adoption of modern technologies and formulation of farmers' friendly policy.

Keywords: Irrigation, Food Security, Boro Rice and food Grain Production

1. Introduction

South Asia is a home of 1.5 billion people most of which live in India and Bangladesh. Bangladesh, the most densely populated country in the world has been suffering from food deficiency for a long time. Food scarcity has remained the major challenge for the government since

liberation (Independence, 1971) as it tries to increase food grain production to meet the demands of the nation's growing population. Since the economy of an agrarian society (like Bangladesh) is dominated by agriculture and the livelihoods of the farmers are largely connected with intensive agriculture production. Food grain occupies the lion's share of agricultural GDP and it em-

ploys about 60 per cent of total labour force [1]. Hence, any internal and external threat (social, political, natural and environmental) to agriculture directly affects food grain production as well as food security of the country.

Food security is defined as access to enough and safe food by all people at all times for maintaining an active and healthy life. Aggregate domestic production and per capita availability of food grains increased in the country over the past decades. But the country still depends on import of food grains (in 2007-08 imported 11.5 percent of total availability) [2]. Therefore, it is timely demand to explore the domestic potentiality and to increase production for attaining the Millennium Development Goal (MDG goal is to reduce the extreme poverty to half by 2015 ensuring food as basic requirements).

Rice is staple food of Bangladeshi people and it constituted about 90% of the total food grain production [3]. Of the three types of rice *aus*¹, *aman*² and *boro*³, the *Boro* rice alone contributed the highest share of total rice production since 1998-99 to date [4]. Therefore, increase of *Boro* rice production would be a significant possible way to overcome food deficiency in the country. *Boro* rice is produced in *Rabi* season (October to March) and it grows totally under irrigated condition. Thus, development of irrigation availability is playing a vital role in this regard.

There are two major sources of irrigation in Bangladesh-surface and ground water. Low Lift pump (LLP), Canal and Traditional (Dhone and Swing basket) are used as a means of technology for surface water irrigation while Deep Tube Wells (DTW)⁴, Shallow Tube Wells (STW)⁵ and Hand Tube wells are used for ground water irrigation. Before 70s, irrigation was mainly dependent on surface sources and in the mid-seventies government emphasised on groundwater irrigation with DTW projects. But government soon shifted to STW because of its suitability to socio-economic status of the farmers (less investment cost, small land holdings, availability in the market, withdrawing restriction on import and STWs spacing) and STWs enclosed 62 per cent of total irrigated area [5]. The total irrigation coverage was increased 1726 to 5898 thousand hectare within the period of 1981-82 to 2006-07 (342 per cent) whereas irrigation potential is estimated at 7,550 thousand hectares [6]. There is still possibility to expand 28 percent of irrigated area according to irrigation potentiality. At present groundwater contributes to 77 percent of total irrigated area in Bangladesh [5].

About 80 percent of groundwater was used for crop

^{1,2}Mostly rain fed rice, ³Irrigated rice, ⁴The discharge capacity of deep tube wells are about 50 lt/sec having greater depths (upto 100-120m) and larger diameter compared to shallow wells. ⁵Shallow Tube wells are small irrigation wells having discharge capacities of 12-15 lt/sec with maximum depths of 40-60m and well diameter of 100-150mm.

production in which *Boro* paddy consumed 73 percent of total irrigation [7]. Hence, *Boro* rice production is increasing at about 1% annually and contributes to 55% of the total rice production [8]. The application of ground-water irrigation increased with the introduction of High Yielding Variety (HYV) seeds to meet the food requirements of a growing population [9]. In contrast the yield potential of the existing HYV rice is more than 4 MT/ha., whereas the average yield realized by the majority of farmers is less than 3.0 MT/ha [2]. Thus, on farm research is important to reduce the production gap. In addition groundwater-based irrigation economy is crucial for increasing domestic production, attaining food security and lifting millions of poor farmers out of poverty. Hence, this paper intends to acquire an integrated understanding of the importance of irrigation, its impacts on food grain production and rural livelihoods and also the role of existing policy and institutional guidance.

2. Methodology

The present paper is mainly based on secondary sources of information. Data were collected from Bangladesh Bureau of Statistics (BBS) in the period of 1980-81 to 2006-07. Moreover, Bangladesh Agricultural Development Corporation (BADC), published articles, Economic Review, and Fifth Five Year Plan was also taken as a crucial source of data. After collecting necessary (time series) data, they were analysed using tabular, graphical and econometric techniques. Microsoft Excel and SPSS program was applied for analysing data in a meaningful way. Both linear and exponential equations were used for representing time series data. The equations are as follows-

$$Y_e = a + bt \quad (1)$$

and

$$Y_e = Ae^{bt}, \quad (2)$$

after taking log the equation is- $\log Y_e = \log A + bt$

Y_e = dependent variables

a = intercept

b = Co-efficient

t = time series

3. Development of Irrigation Technologies and Cropping Intensity

At the initial stage of irrigation development, the main emphasis was on low lift pump for extracting surface water and later on, Bangladesh Agricultural Development Corporation (BADC) initiated capital-intensive methods for DTW installation in Bangladesh and provided subsidized well components (pumps, drilling equi-

pment, etc.) for rapid expansion of larger public groundwater irrigation schemes (1960s started from Thakurgoan area, north-western part of Bangladesh). Privatization and expansion of minor irrigation and withdrawal of Government subsidy in irrigation equipment lead to tremendous development of STWs during last two decades [10]. The percentage contribution of different irrigation technologies is shown in Table 1. Table 1 depicts that the uses of surface irrigation drastically reduced while groundwater irrigation technologies increased significantly.

Modern irrigation mainly consists of DTW and STW which have almost entirely replaced the pioneer Low Lift Pump (LLPs) and at the same time DTWs is gradually losing its application as it is economically and socially inappropriate [11]. The share of surface water irrigation technologies (LLP) reduced by 41 to 16 percent of total irrigated area during 1981-82 to 2006-07. Again the traditional (i.e. dhona, swing basket etc) and canal irrigation

coverage sharply declined to about 10 percent (canal 3 percent and traditional 7 percent). On the other hand, groundwater irrigation increased significantly particularly due to rapid expansion of STWs technologies. In early 90s the STW and DTW irrigation covered 37 and 24 percent of total irrigated area respectively. Within two decades, STWs occupied 62 percent of total irrigated area while DTW irrigation coverage was only 14 percent. This indicated that small farmers' share on STW ownership has increased significantly over the years in Bangladesh because of less investment cost, easy installation, easy maintenance and can be shared among small groups of farmers, convenient for small landholding owners and withdrawal of import restrictions [12]. It appears from Table 1 that the percentage of irrigated area increased over time. In 1981-82 total irrigated area was 16 percent whereas in 2006-07 it observed 56 of total cultivated area.

Table 1. Percentage of irrigated area by various technologies in Bangladesh.

Year	DTW	STW	LPP	Canal	Traditional	Others	Total irrigated area ('000) hectare	Total cultivated area ('000 ha.)	Percentages of irrigated area	Cropping intensity
1981-82	15.7*	40.8	9.5	25.6	8.4	1726	10491	16	153.70	
1985-86	45.9*	29.0	7.8	12.1	5.2	2098	10447	20	154.47	
1991-92	20.3	37.4	22.3	5.7	13.1	3028	10249	32	171.81	
1995-96	19.1	46.3	19.1	4.3	10.3	3554	9946	36	173.18	
2001-02	14.74	56.39	16.71	3.54	7.04	4598	10665	43	176.94	
2004-05	14.24	59.60	15.93	-	9.70	5037	10373	49	176.85	
2005-06	14.29	61.77	15.31	-	7.72	5604	10534	53	175.96	
2006-07	13.82	61.80	16.27	-	7.12	5898	10579	56	176.07	

* Indicates both STW and DTW percentages

Table 2. Shows the rice requirements and availability in domestic sources and also external sources during 1991-92 to 2006-07.

Year	Production ('000MT)			Total rice production/availability ('000MT)	Total requirement ('000 MT)	Gap	Food availability gm/cap/day	External sources aid + import ('000MT)
	Aus	Aman	Boro					
1991-92	2179	9269	6804	18252	18710	-458	454	-
1992-93	2075	9680	6586	18341	19040	-699	445	1183
1993-94	1850	9419	6772	18041	19370	-1329	440	966
1994-95	1791	8504	6538	16833	19700	-2867	428	2568
1995-96	1676	8790	7221	17687	20030	-2343	439	2427
1996-97	1871	9552	7460	18883	20360	-1477	430	967
1997-98	1875	8850	8137	18862	20690	-1828	455	1951
1998-99	1617	7736	10552	19905	21040	-1135	522	5491
1999-00	1734	10306	11027	23067	21380	1687	514	2104
2000-01	1916	11249	11921	25086	21510	3575	545	1554
2001-02	1808	10726	11766	24300	21790	2510	521	1798
2002-03	1850	11115	12222	25187	22090	3097	564	3220
2003-04	1832	11520	12838	26190	22380	3810	554	2788
2004-05	1500	9819	13837	25156	22680	2476	539	3374
2005-06	1745	10810	13975	26530	23010	3520	534	2459
2006-07	1512	10841	14965	27318	23250	4068	540	1440

The cropping intensity is determined as the ratio of total cropped area of multiple crops within a year to net cultivated area, which is expressed in terms of percentage. Farmers typically grow one or two crops per year and leave their lands fallow for rest of the time. The cropping intensity increased by 154 to 176 percent within the period of 1981-82 to 2006-07 (Table 1), while in some regions it was about 200 percent (Bogra and Comilla district). The rapid boost of cropping intensity was possible due to expansion of irrigated area and development of irrigation technologies in Bangladesh.

4. Food Requirements and Availability

It is observed that from 1991-92 towards 1998-99 there were deficit in rice production and the deficit ranged from 458 to 2867 thousand metric tons.

Later, the country reached to a marginally self-sufficient in rice production and it exceeded the country's total requirement of about 1600 to 4000 thousand metric tons. In reality the country with this small amount of surplus production is in a vulnerable situation as it is always threatened by frequent disasters like drought, flood, cyclone and sidr etc, which causes damage to the country's valued rice crops almost every year [1]. As a result, the government has to seek for foreign aid and import every year to make food reserve as buffer stock (Table 2). The amount of import and foreign aid varies according to extent of natural calamity and domestic

production. The external sources of food was highest (5491 thousand MT) in 1998-99 as country was severely affected by flood. *Boro* rice usually, is less affected by natural disaster and consequently occupied largest share (55 percent in 2006-07) of total rice production. Moreover, 98 percent of *boro* rice is HYV and produced under irrigated condition.

5. Trends of Rice Production in Bangladesh

Within the crop sub-sector, food grains particularly the rice dominates in respect to both cropped area and production [13]. The following Figure 1 shows the trend of rice production in Bangladesh during 1980-81 to 2005-06. The production of *aus* rice was decreased while *aman* and *boro* rice was increased over the period of 1981-82 to 2005-06. Again, the fluctuation of *aman* rice as well as *aus* rice production was common due to the above named disasters and natural calamities. In 1988-89, 1998-99 and 2004-05 production year, *aman* rice production was drastically fall because of devastating flood all over the country (Figure 1). In such circumstances, people rely on *boro* rice production and they provide full efforts to overcome the crisis. *Boro* rice compensated the deficits because of its less reliant on nature and varietal improvement. Moreover, effective implementation of rehabilitation programs by the government and timely supply of inputs including irrigation equipments was also another reason of success. The R^2 value was higher for *boro* rice production than *aman* rice production.

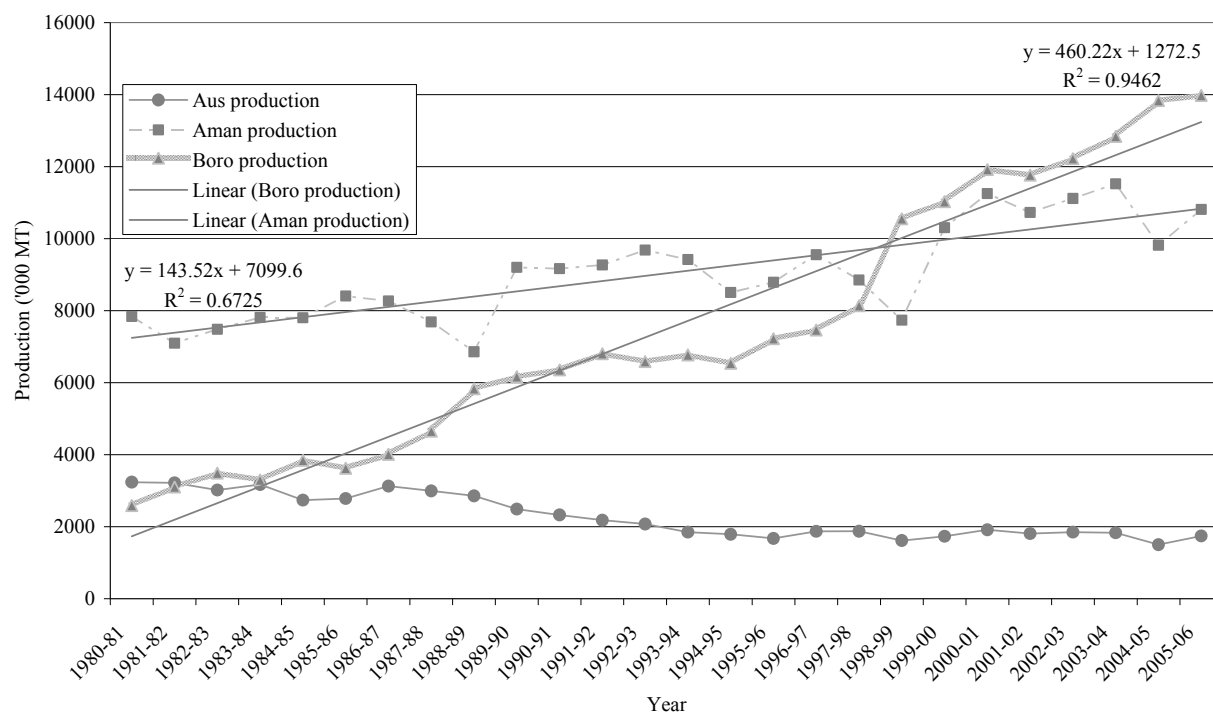


Figure 1. Trend of aus, aman and boro rice production in Bangladesh.

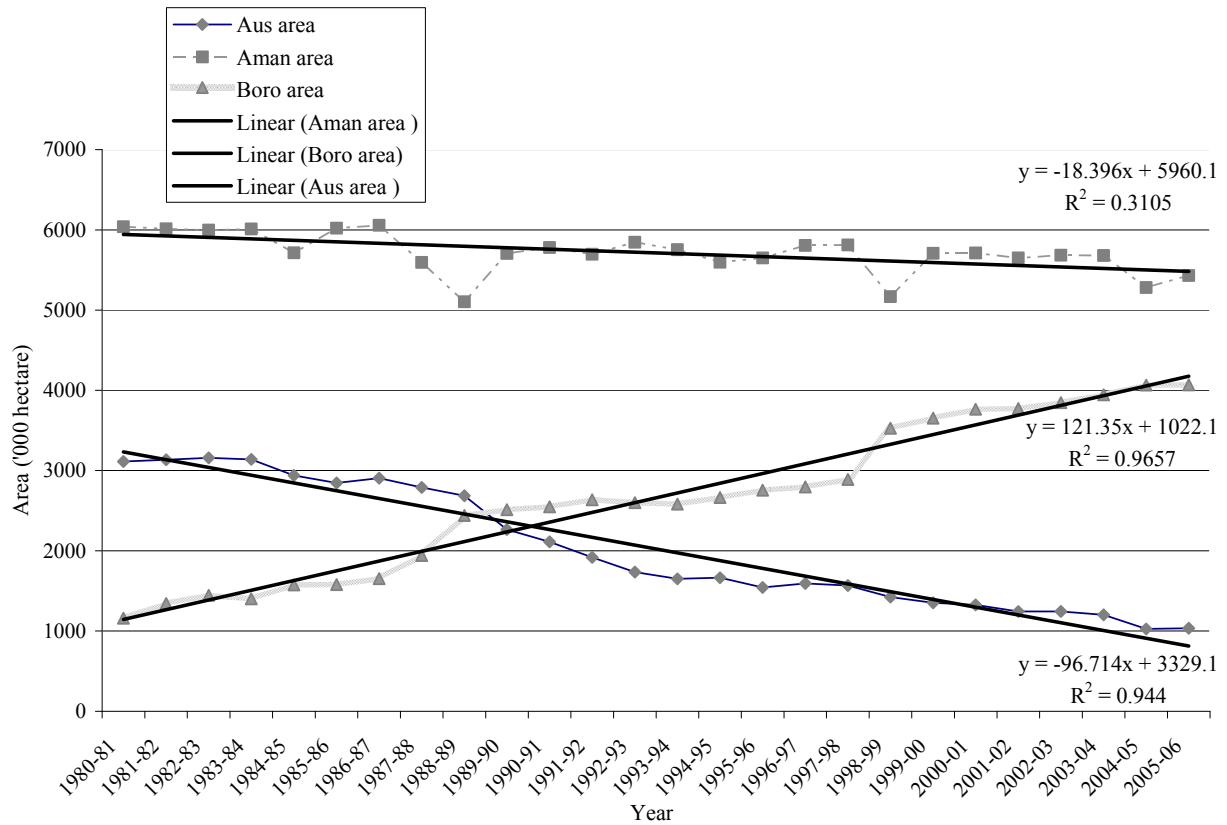


Figure 2. Trend of aus, aman and boro cultivated area in Bangladesh.

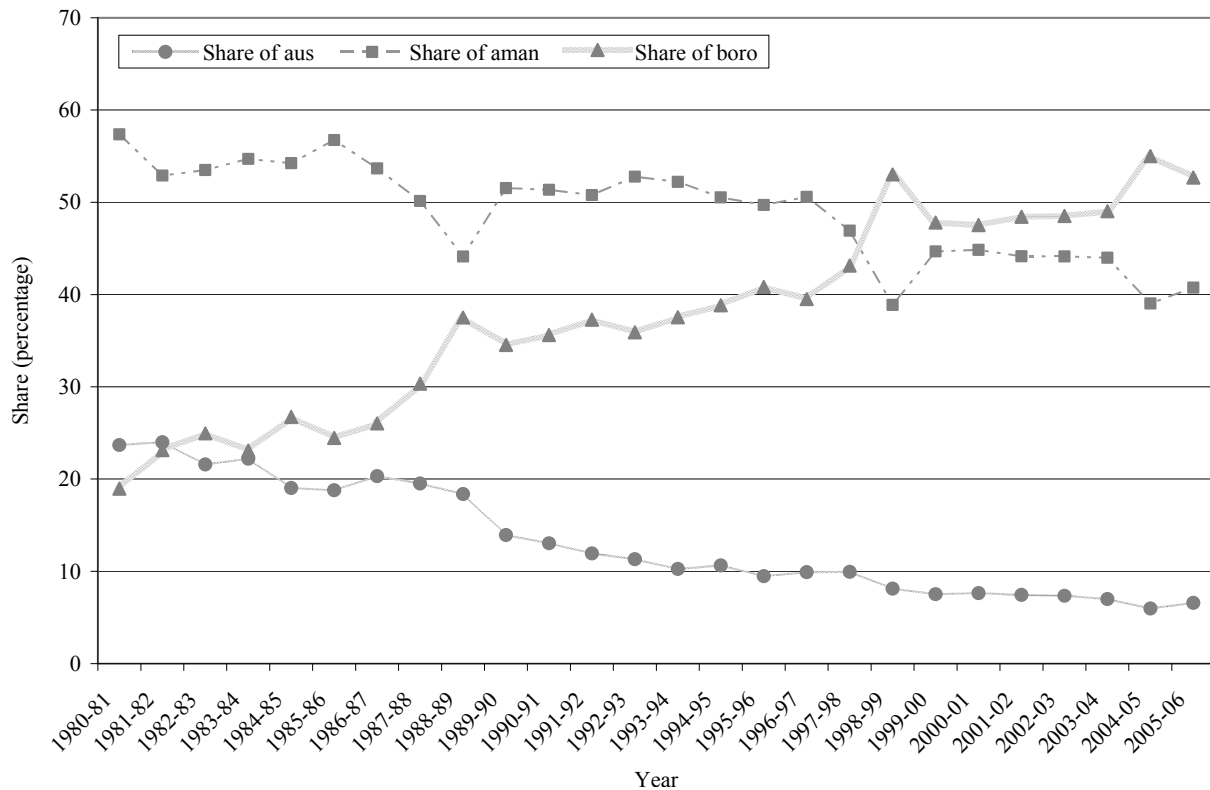


Figure 3. Percentage of aus, aman and boro production of total rice production in Bangladesh.

6. Trend of Rice Cultivated Area in Bangladesh

At present, rice covers 75 percent of total cultivable land in Bangladesh [5]. Figure 2 depicts the trend of different rice cultivated area during 1980-81 to 2005-06. It is interesting that most of *aus* rice cultivated areas were occupied by *boro* rice while *aman* cultivated area slightly declined over the time. It might be the reason of relatively less varietal improvement of *aus* and *aman* rice than *boro* rice and seasonal calamity. In the year of 1980-81 the *boro* cultivated area was 1161 thousand hectares and it was increased by 4068 thousand hectares after three decades of irrigation development while *aus* rice production area decreased by 3113 to 1035 thousand hectares within this period of time. On the other hand, *aman* cultivated area declined but still its occupied higher area than others. The fluctuation of *aman* cultivated area was also observed particularly in the natural disadvantaged years.

7. Contribution of *Boro* Rice to Total Rice Production

Boro rice is relatively free from weather hazard as it is grows in winter season. As a result, quick adoption of *boro* rice by the farmers' remarkably increased which made a substantial contribution to food grain production

as well as agricultural development as a whole in Bangladesh [14]. The share of total rice production in different types of rice for the period of 1980-81 to 2005-06 is shown in Figure 3. At the initial stage of irrigation technology development, *Boro* rice contribution was lowest among different seasonal rice (*aus* and *aman*) but it is occupying the highest position since 1998-99 to date. In 1980-81 *aman* rice dominated and contributed to 57 percent of total rice production while *aus* and *boro* rice contribution was only 24 and 19 percent respectively. Figure 3 show that *boro* rice contribution to total rice production was in an increasing trend and increased by 55 percent in 2004-05 from 19 percent in 1980-81. Meanwhile *aus* rice contribution decreased at a greater length which could be due to traditional cultivation method, less varietal improvement and its replacement by *boro* rice.

8. Per Hectare Yield of Different Seasonal Rice

The average rice yield of Bangladesh is lower than in Asian countries like India, China [7]. Figure 4 shows per hectare yield of *aus*, *aman* and *boro* rice during 1980-81 to 2005-06. However, it was noted that all kind of rice yield was in an increasing trend and the gap between *aus* and *aman* rice yield was more or less similar. But the *boro* rice yield was about two and three times higher than *aman* and *aus* rice respectively. The major reason behind such differences observed was because *boro* rice

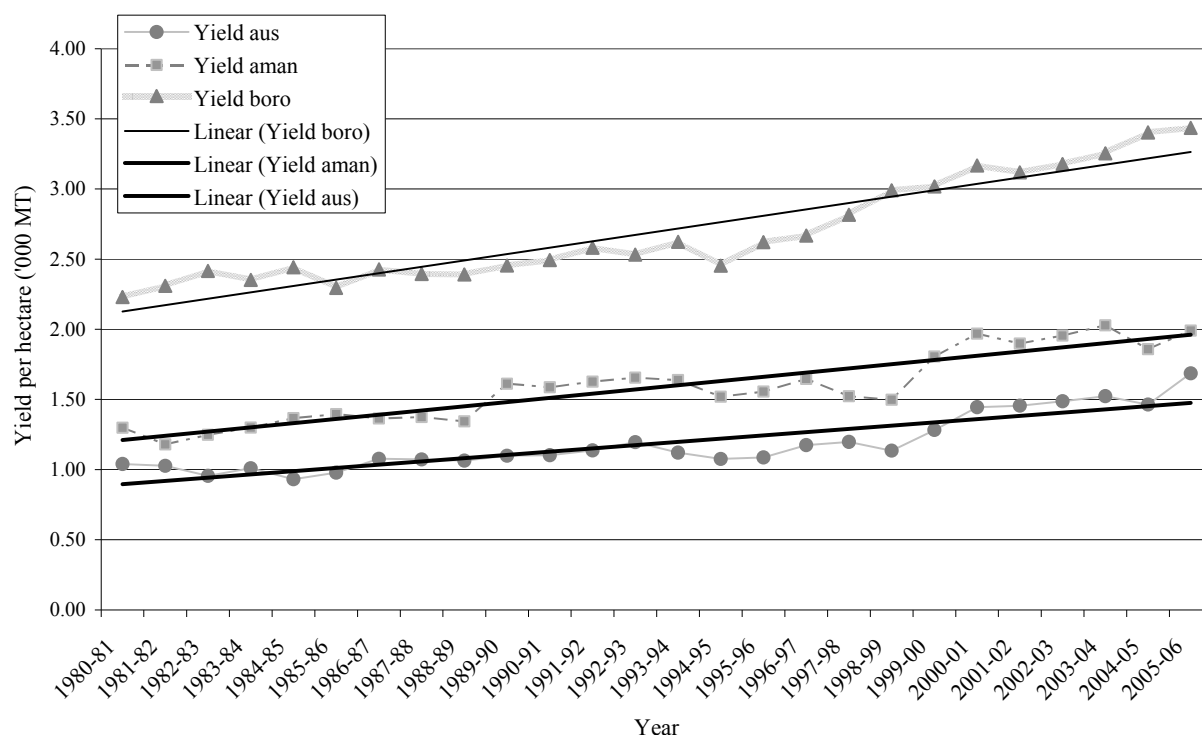


Figure 4. Per hectare yield of *aus*, *aman* and *boro* during 1980-81 to 2005-06 in Bangladesh.

varieties (97 percent) were High Yielding Variety (HYV) while it was less common for *aus* and *aman* rice. Figure 4 represent that though per hectare production increased till (2005-06), it did not exceed 2 MT/ha. for *aus* and *aman* rice yield whereas *boro* rice yield was about 2 MT/ha. in 1980-81 (the initial stage of groundwater irrigation) its yield increased by 65 percent (2.23 MT/ha. in 1980-81 and 3.44 MT/ha. in 2005-06) during last three decades.

9. Irrigation Coverage in Different Region

Irrigation coverage is not equally distributed all over the country because of different topography, availability of modern irrigation technology and socio-economic status of farmers. Map 1 shows the percentages of irrigation coverage in different region of Bangladesh in the production year of 2007-08. Four colours used to indicate the extent of irrigated area in different regions. It is observed that percentage of irrigated area was highest (green colour, 100-75 percent) which constituted 11 districts out of 64 districts and mostly situated in the north and north-western part of the country. There were also 19 districts moderately irrigated (75-50 percent mentioned as sky colour) composing upper middle and mid eastern part of the country. Another 19 districts were 50-25 percent under irrigated condition constituted in the middle and lower part of the country. Remaining 15 districts mostly situated in the hilly and coastal belt of the country had less irrigation coverage (below 25 percent). In recent time government has taken some initiative to expand irrigated area in the coastal belt by protecting coastal water resources [15].

10. Relationship of Different Parameters

10.1. Area and Production

Following Table 3 shows the relationship between cultivated area and production of different rice in Bangladesh.

It can be observed from table 3 that *boro* rice production was highly correlated ($r=0.986$) with cultivated area while *aman* rice production was negatively related. *Aus* rice production was also statistically significant at 1 percent level with cultivated area at a value of 0.703 which indicated strong correlation. The R^2 value of linear model was .943, .012 and .972 for *aus*, *aman* and *boro* respectively which implied that independent variables (cultivated area) could explain 94, 1 and 97 percent of dependent variable (production) of *aus*, *aman* and *boro* rice respectively. More or less similar results also appeared in exponential growth model.

10.2. Irrigated Area and *Boro* Rice Production

Boro rice is grown on fully irrigated condition therefore, only relationship between *boro* rice production and irrigated area has been examined. The summary of the results are shown in Table 4. The result shows that the increase of one hectare irrigated area added 3.22 MT rice considering *boro* rice production with irrigated area in Bangladesh. In addition R^2 value explained about 96 percent of dependent variable (*boro* rice production) by the independent variable (total irrigated area). Moreover, *Boro* rice production was strongly correlated ($r=.986$) with total irrigated area in Bangladesh.

Table 3. Relationship between cultivated area and production of rice during 1980-81 to 2005-06.

Type of rice	Linear model				Exponential model				Pearson Correlation (r)
	R ²	Intercept (a)	Coefficient (b)	t	R ²	Intercept (a)	Coefficient (b)	t	
<i>Aus</i>	.943	752.71	.7548	399.45**	.938	1149.48	.0003	365.33**	.703**
<i>Aman</i>	.012	5897.70	-.0206	.596	.008	5865.00	-3.E-06	.661	-.811**
<i>Boro</i>	.972	-2561	3.7764	818.16**	.993	1579	.0005	3406**	.986**

** indicates as 1 percent significant level (2 -tailed)

Table 4. Relationship between irrigated area and *boro* rice production during 1980-81 to 2005-06.

Type of Rice	Linear model				Exponential model				Pearson correlation (r)
	R ²	Intercept (a)	Coefficient (b)	t	R ²	Intercept (a)	Coefficient (b)	t	
<i>Boro</i> rice	.957	-3225.7	3.220	492.01**	.975	1490.70	.0005	870**	.978**

** indicates as 1 percent significant level (2 -tailed)

11. Conclusion and Suggestion for Policy Implication

Irrigation is one of the key factors making the country self-sufficient in food grain production and contributes greatly towards agriculture GDP (Gross Domestic Production). Irrigation particularly ground water irrigation plays an important role for alleviating rural poverty in Bangladesh. It materialized that irrigation technologies are developing and small and medium farmers are involved more in the production process which enhanced their household food security in particular and national food security in general. From findings it appears that ground water irrigation has been given more emphasis from government as well as individual entrepreneur point of view though National Water Policy (NWPo) has highlighted the conjunctive use of surface and ground water [16]. Further more NWPo suggested to ensure the availability of water to all elements of society (poor, unprivileged), accelerating public and private water delivery system encompassing water right, water pricing, efficient water management considering economic efficiency, environmental degradation and climate change. Therefore, it should be given similar or more attention for the development of surface water irrigation in Bangladesh.

The average yield of rice is low especially for *aus* and *aman* rice as compared to Asian countries (India and China) therefore it is of urgent need to increase government investment in research for varietal improvement and on farm water management. Regarding varietal improvement, only 53 percent land was under HYV rice in case of *aus* cultivated area and it was 62 percent for *aman* rice in 2006-07. On the other hand HYV occupied 97 percent of *boro* rice cultivated area in the same year. Thus, there is a greater chance for varietal improvement to increase per unit production.

Increasing one hectare of irrigated area added 3.22 MT *boro* rice production therefore it is highly recommended for expansion of remaining land (28 percent) under irrigated condition for achieving country food requirements. However, there is a concern of arsenic contamination and declining water level due to ground water extraction over 20-30 years [17]. *Boro* rice production should be emphasized due to its less dependence on natural calamity, high varietal improvement (97 percent), and higher per unit production as compared to other seasonal rice (*aus* and *aman*).

Existing institutions should be strengthened as well as capacity building for sustainable development and management of ground water and surface water irrigation due recent concerns about salinity, declining water level, ground water arsenic contamination, absence of irrigation pricing rules and regulations and power crisis etc. [18]. Hence, formulation of "Groundwater and Surface water Act" is necessary for ensuring farmers benefit and

long-run sustainability of natural resources. Irrigation has direct influence towards farmer's socio-economic status therefore; further study could investigate the implication of irrigation on poverty alleviation in rural Bangladesh.

12. References

- [1] M. S. Alam, M. R. Islam, M. A. Jabber, M. S. Islam and M. A. Salam, "Institutional backup towards food security in Bangladesh," In Proceedings BKAS 13th National Conference and Seminar on Climate Changes: Food Security in Bangladesh, Vol. 13, Dhaka, Bangladesh PP, August 2008.
- [2] R. K. Talukder, "Food security in Bangladesh: National and global perspectives," In Proceedings BKAS 13th National Conference and Seminar on Climate Changes: Food Security in Bangladesh, Vol. 13, Dhaka, Bangladesh PP, August 2008.
- [3] M. Z. Huda, "Regional development of irrigation technologies and its impact on food grain production in Bangladesh," MS Thesis, Department of Agricultural Economics, BAU Mymensingh, Bangladesh, 2001.
- [4] Bangladesh Economic Review (BER), Bangladesh Economic Survey, 2005, Finance Division, Ministry of Finance, Government of Bangladesh, Dhaka, Bangladesh, 2007.
- [5] Bangladesh Bureau of Statistics, Statistical Year, Book of Bangladesh, Bangladesh Bureau of Statistics, Statistics Division, Ministry of planning, Government of People's Republic of Bangladesh, Dhaka, 2008. (http://www.bbs.gov.bd/agriculture_wing/annual_agri_stat.pdf)
- [6] T. Ernest, "Water profile of Bangladesh," In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D. C.: Environmental Information Coalition, National Council for Science and the Environment), FAO, 2007.
- [7] M. W. Rahman and R. Ahmed, "Shallow tube well irrigation business in Bangladesh," Paper Presented at Summary and Synthesis Workshop at Kathmandu, Nepal, March 20-24, 2008.
- [8] Bangladesh Bureau of Statistics, "Statistical year book of Bangladesh," Bangladesh Bureau of Statistics, Statistics Division, Ministry of planning, Government of People's Republic of Bangladesh, Dhaka, 2007.
- [9] Bangladesh Economic Review, Bangladesh Economic Survey, 2005, Finance Division, Ministry of Finance, Government of Bangladesh, Dhaka, Bangladesh, 2006.
- [10] A. Zahid and S. R. U. Ahmed, "Groundwater resources development in Bangladesh: Contribution to irrigation for food security and constraints to sustainability," Groundwater Governance in Asia Series-1, pp. 25-46, 2006.
- [11] R. P. Jones, "Irrigation service market in Bangladesh: Private provision of local public goods and community regulation," Paper Presented in Workshop on Managing Common Resources at the Department of Sociology, Lund University, Sweden, 2001.

- [12] M.A.S Mandal Ed “Dynamics of Irrigation Market in Bangladesh, Changing Rural Economy of Bangladesh. Bangladesh Economic Association, Dhaka, 2000.
- [13] Fifth Five Year Plan “Mid- term review of the Fifth Five Year Plan 1997-2002”, Planning Commission, Ministry of Planning, Government of Bangladesh, Dhaka, Bangladesh, 2000.
- [14] S. Islam and A.N M.R Karim Ed, “Increasing Rice Production in Bangladesh: Challenges and Strategies” International Rice research Institute, Los Banos, 1999
- [15] M. K. Mondal, T.P Tuong, S.P Ritu, M.H.K Chowdhury, A. M Chasi, P.K Majumder, M.M Islam and S.K Adhikary “ Coastal water resource use for higher productivity; Participatory research for increasing cropping intensity in Bangladesh” Paper presented in the international conference on Environmental and livelihoods in the coastal zones; managing agriculture- aquaculture conflicts held in Bac Lieu, Vietnam, March 2005.
- [16] NWPo. (1999). National Water Policy, Ministry of Water Resources, Dhaka, Bangladesh, 1999.
- [17] Stephan K, R. Kipfer, Olaf A. C, Charles F. Harvey, M S. Brennwald, K. N. Ashfaqe, A B M. Badruzzaman, S J. Hug, and Dieter M. (2006) Groundwater Dynamics and Arsenic Mobilization in Bangladesh Assessed Using Noble Gases and Tritium, Environmental Science and Technology, (<http://pubs.acs.org/doi/abs/10.1021/es05124w>)
- [18] M. A Sattar, and M. Moniruzzaman “Innovative Rice-based Farming Practices for Increasing Food Security in the Changing Coastal Environment of Bangladesh”, in proceedings BKAS 13th National conference and seminar on Climate Changes: Food Security in Bangladesh, Vol. 13, Dhaka, Bangladesh, August 2008.