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Irrigated Agriculture in High Barind: Existing Situation and Future Activities.

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ABSTRACT: Normally the north west part of Bangladesh, specially, the high Barind tract, faces more draught every year than the other parts of the country. This study area comprisesthree districts, namelyRajshahi, Chapai Nawabganj and Naogaon, in the north west part of Bangladesh. This area is one of the most important agriculturally important area in the north west part of the country and the coverage of irrigated area has beenincreased significantly during the recent few years with the introduction of high yielding varieties of rice and other grain crops, though during the last two to three decades, it has been experienced more draught condition in the study area. The cropping intensity (202 percent) of the study area is slightly higher than that of the national average (197 percent).The draught tolerant varieties of crops are highly effective and useful inthe high Barind area (study area).The cropping intensity and the crop diversity can be increased with the improvement of nutritional security and soil fertility. To overcome the drought problem, crops can be cultivated with efficient irrigationand effective cropping practices. Ground water development for irrigation in agriculture sector is an essential component for better agriculture. Surface water resources may be increased for supplementary irrigation in the study area. Harvesting of rain water and artificial recharge of the underground aquifers are the pre-requisites for the expansion of future agriculture.These practices should be popularized among the farmers in the study area.

KEYWORDS: HighBarind area; irrigated agriculture; existing situation; future activities.

I. INTRODUCTION

There is a proverb that "Barind is the land, where life is written in water." It is true for all over the Barind areas of Bangladesh. Barind tract is a draught prone area in the north west region of Bangladesh. Among Barind areas, there are some severe drought prone areas in Rajshahidivision named as high Barind tract. The Barind tract, thatlaying in Rajshahi, Chapai Nawabganj and Naogaon districts, is one of the distinct areas of Bangladesh,occupyingaround0.75 million hectares of land, which is 23.97 percent of the north western region of Bangladesh [1].It is completely different from other parts of the country, due to its undulating topography having compact and low fertile soils [2].The region experienced high temperature with limited soil moisture storage along with low and erratic rainfall [2,3].Land in the high Barind Tract exhibits grey terrace soil, silty loam to silty clay in texture, and is poorly drained, with a 6–8cm thick plow pan and low organic matter content (0.8–1.2 percent). These situations make the area severe drought prone along with poor crop productivity [2].

In Barind tract, most of the groundwater abstractions take place in dry months starting from January and continues up to May. The water table decline sharply and reaches to a maximum depth in March/April/May with the change of rainfall pattern. Then the water table starts moving upward and reaches to minimum depth from the land surface in September or October [4].Bangladesh is one of the most climate vulnerable countries in the world. Climate change is accelerating the intensity and frequency of occurrences of draught, irregular rainfall, high temperature, more natural disasters etc., resulting the damage of crops production, directly or indirectly [5].

Agriculture sector is the single most important contributor to the national economic development. It is the single largest productive sector of the economy and it contributes about 14.23 percent to the total gross domestic product (GDP) of the country. About 40.60 percent of the labor forces are employed in agriculture sector [6]. Agriculture is now turning into modern agriculture, which is fully based on trade, business and marketing. Agriculture production is largely dependent on the use of advanced knowledge and technology such as, quality seeds along with timely supply of all other modern inputs and irrigation has

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attained high priority in the National Agriculture Policy. Bangladesh has a high potential for agriculture development though cultivable land is decreasing gradually for many infrastructural developments. Increase of agriculture production, using available water resources in the form of modern irrigation, plays a potential role in accelerating the process of increasing food production. Efficient management of water resources is one of the most vital factors for achieving the desired targets of production. Therefore, available water during monsoon and dry season particularly for cultivation of high yielding crops are crucial factor, which severely restricts diversity of production [7].

This region (Barind tract) is also vulnerable to fragile climate condition, natural disasters along with many other seasonal calamities that caused enormous damages to crops and natural resources in agriculture sector. The people of this area and agriculture production system were neglected for a long time. BMDA (Barind Multipurpose Development Authority) has implemented some ground water-based irrigation projects along with other components which harnessed some positive impacts on increasing production as well as poverty reduction of the people in the area, particularly landless and marginal farmers. As a result,Barind tract is now considered as the most favorable agricultural area for cultivating diversified modern crops. Existing available agricultural land is most essential requirement for any land use planning for agricultural farming system in a sustainable manner.

In the above context, information on irrigated agriculture and agricultural production including different aspects of land resources and its efficient management, existing cropping patterns along with their diversity, cropping intensity are essential for appropriate designing of agriculture system in the study area. This study is also help to find out problems and suggestive mitigation measures.

II. OBJECTIVES OF THE STUDY

Observing the overall situations, the following objectives are desired in the study.

- To understand the existing land use pattern and cropping patterns scenario.
- To observed the impact on agriculture practices in the study area.
- To identify the crop diversity and cropping intensity at district level.
- To know the effect of agriculture production combined with irrigation and rain-fed condition.
- To determine the way forward/directives for water scarcity adaption.

III. STUDY AREA IN BRIEF

The Barind tract in the north west region of Bangladeshlies roughly between latitudes 24°20´N and 25°35´N and longitudes 88°20´E and 89°30´E (Figure 1) and covered an area of 7728 km^2[8]. The study was conducted on three districts, known as high Barind area, in the north west part of Bangladesh, which is a pocket of Barind tract. The studied districts are Rajshahi, Chapai Nawabganj and Naogaon district (Figure 2). The study area is included with 25 upazillas of Rajshahi, Noagaon and ChapaiNawabganj district. Geographical location of the study area is 88° 10' 0.12" E to 88° 58' 30" E longitude and 24° 11' 30.12" N to 25° 8' 39.84" N latitude. It covers an area of 7563 sq. km [1].There are mainly fiveagro-ecological zones (AEZ) in the study area: AEZ-3 (TistaMeandering Flood Plain), AEZ-5 (Lower AtraiBasin), AEZ-11 (High Ganges River Flood Plain), AEZ-25 (Level BarindTract) and AEZ-26 (High BarindTract [9]. The study districts covered with agro-ecological zones (AEZ) is shown in Table 1. The area covered under AEZ-26 occupies most of the area (159964 ha) of the Barind tract [7].

Table 1: Agro-ecological Zones showing districts covered within the study area.

AEZ number	Zonal name	Districts covered(withinthe study area)
AEZ-3	Tista Meandering Flood Plain	Naogaon
AEZ-5	Lower Atrai Basin	Rajshahi and Naogaon
AEZ-11	High Ganges River Flood Plain	Rajshahi
AEZ-25	Level Barind Tract	Rajshahi, Chapai Nawabganj and Naogaon
AEZ-26	High Barind Tract	Rajshahi, Chapai Nawabganj and Naogaon

The area experiences a tropical humid monsoon climate. In summer, the mean maximum temperature is well above 30^0C, whereas in winter the average minimum temperature is well below 10^0C. A cool weather begins in October and continues up to the end of February. The early

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summer is dry, with scorching heat, but the rainy season is quite wet with a range of 180 to 200mm of annual rainfall. The area is relatively high and flat, sloping up towards southeast to the northwest direction. However, the land slope is steeper in the northern part, while the slope is gentle in the southern part. The study area appears to be well drained, because of Padma and a number of small rivers which crisscross the study area. Overall, it is not subject to flooding during average rainfall condition [10]. In case of heavy rain for a few days, causes a flash flood.

The climate of this area is typically dry with comparatively high temperature except for the wet season beginning from mid-June to October. The annual rainfall in the area varies from about 1500 mm to 2000 mm. Temperature ranges from 08°C to 44°C [8].The total cultivable land of the study areais 0.575 million hectares [1], out of which 34 percent is loamy, 10 percentsandy, 49 percent clayed and 7 percent others [8].

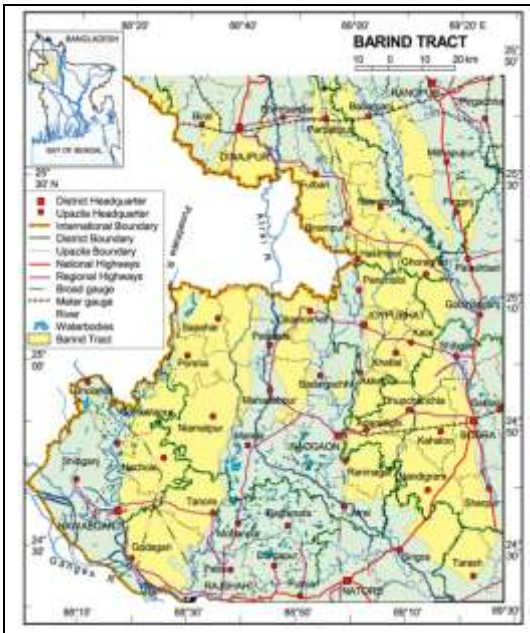

Figure 1: Barind tract in the north western part of Bangladesh.

IV. DATA COLLECTION

While conducting the study, some secondary relevant data were collected from different institutions/departments and websites. The institutions /departments were Bangladesh Agricultural Development Corporation(BADC),Department of Agricultural Extension(DAE),Bangladesh Bureau of Statistics(BBS), Bangladesh Meteorological Department(BMD), and other departments and organizations. Some relevant journals, books, case studies, research papers, institutional reportswere also reviewed. Relevant local data were physically collected through several field visits. In the field visit, farmers were asked about their views and opinionson the issues from their practical experience. On the basis of collected data, the analysis and impact onvarious aspects of agricultural practices were incorporated in the study.

V. RESULTS AND DISCUSSION

A. Exiting Situation of the Study Area

A1. Categorization of the Study Area and Land Types

The study area can be categorized according to agro-ecological condition such as i) high Barind characteristics, ii) medium Barind characteristics and iii) low Barind characteristics. There are 8 upazilas in high Barind areas, 8 upazilas in medium Barind and 9 upazilas in low Barind area (Table 2). These are:

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Table 2: Category wise upazilas in the study area.

High Barindupazilas	Godagari, Tanore, Nawabgang, Gomostapur, Nachole, Niamotpur, Sapahar and Porsha.
Medium Barindupazilas	Mohanpur, Paba, Bholahat, Mohadevpur, Patnitola, Dhamoirhat, Manda and Naogaonsadar.
Low Barindupazilas	Bagmara, Durgapur, Puthia, Bagha, Charghat, Shibganj, Atrai, Raninagor and Badalgachhi.

Virtually all the lands in the study area stand above normal flood level. There are five categories of land in the study area. The average proportions of the landscape, occupied by the different depth of flooding classes, are high land around 55 percent, medium high land 18 percent, medium low land 10 percent, low land 4 percent, very low land<1 percent, and homesteads, water bodies and others around 13 percent [11].

A2. General Soil Conditions

The soils on the summits and terraced slopes are gray to mixed grey and brown in color and silt loam to silty clay loam in texture. The soils are of shallow depth having un-weathered or partially weathered heavy clay substratum occurring at about 60 to 90 cm below the surface. Soil reaction is slightly acidic (pH ranging from 5.5 to 6.5 on the summits and 6.0 to 7.0 in the valleys). The organic matter content is very low ranging from 0.5 to 0.8 percent and 1.2 percent near the homesteads. The natural fertility of the soil ranges from moderate to moderately low. Fertility status of soils in high Barind tract (AEZ-26) is lower than level Barind tract (AEZ-25). Due to poor water holding capacity, soil moisture depletion starts from late October and there exists no available soil moisture by the end of December. As a result, in most of the years T-Aman rice crop faces terminal drought. However, this area is traditionally suitable for many economic and profitable crops due to suitability of land topography for high valued crop farming allowing the farmers to become more interested in cultivation using irrigation water.

A3. Agro-climate:

Temperature and rainfall along with other climatic factors collectively affect crop growth, flowering, fruiting those largely determine crop yield. Barind Tract was in scarce of water during dry season and unfavorable temperature hampered cultivation of modern rice along with other horticulture crops which ultimately compelled the farmers to adopt mechanized irrigation in the dry season.

A4. Water Bodies

Bangladesh was always richly endowed with numerous perennial and seasonal water bodies known locally as haors, baors, khals, beel, pukur and dighies. In the north western region, there were many water bodies like rivers, khals, beel, pukur and dighies etc. Once these rivers and other water bodies were full of water round the year. But now they have very low flow in rainy season and dried up in dry season. Due to occurrence of low rainfall round the year, lowering of ground water table, these sources of natural water are now found almost dry round the year except during the rainy season.

A5. Irrigation Status

Because of uneven and wavy high land with low rainfall, high temperature in summer, scarcity of surface water resources and low level of underground water, irrigation and crop production were difficult in the study area in the past. Significant part of the area always remained fallow and thinly populated with extreme low tree coverage.

Afterwards, people started using tube well as a source of their household water. Tube-well needs deeper installation than dug well (locally called Patkua or Indara). Initially tube well water was available at 9 m to 12 m, but because of underground water level going down, deep tube well (DTW) nowadays is need to be installed at 45 m to 60 m. Although tube well and tara pump are visible everywhere in Barind area, they are unable to lift water during the dry season (December to June). People in this area depend mostly on deep tube well to lift water in areas where it is unavailable. Shallow tube well (STW) and low lift pump (LLP) are used only in low Barindupazilas. Consequently, people in this area depend mostly on deep tube well or shallow machine. A limited number of low lift pump is used, because of scarcity of surface water bodies. Women also collect water from deep tube wells and shallow tube wells (which are installed for irrigation in paddy fields), far from their houses for drinking and domestic purposes. A mode wise irrigation status in the study area is given bellow (Table 3).

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Table 3: Mode wise irrigation status in the study area in 2017-18.

Districts	Cultivable land in ha	Irrigation mode wise irrigated area in hectare (ha).						
		DTW*1 number	Area irrigated	STW*2 number	Area irrigated	LLP*3 number	Area irrigated	Total Area irrigated
Rajshahi	180395	3401	110365	20276	45079	2513	8329	163773
C. Nawabganj	135362	1619	59870	13953	52535	1910	10442	122847
Naogaon	259198	4556	142421	16900	64905	3237	16998	224324
Total	574995	9576	312656	51129	162519	7660	35769	510944

Source: BADC, 2019 [1]. *1=Deep Tube Well, *2=Shallow Tube Well, *3=Low Lift Pump

A6. Agriculture

Agriculture is the single most occupation which involved majority of the people of this region. This area is important for intensive rice and other crops cum fruit production supporting food and nutrition as well as income and employment creation to the people of this region. Different dimension and features of this agriculture sector are briefly described below.

A6.1. Land Use

The majority of the agricultural land resources are occupied by cultivation which is a positive sign for land use in agricultural sector. The cultivable land of Barind Tract is intensively used for diversified agriculture purpose. Selection of crop and cropping pattern largely depend on land elevation. The major land type of this region is medium high land (56 percent), and high land (36 percent). Plenty of modern rice and other high valued crops are grown but the land use and land-based production is hampered due to vagaries of nature, which degraded land quality.

A6.2. Area Covered under Different Crops

Cultivated area covered with different crops and use of irrigation water calculated on the basis of farmer's observation is shown in Table4. About 54 percent area were covered under Local Boro, Hybrid Boro andHYV (High Yielding Variety)Boro in full irrigated condition and other crops also required to supplementary irrigation particularly in dry season. On the other hand, 49 percent area covered under Local T. Aman andHYV T. Aman in rain fed condition, but due to late or early rain subsequently application of supplementary irrigation increased at above 25 percent along with vegetables and other crops. Otherwise, without supplement irrigation, T. Aman cultivation was hampered remarkably. This is one of the dimensions of the study that increasing of water demand in early and late monsoon need to be fulfilled by using surface water which ultimately ensured available water in dry season. This indicates that use of full and supplementary irrigation in Boro and Amon seasons is gradually increasing in this area. However, in Kharif-1 season about 49 percent of land remains fallow which may perhaps be brought into cultivation using surface and ground water.

Table 4: Cultivated area covered under different seasons

Cropping season	Cultivated area covered under different crops and use of irrigation water (%)				Comments
	Paddy	Vegetables	Others	Total	
Rabi (Boromousum)	54 (100***)	5 (25**)	41 (25**)	100	Boro, vegetables and other rabi crops
Kharif 1 (Ausmousum)	21+ 49 F (50**)	5 (25*)	25 (25*)	100	Aus, pulse, chilli, mug beans etc.
Kharif 2 (Aman mousum)	49 (25**)	13 (*)	38 (*)	100	T-Aman, vegetables, jute etc.

Note: *rain fed, **Supplementary irrigation, ***Full irrigation, F= Fallow; Figures in the parentheses denote percentage; T=Transplanted.

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A6.3. Land use, Cropping Pattern and Cropping Intensity

The cropping patterns, especially in the environmentally fragile Barind areas were varied and depended on the land size, land type (medium or high land), early or late rain fall, duration of drought, irrigation facility, and farmers choice. A total of 35 available cropping patterns were recorded in the study areas. Besides, many other cropping patterns cover for many minor crops cultivated in non-irrigated condition.Among the cropping pattern, total 21 number of crops were produced in the study area in 2018-19. Most of the net cropped areas (NCA) were dominated and covered under double cropped area (52 percent) followed by triple cropped 24.47 percent and single cropped 23.26 percent. The quadruple cropped area (QCA)also exists as a very negligible portion (0.27 percent) and is limited in only two districts viz. Rajshahi and Naogaon(Table 5). The crop diversity index (CDI) was 0.976.

Paddy is the common crop which dominates almost all the cropping patterns throughout the Barind areas. At the same time, other diversified crops were cultivated including Wheat, Pulses, Oil seed, Spices along with variety of crops in the minor areas. The present cropping intensity of the surveyed area is 202%, which was encouraging considering the ecological environment of the Barind tracts. The agricultural practices are mainly done by rain fed and ground water irrigation condition. There was ample opportunity to increase cropping intensity by introducing modern cultivation, especially by using surface and sub-surface, or ground water resources.

Table 5: Land use, cropping status and cropping intensity of the study area in 2018-19 [12].

Districts	Total area	Single Cropped Area (SCA)	Double Cropped Area (DCA)	Triple Cropped Area (TCA)	Quadruple Cropped Area (QCA)	Net Cropped Area (NCA)	Gross Cropped Area (GCA)	Cropping Intensity (CI)
Rajshahi	242510	43320	94332	46964	810	185425	376113	203
C. Nawabganj	170445	28745	68016	28340	0	125101	249798	200
Naogaon	343725	59514	131579	63158	809	255061	515385	202
Total	756680	131579	293927	138462	1619	565587	1141296	202

A6.4. Use of Chemical Fertilizers

Generally,our modern agriculture depends on the use of variety of chemical fertilizers. The recommended doses of major chemical fertilizersin the study areaare shown in Table 6. A usual tendency is found to use urea fertilizer apparently in higher amount compared to the other fertilizers. In addition, farmers applied other micro nutrients to soil which increased additional cost in production.

Table 6: Recommended doses of fertilizers in the study area [13].

Crops	Recommended doses of fertilizers in kg/ha					
	Urea (N)	TSP/DAP (P)	MoP (K)	Gypsum	Zinc sulphate (Zn)	Boric acid(Boron)
T. Aus	50	8	25	5	1	-
T. Aman	65	7	28	8	1	-
Boro	95	15	45	6	1	-
Wheat	75	24	62	10	-	1
Black gram	12	8	12	2	-	0.5
Maize	196	36	94	24	2	-
Mustard	85	18	55	15	-	1
Potato	95	25	80	8	2	-
Tomato	85	30	45	10	-	1
Cabbage	50	20	25	-	-	1
Onion	90	30	100	20	1	1
Garlic	65	22	28	14	1	0.5

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Turmeric	50	15	40	10	-	-
Jute	42	12	45	10	-	-
Sugarcane	112	35	104	24	2.5	-

N.B: TSP= Triple Super Phosphate, DAP=Di-Ammonium Phosphate, MoP=Murate of Potash

A6.5. Modern varieties of crops

Barind area is traditionally endowed with diversified crops. Now a day, this area is considered as a greenery zone. Good quality seed can increase rice yield up to 15 percent to 20 percent and variety of modern varieties widely used for cultivation of diversified crops. Plenty of modern varieties of paddy along with other crops such as cheek peas,mug, beans etc. as pulse crop, and onion and mustard, which are economic crops are grown in the area. Similarly different modern varieties of tomato, cabbage and brinjal are also grown in this region. These are considered as high value crops. Varieties of fruits along with other diversified crops, harness economic benefits to the farmers. Conservation of this wide range of agro-biodiversity is essential for this area.

A6.6. Yield and Production of Different Crops

Once upon a time, only one crop used to grow in the Barind Tract, which was considered as food deficit area of Bangladesh. It is now observed that plenty of HYV rice is growing in the high Barind area, which has turned this area into more than double cropped area over the last three decades. The production target of boro rice in Barind areas crossed the target in this current fiscal year. But per unit yield of rice is still low (about 4 to 5 ton/ha) in the field level compared to the scientists' estimation despite of the delivery of extension services. Many other diversified modern crops are grown in the area and the total yields of these increased remarkably. The sharp fall of market price of potato has deprived farmers from their desired economic benefit because of lack of storage facilities. Yields of different crops in the project area is presented below (Table 7).

Table 7: Yield/production of different crops in the study area.

Produced Crops	Yield in metric ton per hectare	Produced Crops	Yield in metric ton per hectare	Produced Crops	Yield in metric ton per hectare
T. Aus	3.01	Maize	7.30	Onion	15.51
T. Aman	4.04	Mustard	1.61	Garlic	7.19
Boro	4.30	Potato	23.50	Turmeric	1.50
Wheat	3.23	Tomato	21.56	Jute	3.10
Black gram	1.10	Cabbage	21.0	Sugarcane	60.00

A6.7. Modern Inputs and Technology

Important modern inputs like seeds, fertilizers, pesticides, and mechanical tillage and irrigation technologies are widely used by the farmers. It was observed that use of surface and ground water was popularized among the farmers having no alternative to fulfill the growing demand of food production in this region. Different types of pump machines (STW, LLP and DTW), and other mechanical instruments are used. Other modern devices used in agriculture are: tractor, power tiller, paddle thresher, dram seeder, sprayer, weeder etc. These are available in the farm level and an indication of mechanized cultivation.

A7. Impacts in Agriculture:

Cultivation of different crops with changing cropping patterns, increasing cropping intensity ultimately caused increased food production, change in food habits and life styles of the people in this region. A positive result of the modern technologies is good production, which turned the area as a granary zone of Bangladesh. Irrigation management in the region has turned vast fallow lands into arable land particularly in rabi season, which helped in poverty reduction. Crop production in the study area is constrained by various natural calamities. According to WARPO (Water Resources Planning Organization), 2005 drought typically affected about 47 per cent area of the country. The other possible impacts might be changing hydrological condition of surface water that ultimately influenced the farmers to use ground water in dry condition. There is ample opportunity to expand the crop yields by improving surface and ground water management on usable water resources availability.

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A8. Major Physical Constraints for Agricultural Development in the Study Area.

Followings are the major physical constraints for agricultural development in the study area:

I. Soils which are wet or flooded in the rainy season and very dry in the dry season.

II. Low organic matter content and low natural fertility relative to the most flood plain soils. Organic matter decomposes very rapidly in grey terrace soils.

iii. Droughty weather and infertile soils

iv. Shortage of surface water

v. Low moisture holding capacity in some areas of the study area

vi. Variable flood levels within the rainy season and between years.

vii. Uncertain ground water supply in some areas mainly in high Barind

viii. the presence of brown colored soil underneath in some areas which has low water holding capacity and reduce discharge.

ix. Uncertain hydrological conditions of the study area

x. Presence of strong plough pan

B. Future Agriculture

BMDA has developed the options for irrigation through underground pipe lines, which is a suitable option of water conservation. Steps need to be taken for supplementary irrigation in the post and pre-monsoon for cultivation of modern 'Aman' rice. Theadditional number of deep tube wells (DTWs) will have positive impact on crop production and is cost effective also as informed by the farmers.

Conjunctive use of surface and ground water is mandatory for expansion of modern agriculture together with timely supply of all facilities to the farmer including quick provision of irrigation water supply through pipe lines, regular supply of electricity, expansion of irrigated command area, pre-paid bill and reasonable price of irrigation per unit land.

B1. Projected Land Use

The total cropped area will be increased as more land will come under triple cropping patterns with the provision of short-term Rabi crops like mustard, lentil,mug beans and different vegetables. Also cultivating onion, garlic, lentil as intercropping. The cropping intensity may be raised from 202 percent to 215 percent. The area under HYVAus,HYVBoro and HYV Aman will be increased particularly in the Level Barind and floodplain areas.

B2. Projected Cropping Patterns

Projected cropping patterns are based on the assurance of more secured irrigation facilities from increased number of deep tube wells (DTWs), dug wells (DWs) where scarcity of water exists and surface water resources through re-excavation of derelict ponds, canals, and other surface water bodies for harvesting rain water. There is ample opportunity to increase cropping intensity by introducing modern cultivation. Sprinkler and drip irrigation may be applied in dry hard Barind area. Droughts and other natural disasters' mitigating measure through adaptation of modern verities and technologies may be a good lesson for the farmers.

VI. CONCLUDING REMARKS

The study was conducted at 25 upazilas of three districts in the high Barind area. The topographic and geo-hydrological conditions of the soil in the study area indicated that the Boro-Fallow-T. Aman was the most predominant cropping pattern among 35 cropping patterns in this area. The numbers of cropping patterns ranged from 11 to 35, maximum in Durgapur upazila and minimum in Charghatupazila. Total 21 number of crops were produced in the study area, while the cropping intensity ranged from 200 to 203 percent. The average cropping intensity of the study area was 202 where the national average was 197 percent, which was slightly higher than the national average.

VII. RECOMMENDATIONS

Based on the above discussion and findings, the following recommendations can be made:

i. Creation of storage in the existing canals/kharies (local name) through restoration and conservation of rain water and artificial recharge of the underground aquifers are pre-requisite for expansion of future agriculture.

ii. A local and regional water management and sharing system needs to be developed.

iii. Re-excavate of small and dry/lean flow rivers, canals and beels (a water body) for water conservation need to be improved to combat prolonged drought.

iv. Initiative to be taken to increase productivity of exclusive rice-based cropping pattern. In the Boro area, rainfall based/supplementary irrigation-based Aman rice and suitable vegetables might be grown in the study area.

v. Modern cultivation including use of high yielding varieties, use of recommended dose of fertilizers, and judicious use of pesticides need to be popularized among the farmers.

vi. Raising awareness among the farmers may ensure sustainable production in this region.

vii. Modern agriculture with intensive use of modern varieties with mechanized irrigation is a defined productive phenomenon in such drought prone areas need to be ensured by using surface water in rainy season and ground water in dry season particularly for the high Barind areas should be popularized among the farmers.

Therefore, more attention should be paid to the probable impacts of irrigated agriculture.

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