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MANAGEMENT OPTIONS FOR CROP PRODUCTION UNDER UNFAVORABLE ECOSYSTEMS: A REVIEW IN BANGLADESH

M. N. YOUSUF[1], M. A. A. KHAN[2] AND S. BRAHMA[3]

Abstract

The agriculture regarded as a major economic activity in Bangladesh, facing the great challenges of ensuring food security and other basic needs to a vast population. There are many obstacles in Bangladesh: decreasing land resources & climatic vulnerabilities, water & salinity stress, drought, heat, high temperature, disease & insect pests' outbreak, unexpected & uneven rainfalls, floods, cyclones, tidal surges, water logging, land sliding, soil erosion, declining soil fertility and productivity etc. In every year about 1% (76,000 to 80,000 ha) of premium agricultural land is being lost for accommodation, infrastructure, industrialization, urbanization etc. in the country. For ensuring food and nutritional security, the highest priority to production of crop. The enormous pressure has been exerted on the natural resources like land, irrigation water, air etc. to produce more foods. There is limited scope for horizontal expansion of food production, vertical expansion with adaptation of technologies under unfavorable ecosystems in Bangladesh. Crop production under unfavorable ecosystems: coastal lands, char lands, hills, *haors*, *baors*, *beels*, *jheel*, piedmonts, Barind Tract and peats areas of Bangladesh should be properly improved & strengthened immediately for ensuring food security to large populations. HYV, hybrid crop varieties and modern appropriate as well as sustainable technologies for crop production should be adapted of the adverse ecosystems of the country. Developed of alternative and improved cropping pattern against traditional cropping pattern which upscaling crop productivity and cropping intensity in those ecosystems. Long term strategy, policy and infrastructure development by government should be generated for improving crop production, increment of income and reduction of poverty of the area. Therefore, this review paper has been designed and discussed adaptation of technologies and diagnosis the unfavorable ecosystems of Bangladesh for crop production.

Keywords: unfavorable ecosystems, diagnosis, management technique and crop production.

Introduction

Bangladesh (lies between $20^0 34^/$ & $26^0 38^/$ North latitude and $88^0 01^/$ & $92^0 41^/$ East longitude) is the largest deltaic floodplain in the world (BBS, 2023; Sarker *et al*., 2022). It has a various but tropical climate characterized by wide seasonal rainfall, high humidity and high rainfall (Reza *et al*., 2015). The total area of 1,47,570 km^2 of which 88,892 km^2 is occupied by rivers, hills and estuaries (BBS, 2023). The

[1]Senior Scientific Officer, [2]Scientific Officer, [3]Principal Scientific Officer, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

great delta is flat throughout and sketches from near foothills of the Himalayas in the north to a southern irregular deltaic coastline is 710 km that faces the Bay of Bengal (BBS, 2023; GED, 2018; MEFCC, 2018). There are three categories of lands: floodplains (80%), terraces (8%) and hills (12%) which only 69% of total area is suitable for crop cultivation and intense in floodplains (Banglapedia, 2021). On the basis of origin and properties, the soils were broadly categorized into seven tracts (Table 1) consisting 30 Agro-ecological zones (AEZ), based on land form, parent materials, land types, soil characteristics and agro-climatology. Mica is the predominant clay mineral followed by smectite, chlorite, vermiculite and kaolinite (BARC, 2018). The major crops produced in the country are rice, vegetables, wheat, tuber crops, spices, oilseeds, pulses, jute, cotton, sugarcane, maize and tobacco (BBS, 2023, Chaki *et al*., 2023). The cropping pattern is mainly rice based and covered 76% areas of cultivable lands (Shil *et al.*, 2016; Hasan *et al*., 2013). Cropping intensity (212%) has increased remarkably, accompanied with use of high yielding verity (HYV) & hybrid crop varieties and agricultural inputs (fertilizers & pesticides) has impacted deterioration of soil health (BBS, 2023, Chowdhury *et al.*, 2018). The top most priority in Bangladesh is to produce food for feed its vast and over increasing population (Aziz *et al.*, 2016). For getting solution, to extend agriculture to the fullest volume the unfavorable ecosystem should be effective through proper management and selection of crops (Bokhtiar *et al*., 2023; Khan *et al*., 2008). The unfavorable ecosystems of Bangladesh are coastal lands, char lands, hills, *haors*, *baors*, *beels*, *jheel*, piedmonts, Barind Tract and peats areas (Bokhtiar *et al*., 2023, GED, 2018, Saha *et al.*, 2016, Karim, 2015). The major crop production constraints are land availability, urbanization, top soil removal, social forestry, land & soil degradation, infrastructural developments, drainage impedance and water logging, fisheries and climatic vulnerability (Xu *et al.*, 2020, Hossain *et al*., 2019, Miah *et al.*, 2018). To extend crop production under adverse ecosystems such as coast lands, char lands, hills, piedmonts, Barind tract, *haors*, *beels* and peats proper management approaches are advisable.

Table 1. Distribution of different soil Tract in Bangladesh

Soil Tract with area	Physiography units	General Soil type
Madhupur Tract (10,000 km^2)	Madhupur Tract	Red-brown terrace soil
Barind Tract (13,000 km^2)	Barind Tract	Grey terrace soil, Deep red-brown terrace soil
Gangetic Alluvium (27,000 km^2)	Ganges river floodplain, Arial Beel, Gopalganj-Khulna peat basins, Ganges tidal floodplain (non-saline part)	Calcareous dark grey floodplain soil, Acid basin clay, Peat, Grey floodplain soil

Soil Tract with area	Physiography units	General Soil type
Tista Tract (16,000 km^2)	Old Himalayan piedmont plain, Tista floodplain	Black terai soil, non-calcareous brown floodplain and grey floodplain soil, grey floodplain and non-calcareous brown floodplain soil, non-calcareous dark grey floodplain soil, non-calcareous alluvium, non-calcareous grey floodplain soil (non-saline phase), non-calcareous alluvium
Brahmaputra Alluvium (40,000 km^2)	Jamuna floodplain, Old Brahmaputra floodplain, Haor Basin, Surma-Kushiyara floodplain, Middle Meghna floodplain, Old Meghna estuarine floodplain, Young Meghna estuarine floodplain (northern part), Chittagong coastal plain, Northern and eastern piedmont plain	Non-calcareous brown floodplain and grey, floodplain soil, grey floodplain and non-calcareous brown floodplain soil, non-calcareous dark grey floodplain soil, grey floodplain soil, Acid basin clay, Surma-Kushiyara floodplain soil, Comilla basin soil, grey floodplain and non-calcareous dark grey floodplain soil, Calcareous alluvium (non-saline part), non-calcareous alluvium, Floodplain soil, Old Piedmont plain soil
Coastal Saline Tract (20,000 km^2)	Young Meghna estuarine floodplain, Ganges tidal floodplain (saline part), Sundarban, Chittagong coastal plain (partly)	Calcareous alluvium (saline phase), Acid sulphate soil, grey floodplain soil (saline phase), Grey Piedmont Soils (saline part)
Hill Tract (17,000 km^2)	Northern and eastern hills	Brown hill soil

Source: Banglapedia, 2021 and BARC, 2018

Coastal Ecosystems

The coastal lands (47,201 km^2) of Bangladesh, consists of 19 districts, covers 32% of the country: Jessore, Narail, Gopalganj, Shariatpur, Chandpur, Satkhira, Khulna, Bagerhat, Pirozpur, Jhalakati, Barguna, Barisal, Patuakhali, Bhola, Lakshmipur, Noakhali, Feni, Chittagong and Cox's Bazar (Islam and Sarkar, 2021; Ahmad, 2019). About 53% land of this region is saline (Haque *et al*., 2018, Haque *et al*., 2008). The coastal and offshore areas are about 2.85 million hectares include tidal, estuarine and meander floodplains (Hasan and Kumar, 2022, Uddin *et al*., 2020). The tidal floodplain occurs mainly in the south of the Ganges floodplain (49%) and also on large parts of Chittagong coastal plains (6%), Estuarine floodplains (18%) of the coastal area located in greater Noakhali, Barisal,

Patuakhali and a smaller area of Chittagong districts (Ahmed *et al*., 2021, Aziz *et al*., 2016b; Ahsan and Sattar, 2010). About 30% of coastal lands are suitable for crop production. Soils of Jessore, Magura, Narail, Faridpur, Gopalgonj, Barisal, Jhalokhati and Patuakhali have been newly salinized and reaches its pick in April - May (Hossain *et al*., 2019; Haque *et al*., 2018; Islam, 2015). This area is relatively flat and suffers from saline soil-water to different degrees. The degree of salinity goes down in rainy season could possible to crop production (Ahmed *et al*., 2021, Islam, 2020). Increasing salinity is the major concerning issue to the people of the coastal region of Bangladesh (Rashid, 2019, Salehin *et al*., 2018). Due to increasing salinity in the water and soil, the people of the region are suffering from scarcity of safe drinking water, irrigation, agriculture and other uses (Buisson *et al*., 2021, Ahsan, 2010). For that 20-40% crop production is reduced in coastal saline belts (Rahman *et al*., 2021; Miah *et al.*, 2020). Many natural and man-made calamities: tidal surge, cyclone, acid sulphate soils, waterlogging in polder areas, salinity intrusion, land erosion & unstable atolls, sedimentation in riverbeds, sea level rise, shortage of rainfall, late draining, heavy soil consistency, poor nutrient status, brackish shrimp cultivation and making dam & barrages (Hossain *et al.*, 2019, Toufique and Yunus, 2013).

Management for crop production

The opportunity of crop intensification to increase crop production in unfavorable and underutilized coastal ecosystem could be achieved by manipulation of soil, desalinization, improved irrigation and drainage system and modern soil & water management practices. Cultivation of salt tolerant shallow rotted crops like wheat, barley, groundnut, chilli, fenugreek etc., could bring substantial changes in agricultural practices in the salt affected soils. The extent of non-saline to very slightly saline and very slightly saline to slightly saline area covers about 8,45,910 ha of coastal districts which are very potential for crop production. Different *Rabi* crops such as mung bean, lentil, grass pea, chickpea, cowpea, mustard, linseed, chilli, wheat, sweet potato, aroids, watermelon, *Rabi* vegetables and HYV and local *Boro* rice could be grown there. Similarly, about 2,40,220 ha of land fall under slightly saline to moderately saline and another 1,98,890 ha lands are moderate to strong saline. Adoption of some soil and crop management practices make those area cultivable for winter (*Rabi*) crops. Cropping system should be improved and developed. There are some technological options for crop production in saline areas-

- Cultivation of released salt tolerant rice varieties of Bangladesh Rice Research Institute (BRRI) as BRRI dhan 47, BRRI dhan, 53, BRRI dhan 54, BRRI dhan 61, BRRI dhan 76, BRRI dhan 78, BRRI dhan 82, BRRI dhan 97, BRRI dhan 99 and Bangladesh Institute of Nuclear Agriculture (BINA): BINA Dhan 8 and BINA Dhan 10.
- Bangladesh Agricultural Research Institute (BARI), Bangladesh Wheat and Maize Research Institute (BWMRI) and BINA released crop varieties:

Wheat (BARI Gom 25, BARI Gom 33, WMRI Gom 2, WMRI Gom 3, BINA Wheat 1, BAW-1147 and BAW-1290), Barley (BARI Barley 4, BARI Barley 8, BARI Barley 10), Sorghum (BARI Sorghum-2), Finger millet (BARI Raghi 1), Mustard (BARI Sarisha 16, BARI Sarisha 18, BINA Sharisha 5, BINA Sharisha 6), Potato (BARI Alu 72, BARI Alu 73, BARI Alu 78, BARI Alu 104), Sweet potato (BARI Mishti Alu 6 and BARI Misthi Alu 7), Taro (BARI Pani kachu 8, BARI Pani kachu 9), Sesame (BARI Til 4 and BARI Til 6), Mungbean (BARI Mung 6, BINA Moog 7) and Soybean (BARI Soybean 5, BINA Soybean 5, BINA Soybean 6) could be grown during *rabi* season.

- Introduction and replacement of local cultivars with high yielding variety (HYV) varieties of mung bean, lentil, grass pea and cowpea.
- Application of organic manure, brown manure with extra 20-25% nitrogenous fertilizers recommended dose.
- Replacing Na^+ in the soil with Ca^{2+} by applying gypsum.
- Application of plant growth promoting bacteria (PGPR).
- Practicing rain water harvest in rainy season for irrigation during dry season.
- Cultivation of salt tolerant crops sugar beet, sorghum, watermelon, groundnut, sunflower and fenugreek.
- Raised bed with mulch followed by drip irrigation is the most suitable technique to reduce soil salinity, save water and to increase production of high value horticultural crops.
- Soybean-T. Aus-T. Aman, Groundnut-T.Aus-T. Aman, Watermelon-T. Aus-T. Aman, Watermelon-Indian spinach-T. Aman, Sunflower-T. Aus-T. Aman, Mustard-Mung bean-T. Aus-T. Aman, Potato-Mung bean-T. Aus-T. Aman, Sunflower-Jute-T. Aman, Potato-T. Aus-T. Aman, Linseed-T. Aus-T. Aman, Mustard-T. Aus-T. Aman, Mustard-Boro-T. Aman, Boro-Jute-T. Aman, Wheat-Mung bean-T. Aman, Chilli-Fallow-T. Aman an alternate and improved cropping pattern

Char land Ecosystems

Char lands can be considered as a 'by-product' of the hydro-morphological dynamics of accretion in the rivers are newly emerged through the erosional and depositional process of fluvial system with sedimentation of huge amount of sand, silt and clay over time (Sarker *et al*., 2024; Khatun *et al*., 2022). It includes all types of bars including both lateral (point-bars) and medial (braid-bars). The sand bars emerging as islands within the river channel (island chars) or as attached land to the riverbanks (attached chars), once vegetated such lands are commonly called

chars in Bangladesh (Tasnim *et al*., 2022, Sarker *et al.*, 2022). This area occurs along the major river systems of the Padma, the Meghna, the Jamuna and the Brahmaputra with their numerous tributaries which have a complex topography (Haque and Jakariya, 2023, Sultana *et al*., 2011). Bangladesh has about 0.83 million hectares char lands of which about 0.52 to 0.79 million hectares are cultivable (Chowdhury *et al*., 2018; Karim *et al*., 2017). Crops are often lost through active changes in river alignment and complete alteration of landscape at a local level (Ahmed *et al*., 2021). The active floodplain and char lands occur in the districts of Kurigram, Lalmonirhat, Sirajgonj, Pabna, Jamalpur, Tangil, Manikgonj, Faridpur, Shariatpur, Madaripur, Mymenshingh, Kishorgonj, Narshingdi, Dhaka, Munshigonj, Brahmanbaria, Cumilla, Chandpur, Noakhali, Lakshmepur and Bhola (Table 2) (Sattar and Islam, 2010; Khan, 2010). Burial of standing crops and good agricultural lands pose serious constraints to crop production by fresh sediment of sandy deposits, land instability, coarse textured soils, low water holding capacity, low nutrient capacity, river bank erosion, seasonal drought, flooding and poor communication are major problems related to crop production (Alam *et al*., 2018, Aziz *et al*., 2016, Naher *et al*., 2016).

Table 2. Distribution of char lands in Bangladesh

Region	Area (thousand ha)	% of total char lands
Dhaka	74.6	9.7
Jamalpur- Tangil	116.0	14.2
Comilla- Noakhali	129.9	15.9
Pabna- Rajshahi	125.8	15.4
Bogra-Pabna-Rangpur	321.5	39.3
Faridpur-Kushtia	17.3	2.1
Faridpur	29.8	3.6
Mymenshingh-Kishorgonj	1.8	0.2
Patuakhali	2.0	0.2
Total	818.7	100

Source: Sattar and Islam, 2010.

Management for crop production

Generally, farmers in char lands grow local variety of different crops such as sweet potato, groundnut, sweet gourd, lentil, grass pea, mungbean, chilli, cheena, watermelon, mustard, onion, sweet corn millets etc. which are usually grown by the farmers during *rabi* season. Farmers usually follow their traditional crop cultivation practices. Therefore, yield of crops is unsatisfactory compared to other ecosystems. To increase crop productivity following options could be suggested:

- Mega varieties (MV) and hybrid varieties (HV) of rice (BRRI dhan 48, BRRI dhan 49, BRRI dhan 50, BRRI dhan 67, BRRI dhan 74, BRRI dhan 81, BRRI dhan 84, BRRI dhan 87, BRRI dhan 89, and BRRI dhan 92),

wheat, maize, oil seeds, pulses, potatoes, sweet potatoes, millets, spices and vegetables should be introduced by replacing local or traditional crops and varieties.

- The crop varieties performed well under char land condition could be introduced: Chickpea (BARI Chola 4, BARI Chola 9), Lentil (BARI Masur 6, BARI Masur 7), Mungbean (BARI Mung 6), Sesame (BARI TIl 5 and BARI Til 6), Mustard (BARI Sharisha 14, BARI Sharisha 18, BARI Sharisha 20, BINA Sharisha-9), Groundnut (BARI Chinabadam-9), Proso millet (BARI Cheena-1), Foxtail millet (BARI Kaon-2), Maize (BARI Hybrid Maize 9, WMRI Hybrid Maize 1, WMRI Hybrid Baby Corn), Sweet pea (BARI Motorshuti 2), Soybean (BARI Soybean 5, BINA Soybean 3), Onion (BARI Piaz 4, BARI Onion 6), Chilli (BARI Morich 4), Fennel (BARI Mouri 2) and Black cumin (BARI Kalozira 1) have been identified as better performer in char land areas.
- Modern and recommended crop production technologies along with IPNS should be practiced for higher yield, income and improvement of soil fertility.
- Intercropping of different crops like potato, leafy vegetables and legume with hybrid maize and sugarcane is another good option to increase production and income generating.
- Organic and synthetic mulch should be used for conserving soil moisture.
- Polythene mulch should be used for conserving soil moisture and controlling weeds.
- Conservation or zero tillage should be practices.
- Crop diversification with legumes such as BARI Kheshari 3 and BARI Masur 8 should be cultivated.
- Sandbar cropping technology should be introduced
- Potato-Groundnut-T. Aman, Mustard-Boro-Jute-T. Aman, Potato-Jute-T. Aman, Wheat-Jute-T. Aman, Mustard-Boro-T. Aman, Garlic/Maize-Fallow-T. Aman, Maize-Jute-T. Aman, Chilli- Fallow-T. Aman, Potato-Foxtail millet-T. Aman, Linseed-Groundnut-T. Aman, Mustard-T. Aus-T. Aman, Potato-Boro-T. Aman, Onion-Sesame-T. Aman an alternate and improved cropping pattern

Hill Ecosystems

Hills are part of the Hindu Kush Himalayas Mountain ecosystem, located in the south-east and north-eastern regions of Bangladesh in Table 3. Maximum hills of the country are situated above 60^0 slopes (Azia *et al.*, 2016a; Chowdhury and

Mallik, 2010). The major constraints for crop cultivation in Hilly regions are soil erosion (by heavy downpours in July-August), inadequate irrigation facility, landslides (causes due to sloppy land and jhum cultivation), heavy rainfall, flash flood in valley, afforestation, depleting ground water table, soil acidity, low nutrient status (except K, Fe and Mn), limited volume of soil for root anchorage, nutrient leaching and low soil organic matter content (Alam *et al*., 2022, Quais *et al*., 2017). Poor communication & marketing facilities, Bengali-Tribal people conflict and land ownership or tenure issues are the further constraints to the food security of the hilly people. Continuous depletion of soil fertility is the major constraint to crop production (Marma and Islam, 2018). Jhum cultivation (shifting cultivation) and deforestation are the predominant form of land degradation (Faisal and Hayakawa, 2022; Islam *et al*., 2020). Jhum cultivation is a traditional farming system, difficult to discard it. Rapid loss of soil fertility and toxicity of Al^{3+}, Fe^{3+} and Mn^{4+} are the two major problems for achieving satisfactory yield of jhum crops (Gafur *et al*., 2003). Soil fertility is in declining trend due to loss of nutrients and organic matter (Zakaria and Majumder, 2019). Jhum cultivation causes gully erosion and losses of soil ranging from 10-120 t $ha^{-1}yr^{-1}$ (Aziz *et al.*, 2016a).

Table 3. Distribution of hill areas in Bangladesh

Hills	Area (km^2)	% of total hills
Chittagong Hill Tract (Khagrachari, Rangamati and Bandarban)	13069	76.38
Chittagong and Cox's Bazar	2317	13.54
Sylhet Division (Sunamgonj, Sylhet, Habigonj and Moulavibazar)	1587	9.28
Others (Comilla, Netrokona, Brahmanbaria, Jamalpur, Sherpur, Mymensingh and Feni)	137	0.80
Total	**17110**	**100**

Source: Hossain *et al.*, 2019.

Management for crop production

The prospect of increased crop production through proper utilization of soil and water conserving technologies in high in Hills. A number of crops can be grown throughout the year provided crops and soil are well managed. The region is especially suitable for horticultural and plantation crops. In Hilly areas BARI is established settled farming, decrease shifting cultivation and to minimize land degradation. Some sustainable technologies have been developed for hills.

- Year round and multi strata crop combination.
- Rain water harvesting in rainy season and used in dry season.
- Practicing settles farming instead of Jhum cultivation.
- Better performing crop varieties like mung bean var. BINA Mug 2, BARI Mung 6, BARI Mung 4, mustard var. BARI Sharisha 20, chickpea var.

BARI Chola 3, BARI Chola 11, Lentil var. BARI Masur 6, Chilli var. BARI Morich 2 and BARI Morich 6, ginger var. BARI Ada 2, BARI Afda 3, turmeric var. BARI Holud 4 and BARI Holud 5, eryngium var. BARI Bilatidhonia 1, sweet potato var. BARI Sweet potato 7, maize var. BARI Maize 5, BARI hybrid Maize 7 and field pea var. BARI Motorshuti 2 should be cultivated.

- Sac culture method for application of ginger should be disseminated.
- Mustard-Seasame-T. Aman, Mustard-Fallow-T. Aman, Potato- T. Aus-T. Aman, Potato-Boro, T. Aman, Potato-Maize- T. Aman, Boro- Fallow-T. Aman an improved cropping pattern.

Piedmonts ecosystem

Piedmont areas, comprises of the feet of some coalesced alluvial fan formed by the rivers, washing the adjacent Himalayan slope, the north-west part of Bangladesh, occur in: Old Himalayan Piedmont Plains (AEZ 1), and Northern and Eastern Piedmont Plains (AEZ 22). The Old Himalayan Piedmont Plains (3982 km^2) covers most of Thakurgaon and Panchagor districts, and north-western part of Dinajpur district (Ratul *et al*., 2021, Sarker *et al*., 2020, Uddin *et al*., 2012). The Northern and Eastern Piedmont Plains (4038 km^2) covers Netrokona, Sunamganj, Sherpur, Sylhet, Habiganj, Mymensingh, Moulvibazar, Comilla and Brahmanbaria districts. Constraints of crop production related to soil management include sandy loams and sandy clay loams soils, high permeability, nutrient leaching, low organic matter content, low pH (very strongly acidic to slightly acidic), Al^{3+}, Fe^{3+} & Mn^{2+} toxicity, macro & micro-nutrient deficiencies, stone lifting in Tetulia upazila (causes degradation of soil), very low to low P availability, deficiencies of N, K, S, Ca, Mg, Zn, B and flash flood (Kamal *et al*., 2019, Yousuf *et al*., 2013). Some technologies should be practices for crop productions under piedmont soil:

Management for crop production

- Use of organic matter for conserving soil moisture
- Balanced utilization of nutrient elements
- Application of lime for reclamation of soil acidity
- Mg and B fertilizers are applied for cultivation of *Rabi* crops
- Seed priming, mulching and conservation agriculture techniques are practiced.
- Cultivation of rice var. BRRI dhan 72, BRRI dhan 88, BINA dhan 11, wheat var. BARI Gom 26, mustard var. BARI Sharisha 14, BARI Sharisha 18, BARI Sharisha 20, chilli var. BARI Morich-2 and potato var. BARI Alu 41, BARI Alu 78, BARI Alu 79, BARI Alu 90, BARI Alu 104.

- Potato-Mungbean-T. Aman, Mustard-Boro-T. Aman, Mungbean-T. Aus-T. Aman, Potato- T. Aus-T. Aman, Chickpea-T. Aus-T. Aman, Potato-Maize-T. Aman, Mustard-T. Aus-T. Aman, Wheat-Mungbean-T. Aman, Chilli-Fallow-T. Aman, Potato-Jute-T. Aman an improved cropping pattern

Peat land Ecosystems

The peat lands of Bangladesh occupy about 4010 km^2 (Uddin and Mohiuddin, 2019; Khan, 2010). Peat is an unconsolidated deposit of semi-carbonized plant matter in a water-saturated environment, certainly high moisture content, Structure less has low bearing capacity (when wet). The rate of decomposition depends on anaerobic conditions (Rashid, 2021, Masud *et al*., 2011). The peat soil contains higher amount of organic matter (Ali *et al*., 2020, Saha *et al*., 2016). The soils are highly permeable, deeply flooded during rainy season, bulk density 0.01-0.4g cm^{-3}, C: O ratio 2:1 and organic matter content more than 30% (Lennartz and Liu, 2019; Liu and Lennartz, 2019). The concentration of carbon in peat soils ranges 30–70 kg m^{-3}, easily burns when dried & also very hard (Clarke and Rieley, 2019; Agus *et al.*, 2011). The peat was also used as an energy source in ancient time (Ali *et al*., 2020, Hossain, 2014). There are three categories of peat soils: Sapric (immature) peat, Hemic (medium mature) peat and Fibric (mature) peat (Deru, 2021). The major peat lands are situated in low-lying areas of Gopalgonj, Madaripur, Khulna, Jessore, Bagerhat, Narail, Barishal, Pirojpur (AEZ 14) and minor scale in the Sylhet, Maulavibazar, Netrokona, Kishoreganj and Brahmanbaria districts (Uddin and Mohiuddin, 2019). The soils are strongly acidic, having medium K and low in S, P, B, Zn and Cu contents, brownish black to black, fibrous (Ali *et al.*, 2020, BARC, 2018).

Management for crop production

Considering physical and chemical properties it shows the management of peat soils are very difficult due to lack of mineral matter in the profile. There are some development possibilities in small area having mineral horizon either at the top or in the horizon close to top soil, still it depends on thickness of mineral horizon. The thicker one will perform better management: tillage, sowing, transplanting etc. There are some possibilities to improve the soils by allowing sediments settling down on these peat basins from the adjoining tidal rivers. This process of sedimentation should be continued for several years to make the land high and make potential for agriculture. Consequently at least two crops should be grown in a year. *Boro* followed by transplanted or broadcast Aman could be grown by irrigation through fresh water. There are several procedures of management of peat soils practiced in this area. Two of them are described below:

a) *Sarjan* procedure: Generally, this procedure is practiced in medium high to medium lowland having late draining phase. In this case land is divided into several subplots. Between two subplots there is a ditch for keeping water permanently. Every subplot is raised by taking the soil from the adjoining side. Optimum size of the plot is 8.0 m X 1.5 m, which may be changed depending on the presence of mineral matter at the surface and size of the plot. The present crops on the raised bed are mainly vegetables, spices and *dhaincha*. Local fishes are grown in the ditches between the two beds.

b) *Gher* procedure: It is one type of fish culture area where both crops and fishes are grown alternatively at the same time. The dyke/ail is raised along the boundary of the plot by taking soil from inside of the plot. The digging part will be turned into a ditch to keep water for long time (dry season). The soils of the ditch are kept by the side of a raised dyke having a certain length, breadth and height. The present land use patterns are Boro-Shrimp (Lobster) and Boro- mixed Shrimp and T. Aman. Vegetables are grown on the raised dyke.

Haors and *Baors* Ecosystem

Haors with their unique hydro-ecological characteristics are large bowl or saucer-shaped floodplain depressions lies between low lying areas of Surma-Kushiyara floodplain and Sylhet basin, covers the upper Meghna River basin in North-Eastern regions of Bangladesh, are most complex of seasonal inundated wetlands (Islam, 2020, Kamruzzaman and Uddin, 2020). The total area of 8,600 km^2 of which around 43% area is *Haor* districts and classified as Acid Basin Clays (Saha *et al.*, 2016, Kamruzzaman and Shaw, 2018). It extends in Sylhet, Maulvibazar, Sunamgonj, Habigonj, Netrakona, Kishoregonj and Brahmanbaria districts (AEZ 21). The *Baor* is an oxbow lake, found mostly in the moribund delta as in greater Comilla, Faridpur, Dhaka and Pabna districts (Mohiuddin, 2022, Yousuf, 2022). The *Haor* soils are peat and muck occurred in top of the soil profile. Due to containing decomposed organic matter and sulphur produced H_2S gas, which injured roots (Masud *et al*., 2011). The major problems related to crop production are: strongly acids soils, heavy soil texture, nutrient deficiency (N, S and Zn), flash flood, excess rainfall in the upstream hilly areas & subsequent runoff, sedimentation in the rivers, deforestation, hill cuts, landslide, improper drainage and unplanned road and water management infrastructure (Rahaman *et al*., 2020, Islam *et al*., 2015). It's also suffering from wave erosion and eutrophication (BHWDB, 2012). Total cropped area is about 1.93 million ha, of which rice is 1.74 million ha (90.2%) and the rest 0.19 million ha (9.8%) is non-rice crops. Around 66% of Haor areas under cultivation (Alam *et al*., 2010). The total rice area of Bangladesh is 11.35 million hectares of which 15.3% falls in the *Haor* area. About 5.25 million metric tons of rice is produced in *Haors* which is 16.5% of the total rice production of Bangladesh (Aziz *et al.*, 2016a). The contribution of *Boro* 60%,

Aman 33% and *Aus* 7% of rice production in *Haor* areas (Hassan *et al.*, 2019.. In *Haor* areas the application of fertilizers is the minimum for crop production than other areas of the country (Aziz *et al.*, 2016a and Khan, 2010).

Table 2. Distribution of *Haor* and their area

District	Upazila	Total area (ha)	*Haor* area (ha)	Number of *Haor*
Sylhet	Jaintiapur, Beanibazar, Fenchuganj, Balagonj, Biswanath	349000	189909	105
Maulvibazar	Maulivibazar Sadar, Kulaura, Rajnagar, Sreemangal	279900	47602	3
Sunamgonj	Sunamganj Sadar, Jagannathpur, Dharmapasha, Jamalganj, Chhatak, Derai, Salla, Tahirpur, Bishambarpur	367000	268531	95
Habigonj	Ajmerigonj, Hobiganj Sadar, Bahubal	263700	109514	14
Netrakona	Atpara, Barhatta, khaliajuri, Mohongonj, Madan, Kandua	274400	79345	52
Kishoregonj	Mithamain, Karimgonj, Austragram, Itna, Nikli, Bazitpur, Kuliarchar, Tarail, Bhairab, Katiadi	273100	133943	97
Brahmanbaria	Bhramanbaria Sadar, Nasirnagar	192700	29616	7
Total		1999800	858460	373

Source: Kamruzzaman and Shaw, 2018, BHWDB, 2012.

Management for crop production

A large area in the country suffers occasional or more frequent waterlogging. The low-lying ecology of the country make this a wide spread natural phenomenon and many areas remain fallow . Waterlogging also limits the nutrient uptake by reducing plant transpiration and restrict root function. Therefore, crop production in waterlogged soils is very difficult. Some options for increasing crop production in waterlogging and flood prone areas:

- Cultivation of flood prone and waterlogging tolerant MV and hybrid rice varieties like BRRI dhan 51, BRRI dhan 78, BRRI dhan 79, BRRI Hybrid dhan1, BRRI Hybrid dhan2, BRRI Hybrid dhan 3, BRRI Hybrid dhan 5, BRRI dhan 92, BRRI dhan 101, BRRI dhan 102, BRRI dhan 107, BRRI dhan 108, Swarna, BINA Dhan 11 and BINA Dhan 12 Short duration crop varieties should be adopted.
- Adoption of short duration crop varieties.
- Floating bed agriculture plays an important role for vegetable and Spices cultivation in waterlogging area.

- Cultivation of different aroids var. BARI Panikachu 5. BARI Panikachu 6 and BARI Panikachu 7.
- Cultivation of mustard varieties like BARI Sharisha 14, BARI Sharisha 15, BARI Sharisha 16, BARI Sharisha 18, wheat var. BARI Gom 25, BARI Gom 26, field pea var. BARI Motorshuti 2, lentil var. BARI Masur 6, BARI Masur 8, mungbean var. BARI Mung 6, chickpea var. BARI Chola 8, chilli var. BARI Morich-3, BARI Morich 6 and maize var. BARI Hybrid maize 9 in high and medium highland area of haor.
- Cultivation of traditional deep water rice cultivars in low lying flood prone area.
- Fallow-Boro-Fallow, Potato-Groundnut-Fallow, Sunflower-Kenaf-Fallow, Sweet potato-Kenaf-Fallow, Wheat-Fallow-Fallow, Boro-Fallow-T. Aman, Fallow-B. Aus-T. Aman, Groundnut-Fallow-Fallow cropping pattern

Beel and *Jheel* Ecosystem

Beels are countless shallow lakes or ponds, surrounded by flooding fields. A *Beel* is usually a depression or topographic low generally produced by erosion or other geographical process (Yousuf, 2022; Kakon *et al*., 2020, Khondoker *et al.,* 2014). These are marshy in character. Sometimes beels are remains of a river that has changed its course. Many of the *Beels* dry up in the winter but during the rains expand into broad and shallow sheets of water, which may be described as fresh water lagoons (GED, 2018, CIAT, 2017). There is 6300 *Beels*, and 3,500 of them are permanent and 2,800 of them are seasonal (BHWDB, 2020). The riverbanks of the Jamuna and the Padma make the region basin-shaped; the *Chalan Beel* is an extensive low land area at the lower Atrai basin, spread across the districts of Natore, Pabna and Sirajganj. The *Aril Beel* a basin like shape of the riverbanks of the Padma and Dhaleshwari rivers in Dhaka and Munshiganj districts. *Jheels* as an oxbow lake of an old river channel bed clogged with silt, in the south western Ganges deltaic flood plain. The area of *Beels* and *Jheels* have been reduced and land use has been changing. The soils have high organic matter content above 2%, high CEC, N, S, Zn, B, K and P content is low to medium and low moisture holding capacity (BARC, 2018; Khan *et al.*, 2008).

Management for crop production

- Cultivation of rice var. BRRI dhan 33, BRRI dhan 51, BRRI dhan 78, BRRI dhan 79, BRRI dhan 103, BINA Dhan 11, BINA Dhan 12, BINA Dhan 25, sesame var. BARI Til 4, mustard var. BARI Sharisha 14, BARI Sharisha 18, onion var. BARI Piaz-1, BARI Piaz-4, BARI Piaz-6, BARI Piaz-7, Garlic var. BARI Rasun-3, BARI Rasun-4, BARI Rasun-5, BAU Rasun 1, BAU Rasun 2, chilli var. BARI Morich-3, coriander var. BARI

Dhonia-2, patato var. BARI Alu 79 and ground nut var. BARI Cheenabadam-7, BARI Cheenabadam-8 and other *rabi* crops

- Mulching practices for moisture conservation
- Use conservation tillage practices
- Intercropping for increasing total productivity
- Application of Zn and B fertilizers for *Rabi* crops
- Traditional deep water rice cultivars should be cultivated in low land areas.
- Popularized Mustard-Boro-Fallow cropping pattern instead of Fallow-Boro-Fallow pattern.

Barind Tract Ecosystem

The Barind Tract (7,770 km^2) is developed over Madhupur clay in old alluvial formation, covering AEZ-25 (Level Barind Tract), AEZ-26 (High Barind Tract) and AEZ-27 (North Eastern Barind Tract) most parts of the Noagaon, Bogura, Dinajpur, Joypurhat, Siarjgonj, Natore, Rajshahi, Gaibandha, Chapai Nawabganj districts (Banglapedia, 2021, Salam *et al*., 2017). The greater part of the Barind Tract is almost plain and is crisscrossed by only a few minor rivers. This tract is considered as an ecologically fragile ecosystem with extremely low vegetation coverage (Aziz *et al*.,2016c, Ali, 2018). High temperature, low and erratic rainfall, heavy dependency on ground water for irrigation causes lowering of ground water table, prolonged dry season, fluctuation in diurnal temperature and land degradation which could be the major problems for crop production (Saifullah *et al.*, 2024, Islam *et al.*, 2019). The soil characteristics is silty loam to silty clay loam in texture, very low to low pH, low water holding capacity, very low to low status of N, P, K, Zn & B and low to medium organic matter content (Sarker *et al*., 2022, Riches *et al.*, 2008, Khan *et al*., 2008).

Management for crop production

- Cultivation of drought tolerant rice varieties: BINA Dhan 7, BINA Dhan 25, BRRI dhan 39, BRRI dhan 56, BRRI dhan 57, BRRI Dhan 66, BRRI dhan 71, BRRI dhan 75, BRRI dhan 103 and BRRI dhan 107. Barley (BARI Barley 8), Proso millet (BARI Cheena-2), Mustard (BARI Sharisa-14, BARI Sharisa-18, BARI Sharisa-20), Chickpea (BINA Chola-4, BARI Chola-10, BARI Chola-11), Grass pea (BARI Kheshari-3), Garlic (BARI Rasun-4, BARI Rasun-5, BAU Rasun-1), Garden pea (BARI Motorshuti-3), Lentil (BARI Masur-7, BARI Masur-9), wheat (BARI Gom-28), Onion (BARI Piaz-1)
- Minimum or zero tillage for conservation of soil moisture
- Relay cropping T. *Aman* with pulses
- Alternate wetting and drying technique used for rice production

- Harvesting rain water during rainy season
- Used balance fertilizers, lime, organic matter and brown manuring should be practiced.
- Practicing mulching and conservation agriculture technique.
- Potato-Onion-T. Aman, Potato-Maize-T. Aman, Potato-Mungbean-T. Aman, Wheat-Mungbean-T. Aman, Potato-Boro-T. Aman, Black gram-Boro-T. Aus, Mustard-Fallow-T. Aman, Lentil-Sweetcorn-T. Aman, Sorghum-Maize-T. Aman

Conclusion

Assuring future growth in agriculture will be a difficult endeavor; though, it is not possible. In order to fed the ever-increasing population from a very limited land resource. Future thrust should be given to increase crop production in adverse ecosystems like, coastal, hills, *haor*, *beels*, *jheel*, peats, piedmonts, Barind Tract and char lands. Adoption of modern with climate resilient crop varieties in cropping system and appropriate as well as sustainable technologies could increase crop production in these unfavorable ecosystems. Government should take initiatives to implement unfavorable ecosystem management technologies for upliftment of these socio-economic status of the areas for making a hunger free, happy and prosperous Bangladesh.

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