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Cropping Intensification and Environmental Degradation in Bangladesh

Indrajit Roy[1*]

Abstract

This paper describes how ongoing intensification of cropping in Bangladesh agriculture is contributing to environmental degradation by stressing natural resources that support agricultural production. In the backdrop of shrinking land resources, the pressure on cultivated lands for crop production is increasing. The average intensity of cropping has increased to 198 percent in 2021-2022 from 168 percent in 1989-1990. In the total annual cropped area in 2019-2020, the share of double cropped area was 25.7 percent and that of triple cropped area 11.7 percent. The share of single cropped area in total cropped was 13.1 percent declining at 2.8 percent annually between 2008-2009 and 2019-2020. Intensive cropping without application of appropriate soil fertility maintenance and soil conservation practices has depleted natural fertility and triggered land degradation through decline of soil organic matter and mining of essential plant nutrients. Excessive reliance on chemical fertilizers for maintenance of soil fertility has contributed to freshwater pollution by run-off and drainage apart from adverse effects on soil health. Increasing use of water for irrigation has led to drawdown of groundwater tables in the northern areas of the country amplifying the impact of climate change. Increasing use of chemical pesticides has triggered widespread degradation of the environment by toxic chemical residues accumulating in the soil, released in the natural ecosystem and adversely impacting both aquatic and terrestrial biodiversity.

Keywords: Intensification of cropping; Environmental degradation; Bangladesh agriculture; Aquatic and terrestrial biodiversity.

Introduction

Agricultural production is not neutral to the environment because the footprints it leaves have consequences for resources of the environment that support agricultural production. It does so by interacting with soil, land, water, air, and biological diversity with the results reflected at the ecosystem level. In this process the capacity of resources for regeneration, that is regaining their original state, is affected. When the capacity of regeneration of those resources starts deteriorating, a process called environmental degradation sets in. Degradation literally means loss of original quality or lowering of original worth which reduces the capacity of a resource to produce output at the same level as before. When concerted efforts are lacking to counteract the impact of farming practices that contribute

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to degrading the environment, the process becomes irreversible. Frequent incidence of climate change-related extreme weather events (drought and heat waves, short-term high intensity rainfall, cyclones) steps up this process. In the long run the capacity of local agriculture to sustain growth in food production to meet rising demands and support rural -based livelihoods is eroded. Globally, the interconnected systems of land, soil and water are stretched to the limit. Convergence of evidence points to agricultural systems breaking down, with impacts felt across the global food system. Current patterns of agricultural intensification are not proving sustainable. Pressures on land and water resources have built to the point where productivity of key agricultural systems is compromised and livelihoods are threatened (FAO, 2021).

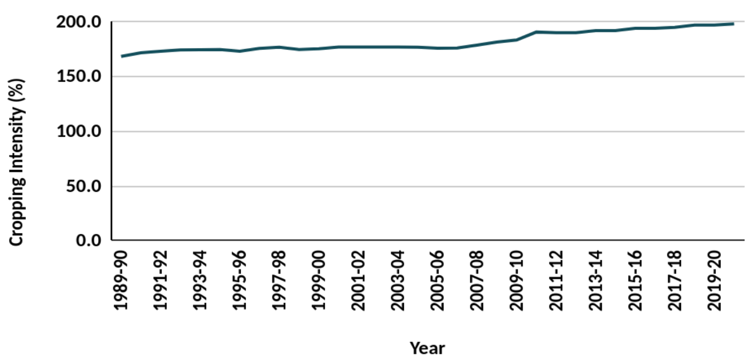
This paper looks at the broad picture of how this phenomenon is playing out in Bangladesh. It focuses on how increasing intensity of cropping along with application of chemical inputs are stressing land, soil, and water resources of Bangladesh with spillover effects across the ecosystem that in turn contribute to wider environmental degradation.

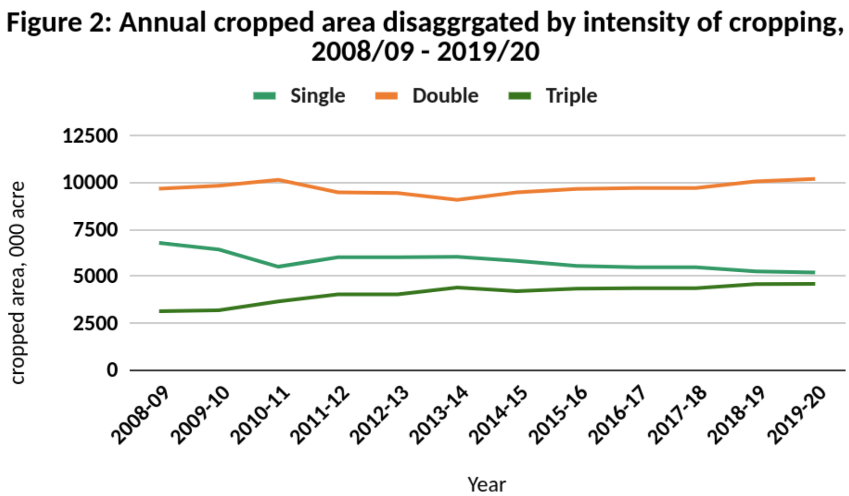
Land use

Land is the key resource upon which terrestrial agriculture is centered. Arable land is a shrinking resource in Bangladesh. It decreased from 8.605 million ha in 1961 to 8.00 million ha in 2020 (FAOSTAT). The supply of net cultivated area in the country decreased from 8.157 million ha in 1983-84 to 7.452 million ha in 2019 (BBS). One of the pressures during this period that population growth exerted on land was fragmentation of cultivated land holdings. It led to a decrease of net cultivated area per farm from 2.0 acre in 1983-84 to 1.1 acre in 2019. The need to produce more food from shrinking arable land resources has led to increasing intensity of cropping, that is cultivating the same land more than once round the year.

As evident from Figure 1, cropping intensity (measured as total cropped area/net cropped area x 100) has increased from 168 percent in 1989-90 to 198 percent in 2021-22 (BBS Yearbook of Agricultural Statistics 2022).

Figure 1: Increase of cropping intensity in Bangladesh, 1989/90-2020-21





During the period 2008/09 - 2019/20, single cropped area decreased from 6.786 million acres to 5.216 million acres, double cropped area increased from 9.677 million acres to 10.194 million acres, and the triple cropped area increased from 3.158 million acres to 4.613 million acres. In 2019-20, the share in total annual cropped area was 13.1 percent for single cropping; 25.7 percent for double cropping; and 11.6 percent for triple cropping (Figure 2). The extent of current fallow area (cultivated land left vacant) decreased from 3.3 percent to 2.7 percent during this period. In some areas of the country, quadruple cropping has been reported since 2010-2011. In 2019-20, the extent of quadruple-cropped land was 56,000 acres. It is therefore likely intensification of land use for food production in Bangladesh will continue.

But the practice, applied business as usual, contributes to environmental degradation. Because it depletes natural fertility of soils and triggers land degradation. It happens in many ways but mainly by consistent decline of soil organic matter content, mining of essential plant nutrients because of inadequate and imbalanced use of fertilizers, and worsening of soil structure all of which impact the soil quality. Historically, crop intensification while driving growth in food production in Bangladesh also impacted its soil resources. The impact of crop intensification on land use also depends upon the cropping patterns practiced. A field study conducted in 2017 encompassing all upazilas (sub-districts) of Bangladesh identified 316 cropping patterns (CPs), which farmers practiced during 2014-2015 excluding the very minor ones. Rice containing CPs ranked among top five CPs, which covered 51 percent of the net cropped area. The most dominant CP was Boro-Fallow-T. Aman, which covered 27 percent of net cropped area (Nasim et al.. 2017).

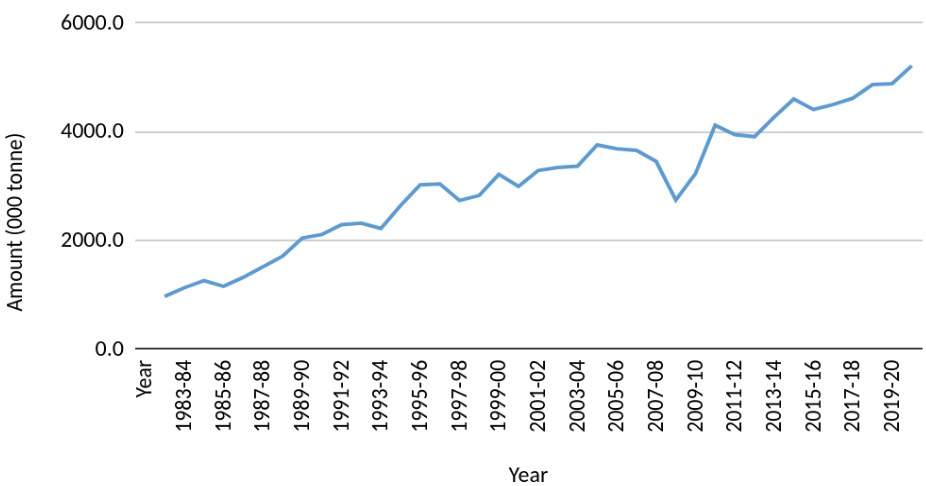
The introduction of high-yielding varieties since the late 1960s caused rapid depletion of fertility; N deficiency in all and P, K, and S in most soils, besides micronutrient deficiencies (zinc, boron, and magnesium) in specific soil groups. Most of the soils are depleted and in urgent need of replenishment with manures and fertilizer. Ideally, organic matter content in soils should be at least 3.5 percent to support maintenance of natural fertility. But in Bangladesh, organic matter content in most soils has dropped to 1.0 - 1.5 percent and farmers are becoming increasingly dependent on chemical fertilizers to maintain crop production (Abedin, 2023). It is estimated that more than 100 kg nutrients /ha /year are mined out from the soil system. (Islam, M.S., 2008). Intensification of cropping in the backdrop of declining soil fertility ranks top in the list of factors contributing to environmental degradation due to agricultural production in Bangladesh.

Chemical fertilizer use

In Bangladesh, the use of chemical fertilizers started in 1951 with 2,698 tonnes of ammonium sulphate. Urea and TSP were introduced in 1957 and MP in 1959 (Islam, M.S.). Consumption of fertilizer increased from 2,698 tonnes in 1951 to 68,017 in 1962. Since then fertilizer consumption rose steadily with intensification of cropping.

As evident from Figure 3, total fertilizer sales in Bangladesh increased from 968, 418 tonnes in 1982-83 to 5.208 million tonnes in 2020-21. Fertilizer sales during this period increased at 3.8 percent annually that far exceeded growth rates of production of rice and other staple crops during this period, where most fertilizers were applied. The rapid growth of fertilizer use in farm production was facilitated by government subsidies that kept the prices low allowing farmers to apply large quantities of fertilizer at their discretion in each cycle of crop production. As a result, a culture of excessive and indiscriminate use of chemical fertilizers had taken root in the farming practice. Application of chemical fertilizers to increase or maintain yields had significant adverse effects on soil health and has contributed to freshwater pollution by run-off and drainage.

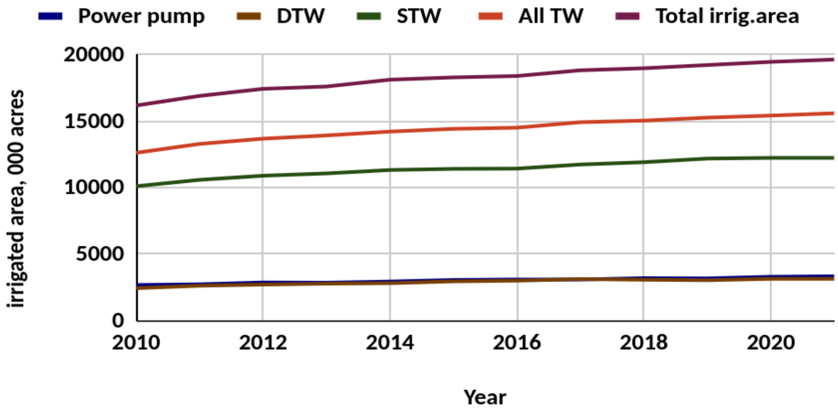
Figure 3: Total fertilizer sales in Bangladesh, 1982/83 - 2020/21



Irrigation

Besides increase in chemical fertilizer use, expansion of irrigation facilities drove intensification of cropping in Bangladesh (Figure 4).

Figure 4: Area irrigated by different means, 2009/10-2020/21



The share of irrigated area in total cropped area increased from 45.3 percent in 2009 - 2010 to 49.1 percent in 2019-2020. Historically, the growth in irrigation coverage in Bangladesh was driven by faster expansion of irrigation systems based on withdrawal of groundwater. It was facilitated by government subsidies on irrigation equipment, electric power and diesel fuel in attempts to promote cultivation of Boro rice in upland areas. Of all means of irrigation, groundwater-based irrigation systems (deep tubewell, shallow tubewell, and hand tube well) accounted for 78.0 - 79.3 percent share in total irrigation coverage over the period 2009/2010 - 2019/2020. The growth of DTW-based irrigation during this period was 2.3 percent per year and that of STW-based was 1.8 percent per year. But it had consequences on the environment because exploitation of groundwater, which is a finite resource and variable depending upon land, physiography and other characteristics, has to be sustainable in order to avoid adverse impacts on the environment. Sustainable exploitation of groundwater means drawdown should be replenished by recharge of the aquifer in order to avert mining of groundwater. Several studies conducted in Bangladesh point to the unsustainable nature of using groundwater for the purpose of irrigation. As reported in a study, in many areas of Bangladesh, the fall in pre-monsoon groundwater levels (at the regional average level) over the last few decades may be largely explained by the continual withdrawal of ever greater volumes of water with the three-fold increase in the area of irrigation (Kirbi et al. 2015) .

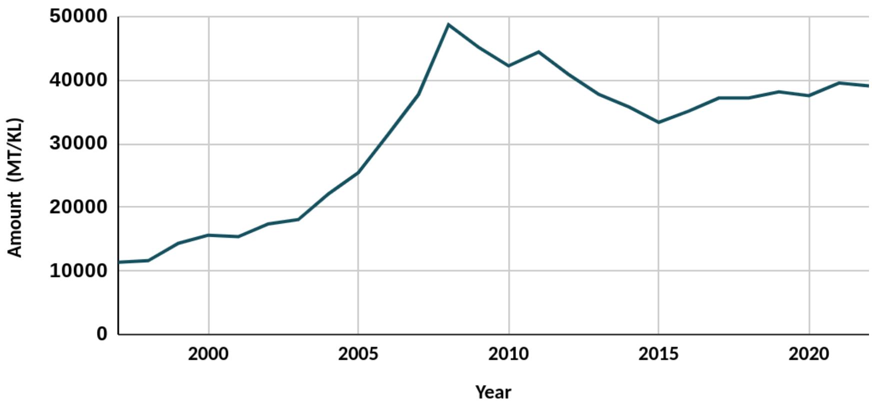
Expansion of deep and shallow tube wells resulted in serious problems, most notably excessive drawdown in intensively irrigated areas, and the deterioration of groundwater quality (Qureshi et al. 2014). In another research, a declining trend of groundwater table over the last 30 years (1981-2011) has been revealed, which implies groundwater use was not sustainable in the study area. The severely depleted district has been identified as Rajshahi followed by Pabna, Bogra, Dinajpur and Rangpur. The magnitude of the decline in groundwater table has been found between -2.3 to -11.5 m during the study period. It was mainly attributed to over exploitation of groundwater rather than recharging aquifers (Dey et al. 2013). The Government of Bangladesh has enacted rules in 2019 to regulate groundwater use in agriculture that among others specify distances between two pumps to be sited for lifting groundwater depending upon their pumping capacities to avoid excessive exploitation of groundwater. The GoB has also a policy in place named Integrated Minor Irrigation Policy 2107.

Pesticide use

Intensification of agriculture in Bangladesh witnessed dramatic growth in application of chemical pesticide as the primary pest control method in crop production. Until 1974, the Government promoted the use of pesticides by supplying them free of cost to farmers (100 percent subsidy). The subsidy was reduced to 50 percent in 1974. The Government withdrew subsidy completely in 1979 and the pesticide business was transferred to the private sector. After the withdrawal of subsidy, the use of pesticides declined during early years, but it has been on the increase since keeping pace with intensification of cropping.

Unlike other external inputs applied in crop production, pesticides degrade the natural environment via the soil-water-plant, animal and microbial biodiversity nexus and thus pose the gravest threat to the environment. There are many scientific studies available that document wide-ranging interactions of pesticides in this process. Mobilization of insecticides (the dominant pesticide product applied in crop fields) can occur via runoff (dissolved or sorbed to soil), atmospheric deposition, or subsurface flow (Goring and Hamaker 1972, Moore and Ramamoorthy 1984). Soil erosion from high intensity agriculture facilitates the transport of insecticides into waterbodies (Kreuger et al. 1999). Findings from other studies also illustrate how pesticides kill other beneficial insects which are natural enemies of many crop pests; pollute soil and water bodies and those effects add up to disrupt ecosystem services and biodiversity. Pesticide residues enter the food chain when people consume foods treated with excessive amounts of pesticides causing serious illnesses.

Figure 5: Use of pesticides in Bangladesh, 1997-2022



A field study conducted in Bangladesh reports excessive, irrational use of pesticides in agriculture, and lack of knowledge on pest management have caused widespread pesticide pollution which is now posing a substantial threat to the environment and local people. The presence of a considerable level of pesticides in soil, water, and vegetables indicates that farmers overuse pesticides that are deteriorating the environment (Barmon et al. 2021)..

These studies based on their findings recommend to authorities various alternative measures to restrict the use of pesticides. But instead of decreasing, pesticide use in Bangladesh is increasing as crop production is becoming more intensive. Recognizing the importance of reducing the use of chemical pesticides, the Ministry of Agriculture adopted the National Integrated Pest Management Policy (IPM) in 2002. The importance of IPM was reemphasized in the National Agriculture Policy 2018. IPM was introduced in Bangladesh in 1981 with the support of FAO in the first phase of FAO's inter-country programme (ICP) on IPM in rice crop. While there has been considerable progress in increasing awareness and knowledge among the farmers about harmful effects of chemical pesticides, the progress in promoting non-chemical means of pest control (baits, light traps, biological control agents, etc.) was limited and the use of chemical pesticides witnessed rapid increase.

As evident from Figure 4, pesticide consumption in Bangladesh was 11,367 MT/KL in 1997 which increased to 48,690 MT/KL in 2008 followed by a declining trend until 2015 (33, 372 MT/KL). Since 2016, pesticide use started increasing again which reached 39,543 MT/KL in 2021 (data source: Bangladesh Bureau of Statistics, Statistical Yearbook of Bangladesh, various years). Over the past 25 (1997-2021) years, the annual growth rate of pesticide use was 5.2 percent which surpassed the overall agricultural growth rate in this period. In addition to officially reported imports, a significant amount of unapproved and banned pesticides enter the country through illegal cross-border trading. How do pesticides end up when they are applied to crop fields? That, to a large extent, depends on how they are applied.

Chemical pesticides are toxic compounds. They are inherently hazardous with varying levels of toxicity; pose a threat to non-target organisms and the environment into which they are released. In true sense, there is no absolutely safe use of pesticides. To minimize unintended negative effects of pesticide application, standard operating procedures (SoPs) are developed that specify the dose of application of each product, protective measures to be taken during application, time of application, intervals between successive applications on the same crop; cut-off time of the last application from the harvest time; a tolerance level (maximum residue limit) for the presence of pesticide residues on food deemed to be safe, and some other aspects. But pesticide application following standard operating procedures (SoPs) requires field monitoring and technical oversight from regulatory agencies.

But in Bangladesh, regulatory control of pesticide application isn’t adequate particularly in the context of enforcement of pesticide rules. As a result, pesticide use is indiscriminate, excessive and often violates basic safety precautions. Because of these practices, some of the pesticides applied on the crop is retained in the soil, some is carried into streams, canals and rivers. As a result, the ecosystem is degraded and food safety is undermined by pesticide residues accumulated on edible parts of the produce often in excess of the allowed minimum residue level (MRL). There are studies that show indiscriminate and excessive use of pesticides in crop production in Bangladesh. A field survey conducted by Cornell University in 2020 found a 5-fold increase in the use of all agricultural pesticides (insecticides, herbicides and fungicides) between 1990 and 2010). In this same study the use of insecticides was reported to have increased more than 20-fold during this period (Cornell University, 2022).

Despite well-documented evidence of excessive and inappropriate application of pesticides, its use is increasing in Bangladesh. One reason might be the rapid increase in the number of stakeholders in pesticides than in IPM-based non-chemical approaches. Honestly, the stakeholders in IPM are only a few including researchers, extensionists, environmentalists and the farmers who have been trained in IPM. But pesticides have a broad spectrum of stakeholders because of enormous opportunities for business and making profits. As a result, over the past 30 years pesticide use in Bangladesh has grown into an industry. The change in marketing approach of rebranding pesticides as crop protection chemicals also helped in expansion of pesticide consumption.

Apparently both terms are the same; still there are nuances that make them somewhat different. Pesticide emphasizes the exact job it does, namely killing of insect pests, which evokes a negative perception. When the name "pesticide" is changed to "crop protector", the emphasis includes something extra besides killing pests. But pests are not the only harmful factors from which a growing crop plant (future food) needs to be protected. There are many other factors that stress crop growth and impact yield, for example, drought, flood, unexpected high temperatures, and frosts and so on. But pesticides don't protect crops from such hazards. On the contrary, they cause a wide range of harms which are ultimately transmitted to the food marketed for sale compromising its quality and safety for human consumption. More than 5,500 of various pesticide products are officially registered for use on agricultural crops in Bangladesh. Currently 22 companies produce and sell pesticide products in Bangladesh (Agropages). Considering multiple negative and harmful effects apart from environmental degradation arising from pesticide use, regulatory measures should consider clamping down on pesticide manufacturing, trade and marketing aimed at restricting the scope of its application in crop production. Non-chemical approaches such as IPM need to be promoted through research, extension, and training as a strategy to drastically reduce pesticide use and promote achieving the coveted goal of sustainability in agriculture.

Climate change

Apart from the use of external inputs, the effects of climate change play a significant role in the process of environmental degradation in Bangladesh. It is happening through shifts such as rising temperatures, increasing GHG emissions, shortening of the winter season and increase in average winter temperatures, intrusion of salinity in coastal areas, increase in frequency and intensity of extreme weather events (heat waves and drought, flooding, riverbank erosion) and changes in frequency and patterns of precipitation. Agriculture also contributes to GHG emissions. According to a study, in Bangladesh agriculture is anticipated to emit around 50 million tons of CO2 per year, primarily through rice cultivation, fertilizer-induced field emissions, field residue burning, and livestock production, including manure management. At the going rate, total agricultural emissions from Bangladesh are expected to reach 86.87 Mt CO2e by 2030, and 100.44 Mt CO2e by 2050 (Sapkota et al. 2021).

Increase in intensity of cropping contributes to environmental degradation due to climate change mainly through deepening the impact of climate change on land, soil and water resources. A study conducted in Bangladesh in 2017 found differences in emission of GHG from crop fields depending upon the cropping patterns practiced. The non-rice based cropping patterns had lower global warming potential (GWP) than rice-rice based cropping patterns. Other cropping patterns, such as Onion-Jute-Fallow, Jute-Rice-Fallow, Wheat-Mungbean-Rice and Maize-Fallow-Rice patterns were relatively more suitable for reducing GHG emission and subsequent GWP. There were spatial variations in CH4 emissions and the higher amounts were found in Mymensingh and Dinajpur districts of Bangladesh. On an average, about 1.39-1.56 Tg per yearCH4 emissions took place from paddy fields in Bangladesh during 2012-2015. However, Potato-Boro-T. Aman and Mustard -Boro-T. Aman cropping pattern showed highest total rice equivalent yield (REY) and low GWP than Boro-T. Aman-Fallow cropping patterns. But intermittent drainage for growing dry season irrigated rice under Potato-Boro-T. Aman and Mustard-Boro-T. Aman patterns can be adopted to reduce about 24-26 percent of total GHG emissions than continuous flooding and also to maintain higher crop productivity and food security in Asian countries like Bangladesh (Haque et al., 2017).

Prolonged heat waves trigger loss of soil moisture through increased evapotranspiration which in presence of drought can lead to depletion of groundwater resources. The trend over the past few years indicates this process may have begun in the north-western part of the country.

Containing environmental degradation

As cultivable land resources become scarcer, agriculture in Bangladesh is set to become more intensive to continue increasing food production. It can happen if the process of environmental degradation, which is alarming at its current pace, is halted and reversed. It is a key prerequisite for regeneration of natural resources and revitalization of ecosystem services to foster sustainability of agricultural production from a shrinking resource base. There are many agricultural technologies and farming practices that are now widely applied to mitigate GHG emissions and promote sustainability of agriculture.

According to Sapkota et al. (2021), Bangladesh could mitigate 9.51 Mt and 14.21 Mt CO2e from its agriculture sector by 2030 and 2050 by deploying targeted and often readily-available methods. For crops, examples of mitigation strategies include alternate wetting and drying in rice (intermittently irrigating and draining rice fields, rather than having them continuously flooded) and improved nutrient use efficiency, particularly for nitrogen. The research shows that better nitrogen management could contribute 60-65 percent of the total mitigation potential from Bangladesh's agricultural sector. Other options include adopting strip-tillage and using short duration rice varieties. For livestock, mitigation strategies include using green fodder supplements, increased concentrate feeding and improved forage/diet management for ruminants. Improved manure storage, separation and aeration is another potential tool to reduce greenhouse gas emissions. The mitigation options for livestock would make up 22 and 28 percent of the total potential emission reductions in the sector by 2030 and 2050, respectively.

The terms that are often used to describe the technologies and practices promoting sustainability are Sustainable Intensification, Climate-Smart Agriculture, Ecological Agriculture, Nature Friendly Farming, etc. All of these approaches emphasize reduction of the use of chemical fertilizers, pesticides, harnessing of ecological principles and biodiversity in farming practices; organic recycling and conservation practices to manage soil fertility; efficient utilization of water resources and avoidance of excessive utilization of groundwater resources, and other farming practices that restrict utilization of external inputs and seek harmony with Nature's principles of regeneration of resources.

There are also global and regional initiatives and platforms to promote sustainable agricultural practices. For example, FAO Global Soil Partnership (GSP), established in 2012 and FAO's scaling up of Agroecology Initiative launched in 2018. In Bangladesh, CSA practices are being introduced through participation of government and non-government organizations. A comprehensive list of such practices and technologies has been provided by a World Bank-conducted study.[2] But beyond CSA, more needs to be done at the policy and regulatory level to contain ongoing environmental degradation and promote sustainable agriculture. Those initiatives among others should focus on restricting indiscriminate use of external inputs, particularly drastic reduction of pesticide use and rationalization of the use of chemical fertilizers and groundwater resources; conservation of land and soil resources. Particular attention should focus on restoring natural fertility of soils to reduce dependence on chemical fertilizers and exerting control on pesticide manufacturing, trade and marketing. Key elements of sustainable agriculture need to be promoted at the farm level much in the same way the Green Revolution was introduced in the past century.

Conclusion

In the post-Green Revolution era, intensification of agriculture in Bangladesh is still on the same path as it was then despite the shift of emphasis to changing its course toward sustainability. It is happening with application of chemical fertilizers, pesticides and utilization of groundwater resources for irrigation more frequently as land use is becoming more intensive. As a result, total annual use of chemical inputs and other non-renewable natural resources in agricultural production is increasing. Climate-Smart Agriculture (CSA) practices are being introduced to promote sustainability of farming but at a pace which falls far short of making a meaningful difference in the current state of application of chemical fertilizers, pesticides and use of water resources in agriculture.

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Floristic composition and population structure of vascular plant diversity of Bangabandhu Sheikh Mujib Safari Park (BSMSP) at Dulahazara, Cox's Bazar, Bangladesh

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Abstract

Bangabandhu Sheikh Mujib Safari Park (BSMSP) is one of the richest ecosystems in regard to floristic composition in Bangladesh. The main purpose of this study was to assess the composition, distribution and diversity of flora of BSMSP at Dulahazara, Cox's Bazar from January-July, 2021. A total of 41 sample plots were taken from large 6 blocks and samples were taken from each block based on block size, each of 20m × 20m in size for tree, shrub, herb, climber; and 5m × 5m for regeneration survey. Results of the survey revealed a total of 201 plant species under 83 families and among the families Poaceae was represented by maximum (13 species). Among the flora, tree species were highest (94) followed by herb (40 species), climber (27 species), shrub (23 species), fern (8 species), epiphyte (5 species) and parasite (4 species). Among the 94 tree species, a total of 64 tree species from 1.64 ha sampled area; 77 sapling and 56 regenerating tree species from 0.1025 ha sampled area were recorded. The information provides a baseline of plant species, composition, diversity, and population structure that will be helpful to track the future changes and inform policy makers to take proper decisions for the sustainable management of the Safari Park.

Keywords: Diversity, Safari Park, Floristic, Regeneration, Conservation.

Introduction

Biodiversity is an important resource because it supplies food, medicines, fiber, fuel, building materials and other needs (Green, 2009). Tree species diversity may be considered as a preliminary indicator of diversity of plant forms in a forest type and information on floristic composition, their quantitative structure and diversity are vital to understand the functions and dynamics of forest ecosystems (Rahman et al., 2019). An extensive list of flora and fauna including all lower plants and animals along with their

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present conservation status and a healing plan is needed for management of biodiversity in a Protected Area (Chowdhury et al., 2018; Hossen et al., 2019; Hossain et al., 2020).

During the last few decades, the whole terrestrial natural forest structure of Bangladesh is negatively changed by both biotic and abiotic disturbances which ultimately affect the regeneration and population dynamic (Hossain et al., 2015; Hossen et al., 2019) and mainly anthropogenic disturbances is accelerating encroachment and degradation of the natural forest patches of Bangladesh (Rahman et al., 2017; Hossain et al., 2018). The extent of biodiversity loss in Bangladesh is not exactly known due to poor survey, database and scarce information (Mamun et al., 2015). Moreover, numerous plant species are also at risk of being lost in all or part of their distribution ranges because of their population number reduction due to overexploitation in Bangladesh (Rahman et al., 2000; Hossain et al., 2018). So it is an urgent need in Bangladesh to protect and manage the existing natural forests for sustainable livelihoods for the future generation (Hossen & Hossain, 2018) and to develop national forest management strategies (Hossen et al., 2021; Hossain et al., 2020).

Except for the three Protected Areas of National Park, Wildlife Sanctuary, and Game Reserve, Safari Park is a notion as a specialized protected area together with eco-park in Bangladesh (Hossen et al., 2014). Previously, several native tree species, e.g. Garjan (*Dipterocarpus* spp.), Boilam (*Anisoptera scaphula*), Telsur (*Hopea odorata*), Civit (*Swintonia floribunda*), Chapalish (*Artocarpus chama*), Champa (*Michelia champaca*), Gutgutya (*Protium serratum*), and wildlife, e.g. Spotted deer, Leopard, Wild cat, Foxes, Sojaru, Ajgor, Monkeys, Tiger, Elephant, and various birds were found in Dulahazara, Cox's Bazar. Due to settlement, illegal felling, encroachment on forest lands and land use conflicts, population of wildlife is now becoming very rare. So, to protect these wildlife and valuable indigenous rare plants, steps have been taken to establish the Bangabandhu Sheikh Mujib Safari Park (BSMSP), Dulahazara with tourism, education, and research facilities. Since the endemics have a high conservation value because of their distribution is extremely limited and they may become extinct due to human-caused threats (Mesta and Hegde, 2018). As a result, understanding floristic composition and natural regeneration patterns is critical for conserving and restoring the valuable indigenous species. But, still no research work has been conducted to investigate total floristic composition and regeneration potentiality in this park. Considering these issues, the recent study was conducted to provide a detailed assessment of floral diversity and composition in Bangabandhu Sheikh Mujib Safari Park (BSMSP).

Materials and Methods

Description of the study area

Bangabandhu Sheikh Mujib Safari Park (BSMSP) is located on previously declared reserve forest land of Fashiakhali Forest Range of Cox’s Bazar North Forest Division in Chakaria upazilla, Cox’s Bazar district. It was established in 1996 and situated beside the Chittagong - Cox’s Bazar Highway, 47 km north of Cox’s Bazar town. It comprises an area of 900 ha (Masum et al., 2012). The Safari Park is under Wildlife Management and Natural Conservation Division, Chattogram and lies between 20°50' to 21°50' North latitude and between 92° 00' to 92°15' East longitude. The climate of this park is ‘moist tropical maritime' and mean annual rainfall (MAR), average annual humidity (AAH) and mean annual temperature (MAT) are 1,740.8 mm, 79.3% and 26.60^{0}C respectively (Uddin and Misbahuzzaman, 2007). The topographic landscape of BSMSP is undulated hilly area with green and semi-green coverage. Many depressions, narrow valleys and perennial natural streams flow inside the park that contain good quality of water for the year round. This park is enriched by native flora along with wild, semi-wild and captive wild animals. Some ornamental plants also exist there (Hossen et al., 2014).

Data collection method

The data collection was conducted from January-July, 2021. In this study, a complete random block sampling method was used for getting accurate information about regeneration, recruitment and species composition of the study area. The whole park was divided into 6 block and randomly 41 plots were taken from those blocks. Plot number was based on block size like 6 in old deer breeding centre, 3 in Tiger enclouser, 4 in Lion enclouser and Asian and African herbivorous animal roaming zone, elephant enclouser, grazing land and plantation zone comprises 9, 12, 7 plots repectively (**Fig. 1**). Each of the plots was 20m × 20m in size. Plants within plot having dbh ≥10 cm were recorded as tree in note book. Height and dbh of each tree of the plot were recorded. Within the 20m × 20m plot, all vascular plants were recorded. In the centre of 20m × 20m plot, a 5m × 5m plot was laid out to record sapling having dbh <10cm to dbh ≥ 2cm. Within the 5m × 5m plot, all seedlings individually having dbh <2cm were counted and recorded to understand the regeneration potential of the park. All the recorded data were anlysed with the help of MS Excel.

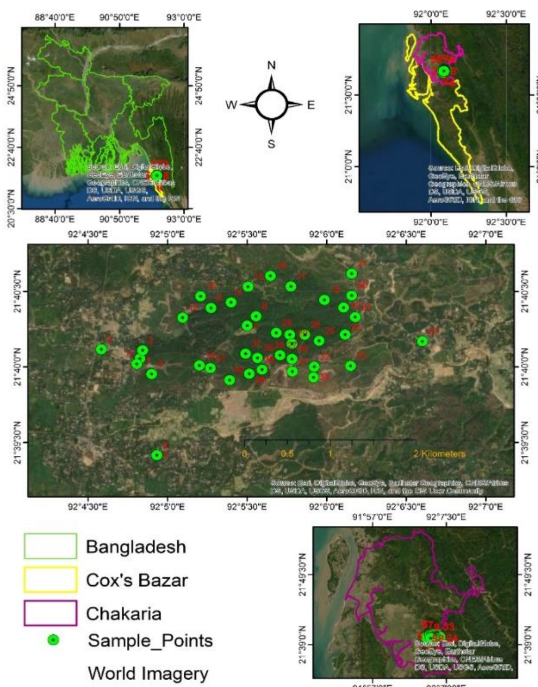

Figure 1. Location of Bangabandhu Sheikh Mujib Safari Park and surveying points

Results and Discussions

Floristic composition

The study revealed a total of 201 plant species under 83 families from the Bangabandhu Sheikh Mujib Safari Park. Lists of the plant species were arranged according to families in alphabetic order with their local name, scientific name and their uses. The study also revealed top 5 families contain more than 26% (53 species) of all plant species, whereas 51 families contain only 1 species each. Among the 83 families, Poaceae was represented by maximum 13 species followed by Euphorbiaceae (12 species), Moraceae (10 species), Combretaceae (9 species), Rubiaceae (9 species). All the recorded plants fall under tree (including sapling and seedling), shrub, herb, climber, fern, epiphyte and parasite habit forms, where trees were represented by maximum 94 tree species followed by herb (40 species), climber (27 species), shrub (23 species), fern (8 species), epiphyte (5 species) and parasite (4 species) (Fig. 2).

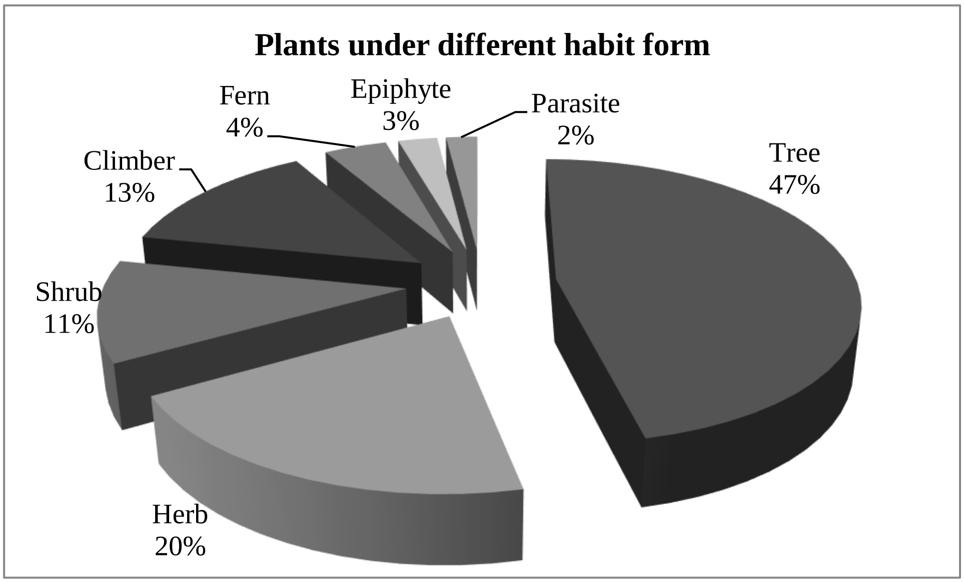

Figure 2. Distribution of plant species (%) into different habit forms recorded from BSMSP

Tree species composition

A total of 94 tree species including sapling and seedling belonging to 37 families were recorded from Bangabandhu Sheikh Mujib Safari Park (Table 1 and Fig. 3). Out of 37 families, highest 10 species were found in Euphorbiaceae family and Moraceae, Myrtaceae, Combretaceae family contain 9, 6, 6 species respectively. Each of Dipterocarpaceae and Fagaceae families possess 5 species and the remaining families contain 1-4 species (Table 1).

A. Trees

Tree coverage is the major part of any forest. A total of 64 tree species belonging to 24 families were recorded from the total 1.64 ha sampled area of BSMSP (Table 1 and Fig. 3). Out of 24 families, highest 8 species were found in Euphorbiaceae family followed by 6 species in Moraceae, 5 species in Myrtaceae family. Each of the Dipterocarpaceae, Combretaceae, Mimosaceae and Verbenaceae family contains 4 species (Table 1).

B. Saplings

A total of 77 tree species belonging to 30 families were recorded from the 0.1025 ha sampled area of BSMSP (Table 1 and Fig. 3). Out of 30 families, highest 9 species were found in Euphorbiaceae family and Moraceae, Myrtaceae, Dipterocarpaceae, Combretaceae and Fagaceae contain saplings of 6, 6, 5, 5 and 5 species respectively (Table 1).

C. Regenerating tree species (seedlings)

Total 56 tree species belonging to 30 families were recorded from the total 0.1025 ha sampled area of BSMSP (Fig. 3 and Table 1). Out of 30 families, highest 7 species were found in Euphorbiaceae family and Myrtaceae, Combretaceae and Fagaceae contain seedlings 6, 4 and 4 species respectively (Table 1).

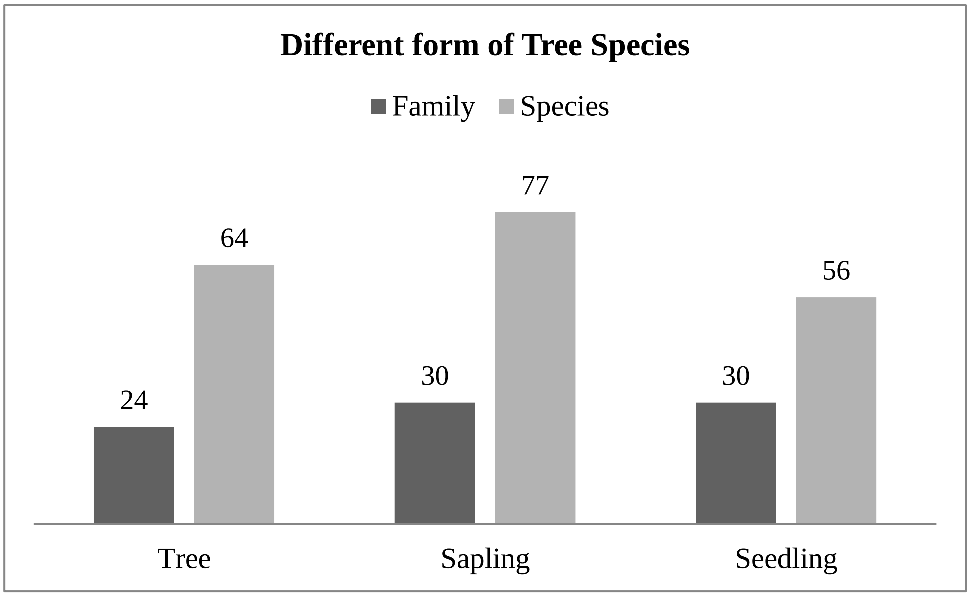

Figure 3. Number of family and species in different form of tree species

Table 1. Recorded tree species including their stages from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses	Tree form
1	Anacardiaceae	*Swintonia floribunda*	Civit	N, T	Tree, Sapling
		Lannea coromandelica	Jial bhadi	Fd, M, T	Tree, Sapling
		Anacardium occidentale	Kaju Badam	Fd, M, T	Sapling
		Mangifera sylvatica	Uriam	Fd, N, T	Sapling, Seedling
2	Apocynaceae	*Alstonia scholaris*	Chatim	N	Tree
		Holarrhena antidysenterica	Kuruch, Kuruj	M	Sapling, Seedling
3	Arecaceae	*Didymosperma gracilis*	Bon Supari	N, M	Seedling
		Pinanga gracilis	Ram supari	Fd, N	Tree
4	Bignoniaceae	*Fernandoa adenophylla*	Kala oisha	M	Sapling, Seedling
5	Bixaceae	*Bixa orellana*	Rong gula	Dye	Sapling, Seedling
6	Bombacaceae	*Bombax insigne*	Bon Tula	N	Seedling
		Bombax ceiba	Shimul tula	M, T	Tree, Sapling
7	Burseraceae	*Garuga pinnata*	Bhadi	Fd, M, T	Tree, Sapling, Seedling
		Protium serratum	Gutgotiya	Fd, T	Tree, Sapling
8	Caesalpiniaceae	*Cassia fistula*	Sonalu	Fd, M, T	Seedling
9	Capparaceae	*Crateva magna*	Barun	F	Sapling
10	Clusiaceae	*Garcinia cowa*	Kao	Fd, N, T	Tree, Sapling, Seedling
		Calophyllum inophyllum	Punnayl	M, N, T	Seedling
11	Combretaceae	*Terminalia arjuna*	Arjun	M, T	Tree, Sapling
		Terminalia bellirica	Bohera	Fd, M, T	Tree, Sapling
		Terminalia chebula	Haritaki	M, N, T	Tree, Sapling, Seedling
		Terminalia sp.	Jungalia Haritaki	M	Tree, Sapling, Seedling
		Terminalia catappa	Kat badam	Fd, M, T	Sapling
		Anogeissus acuminata	Sikori, Sheori	N, T	Seedling
12	Dilleniaceae	*Dillenia indica*	Chalta	Fd, M, T	Tree, Sapling, Seedling
		Dillenia pentagyna	Hargeza	F, T	Tree, Sapling, Seedling
13	Dipterocarpaceae	*Dipterocarpus costatus*	Baitta Garjon	F, N, T	Tree, Sapling, Seedling
		Dipterocarpus alatus	Doilla Garjon	M, T	Tree, Sapling, Seedling
		Shorea robusta	Sal, Gazari	M, N, T	Sapling
		Dipterocarpus turbinatus	Telia Garjon	N, T	Tree, Sapling, Seedling
		Hopea odorata	Telsur	M, N, T	Tree, Sapling, Seedling
14	Elaeocarpaceae	*Elaeocarpus tectorius*	Jalpai	Fd, T	Tree, Sapling, Seedling
15	Euphorbiaceae	*Phyllanthus emblica*	Amloki	Fd, M, N	Tree, Sapling, Seedling
		Chaetocarpus castanocarpus	Atailla	F	Tree, Sapling, Seedling
		Macaranga denticulata	Bura	M	Tree, Sapling
		Sapium baccatum	Champata	M	Sapling
		Antidesma acidum	Elena	Fd, M	Tree, Sapling, Seedling

		Aporosa wallichii	Kechua	NK	Tree, Sapling, Seedling
		Antidesma ghaesembilla	Khudi Jam	M, N	Tree, Sapling, Seedling
		Glochidion lanceolarium	Lomba kechua	N	Seedling
		Glochidion multiloculare	Pannyaturi	T	Sapling
		Mallotus philippensis	Sindur	F, Fd, M	Tree, Sapling
16	Fabaceae	*Butea monosperma*	Palash	F, Fd	Seedling
17	Fagaceae	*Lithocarpus sp.*	Batna	F, T	Sapling, Seedling
		Lithocarpus polystachyus	Gappa batna	T	Tree, Sapling, Seedling
		Lithocarpus elegans	Kali batna	F, N, T	Sapling
		Quercus gomeziana	Khossa batna	T	Tree, Sapling
		Castanopsis indica	Shil batna	F, N	Tree, Sapling, Seedling
18	Flacourtiaceae	*Flacourtia jangomas*	Painnagula	Fd, M, T	Tree, Sapling, Seedling
		Thespesia populnea	Parash, Ladum	M	Tree, Sapling, Seedling
19	Juglandaceae	*Engelhardtia spicata*	Dad	M	Sapling
20	Lauraceae	*Litsea monopetala*	Menda	M	Tree, Sapling
		Cinnamomum iners	Tez-bohu	M, T	Tree, Sapling, Seedling
21	Lecythidaceae	*Barringtonia acutangula*	Hijol	M	Tree, Sapling, Seedling
22	Magnoliaceae	*Michelia champaca*	Champa	N, T	Tree, Sapling, Seedling
23	Meliaceae	*Chukrasia tabularis*	Chickrassi	M, N, T	Tree
		Azadirachta indica	Neem	M, N	Sapling, Seedling
		Aphanamixis polystachya	Pitraj, Royna	M, T	Tree, Sapling
24	Mimosaceae	*Acacia auriculiformis*	Akashmoni	F, N, T	Tree, Sapling, Seedling
		Albizia lebbeck	Kala Koroi	F, N, T	Tree, Sapling
		Pithecellobium angulatum	Kuramara	N	Tree, Sapling, Seedling
		Xylia xylocarpa	Lohakath	M, N, T	Tree, Sapling
25	Moraceae	*Artocarpus lacucha*	Borta	Fd, M, T	Sapling
		Ficus benghalensis	Bot	Fd, M, N	Tree, Sapling
		Ficus lanceolata	Buti dumur	Fd	Tree
		Artocarpus chama	Chapalish	Fd, T	Tree, Sapling
		Ficus hispida	Dumur	Fd, M, N	Tree, Sapling, Seedling
		Ficus lamponga	Jig bot	F	Tree
		Ficus auriculata	Lal dumur	Fd	Sapling
		Ficus benjamiana	Pakur	F, N	Seedling
		Streblus asper	Sheora, Harba	Fd, M	Sapling
26	Myristacaceae	*Myristica linifolia*	Lowbarela	F, T	Sapling
27	Myrsinaceae	*Maesa indica*	Maesa	Fd, M	Seedling
28	Myrtaceae	*Syzygium firmum*	Dhaki jam	Fd, N	Tree, Sapling, Seedling
		Syzygium praecox	Dhuli jam	Fd, T	Tree, Sapling, Seedling
		Syzygium jambos	Gulap jam	Fd, M, T	Tree, Sapling, Seedling
		Syzygium cumini	Kalo jam	F,Fd,M,T	Sapling, Seedling

		Syzygium claviflorum	Noli jam	Fd	Tree, Sapling, Seedling
		Syzygium fruticosum	Puti jam	F, Fd, N	Tree, Saplin, Seedling
29	Rhamnaceae	*Ziziphus mauritiana*	Boroi	F, Fd	Seedling
30	Rubiaceae	*Mitragyna parvifolia*	Dakrum	F, T	Tree, Sapling, Seedling
		Haldina cordifolia	Haldu	T	Tree, Sapling
		Neolamarckia cadamba	Kadam	M, T	Tree
31	Sapindaceae	*Dimocarpus longan*	Ashphal	Fd, N, M	Tree, Sapling, Seedling
		Lepisanthes senegalensis	Gota harina	Fd, T	Tree, Sapling, Seedling
		Lepisanthes rubiginosa	Horina gula	F, M	Tree, Sapling, Seedling
32	Sonneratiaceae	*Duabanga grandiflora*	Bandarhaula	T	Tree, Sapling
33	Sterculiaceae	*Firmiana colorata*	Udal	Fd	Seedling
34	Tiliaceae	*Grewia nervosa*	Assargola	F, M	Tree, Sapling, Seedling
35	Verbenaceae	*Gmelina arborea*	Gamar	M, T	Tree, Sapling
		Vitex peduncularis	Goda	Fd, M, T	Tree, Sapling, Seedling
		Vitex glabrata	Goda arsol	Fd, M, T	Tree, Sapling, Seedling
		Vitex pinnata	Horina arsol	T	Tree, Sapling, Seedling
36	Xanthophyllaceae	*Xanthophyllum andamanicum*	Hanshuk	T	Tree, Sapling, Seedling

[Here, F = Fuel wood, Fd = Food and Foodder, M = Medicinal, N = Multiple non-timber use (other than fuel, food, fodder and medicine), T= Timber, Nk = Not known.]

Shrubs

A total of 23 species belonging to 17 families were recorded from the sampled area of BSMSP (Table 2 and Fig. 4). Out of 17 families, Rubiaceae, Verbenaceae and Combretaceae family contain 4, 3 and 2 species respectively. The remaining families possess 1 species only. *Gigantochloa nigrociliata* (Kali bansh), *Clerodendrum viscosum* (Bhant), *Calycopteris floribunda* (Guichalata), *Melastoma malabathricum* (Bontezpata) are some of the shrubs that were found commonly in BSMSP.

Table 2. Recorded shrubs from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses
1	Acanthaceae	*Justicia adhatoda*	Bashokpata	M
2	Apocynaceae	*Allamanda cathartica*	Mikeful	M, N
3	Arecaceae	*Licuala peltata*	Kurukpata	N
4	Bignoniaceae	*Tecoma stans*	Holde	M, N
5	Clusiaceae	*Garcinia lancifolia*	Badijjara	M
6	Combretaceae	*Calycopteris floribunda*	Guicha lata	M
		Combretum latifolium	Sada guicha	Nk
7	Convolvulaceae	*Ipomoea fistulosa*	Dhol kolmi	F, N
8	Dilleniaceae	*Tetracera sarmentosa*	Lata chalta	M
9	Euphorbiaceae	*Acalypha hispida*	Hatisur	M
10	Malvaceae	*Abelmoschus moschatus*	Mushak-dana	N, M
11	Melastomataceae	*Melastoma malabathricum*	Bon tezpata	M

No.	Family	Scientific name	Local name	Uses
12	Plumbaginaceae	*Plumbago zeylanica*	Chitra	M
13	Plumbaginaceae	*Aeqialitis rotundifolia*	Nunia	F, M
14	Poaceae	*Gigantochloa nigrociliata*	Kali bansh	Fd
15	Rhamnaceae	*Ziziphus oenoplia*	Bon boroi, Got boroi	Fd, M, N
16	Rubiaceae	*Canthium parvifolium*	Bish-main	M
		Oxyceros kunstleri	Moish kanta	M
		Mussaenda erythrophylla	Muchonda	N
		Morinda angustifolia	Rong, Banamali	M, N
17	Verbenaceae	*Clerodendrum indicum*	Bamunhatti	M, N
		Clerodendrum viscosum	Bhant	M
		Premna esculenta	Lelom pada, Lalana	Fd, M

Herbs

A total of 40 species belonging to 25 families were recorded from the sampled area (1.64 ha) of the BSMSP (Table 3 and Fig. 4). Out of 25 families, highest 12 species were found under Poaceae family. *Chromolaena odorata* (Assam gach), *Flemingia triphylla* (Dai lata), *Cynodon dactylon* (Durba grass) and *Capparis zeylanica* (Kata lata) are some of herbs that were found frequently in BSMSP.

Table 3. Recorded herbs from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses
1	Amaranthaceae	*Alternanthera philoxeroides*	Helencha	Fd
		Amaranthus spinosus	Kantashak	Fd, M
2	Apiaceae	*Centella asiatica*	Thankuni	Fd, M
3	Apocynaceae	*Catharanthus roseus*	Nayantara	N, M
4	Asclepiadaceae	*Asclepias curassavica*	Moricha	M
5	Asteraceae	*Chromolaena odorata*	Assam gach	M
6	Boraginaceae	*Heliotropium indicum*	Hatisur	M
7	Capparaceae	*Capparis zeylanica*	Kata lata	N
8	Caryophyllaceae	*Spergula arvensis*	Pargula	M
9	Crassulaceae	*Bryophyllum pinnatum*	Pathorkuchi	Fd, M
10	Cymodoceaceae	*Costus speciosus*	Bonroi	M
11	Cyperaceae	*Cyperus cyperoides*	Kucha	Fd, M
12	Fabaceae	*Tephrosia purpurea*	Bon nil	M, N
		Sesbania bispinosa	Dhouncha	Fd, M, N
		Crotalaria juncea	Jhun-jhuni	M
13	Heliconiaceae	*Heliconia psittacorum*	Kola phul	N
14	Hydrophyllaceae	*Hydrolea zeylanica*	Kasschara	Fd, M
15	Lamiaceae	*Hyptis suaveolens*	Tokma	M, N
16	Liliaceae	*Curculigo latifolia*	Biddiri pata	N, M
17	Marantaceae	*Schumannianthus dichotomus*	Patipata	N

No.	Family	Scientific name	Local name	Uses
18	Mimosaceae	*Mimosa pudica*	Lajjabati	M
19	Molluginaceae	*Glinus oppositifolius*	Gima shakh	M
20	Musaceae	*Musa ornata*	Ram kola	Fd
21	Papilionaceae	*Flemingia triphylla*	Dai lata	N
22	Poaceae	*Axonopus compressus*	Carpet durba	Fd, N
		Hemarthria protensa	Chalia ghas	Nk
		Imperata cylindrica	Chan	Fd, M, N
		Brachiaria distachya	Cori ghas	Fd, N
		Cynodon dactylon	Durba grass	Fd, M, N
		Thysanolaena maxima	Jharuful	Fd, N
		Saccharum spontaneum	Kash	Fd, N
		Phragmites karka	Nalkhagra	Fd, M, N
		Eriochloa procera	Nolghass	Fd
		Brachiaria reptans	Para ghas	Fd
		Chrysopogon aciculatus	Prem kanta	Fd, M, N
		Echinochloa crusgalli	Shama ghas	Fd, N
23	Polygonaceae	*Persicaria hydropiper*	Biskatali	M
		Polygonum effusum	Rani phul	M
24	Pontederiaceae	*Eichhornia crassipes*	Kochuripana	Fd
25	Zingiberaceae	*Zingiber sp.*	Ketra	Fd, M

Climbers

A total of 27 species belonging to 20 families were recorded from 1.64 ha sampled area of BSMSP (Fig. 4 and Table 4). Out of 20 families, highest 3 species are found under each of Arecaceae and Fabaceae family. *Smilax ovalifolia* (Kumari lata), *Acacia concinna* (Hat pusia kata), *Piper hamiltonii* (Jungalia pan), *Calamus tenuis* (Sanchi bet) and *Capparis zeylanica* (Kata lata) are some of herbs that were found frequently in BSMSP.

Table 4. Recorded climbers from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses
1	Annonaceae	*Desmos chinensis*	Jokelata	M
2	Apocynaceae	*Ichnocarpus frutescens*	Paralialata	M, N
		Willoughbeia endulis	Lata aam	Fd, M
3	Arecaceae	*Calamus longisetus*	Uddum bet	Fd, N
		Calamus latifolius	Korak bet	Fd, N
		Calamus tenuis	Banduri bet, Sanchi bet	Fd, N
4	Asclepiadaceae	*Cynanchum callialata*	Chagolbati	Nk
5	Asteraceae	*Mikania cordata*	Assam lota	Fd, M
6	Combretaceae	*Combretum ternatum*	Guicha lota	Nk
7	Connaraceae	*Rourea minor*	Kawaturi lata	M, N
8	Convolvulaceae	*Argyreia capitiformis*	Padura lota, Vogalata	M

No.	Family	Scientific name	Local name	Uses
		Merremia vitifolia	Kormo lota	M
9	Cucurbitaceae	*Luffa cylindrica*	Purul	Fd, N
10	Dioscoreaceae	*Dioscorea pentaphylla*	Alu lota	Fd, M
11	Euphorbiaceae	*Tragia involucrata*	Chotrapata	M
12	Fabaceae	*Dalbergia volubilis*	Saban phul	N
		Mucuna pruriens	Al-kushi	M
		Acacia concinna	Hat pusia kata	M
13	Menispermaceae	*Pericampylus glaucas*	Goria lota	M, N
14	Mimosaceae	*Entada rheedii*	Gila lata	M, N
15	Oleaceae	*Jasminum scandens*	Jasmin	Nk
16	Piperaceae	*Piper hamiltonii*	Jungalia pan	Nk
17	Rubiaceae	*Hedyotis scandens*	Bishlata	M
		Paederia foetida	Badali, Modhu lota	M
18	Smilacaceae	*Smilax ovalifolia*	Kumari lata	Fd, M
19	Sterculiaceae	*Byttneria pilosa*	Harjoralata	M
20	Thymeliaceae	*Linostoma decandrum*	Mellata	Nk

Fern

A total of 8 species belonging to 8 families were recorded from 1.64 ha sampled area of the BSMSP (Fig. 4 and Table 5). Each family possesses only 1 species. These ferns were very much common in BSMSP.

Table 5. Recorded fern family and species from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses
1	Adiantaceae	*Adiantum incisum*	Biddapata	N
2	Angiopteridaceae	*Angiopteris evecta*	Dhakia shak	Fd, M, N
3	Athyriaceae	*Diplazium polypodioides*	Dhekia	Nk
4	Gleicheniaceae	*Dicranopteris linearis*	Lombadekia	M, N
5	Lindsaeaceae	*Lindsaea ensifolia*	Bon dhekia	Nk
6	Lygodiaceae	*Lygodium flexuosum*	Lata dhekia	M, N
7	Marsileaceae	*Marsilea quadrifolia*	Susnishak	Fd, M
8	Polypodiaceae	*Drynaria quercifolia*	Pankhiraj	Nk

Epiphyte

Total 5 species belonging to 3 families were recorded from 1.64 ha sampled area of the BSMSP (Fig. 4 and Table 6). 3 species were found under Orchidaceae family and the other families possess only 1 species. The species were frequently found in BSMSP.

Table 6. Recorded epiphytes from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses
1	Araceae	*Pothos scandens*	Hatilota, Sunat	M
2	Asclepiadaceae	*Dischidia major*	Majarula	Nk
3	Orchidaceae	*Aerides odorata*	Sukh phul	M
		Bulbophyllum lilacinum	Gota parchallow	N
		Rhynchostylis retusa	Orchid	N, M

Parasite

Total 4 species belonging to 3 families were recorded from the 1.64 ha sampled area of the BSMSP (Fig. 4 and Table 7). 3 species were found under Orchidaceae family. Parasites were very much common in BSMSP.

Table 7. Recorded parasite from BSMSP along with their uses

No.	Family	Scientific name	Local name	Uses
1	Asclepiadaceae	*Hoya parasitica*	Porgacha	Nk
2	Cuscutaceae	*Cuscuta reflexa*	Swarna lata	M
3	Loranthaceae	*Macrosolen cochinchinensis*	Phorolla, Reuda	N
		Scurrula gracilifolia	Phorolla, Porgacha	Nk

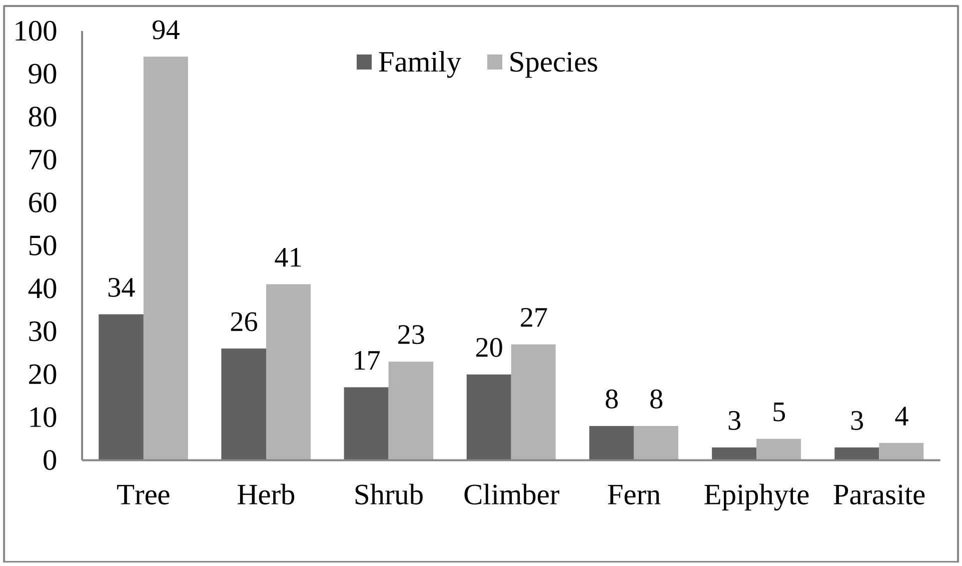

Figure 4. Number of plants under different categories of family and species recorded from BSMSP

Discussion

The results of the present study are comparable with previous results that were conducted in differents forest areas in Bangladesh. It will be also helpful to know the actual conditions of floristic composition, distribution and diversity of BSMSP. Mamun et al. (2015) found 99 species belonging to 36 families in secondary hill forest of Chunati WS, Chittagong. 285 angiosperm species belonging to 67 families were found by Uddin et al. (2011) in Fashiakhali WS, Cox's Bazar and 68 species of trees (31 families), 14 species of shrubs, 31 species of herbs and climbers under 29 families were found in Chittagong (South) Forest Dvision by Alamgir and Al-Amin (2005). BSMSP's tree species composition (94 tree species, 36 families) with sapling and regenerating tree species was higher than that of many tropical forests, including 50 tree species belonging to 28 families in Rampahar natural forest (Chowdhury et al., 2018), 38 tree species in Ukhia range, Cox's Bazar (Ahmed and Haque, 1993), 62 tree species from Tankawati natural forest (Motaleb and Hossain, 2011), 78 tree species in Lawachara forest (Malaker et al., 2010), 85 tree species in Chittagong Hill Tracts (South) Forest Division's Sitapahar Reserve forest (Nath et al., 1998), 85 tree species in Bamu Reserve forest of Cox's Bazar (Hossain et al., 1997), 92 tree species in Chunati Wildlife Sanctuary (Rahman and Hossain, 2003). But, it is lower than that of 150 tree species in Teknaf Wildlife Sanctuary (Uddin et al., 2013), 151 tree species in Inani Protected Forest (Feeroz, 2013) in Bangladesh.

On the other hand, the number of naturally regenerating species (56) and families (29) was lower in this study than in similar natural forests in Bangladesh. It is reported 120 naturally regenerating tree species from natural forests of Dudhpukuria-Dhopachari Wildlife Sanctuary (Hossain et al., 2013), Chunati Wildlife Sanctuary (105 species) (Rahman et al., 2020), Hazarikhil Wildlife Sanctuary in Chittagong North Forest Division (90 species) (Rahman et al., 2019), Chittagong (south) Forest Division (64 species) (Hossain et al., 2004). But, the number of regenerating tree species is higher than that of Khadimnagar National Park and Tilagor Eco-Park (55 species) (Rahman et al., 2011), Durgapur hill forest of Netrokona (27 tree species) (Rahman et al., 2019a), Tankawati natural Forest of Chittagong South Forest Division (29 tree species) (Motaleb & Hossain, 2011) and Madhupur National Park (47 species) (Rahman et al., 2020).

However, it is inappropriate to compare with their findings because many of them evaluated not only seedlings but also saplings. Disturbance in natural forests can alter habitat suitability of plant species which affects ecosystem functions and plant species composition (Berhane et al., 2013; Wilcox et al., 2006). However, based on the findings of these and other research, it can be concluded that the BSMSP has more diverse natural forests with a greater number of plant species. Therefore, in comparison to other studies, it can be claimed that the Bangabandhu Sheikh Mujib Safari Park occupy more diversified plant species with regeneration potential.

Conclusion

Bangabandhu Sheikh Mujib Safari Park is the first Safari Park of Bangladesh. It is one of the richest ecosystems in regard to floristic composition in Bangladesh. Though the park is protected by wall, severe threat of anthropogenic disturbances caused by local people leads to disappearance of some of the species. However, till now this park has diversified plant species. The present study finds 202 plant species of which tree (64), sapling (77) and regenerating species (56). This indicates that the park is extremely rich in plant biodiversity. It is the habitat of mother trees of various species *like Dipterocarpus costatus, D. turbinatus, D. alatus, Aporosa wallichii, Syzygium fruticosum, Swintonia floribunda, Hopea odorata, Fernandoa adenophylla, Macaranga denticulata, Grewia nervosa, Mallotus philippensis, Lithocarpus polystachyus* etc. Information on occurrence and composition of plant species in Safari Park is promising and seems to be harbor of many native forest genetic resources. So, it has great importance to conserve rare and threatened species for biodiversity conservation. For conserving the gene-pool of both native and naturalized plant species, it is right time to protect, conserve and manage the park properly. It is enriching our eco-tourism industry, helping in research area for both students and teachers. It is also playing a vital role in recreation of people and government earning revenue from this park. So, the proper management of this wonderful Park can give us a beautiful enriched biodiversity of all kinds of animals and plants keeping balance in our environment.

Recommendations

Considering the findings, the following recommendations are highlighted to get a satisfactory natural regeneration and recruitment, to increase a growing stock of plant diversity and for the sustainable management and conservation strategies of flora of BSMSP

1. The awareness of all sectors of the society about the biodiversity and the importance of its preservation should be raised,
2. Carrying and use all types of solid and non-degradable waste materials around the park area must be prohibited,
3. Smoking, outcry should be strictly prohibited inside the park,
4. Emphasis should be given on rare, and threatened tree species to protect them from extinction,
5. Tendency of excessive infrastructure development inside the park area must be avoided to rescue the natural beauty,
6. Plantation of native tree species over exotic species should be encouraged to restore the degraded zone,
7. Strong boundary needed with well demarcation to protect from unwanted deforestation over day and night by local people,
8. Patrolling of forest guard over day and night with safety should be raised to stop deforestation by local communities,

9. Manpower needs to be increased recruiting local skilled people,
10. Grazing of animals during regenerating period needs to be controlled,
11. Rules and regulations regarding biodiversity conservation should be built up, and
12. Tourists should not be allowed beyond carrying capacity of the park.

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Conflict of Interest

The authors declare that there is no conflict of interest exists.

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Use of Advanced Technologies for Development of Fisheries Sector Towards Building Smart Bangladesh

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Abstract

The fisheries sector in Bangladesh is delineated as a confluence of three distinct components of fish production: inland capture fisheries, aquaculture, and marine capture fisheries. Their respective contributions to the total fish production stand at 27.72%, 57.39%, and 14.83% respectively. Globally, Bangladesh ranks 3rd in inland capture fisheries production, 5th in aquaculture production, and 11th in marine fisheries production. The most robust growth is observed in aquaculture production, more than doubling from 1.06 million MT in 2008-2009 to 2.73 million MT in 2021-2022. Hilsa dominates commercial species in capture fisheries, contributing 11.91% to total fish production. In aquaculture, pangasius and tilapia become the dominant species, contributing 18% and 16% to total aquaculture production, respectively. The fisheries and aquaculture sectors have established intricate value chains nationwide, engaging approximately 17 million people across 25 value chain segments, irrespective of religious and socioeconomic classes. Backward linkages involve stakeholders in hatchery-based fish seed production, nursing and transportation, feed manufacturing and marketing, drugs and chemical supply, and other associated activities. Forward linkages have reinforced a diverse actor-based fish marketing system. However, the extensive diversification of activities poses a key constraint to ensuring quality fish production. Despite notable improvements in recent years, the fisheries sector in Bangladesh grapples with various challenges, including low productivity, high costs of fish feed and inputs, inadequate fish disease diagnosis and treatment facilities, limited adoption of modern technologies, weak policies for capture fisheries, inability to produce safe fish, and failure to meet international export market compliance requirements. Addressing these issues necessitates the implementation of responsible fisheries and aquaculture practices under certification schemes following international standards. To meet compliance standards, with the vision of Smart Bangladesh, which represents a forward-looking vision aligned with the principles and opportunities presented by the Fourth Industrial Revolution (4IR), cutting-edge smart technologies such as robotics, drones, sensors/remote sensing, artificial intelligence, augmented reality, 3D printing, IoT, and blockchain need to be initiated and adopted. This article explores the prospective uses of these emerging smart technologies at various points along the value chain of fisheries and aquaculture sector in Bangladesh.

Key words: Fisheries, Aquaculture, Value chain, Certification, Smart technologies, Bangladesh

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1. Introduction

Bangladesh holds a significant position in the Ganges or Bengal Delta, recognized as the world's largest delta. The majority of the country locates on this delta, formed by expansive rivers flowing mainly from the Himalayas. Bangladesh has the third largest aquatic fish biodiversity in Asia, after China and India, with about 800 species in fresh, brackish and marine waters (Hussain and Mazid, 2001). The Ganges converges with the Jamuna (the primary channel of the Brahmaputra), subsequently merging with the Meghna and finally emptying into the Bay of Bengal. This delta, encompassing Bangladesh and the Indian state of West Bengal, is renowned for its fertility, receiving the nickname "the Green Delta." The rich land and water resources of this region are pivotal to the agroecology supporting fish production across its numerous tributaries and various water bodies, including small ponds, ditches, lakes, canals, small and large rivers, and estuaries, covering approximately 4.70 million hectares (DoF, 2022). With a coastline of 714 km along the Bay of Bengal, Bangladesh sustains a robust artisanal and coastal fisheries sector, thriving in its fertile and highly productive water bodies. The fisheries sector comprises three key components: inland capture fisheries, aquaculture, and marine capture fisheries. In the fiscal year 2021-2022, the total fish production from the entire fisheries sector reached 4.75 million MT, surpassing the Vision 2021 target of 4.55 million MT set by the government. Furthermore, multiple development initiatives are underway, aiming to achieve a targeted fish production level of 6.5 million MT by 2031 and 8.5 million MT by 2041. Fisheries sector contributes 2.08% to the national GDP and approximately 21.83% to the agricultural GDP (DoF, 2022), with an impressive average growth rate of 5.43% over the past decade. Bangladesh has achieved global recognition, ranking 3rd in inland fish production, 5th in aquaculture production, and 11th in marine fish production in 2018 (FAO, 2022). Despite its relatively small geographical size compared to other leading aquaculture-producing countries, Bangladesh boasts the highest geographical yield (15 MT/sqKm) in its aquaculture sector, achieving self-sufficiency and recognition as one of the world's largest fish producers.

In this milieu, the pursuit of Digital Bangladesh was a pivotal national goal, with a specific focus on leveraging digital technologies to realize Vision 2021. This vision, often referred to as Digital Bangladesh, envisions the country achieving middle-income status with peace, prosperity, and dignity by 2021, marking 50 years of independence. The government of Bangladesh has actively undertaken numerous projects cantered around digital technologies, several of which are currently in progress. The formulation of the National ICT Policy-2009 reflects a strategic commitment to attaining middle-income status by 2021 and developed status by 2041. In response to encouraging economic growth, the government has embarked on a "Smart Bangladesh" initiative, envisioning a transformative path for the country through the integration of cutting-edge technologies to enhance efficiency, connectivity, and overall quality of life of the entire nation. Smart Bangladesh represents a forward-looking vision aligned with the principles and opportunities presented by the Fourth Industrial Revolution (4IR). The 4IR is characterized by the fusion of technologies, including artificial intelligence, robotics, the Internet of Things, and advanced data analytics, that are transforming the way we live, work, and interact. In the context of Bangladesh, the vision of a Smart Bangladesh involves harnessing the power of 4IR technologies to drive innovation, economic growth, and societal progress. This includes the integration of smart solutions across various sectors such as governance, healthcare, education, agriculture, and infrastructure. The vision of a "Smart Bangladesh" underscores the nation's commitment to leveraging technology for sustainable development, economic growth, and improved living standards of the people (Sayem et al., 2023). The burgeoning growth of the fisheries sector has led to the creation of a complex value chain, offering employment opportunities for millions. However, emerging constraints pose implications for increasing fish production to meet domestic consumption and export demands. This paper focuses on the trend in fish production in Bangladesh, highlighting the challenges and exploring the application of smart technologies to overcome these obstacles, ensuring the production of safe fish for both domestic consumption and export trade.

2. Methodology

An exhaustive literature review related to the different aspects of capture fisheries and aquaculture, and their direct and indirect relationships with the value chain stakeholders, constraints to the value chain of fisheries sector, potential smart technologies adoption to overcome the constraints, was carried out. Documents such as published manuscripts, reports, theses, databases, and other pertinent materials covering essential aspects of fisheries and aquaculture in Bangladesh and other relevant global regions were pinpointed through searches in both library repositories and accessible electronic sources.

2.1 Digital transformation of Bangladesh

The digital transformation of Bangladesh refers to the comprehensive integration and adoption of digital technologies across various sectors to enhance efficiency, connectivity, and overall development. This transformation involves leveraging digital tools, technologies, and platforms to bring about positive changes in governance, education, healthcare, business, and other aspects of daily life. Key components of the digital transformation in Bangladesh include E-Governance, ICT Infrastructure Development, Digital Education, E-Healthcare, Digital Financial Inclusion, Cybersecurity Measures, Digital Literacy Programs, E-Commerce Development, Smart Agriculture and Innovation and Entrepreneurship. The digital transformation of Bangladesh is a multifaceted process aimed at leveraging the power of technology to drive economic growth, improve public services, food safety and enhance the overall quality of life for its citizens. Mobile phones have played a pivotal role in shaping the landscape of Digital Bangladesh. As a key component of the Information and Communication Technology (ICT) revolution, mobile phones have become ubiquitous tools for communication, access to information, networks and financial transactions, contributing significantly to the vision of a Digital Bangladesh. In the global context of mobile phone usage, Bangladesh secures the 9th position among the top 15 countries, boasting a substantial number of 180,780,000 mobile phones. This placement underscores the significant penetration of mobile technology in Bangladesh, reflecting its crucial role in communication and access to digital services within the country. There were 66.94 million internet users in Bangladesh at the start of 2023, when internet penetration stood at 38.9%. Bangladesh was home to 44.70 million social media users in January 2023, equating to 26% of the total population. A total of 179.9 million cellular mobile connections were active in Bangladesh in early 2023, with this figure equivalent to 104.6 percent of the total population. Approximately 44% of the population currently utilize mobile internet services, and this figure is anticipated to rise to 63% by the year 2025.

2.2 Growth trend of fisheries sector

In the early days in Bangladesh, fish production primarily relied on open water-based capture fisheries. The overall trend in capture fisheries production exhibited a gradual increase from 2000-2001 to 2008–2009. Subsequently, there was a decline in production (Figure 1) attributed to the indiscriminate exploitation of fish, depletion of water resources, degradation of habitats and adverse impacts of climate change (DoF, 2022). To offset the fish deficit, there has been a rising trend in aquaculture production. Since Bangladesh gained independence in 1971, aquaculture production has surged by 40 times, escalating from 68,080 MT in 1971 to 2,731,070 MT in 2022 (Figure 1). Aquaculture now contributes 57% to the country's total fish production of 4.75 million MT. The notable upswing in aquaculture production began in 2008-2009, primarily attributed to technological innovation and advancements through research, especially in artificial breeding and seed production in hatcheries, commercial fish feed production, adoption of aquaculture technologies and commercial supplies of drugs and chemicals. This progress has been fueled by widespread rural electrification and the construction of roads throughout the country. Consequently, the aquaculture sector has experienced consistent growth over the past 12 years, with total aquaculture production doubling from 1.06 million MT in 2008-2009 to 2.73 million MT in 2021-2022 (DoF, 2022).

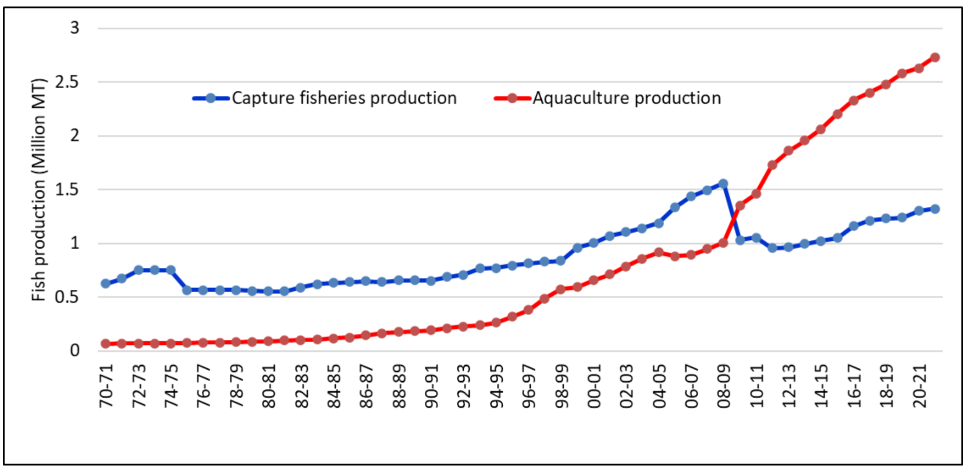

Figure. 1: The trend of inland capture fisheries and aquaculture production in Bangladesh since the independence of Bangladesh.

To enhance capture fisheries production, a set of technical interventions like establishment of fish sanctuaries, fish habitat restoration, in-situ conservation and stocking of endangered species have been undertaken in recent years. Due to the establishment of more the 500 sanctuaries across the country by the DoF, a substantial increase in fish production as well as abundance of endangered species occurred. For the conservation and development of hilsa fishery, six sanctuaries were established in the potential river systems. On the other hand, to ensure fish migration during the breeding period excavation and re-excavation of different connecting canals of rivers, dead rivers and beels were undertaken in recent years. Hilsa is the national fish of Bangladesh that contributes 11.91% of the total national fish production. To achieve the increased target of hilsa production, the government is implementing a unique coordinated management program to protect Jatka (juvenile) and brood hilsa. In 2000-2001, hilsa production was very low at 0.2 million tons per year; therefore, the government of Bangladesh commissioned BFRI to formulate the Hilsa Management Action Plan (HMAP), which was implemented by the DoF in 2003. This plan was designed to help with conserving natural hilsa breeding grounds and protecting young hilsa, known as Jatka, through periodic fishing bans. These bans, which originally included 10-22 days during October and recently added up to 60 days in March and April, apply to all the hilsa-spawning water bodies (selective southern rivers, coastal, and marine waters). Through these regulations, Bangladesh was able to achieve sustainable growth of hilsa production, and production in 2017-2018 increased to 0.52 million tons (Hussain 2019). The program ensures the participation of all stakeholders including local public representatives, DoF, local administration system, Coast Guard, Bangladesh Navy, fishers, and mass people residing around the hilsa rich river system. Jatka or hilsa fishers were provided with food-grains to live with and inputs to start alternative income generating activities.

Bangladesh has received entitlement to 118,813 km2 in the BoB after the end of the final settlement of maritime boundary disputes with neighboring countries Myanmar and India in 2012 and 2014, respectively (MoFA, 2014a). This award allowed Bangladesh to establish sovereign rights over the living and non-living resources of BoB territorial waters of 12 nm, Exclusive Economic Zone (EEZ) within 200 nm and Continental Shelf extending up to 354 nm from the Chittagong coast (MoFA, 2014b; Hussain et al. 2017a). There, the Government has recently started dialogues with the stakeholders to adopt the concept of Blue Economy across relevant policies and plans (Hussain et al. 2017a; Hussain et al. 2017b). The blue economy-related economic activities can generate jobs and bring about significant tangible benefits to change the lives and livelihoods of millions of people living in the coastal areas. However, this can only be achieved with a government strategy in line with United Nations Environment Programme blue economy objectives, and also with support from the international arena to protect the national interests and objectives of blue economy development in Bangladesh (Hussain et al. 2017a; Hussain et al. 2017b).

About 2,70,000 fishing households directly and indirectly dependent on the marine fishery for their livelihoods. Bangladesh government has emphasized on enhancing blue growth and achieving sustainable development goals (SDGs), where marine resources will play the key role. Despite the abundance of marine waters, only about 14.83% of country's total fish production is derived from the marine sector. The government sets utmost priority regarding the protection, conservation and biodiversity of marine and coastal resources.

The St. Martin's Island and the Sundarbans, the world-famous mangrove forest, have been declared as sanctuaries to develop and protect the fisheries resources. The government has declared a marine reserve (covering 698 sqKm) and one marine protected area (covering 1738 sqKm) in the Bay of Bengal to protect and preserve the breeding grounds of marine flora and fauna. The value chain of the inland capture and marine fisheries is largely linked to harvesting and marketing of fish in the domestic market, but these have huge scope to add value in the processing plants. This sort of value addition can engage various actors in the value chain for domestic and export markets.

Despite Bangladesh being home to 260 native freshwater fish species (Rahman, 2005; DoF 2022), only a limited number of them have been incorporated into aquaculture practices. This is primarily due to the fact that specific characteristics, such as artificial seed production, responsiveness to artificial feed, faster growth rates in higher stocking densities, and consumer demand, have been identified for only a select few species. Among these, carp species like *Catla catla, Labeo rohita, Cirrhinus mrigala*, and *Labeo calbasu*, along with exotic carp such as silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*), are the most widely cultivated and available in the domestic market. Farmers are increasingly showing interest in the cultivation of live fishes like koi (*Anabas testudineus*), singh (*Heteropneustes fossilis*), magur (*Clarias batrachus*), pabda (*Ompok pabda*), gulsha (*Mystus cavasius*), etc. pangasius (*Pangasianodoan hypothalamus*) and tilapia (*Oreochromis niloticus*) have become the most commercially important cultured species in Bangladesh, with Pangasius and the improved strain of tilapia (GIFT) being introduced in the early 1990s. According to FRSS data, the combined contribution of these two species to total aquaculture production in 2021-2022 was 34%, and their production and contribution to total aquaculture production are on an upward trend. Aquaculture industry has witnessed the emergence and growth of several specialized companies engaged in the production and distribution of fish seed, feed, drugs and chemicals.

Hatchery-based fish seed production plays a pivotal role in the aquaculture landscape of Bangladesh. With a burgeoning demand for fish in the country, the establishment of hatcheries has become instrumental in meeting the needs of the industry. These specialized facilities are dedicated to the controlled breeding, hatching, and early rearing of fish, ensuring a sustainable and efficient supply of high-quality fish seeds. According to DoF (2022), the total number of fish hatcheries is 984, out of which 110 are government and 874 are private hatcheries. These hatcheries employ advanced techniques for artificial seed production, ensuring the genetic quality and health of the seeds. The production of fish seeds in hatcheries not only supports the aquaculture sector's growth but also contributes to the conservation of native fish populations. Moreover, it facilitates the dissemination of improved breeds, promoting enhanced growth rates and disease resistance in farmed fish.

Meanwhile, genetic improvement research in tilapia and carp species especially in silver barb and rohu has already been initiated and made a good progress in Bangladesh. Both mass selection and family selection techniques were in practice to improve their stocks, and significant genetic gain in growth across several generations, meanwhile, has been achieved in genetically improved farmed tilapia (GIFT) strain, genetically improved silver barb strain, and genetically improved rohu at Bangladesh Fisheries Research Institute (BFRI) and WorldFish, Bangladesh and South Asia (Hussain et al. 2023). Bangladesh is one of the leading countries in Asia where freshwater aquaculture industry is booming due to the development of a number of carp and tilapia seed production facilities recently (i.e., hatcheries and nurseries). In view of addressing inbreeding depression and genetic deterioration in hatchery population, meanwhile, breeding plan and genetic stock improvement research has been conducted and achieved most positive success to develop genetically improved breeds of most popular freshwater species of carps (i.e., rohu and silver barb strains) and tilapia (GIFT strain). Such genetically improved strains have been utilized and positively impacted for high-quality seed production to support sustainable aquaculture production in the country (Hussain et al. 2023).

The fish feed industry and trade in Bangladesh have experienced significant growth, playing a crucial role in the development of the country's aquaculture sector. A multitude of fish feed companies and fish feed mills have emerged and established, contributing to the diverse nutritional needs of farmed fish. These companies/mills formulate and produce specialized feeds tailored to various fish species aiming to enhance growth rates, reproductive performance, and overall health. The trade of fish feeds has also expanded, with a well-established market that includes both domestic consumption and export. This industry not only supports the nutritional requirements of farmed fish but also contributes to the economic livelihoods of farmers and the overall sustainability of aquaculture. Since Bangladesh continues to strengthen its position in the global aquaculture markets, the role of fish feed companies and the associated trade remains integral to meeting the demands of a thriving and dynamic industries.

Aquaculture sector has seen the rise and expansion of various specialized companies dedicated to the manufacturing and distribution of drugs and chemicals tailored for aquaculture (Heal et al., 2021). According to the information of Animal Health Companies Association of Bangladesh (AHCAB https://www.ahcab.net) the number of drug and chemical companies in Bangladesh is >600, among which many companies sell only the products for fish and many sell the products for both fish and other animals (livestock and poultry). These companies play a crucial role in supporting the aquaculture sector by providing a range of products designed to enhance the health and productivity of farmed fish. These drugs and chemicals are often formulated to address issues such as disease prevention, water quality management, and growth promotion in aquaculture systems. The companies involved in this sector contribute significantly to the overall success and sustainability of aquaculture operations across the country. Their products are essential tools for farmers seeking to optimize production and ensure the well-being of their aquatic stock. The aquaculture industry has evolved into a commercial enterprise with extensive backward and forward network linkages involving a diverse range of value chain stakeholders. However, various constraints have plagued the entire fisheries sector, ranging from low productivity of fish to domestic marketing in Bangladesh and export.

2.2.1 Low productivity in aquaculture farms

Lower fish productivity in ponds in Bangladesh can be attributed to a combination of factors that impact the overall aquaculture systems. Issues such as inadequate water quality management, suboptimal feeding practices, use of illegal drugs and chemicals and contagious disease outbreaks contribute to reduced productivity and food safety issues. In many cases, poor pond management techniques, including overstocking, can lead to crowded and stressed fish populations, negatively affecting growth rates and overall health. Additionally, limited access to genetically improved breeds and quality seeds, insufficient aeration, and fluctuations in water temperature can further hamper fish productivity. Economic constraints may also play a role, as small-scale farmers may face challenges in adopting modern technologies and best practices. Addressing these multifaceted challenges requires a holistic approach that encompasses improved training for farmers, better access to resources, and the adoption of sustainable and efficient aquaculture practices to enhance fish productivity in ponds across Bangladesh

2.2.2 High price of fish feed

The high price of fish feed in Bangladesh compared to other countries around the world poses a significant challenge to the aquaculture industry in the country. Several factors contribute to this discrepancy, including the cost of raw materials, transportation, and production processes. Over 90% of the feed ingredients and feed used for fish farming in Bangladesh has to be imported from abroad. Fluctuations in global commodity prices, such as those of fishmeal and soybean, impact the overall cost of fish feed. Additionally, inefficiencies in the supply chain, lack of competition among feed manufacturers, and import duties on raw materials can further contribute to the elevated prices. The high cost of fish feed has implications for the profitability and competitiveness of aquaculture operations in Bangladesh, affecting the livelihoods of fish farmers and the overall sustainability of the industry. Addressing these challenges may require a comprehensive approach involving improved efficiency in production processes, exploring alternative and cost-effective feed ingredients, and creating a more competitive and transparent market for fish feed in the country.

2.2.3 Fish diseases

Fish diseases in aquaculture farms in Bangladesh represent a persistent challenge, impacting the health and productivity of farmed fish. Various factors contribute to the prevalence of these diseases, including poor water quality, overstocking, and the introduction of pathogens through contaminated water sources or inadequate biosecurity measures. Common diseases affecting aquaculture farms in Bangladesh include bacterial infections like *Aeromonas hydrophila*, viral diseases such as Infectious Pancreatic Necrosis (IPN) and TiLV in tilapia, and parasitic infestations. The spread of these diseases can lead to substantial economic losses for fish farmers, affecting both small-scale and commercial operations. Limited access to fish health services and diagnostic facilities further complicates disease management, making early detection and effective treatment challenging. Efforts to address fish diseases in aquaculture farms involve promoting good farm management practices, enhancing biosecurity measures, disease resistant aquaculture strain(s) and SPF variety development and providing education and training to farmers to improve their capacity for disease prevention and control. These initiatives are crucial for sustaining the growth and economic viability of the aquaculture industry in Bangladesh.

2.2.4 Long and complex value-chain

The expanding value chains of capture fisheries and aquaculture in the country have generated substantial employment opportunities. Directly engaging approximately 1.32 million fishermen, 14.7 million fish farmers, and 0.83 million shrimp farmers, these value chains contribute significantly to the socio-economic condition. In the realm of capture fisheries, the value chain primarily spans domestic fish marketing channels, involving participants from fishing and fish marketing domains. In aquaculture, the value chain encompasses a broad spectrum, incorporating farmers, input suppliers, and stakeholders across primary, secondary, retail, and export markets. Beyond this, associated value chains in the aquaculture sector, including the feed industry, drugs, and chemical companies, employ numerous individuals. Reports from commercial fish farms indicate a wide array of value chain benefits, positively impacting various livelihood assets, albeit with a few noted negative consequences (Haque, 2009). However, the intricate and convoluted value chain in Bangladesh's aquaculture sector has been identified as a contributing factor to the issue of poor-quality fish. The elongated chain, involving numerous intermediaries and processes, can result in challenges related to quality control and monitoring at each stage. From the production of fish feed to farming practices, transportation, and distribution, the complexity introduces multiple points of potential contamination, mishandling, or degradation of fish quality. Lack of standardized procedures, proper implementation and insufficient monitoring mechanisms within this extended value chain can lead to variations in the quality of fish produced, impacting not only the economic viability of the aquaculture industry but also consumer trust. Addressing this issue requires a holistic approach, involving the streamlining of processes, implementation of quality assurance measures, and fostering collaboration among stakeholders to ensure the delivery of high-quality fish and aquaculture products to the market.

2.2.5 Multiple actors in value chain

The aquaculture value chain in Bangladesh involves multiple actors across various stages, reflecting the complexity and diversity of the industry (Fig. 2). Pangasius and tilapia farming in Bangladesh have strategically diversified the value chain, creating and supporting 25 different types of employment opportunities for a diverse group of individuals (Table 1). For many years, fish production from both capture and cultured water bodies has contributed significantly to the livelihoods of various communities. Historically, a study by Gupta (1908) revealed that capture fisheries pioneered impacting the livelihoods of low-caste Hindus, while professional Hindu fishermen belonged to the poorest segment of the population. Fishing was once considered a taboo for Muslims in the socially stratified society of Bangladesh, but in the last few decades, there has been a huge shift, with Muslim individuals actively participating in fishing as a major occupation (FAP 17, 1995). Regardless of socio-economic and religious boundaries, numerous people are engaged at different levels of the forward and backward linkages within the aquaculture value chain. In the backward linkages, stakeholders are involved in fish seed production, nursing, transportation, and other associated activities (Table 1). Fish hatcheries employed a substantial number of people on both part-time and full-time bases. In recent years, growth of feed companies, and the increased use of drugs and chemicals in response to disease occurrences in aquaculture farms has led to the development of employment opportunities for suppliers within fish-producing communities. This segment of the value chain, however, is complex and policy-sensitive, with various implications for ensuring the safety of fish production for both local consumption and export trade. The involvement of such multiple actors in the aquaculture value chain in Bangladesh contributes to challenges in maintaining fish quality. The complexity of the chain, encompassing various stages from production to processing and marketing, introduces opportunities for lapses in quality control.

2.2.6 Lack of modern technologies

The fisheries and aquaculture sector in Bangladesh faces challenges due to a perceived lack of improved aquaculture and management technologies, which hinders the industry's progress and sustainability. The production of capture fisheries relies on harvesting fish from natural water bodies like seas, rivers, canals, and beels. However, except hilsa fisheries, it is essential to note that fish harvesting in these environments is often not conducted in accordance with responsible fisheries principles. The development of aquaculture technologies started from the research work at the university level notably at the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, and later developed by BFRI, universities and other research organizations in Bangladesh is predominantly cantered around hatchery based seed production and pond-based aquaculture. However, there have been recent advancements in cage and pen fish farming. Although some experimental trials have been conducted, advanced aquaculture technologies such as recirculatory aquaculture systems (RAS), raceway aquaculture systems, biofloc systems, IPRS, aquamimicry etc. by some universities and private organizations, are yet to be fully developed and integrated into mainstream practices. The absence of modern and advanced technologies can impede efforts to improve productivity, address environmental concerns, and ensure the long-term viability of the sector. Limited and insufficient investment in research and development, inadequate infrastructure, and a reliance on traditional fishing methods contribute to this technological gap. In the fisheries sector, outdated fishing gear and practices may lead to overfishing and depletion of fish stocks. In aquaculture, the adoption of cutting-edge technologies, such as aquaculture genetics and biotechnology; efficient water management systems, disease-resistant breed development, development of antibiotics and advanced feed formulations, is crucial for enhancing production and minimizing environmental impact. Bridging the technological divide requires concerted efforts from government bodies, private enterprises, universities and research institutions to promote innovation, scientists should render dedication and give proper attention in research and technology development; indulge sufficient investment and provide training to fishers and aquaculture technicians and researchers.

Embracing modern technologies can not only improve yields but also contribute to the overall sustainability of the fisheries and aquaculture industry in Bangladesh

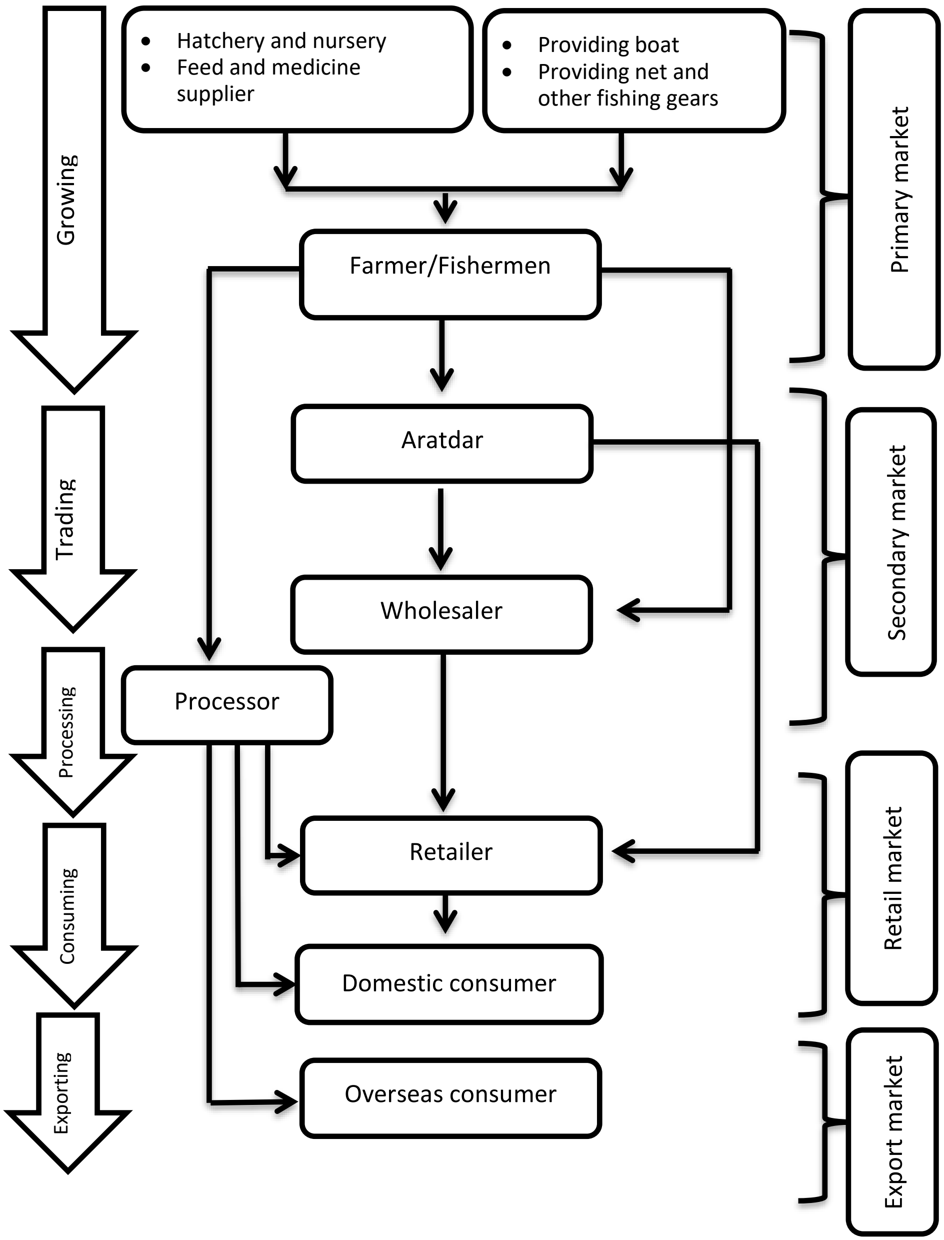

Figure 2: A typical fish value chain in capture fisheries and aquaculture in Bangladesh (adapted from Uddin et al., 2018).

Table 1: Actors involved in aquaculture value chain in Bangladesh (adapted from Faruque, 2007; Haque, 2009; Haque et al., 2010)

	SL No.	Actors: Local name	Actors: English	Brief description/responsibilities of actors
Backward linkage	1	Hatchery Malik/Parichalak	Hatchery owner/operator	Own fish hatchery and manage whole activities, and deal with customers
	2	Hatchery Karmachari	Hatchery labour	Brood rearing, induced breeding, fry nursing and selling fry/fingerlings
	3	Feed dealer	Feed dealer	Deal the commercial feed to sell locally to the fish farmers
	4	Oushod Supplier	Medicine representative	Deal the aqua drugs/chemicals to sell locally to the fish farmers
	5	Workshop Malik	Workshop owner/mechanics	Manufacture mini fish feed (pelleted) machine locally and sell to fish farmers
	6	Pump Mechanic	Pump mechanic	Repair pumps in farms which is used for water in and out of ponds
	7	Nursery Malik	Nursery operator	Collect fry from hatchery and rear to produce fingerlings for sale to fry trader
	8	Pona/Patil Wala	Fingerling trader	Trade fingerlings from hatchery and nursery to the fish farmer level
Fish farm	9	Matsho Khamar Malik/Parichalak	Fish farm owner/operator	Own/operate fish farms
	10	Khamar Karmachari	Farm labour	Work in fish farms for feeding fish and guarding fish farm as a whole
Forward linkage	11	Biddot Mechanic	Electric mechanics	Install and repair electric facilities at the farm level
	12	Jele	Fishers	Harvest fish from fish farms
	13	Pani Supplier	Water supplier	Supply water to the truck carrying fish in drum from farm to market
	14	Drum Malik	Drum renter	Rent drum to the middleman to carry fish by truck
	15	Truck Malik	Truck renter	Rent truck to carry fish from farms to auction markets
	16	Van Wala	Van puller	Carry fish feed and fish from shop feed shop and fish farm respectively
	17	Nikari	Middlemen	Collect (buy) fish from farmers at farm gate and sell at auction and retail markets. Usually Nikari buy fish within own village and neighboring villages.
	18	Arot	Auction house/market	Usually in the established markets there is fixed place for auctioning fish. There are few to several auction houses in a market. The individual auction house is called arot.
	19	Arotdar	Auctioneer	Owner of individual auction house and runs the auction process.

20	Paiker	Retailer	Buy fish from auction markets by bidding and retails to consumers at retail markets.
21	Sharkar	Manager	Employee of auctioneer and is paid monthly. Maintain records of all kind as required by auctioneer mainly financial records such as payments, providing credit, recovery, etc.
22	Koilder	Assist bidding process	Koilder assist auctioneers in the bidding process. He also weighs fish for bidding.
23	Helper	Fish sorter	Sort fishes into different species and sizes, and weight them for bidding. He also sometimes helps in making loading and unloading fish.
24	Kuli	Labourer	Unload and load fish. Download fish from vehicle to auction place and vice-versa.
25	Sweeper	Cleaner	Clean the auction market daily usually early in the morning before the auction starts.

2.2.7 Domestic demand-based market and poor access to export trade

In Bangladesh, the dynamics of the fish trade industry reveal a notable contrast between the domestic market and the challenges faced in the export sector. The domestic market for fish trade is robust and driven by local demand, with a diverse array of fish species meeting the preferences of the population (Anwar, 2011). Fish is the primary source of animal protein for Bangladeshis, especially poor rural households. Currently 60% of animal protein to the daily meal of entire nation comes from fish (DoF, 2022). The existing supply of fish is 22.84 Kg/capita/year, which is higher than the demand (21.90 Kg/capita/year). However, the export market experiences difficulties related to poor supply, limiting its potential for growth and global competitiveness. Various factors contribute to this disparity, including challenges in meeting international quality standards, inadequate infrastructure, and inconsistent adherence to sanitary and phytosanitary measures. While the domestic market benefits from a wide range of fish varieties and a well-established distribution network, the export sector struggles with limitations in cold storage facilities, transportation, and processing capabilities. Bangladesh stands among the top 10 global aquaculture-producing nations, excelling in the cultivation of aquatic animals such as fish, mollusks, crustaceans, and other aquatic species. Within the country, the fisheries sector ranks as the second-largest export industry, playing a crucial role in earning foreign currency. Despite its significant aquaculture production, Bangladesh faces challenges in establishing a notable presence in the international fish export market. Countries in Asia, particularly China, Vietnam, Thailand, and India, dominate the global fish export market. Notably, in the list of the top 10 fish-importing countries, the majority are developed western nations. This trend suggests that exporting Asian countries, with the exception of Bangladesh, are successfully generating substantial foreign currency earnings from western markets (Table 2).

Table 2: Top ten exporting and importing countries of fish in 2020 (adapted from FAO, 2022)

Exporting countries of fish		Importing countries of fish	
Country	**US$ billions**	**Country**	**US$ billions**
China	18.25	USA	21.25
Norway	11.15	China	14.9
Vietnam	8.55	Japan	13.5
Chile	5.95	Spain	7.15
India	5.75	France	6.50
Thailand	5.65	Italy	6.10
Netherlands	5.55	Germany	6.00
Ecuador	5.50	Republic of Korea	5.15
Canada	5.00	Sweden	5.00
Russian Federation	4.85	Netherlands	4.50

When considering the global net trade of agricultural products from developing nations, fish has consistently held the top position. Over the past two decades, there has been a notable increase in the net export of fish from developing countries to developed ones, as reported by the Food and Agriculture Organization (FAO, 2022). Despite being a vibrant aquaculture producer on the global stage, Bangladesh, as a developing country, has yet to fully capitalize on the export trade of fish. This underscores a significant gap between Bangladesh's aquaculture prowess and its participation in the international fish export market (Fig. 3).

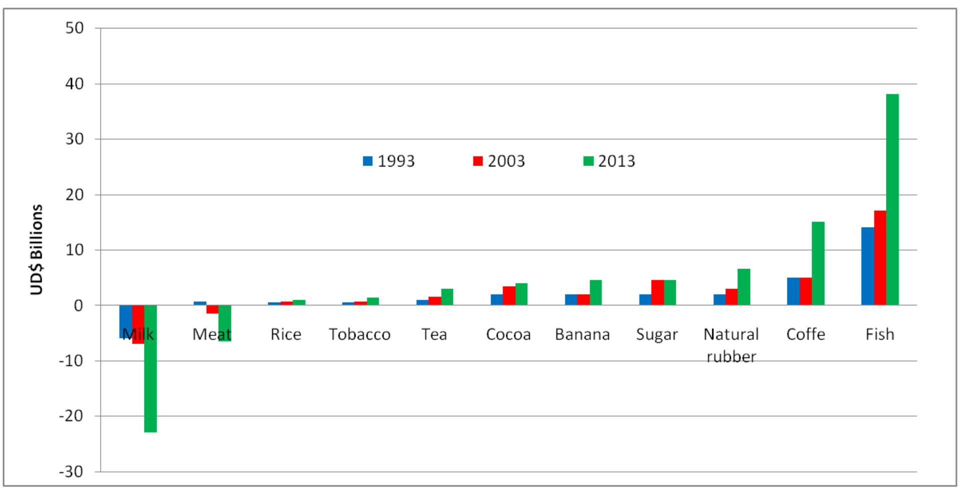

Figure 3: Net export of selected agricultural commodities from developing countries (adapted from FAO, 2016).

Bangladesh predominantly exports ten categories of fish products, including frozen freshwater fish, frozen marine water fish, frozen shrimp, chilled fish, live fish, dry fish, salted dehydrate, live Cuchia (*Monopterus cuchia*), live crab, and fish scale/shrimp scull, to more than 55 countries. Notably, large-sized frozen prawn (*Macrobrachium rosenbergii*) and shrimp (*Penaeus monodon*) constitute the primary export items, accounting for 80% of the total export, particularly in the EU market, with Belgium, Germany, the UK, and the Netherlands being major destinations. Despite these achievements, the export quantity of large-sized farmed shrimp is relatively small, contributing only 3.24% of the country's total production and 5.53% of total aquaculture production (DoF, 2017). While Bangladesh earned foreign currency by exporting over 50,000 MT of quality shrimp, the country faces challenges in exporting finfish such as pangasius and tilapia, despite their production being significantly higher than shrimp/prawn.

Efforts have been made to establish six finfish processing factories, with four located in the north-east region and two in the north-central region. The plants in the northeast primarily process indigenous white fishes, exporting products in various forms like IQF (Individual Quick Freezing), clean block, steak block, and whole block to countries including the EU, UK, USA, and the Middle East. The aim of the recently established plants in the north-central region was to process pangasius and tilapia for value addition, diversification, and increased foreign exchange earnings. However, despite international demand, significant farm-level production, and government subsidies, these new plants have faced challenges in exporting these species to mainstream markets. In contrast, several Asian countries are successfully exporting pangasius and tilapia by adhering to responsible aquaculture standards and certification schemes. For example, Vietnam exports pangasius to over 130 countries, with the European Union remaining a significant market. China, Indonesia, and Vietnam are key tilapia suppliers in Europe, with the USA being the largest international tilapia importer. The four major EU importers of frozen tilapia fillets are Spain, Poland, Netherlands, and Germany, while France, Netherlands, the United Kingdom, and Belgium are the largest importers of frozen whole tilapia. The success of these countries in international markets emphasizes the importance of responsible aquaculture practices for market access and underscores the need for Bangladesh to follow similar guidelines to ensure the sustained success of its aquaculture industry.

2.3 Improving value chain through responsible and smart aquaculture

Certification or responsible aquaculture processes have become increasingly integral to addressing aquaculture production, serving as a fundamental requirement for governance in the production of safe fish for both domestic consumption and export trade. Certification, in this context, pertains to the assessment of whether a product, process, or service conforms to specific standards or regulations (May et al., 2003). In Vietnam, farmers have embraced various certification schemes to gain access to the export market. The Best Aquaculture Practice (BAP), developed by the Global Aquaculture Alliance (GAA) and certified by the Aquaculture Certification Council (ACC), is one such scheme.

Global G.A.P, established by European retailers, serves as a benchmark for local producers to meet minimum requirements, encouraging sustainable fish farming practices. The Aquaculture Stewardship Council (ASC) has initiated a certification and labeling program for responsible aquaculture production of pangasius and other fish species (ASC, 2010). The Vietnamese government has introduced its certification scheme, VietG.A.P, since 2011, focusing on national guidelines for good aquaculture practices (Marschke and Wilkings, 2014). Certified aquaculture systems consider criteria across social, environmental, economic, and management domains. Farmers, aiming for certification, must adhere to key sustainability issues in each criterion, indicating that the quality of aquaculture products depends not only on farm-level management practices but also on compliance with practices across the social, environmental, and economic domains of the aquaculture value chain. To enter the certification scheme, farmers must meet baseline requirements across social, environmental, economic, and management dimensions (Table 3). These requirements empower farmers to work towards sustainability, ensuring the production of safe fish for both domestic consumption and the export market. Implementing an aquaculture certification system necessitates institutional development at both government and non-government levels, requiring the employment of skilled personnel to ensure compliance with the stipulated requirements. This institutional development not only creates employment opportunities, including for fisheries graduates, but also guarantees the production of safe fish for local consumption and export trade.

Table 3: The requirements for Vietnamese shrimp farmers at the baseline level to get into the certification scheme (adapted from Marschke and Wilkings, 2014)

Dimension	**Category**	**Major requirements**
Social	Training	Training to improve farmer's skills and capacities (record-keeping, disease management, etc.)
	Gender	Access to specific training for women in aquaculture
	Labor	Fair wages for hired workers
	Health & safety of workers	Workers have access to clean drinking water, sanitary conditions and a safe working environment.
Major inputs	Feed	Documented sources of feed (wild and bought)
	Seed	Documented sources of seed
	Drugs and chemicals	Documented sources of drugs and chemicals
Environment	Hazardous chemicals	Regulate/manage the use of drugs, chemicals and biological products, with increased support for disease management
	Waste water	Proper storage and disposal of waste (depending on pond size/intensity)
Economic	Payment	Timely payment to farmers for product and transparency of payment process

	Subsidy/premium	Provide subsidies or premiums for farmers during initial phasing in of guidelines. Subsidies would be for a limited time as farmers change cultivation practices; premiums would enable farmers to purchase feed and seed
Management	Legal requirements	Farming must be registered with the government; government helps to map location of farms

The successful implementation of aquaculture certification necessitates the integration of smart technologies to ensure adherence to stringent standards and promote sustainable practices. Smart technologies collectively contribute to efficient, transparent, and environmentally responsible aquaculture, aligning with the requirements of certification programs. The integration of smart technologies not only facilitates compliance with certification standards but also promotes a more sustainable and resilient aquaculture industry. A brief discussion of some potential smart technologies that can be used in fisheries and aquaculture is given below.

Robotics

The integration of robotics in aquaculture has revolutionized the traditional methods of fish farming, offering unprecedented efficiency, precision, and sustainability. Robotics plays a crucial role in various aspects of aquaculture, from monitoring water quality to feeding, harvesting, and environmental management. Automated underwater vehicles equipped with sensors can navigate through fish cage/pens, collecting real-time data on water parameters such as temperature, oxygen levels, and pH, ensuring optimal conditions for fish health (Biazi and Marques, 2023). Automated feeding systems equipped with robotics can precisely dispense feed, reducing waste and optimizing the nutritional intake of fish. This advancement can significantly enhance the profit margins of fish farming, addressing a key necessity in Bangladesh. Additionally, robotic arms are employed in the harvesting process, enhancing speed and accuracy while reducing labor costs. Since technology continues to advance, the use of robotics in aquaculture holds the promise of further innovation, fostering a more sustainable and efficient approach to seafood production.

Drones

Drones, or unmanned aerial vehicles (UAVs), have emerged as invaluable tools in the field of aquaculture, offering a range of applications that enhance efficiency and productivity. Equipped with advanced imaging technology, drones provide a unique aerial perspective for monitoring and managing fish farms. Companies like DJI and PrecisionHawk have developed specialized drones with high-resolution cameras and sensors capable of capturing detailed images and data. These UAVs enable aquaculturists to assess the health of fish populations, monitor water quality, and identify potential issues, such as disease outbreaks or irregularities in fish behavior (Wu et al., 2022). Utilizing drones can significantly improve the implementation of hilsa fisheries management in open water bodies, particularly in initiatives such as the Jatka conservation campaign and the mother hilsa conservation campaign. This application of drone technology not only streamlines operational processes but also contributes to the overall sustainability of aquaculture practices by improving resource management and reducing environmental impact.

Sensors/remote sensing

The application of sensors and remote sensing technologies in aquaculture has significantly advanced monitoring and management practices, fostering more efficient and sustainable fish farming. Sensors are employed to gather real-time data on crucial parameters such as water quality, temperature, dissolved oxygen levels, and salinity. Remote sensing technologies, including satellite imagery and aerial surveys, provide a broader perspective for assessing large-scale aquaculture operations (Chatziantoniou et al., 2022). Companies like Xylem and Vaisala offer sensor solutions that allow aquaculturists to monitor and control environmental conditions in fish farms. Satellite-based remote sensing, exemplified by platforms like Planet and Sentinel-2, enables continuous observation of aquaculture facilities, helping identify trends, optimize resource allocation, and detect potential issues like habitat changes. The application of satellite-based remote sensing technology holds the potential to enhance hilsa fisheries management across a wider geographical area in Bangladesh. The integration of sensors and remote sensing not only improves the health and productivity of aquatic species but also enhances overall sustainability in aquaculture management.

Artificial intelligence

Artificial Intelligence (AI) is increasingly finding applications in aquaculture, revolutionizing the industry by optimizing various processes and enhancing productivity. AI algorithms analyze vast sets of data to make informed decisions, improving efficiency in tasks ranging from monitoring water quality to managing fish health (Biazi and Marques, 2023). For instance, machine learning models can predict the onset of diseases in shrimp farms (where viral diseases cause huge mortality and economic loss within a short period of time) by analyzing patterns in environmental data, allowing for proactive measures to mitigate risks. Companies like Innovasea and Aquabyte leverage AI to automate fish monitoring, using computer vision to assess fish size, behavior, and overall health. AI-driven predictive analytics also assist in optimizing feeding strategies, reducing waste, and improving feed conversion ratios. These applications not only streamline aquaculture operations but contribute to sustainability by minimizing resource usage and environmental impact. The integration of AI in aquaculture exemplifies a data-driven approach, fostering innovation and efficiency in the responsible management of aquatic ecosystems.

Augmented reality (AR)

The application of Augmented Reality (AR) in aquaculture introduces innovative solutions to enhance operational efficiency and decision-making processes. AR overlays digital information onto the real-world environment, providing aquaculturists with valuable insights and guidance. For example, AR can be utilized in aquaculture training programs, where workers wearing AR-enabled devices receive real-time information and instructions on tasks such as fish grading or equipment maintenance (Rahman et al., 2021). Additionally, AR can assist in monitoring fish health by superimposing vital statistics and data onto the physical fish ponds (e.g. pangasius/tilapia/shrimp/prawn ponds) through AR glasses or devices. This technology allows for quicker and more accurate assessments of fish condition and enables timely interventions. Companies like Microsoft's HoloLens and Daqri are at the forefront of developing AR applications for various industries, and the integration of AR in aquaculture showcases its potential to improve operational processes, reduce errors, and contribute to the overall sustainability and effectiveness of fish farming practices.

3D printing

The application of 3D printing technology in aquaculture holds promising potential for creating customized equipment, structures, and components that enhance efficiency and sustainability in fish farming. 3D printing allows for the fabrication of complex structures with precision, tailored to the specific needs of aquaculture operations (Biazi and Marques, 2023). For example, 3D-printed artificial habitats can provide shelter and breeding spaces for fish, promoting natural behavior and improving overall fish health. The technology is also employed in creating specialized tools and components for aquaculture systems, such as water pumps, aeration devices, and feeding equipment. This bespoke approach reduces costs, minimizes waste, and supports a more resource-efficient and environmentally friendly aquaculture industry. As 3D printing technology continues to advance, its application in aquaculture has the potential to drive further innovation in the development of sustainable and tailored solutions for fish farming.

IoT

The Internet of Things (IoT) is playing a transformative role in the aquaculture industry by enabling real-time monitoring and data-driven decision-making. IoT devices, such as sensors and actuators, are deployed in fish farms to collect and transmit data on various parameters, including water quality, temperature, dissolved oxygen levels, and fish behavior. This information is then analyzed through cloud-based platforms, providing aquaculturists with valuable insights into the health and conditions of their aquatic stocks (Chiu et al., 2022). For instance, IoT systems can alert shrimp of pangasius farmers to potential issues such as changes in water quality or equipment malfunctions, allowing for timely interventions and preventive measures. Companies like AKVA Group and Pentair Aquatic Eco-Systems offer IoT solutions that optimize feeding processes, monitor environmental conditions, and enhance overall farm management. The integration of IoT in aquaculture not only improves operational efficiency but also contributes to sustainability efforts by minimizing resource use and environmental impact through more precise and informed decision-making.

Blockchain

Blockchain technology is finding innovative applications in the aquaculture industry, offering transparency, traceability, and enhanced supply chain management. By leveraging blockchain, aquaculture stakeholders of particularly shrimp/prawn industry can establish secure and unalterable records of every stage in the production and distribution process. This ensures that consumers have access to accurate information about the origin, handling, and quality of fish products. For example, the company IBM Food Trust utilizes blockchain to create a transparent and traceable seafood supply chain. Each participant in the supply chain, from farmers to processors and distributors, can record and verify information on the blockchain, creating a decentralized and tamper-resistant ledger (Luna et al., 2024). This not only helps combat fraud and mislabeling but also enhances food safety by quickly identifying and addressing potential issues. The application of blockchain in aquaculture in Bangladesh can contribute to a more accountable and sustainable industry, meeting the increasing demand for transparency and ethical sourcing in the global market.

3. Conclusion

Globally wild stock fisheries are diminishing at an alarming rate, emphasizing the urgent need for innovation and sustainability in aquaculture. The growing global population has placed substantial pressure on aquaculture to play a crucial role in providing high-quality protein. Aquaculture currently stands out as the world's fastest-growing food industry. This growth is driven by the escalating global demand for fish as a safe source of animal protein, fueled by a rapidly expanding population. Despite being more diversified than other agricultural sectors, aquaculture faces significant challenges. Fish, recognized as a primary source of high-quality food, enjoys widespread popularity worldwide, and the demand for fish in both local and global markets continues to rise. Market research data indicates a projected increase in the fish market from US$ 62.5 billion in 2018 to US$ 86.6 billion by 2025. Despite being a millennia-old industry, aquaculture remains youthful and dynamic but faces various challenges. The integration of digital technologies presents an opportunity to address the challenges of the aquaculture sector. Bangladesh government has taken proactive measures by formulating an action plan to address challenges and harness the potential of the 4IR. With a global population estimated to reach 9.7 billion by 2050, and Bangladesh's population expected to reach around 220 million, there is a critical need to not only secure safe food and nutritional requirements for this vast population but also to formulate action plans for Industry 4.0 and Aquaculture 4.0. These plans involve incorporating smart fisheries and aquaculture technologies aligned with the attainment of Sustainable Development Goals (SDGs) by 2030. The imperative of the time is to integrate modern and suitable technologies into the fisheries sector, fostering the development of sustainable production and marketing systems for fish and fishery products. To achieve this, manufacturers, business leaders, and policymakers at all levels must embrace and implement the principles of the 4IR towards building “Smart Bangladesh”. This requires positive changes, expansion, and modernization of current education systems and research initiatives. The ultimate expectation is that Bangladesh's rapidly growing fisheries sector will proactively meet the challenges posed by the Fourth Industrial Revolution.

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Status of Fishery Wastes and Its Utilization in Bangladesh

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Abstract

Fishery wastes are the by-products of fish and shrimp processing and marketing, such as offal (gut, scale, skin, fin and air bladder), head, shell, carapace, appendages, etc. These wastes are often discarded in the garbage bin, as there is no systematic way of collecting, using, and managing them in Bangladesh. However, these wastes have potential value as feed or food, which can reduce farming cost, enhance human and animal nutrition, increase the income of the value chain actors, and contribute to reducing post-harvest fish loss (PHFL). This review study aims to explore the different forms of fishery wastes in Bangladesh, both in the freezing plants and in the domestic markets, and their availability, nutritional composition, and current innovations in utilization. The study also provides a conclusion and a way-forward for more effective, useful, and affordable utilization of fishery wastes in the country. The study sources data from: i) published papers/reports, books, government documents and online information; ii) key informants through informal interviews, especially from the Fish Inspection and Quality Control (FIQC) officials of DoF stationed in Chattogram, Dhaka and Khulna; and iii) grassroots level beneficiaries. The study estimates that fish dressing and cutting wastes in the country were 6.5 lac (metric tons) MT in 2019-20, besides other forms of fishery wastes like spoiled trash fish, non-harvested dead fish, non-edible fish and aquatic invertebrates, snails, mollusks, crabs, etc. The fish processing plants produced 2024 MT of offal in 2018-19, which were mostly dumped outside, except for some small enterprises that used a portion of the offal to produce fish meal, fish oil, fish scale, etc. The shrimp processing plants produced 19,600 MT of solid shell wastes in 2018-19, of which about 90% were sun dried and exported. The country has innovated several products from fish and shrimp offal wastes, both for animal feed and human food, such as fish meal, fish oil, powder fish silage, chitin and chitosan, fish glue, collagen, protein-fortified crackers, loaf, etc. However, these products are limited in scale and quality, and need more technical and logistic support for a sustainable and environment-friendly fishery wastes valorization process. The government should adopt policies for proper disposal, collection, and utilization of fishery wastes, in collaboration with the concerned ministries and departments. Quality standards and surveillance should be developed and monitored by the appropriate authority, as the product quality standards would differ from those prepared from fresh fish.

Keywords: Fishery wastes; present status of fish and shrimp wastes; policy for waste disposal; innovation and utilization process

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1. Introduction

Post-harvest fish loss (PHFL) reduction is a global agenda set about in the SDGs as goal No. 12 for ensuring sustainable food and nutritional security by reducing food loss (UN, 2016). The PHFLs occur in fisheries in many ways, accounting for 10-30% in different countries, based on awareness level, geographical locations, availability of inputs and resources and fish handling, preservation, processing and marketing conditions (FAO, 2011).

Figure. 1. Guts of some fishes are sold as food in the markets while other cutting wastes are dumped into municipal garbage bin (Nowsad, 2015)

Waste generated by seafood processing in the forms of gut, bone, scale, skin, fin, air bladder, head, shell, carapace, appendages, etc., typically ranges from 20% to 60% of the initial raw material, with an average of 20 million metric tons (MT) globally (Suresh and Prabhu, 2013; Pangestuti and Kim, 2014). Fish waste mainly consists of true offal (mainly gut, fin and air bladder), fish head and tails (27%) collected by the eviscerating, cutting, and filleting processes. A second major offal residue is represented by skins, bones and blood (25%) (Awarenet, 2004). These wastes are sometimes considered as the subset of food loss, since many of them are potentially recoverable for human consumption (Hodges et al., 2011). But if not consumed, fish wastes are valuable resources to be utilized as animal feed and fertilizer.

As a general phenomenon, during preparation, processing and marketing of fish in the value chain, a significant quantity is wasted, which if recovered and utilized as feed or food, may reduce farming cost, add value to human and animal nutrition, increase the income of the value chain actors and thus contribute towards reduction of PHFL in a substantial way. Due to its prime value, fishery waste is now considered not as a critical discard, but a valuable biomass that can be successfully converted into profitable products. Fish wastes are the cheaper, renewable sources of carbohydrates, proteins, lipids, and bioactive molecules (Elmekawy et al., 2013; Ravindran and Jaiswal, 2016). Because of these important characteristics, fishery wastes have been exploited not only to obtain feed, food, energy and biofuels, but also many bioactive ingredients like enzymes, antioxidants, novel biodegradable materials, and many other derivatives with a commercial value (Plazzotta and Manzocco, 2019a).

There are many different types of fishery wastes in Bangladesh. Processing of fish in the factory produces huge quantity of wastes in the form of head, frame, skin, bones, fins, guts, etc. Shrimp processing factories also produce an ample quantity of wastes in the form of head, shell, carapace, legs and appendages. All these wastes are collectively called as offal also. In the retail fish markets, there are also huge quantity of wastes during dressing and cutting of fish for the buyers. Survey conducted by Nowsad (2010a, 2010b) nearly a decade ago, estimated a 12-15 MT wastes/day produced by cutting/preparation of fish in 4 metropolitan cities, i.e. Dhaka, Chattogram, Khulna and Rajshahi. The quantity might be higher in recent days. All these wastes have valuable use in definite specialty products (Nowsad, 2010a). For example, a portion of fish cutting wastes, in its simplest form, can be boiled, dried and pulverized to produce fish meal, and the rest can be converted into fish silage for fish and poultry feeding (Hossain and Nowsad 2015; Hossain et al. 2020; Nowsad, 2015; Shikha et al. 2018). Some of the offal wastes in Dhaka city markets are being used by several entrepreneurs for making fish meal (Bashar, 2020).

In the fish mince and filleting industries, fish head constitutes 12-15% of the total fish body weight where 4-5% are meat and rest are bones and lipid (Nowsad, 2010a; Nowsad, 2015). The frames, the remaining parts retained with the skeleton and fins after separating fillets from two sides, are very useful as these contain further 10-15% flesh, 2-5% lipid, about 60% bones and 5% skins (Nowsad, 2015). During filleting pangas and tilapia, a maximum of 30 to 35% meat are retained with the fillet and the rest is treated as wastes in the form of frame, head and offal. Both scales, skin and fins, either from factory or fish markets, are valuable sources of collagen that can be made into fish glue (Gopakumar, 2002; Akter et al., 2016). Fish glue is an important element in chocolate and bakery goods, in color and varnish manufacture and also in gum and adhesive industry. Bangladesh imports 25-30 MT of fish glue every year (BBS, 2022). After recovering collagen for glue and gelatin, the remaining bones with adherent meat can be dried and crushed into fish meal, bone meal, silage, pet foods, fertilizer, etc. (Akter et al., 2016, 2017). The recovered mince from head and frame (15-20%) can be used to produce various value-added human food products, like fish mince block, fish nugget, fish ball or sausage (Nowsad and Hoque, 2008). Shrimp and prawn industry wastes have enormous potential as nutraceutical or in medicine and can be very successfully used in human food, since only shrimp shell contains more than 50% protein (Khan et al. 2010; Nowsad, 2009b). At present in Bangladesh, shrimp and prawn processing wastes of Khulna region, in the form of head, shell and appendages, are sold to private enterprises to dry and export to China (Hossain et al; 2018; FIQC, 2020). Shrimp processing wastes from Chittagong are dried by private agencies and sold to fish meal factories (FIQC, 2020). In Indonesia, Viet Nam, India, Thailand and other Southeast Asian countries, many ancillary industries have been established based on pangas and tilapia processing wastes as the only raw material (FAO, 2011; Gopakumar, 2002). So, there exists great scopes to utilize fish offal wastes in Bangladesh into valuable animal feed, human food or medicinal products. This study, therefore, assesses the existing knowledge on production and management of fishery offal wastes in Bangladesh and suggests ways for useful applications in both animal feed and human food.

2. Methods of Review Study

Review study covered: i. secondary sources of data from published papers/reports, books, government documents and online information pool; ii. primary sources of data from key informants through informal interview, especially from the FIQC officials of DoF stationed in Chattogram, Dhaka and Khulna; and iii. primary sources of data from the grassroots-level beneficiaries over the phone.

The majority of the secondary data were taken from the published papers, annual and final reports of different research projects, DoF souvenirs and Fisheries Resources Survey System. Online published sources include research articles and reports in journals, media groups and blogs of different organizations and independent groups, as cited in the reference section.

An informal checklist was prepared for collecting primary data on different types of fishery wastes production. Field officials of concerned organizations, like Fish Inspection and Quality Control (FIQC) wing of the DoF from Chattogram, Khulna and Dhaka stations, Bangladesh Fisheries Development Corporation (BFDC), were interviewed. Offal production and management data were also taken from fishing and processing communities including private sector, fish and shrimp processing plants, etc.

Secondary data have been used in the report with citations. Primary data were computed into simple tabular form. No statistical analysis was done.

3. Existing Knowledge on Production of Fish Offal and Other Fishery Wastes in Bangladesh

3.1. What is fishery waste?

In its wider meaning, the definition of "fish wastes" includes anything that is wasted in farming or fishing to harvest, transportation, processing and preparation for marketing and cooking. In that perspective, sometimes, many underutilized fish species or by-catch in the sea having no or low commercial value, undersized or damaged commercial species as well as species of commercial value but not caught in sufficient amounts to warrant sale, are also termed as fish wastes (Caruso, 2016). On the other hand, fish wastes are sometimes synonymous with *by-products*, although these two are defined elsewhere (Plazzotta and Manzocco, 2019b). According to the European Commission Directive (EC, 2008), a substance or object resulting from a production process, the primary aim of which is not the production of that item, may be regarded as *by-product* and not as waste only if: a) the further use of that substance is certain; b) the substance can be directly used, without any further processing other than normal industrial practice; c) the substance is produced as an integral part of the production process; and d) further substance use fulfills legal requirements in terms of environment, safety and quality. The same Directive also defines the “end-of-waste” status: in this case, waste shall cease to be a waste if it has been somehow recovered and is in accordance with the following conditions: a) the substance is commonly used for specific purposes; b) a market or demand exists for such a substance; c) the substance meets technical requirements, existing legislation and standards; and d) the recovery will not lead to adverse environmental or human health impacts.

In this study report, the term *fish waste* will be used to generally indicate substances discarded during the fish process, which have a potential for valorization. Fishery wastes are generally obtained from the discards during preparation, marketing, processing or value-addition of fish. The term *"offal waste"* has a more specific meaning of indicating a thing having no or minimum value at present condition, and so, completely discarded. In the present context in Bangladesh, most of the processing and cutting wastes of fish are of this type.

3.2. Post-harvest fish loss and fish wastes

According to FAO (FAO, 2020, *published online*) food waste is part of food loss and refers to discarding or alternative (non-food) use of food that is safe and nutritious for human consumption along the entire food supply chain, from primary production to end household consumer level. In terms of fish, food loss includes fisheries and aquaculture products which are intended for human consumption but are ultimately not eaten or consumed by people, or that have incurred a reduction in quality. An important part of food loss is "food waste", which refers to the discarding or alternative (non-food) use of food that was fit for human consumption – by choice or after the food has been left to spoil or expire as a result of negligence.

Therefore, this above FAO definition hardly supports fish offal waste as food loss or post-harvest fish loss, until or unless a part or full of this waste is utilized as human food. Many authors, however, defined offal wastes as a subset of food loss (Hodges et al., 2011; Plazzotta and Manzocco, 2019a,b).

3.3. Fish processing factory wastes

Industrial fishery wastes management is a new approach in Bangladesh. No work has so far been done in this theme considering a "*total utilization*" concept in the industry, although there have been piecemeal activities in some plants with different fishery raw materials. Before compiling all this information, a review of pangas and tilapia aquaculture and its value-addition potentials need to be understood, because pangas and tilapia processing wastes would be one of the major sources of raw material in this valorization process.

Pangasius catfish, *Pangasianodoan hypophthalmus,* farming has evolved to a shape of commercial enterprise over the last two decades in north-central part of Bangladesh, particularly in Mymensingh area. The higher yield of pangas and increased booming of production made some farmers interested to export pangas to some importing countries (Haque, 2012). The seafood processing and marketing industry has been established in Bangladesh from the very beginning of independence, but most of the plants run well below their capacity utilization. The situation has provoked some big pangas farmers to process and export their farm products through the existing commercial process lines. Several plants, viz. Seven Ocean Seafoods, Virgo Fish and Agro-Processing Ltd., Earth Agro-Industries Ltd., etc. were established for exclusive production and export of pangas fillets. After launching and operation for a few years, these plants closed down because of scarcity of adequate size and quality pangas. These processing plants also had limited experience in exporting white fish fillet (Haque, 2012) and their markets abroad were not stable. The entrance of white fish to mainstream native European export market is not possible until or unless the white fish is processed as fillet or other ready-to-cook value-added products, as has been practiced by other exporting countries like Viet Nam, Thailand, etc. However, Bangladesh has been producing and exporting substantial quantity of frozen whole white fish, exported mainly for expatriate Bangladeshi living abroad.


Figure. 2. Fish offal displayed for sale in fish market (Nowsad, 2015)

During the present study, offal wastes production by different fish freezing plants of the country in 2018-19 were investigated (Table 1). In Chattogram and Sunamganj, many white fish processing plants are involved in processing semi-individual quick freezing (semi-IQF) of large size inland and marine fish, dressed and washed, whole IQF, frozen block (for small fish), etc. In Chattogram, the average offal production was calculated to be 10% of the total fish processed. On the other hand, average offal production of the plants in Sunamganj, Kulierchar and other BFDC plants, involved in dressed fish processing, was about 25% of the processed products. Other processing plants in Cox's Bazar, Noakhali and Khulna are also processing fish in limited scale along with prime processing of shrimp and prawn. The total average offal production of the processing plants has been estimated at 2024 MT in 2018-19 (Table 1). The fish processing plants, however, do not necessarily process offal wastes, with a few exceptions. Most of the offal wastes are dumped into outside garbage bin, from where these are collected by the municipal garbage vehicle for land fill. Some small enterprises used a portion of the offal into fish meal production through boiling and drying oil-free solid parts (Table 2). Oil extraction has not yet been initiated from the gut by the private sectors, except Versatile Waste Management Ltd in Dhaka who uses a traditional method to extract fish oil in crude form (Table 2). However, oily gut can be utilized in fish silage production through organic acid digestion (Hossain and Nowsad, 2015).

Some entrepreneurs in Dhaka have established fish scale processing plants (Table 2). As for present practice, the plants collect scales from different fish markets and processing plants by the agents, wash and clean and then dry finely in the yard, sieve and grade to eliminate smaller or broken scales and export top 2 size grades. The export destination is South Korea.

Table 1. Quantity of fish processing plant offal wastes in the country in 2018-19*

Sl	Name of Factory	Location	Type of Processing	Container /Year (No.)	Offal production (MT/Year)	Present use of offal wastes
1	BDC Food Ltd	Chattogram	FW-IQF, dressed whole	70	126	FM, discard gut
2	Sabjiana Ltd	Chattogram	FW-IQF, dressed whole	25	45	FM, discard gut
3	Sea Mark BD Ltd	Chattogram	FW-IQF, dressed whole	70	126	FM, discard gut
4	Riverine Fish Processing Ltd	Chattogram	FW-IQF, dressed whole	70	126	FM, discard gut
5	Anraj Fish Products Ltd	Chattogram	FW-IQF, dressed whole	50	90	FM, discard gut
6	Pacific Seafood Ltd.	Chattogram	FW-IQF, dressed whole	80	144	FM, discard gut
7	Masud Fish & Ice-cream Co.	Chattogram	FW-IQF, dressed whole	10	18	FM, discard gut
8	Frozen Food Ltd	Chattogram	FW-IQF, dressed whole	5	9	FM, discard gut
9	Ark Seafood Ltd	Chattogram	FW-IQF, dressed whole	4	7.2	FM, discard gut
10	Nihyo Sefood Ltd	Chattogram	Marine fish, block, IQF	70	126	FM, discard gut
11	Fish Garden Ltd	Chattagram	Marine fish IQF, block	60	108	FM, discard gut
12	BFDC Fish Processing Ltd.	Chattogram	Marine, FW, IQF, block	5	22.5	FM, discard gut
13	Cox's Bazar Seafood Ltd	Cox's Bazar	Marine fish IQF, block	3	5.4	FM, discard gut
14	BFDC Fish Processing Ltd.	Cox's Bazar	Marine fish IQF, block	3	13.5	FM, discard gut
15	Globe Fisheries, Noakhali	Noakhali	FW-IQF, dressed whole	60	108	FM, discard gut
16	Rupsha Fish & Allied Industries	Khulna	Marine, FW-IQF, whole	10	45	FM, discard gut
17	Saidullah Enterprise	Shunamganj	FW-IQF, whole, block	30	135	FM, discard gut

18	Premium Fish & Agro Products ltd.	Sylhet	FW-IQF, whole, block	24	108	FM, discard gut
19	Unipex Trade Corporation	Sylhet	FW-IQF, dressed whole	15	67.5	FM, discard gut
20	Urocross BD Ltd.	Sylhet	FW-IQF, whole, block	30	135	FM, discard gut
21	Kulierchar Cold Storage Ltd	Kishoreganj	FW-IQF, whole, block	60	270	FM, discard gut
22	Virgo Fish & Agro- Process Ltd.	Trishal	FW-IQF, dressed whole, block, shrimp/prawn	20	90	FM, discard gut
23	Seven Oceans Fish Processing Ltd.	Trishal	FW-IQF, dressed whole, block	12	54	FM, discard gut
24	Earth Agro Industries Ltd	Gazipur	FW-IQF, whole, fish meal	10	45	FM, discard gut
	Total				**2024.1**	

FM= fish meal, FW= Fresh water, SU= selected use discarding oily offal, IQF= individual quick freezing, MT= Metric tonnes

* Data were collected from the processing plants directly and then validated through the FIQC personnel in Chattogram and Khulna

Table 2: Enterprise involved in secondary processing of fish and shrimp wastes in 2018-19*

Sl	Name of Enterprise	Location	Nature of Operation	Final Product	Qty Produced (MT)	Destination
Shrimp shell and head processing						
1	M/S Nahar Traders	Khulna	Collect dried shrimp shell from traders and export	Dried shrimp shell	10,000	China
2	M/S Raka Enterprise	Khulna				
3	M/S Maximco Ltd	Khulna				
Fish scale processing						
4	Biotech Ltd	Lalbagh, Dhaka	Dry in own yard, grade and export top 2 size grades	Dried fish scale	450	South Korea
5	ABC Alam Fish Scale Corp.	Dhaka				
6	Yeaser Trading Corporartion	Dhaka				
Offal wastes used in fish meal and oil production						
7	Earth Agro-Industries Ltd	Gazipur	Discard oily gut, dry solid part & crush as FM	Fish meal	20-25	Local feed company
8	Versatile Sea Resources Ltd	Cox's Bazar	Trash fish dried and crushed into meal	Fish meal	720	Local poultry feed

9	Versatile Wastes Management Ltd	Gabtoli, Dhaka	Fish market wastes of Dhaka City North, collected by staff, boil to separate oil & solid part dried & crushed as FM	Crude fish oil & fish meal	60 - FM 10 - fish oil	Local feed factories

* Production and export data were collected from the plants and validated through FIQC

Since some processing plants are involved in fish filleting, they may produce huge quantity of utilizable wastes. The frames, the remaining part that retained with skeleton and fins after separating fillets from two sides, contains further 10-15% flesh, 2-5% lipid, about 60% bones and 5% skins (Nowsad, 2015). In filleting pangas, a maximum of 35% meat can be obtained and the rest are treated as wastes in the form of frame, head and offal (Nowsad and Hoque, 2008). Both skin and fins are valuable sources of collagen that can be made into fish glue (Gopakumar, 2002). As stated, Bangladesh imports 25-30 tons of fish glue every year. After recovering collagen for glue, the remaining bones with adherent meat can be dried and crushed into fish meal, bone meal, silage, pet foods, fertilizer, etc. The recovered mince from head and frame (15-20%) can be used to produce various value-added human food products, like fish mince block, fish nugget, fish ball or sausage. As the pangas and tilapia processing industries in the country have been growing bigger with increased quantity of processed products produced both for domestic and international markets, the country essentially needs to explore the useful utilization of these processing wastes. There is an estimated five to eight processing factories in the country planning to process 100,000 to 120,000 MT of pangas and tilapia every year, and this will produce an additional 15,000 to 20,000 MT of recyclable wastes (Nowsad, 2015).

3.4. Shrimp processing wastes

While producing exportable frozen products, the shrimp processing industries also produce a vast amount of waste varying from 40-80% depending upon species and process (Irianto and Giyatmi, 1997). The solid waste comprises mainly head, tail, vein/viscera and shell. All raw material (fresh shrimp) received in factory's window for processing could not satisfy the raw material quality to be processed. Sometimes raw material becomes spoiled before reaching the processing line. Such a type of spoiled or semi-spoiled raw material increases the volume of waste. In the processing factory in Bangladesh, except bigger sized head portion of *Macrobrachium rosenbergii*, other smaller prawn and shrimp heads, shells and appendages were generally treated as garbage and dumped just outside the factory premises, but within same factory compound or thrown to the rivers. This unauthorized dumping of waste might contaminate shrimp processing and paved the way for environmental pollution. A significantly high biological oxygen demand (p = 0.05) was found in the Rupsha River, adjacent to about 16 processing plants about a decade ago

(Begum et al. 2006). On the other hand, in each factory, additional human resources were employed in that time or money spent to dispose such valuable wastes from the factory premises to outside (Nowsad, 2009a,b). However, the situation has changed now and much of the shrimp waste is being utilized either in feed mills or exported after drying.

Figure. 3. Shrimp processing factory wastes (Nowsad, 2009a)

After trimming, 40-50% of the shrimp is eventually wasted in the form of leg, appendages, head, shell and tail. According to an estimate by Fish Inspection and Quality Control section of DoF (FIQC, 2020), the country's shrimp processing industries are dumping nearly 20,000 MT of shrimp waste annually (Table 3). Although most of the wastes are dried and exported, there still exists the opportunity to utilize such wastes in the manufacture of value-added human food, animal and fish feed and valuable medicinal products like chitin and chitosan. Shrimp processing plants are equipped with modern process lines. If nominal care is taken, value-added food products can be produced in the extended process line in the plants. The products can be marketed locally or abroad. Thus, the production of value-added products from waste may serve five important purposes: i.) the products could supply cheaper nutrition to the people where 80% of the population remains undernourished; ii.) the factory could earn a handsome profit by introducing simple process-line for the products; iii.) utilization of the waste can minimize the cost of waste disposal that will realize substantial savings; iv). rural fisher-women processors/entrepreneurs can operate risk-free business to generate additional income for the family; and v.) an environment-friendly waste management technique could be developed so the environment will remain unpolluted and fresh.

Study conducted by Hossain et al. (2018) counted a production of 248.8 MT of waste out of 671.84 MT raw shrimp used in 52 plants / day in Khulna-Chittagong region. The study showed about 80% of the plants sold the raw waste to others, while the rests were discharged into rivers. Present survey studies, however, conducted in 55 shrimp processing factories of Khulna, Chittagong, Cox’s Bazar and Dhaka zones revealed that about 43,500 MT of frozen shrimp were produced in 2018-19, with solid shell wastes of 19,600 MT (Table 3). About 90% of the plants were found to sell their wastes to private entrepreneurs, who dried the shell and sold it to the exporters.

Table 3 Quantity of shrimp processing plants offal wastes in the in 2018-19*

Sl	Location/Zone	No of plants	State of Processing	Production (MT)	Wastes production (MT)	Present use of offal wastes
1	Chottogram	6	Fully operational, 25-30% CU	15,000	6,000	Traders collect & dry shrimp shell and sell to exporters.
2	Cox's Bazar	7	Occasional, 5-10% CU	2,000	2,100	
3	Khulna	35	Active + occasional, 12% CU	25,000	10,000	
4	Dhaka & others	6	Occasional, 5-10% CU	1,500	1,500	
Total				43,500	**19,600**	

CU= Capacity utilization

* Data collected from the plants in association with FIQC of the DoF

The main export market of dried shrimp shell is China. Several licensed enterprises from Khulna are involved in exporting dried shrimp shell (Table 2). They purchase dried shells from the traders directly as practiced in Khulna or collect raw shell by own agents, sun-dry in own yard and sell to local feed millers or abroad, as practiced in Chattogram. Most of the traders in Chattogram have no license to export, so they found difficulty in exporting shrimp shell. Wastes shells are generally collected in tin containers; many of them are still thrown to the rivers from the factory in Chattogram.

3.5. Fish market wastes

Fish market wastes and other fishery household wastes are generally mixed with municipal wastes and dumped outside the fish markets. In the metropolitan cities, municipal wastes are collected by the city corporation staffs, whereas in peri-urban or rural areas these are simply thrown at road-sides or ditches nearby. On the other hand, there is no existing comprehensive waste collection system in the municipalities and city corporations, except Dhaka and Chattogram. These two city corporations adopted an acceptable process of waste management. In other cities, however, market wastes are mostly dumped in open places, ditches or ponds nearby; in some places some are burnt. In Dhaka and Chattogram, the common practice is that various waste transfer points or garbage bins are developed around the cities from where motor vehicles carry the waste to nearby landfills or dumping sites. There is no available proper sanitary landfill to manage the generated waste in the country and with the alarming rate of waste generation for last few years the existing dumping sites are at stake (Bhuiyan et al., 2012). According to JICA (2005), a total of 12,332.89 MT/day waste was generated in urban areas in 2002 which accounts for 2.19

million ton CO_2e/year. With the existing waste collection efficiency, 140.99 acre, 4 m depth landfill area is required, which is completely unbearable for a resource-poor land-scarce country like Bangladesh.

The country's urban waste generation was estimated at 16,382 MT/day with wastes generation rate (kg/capita/day) of 0.5 in 2004 (Table 4). The daily urban waste generation is projected to reach 47,064 MT with waste generation rate of 0.6 in 2025 (Islam, 2016), of which Dhaka city alone accounts for 37%. Four types of waste streams i.e. domestic (49%), commercial (21%), industrial (24%), and hospital (6%) constitute the total solid wastes of Dhaka city (Islam, 2016). Out of 49% domestic wastes, fish market wastes may constitute 8-10%.

Table 4: Growth in solid waste generation in urban cities of Bangladesh (Islam el al., 2016)

Year	Total Population	Urban population (% total)	Wates generation rate (kg/capita/day)	Total wastes generation (tonnes/day)
1991	20872204	20.15	0.49	9873.50
2001	28808477	23.39	0.50	11695.00
2004	32765152	25.08	0.50	16382.00
2025	78440000	40.00	0.60	47064.00

There are no dependable fish market waste statistics available in the country. However, according to an estimade made by the DoF, out of 3.5 million MT fish produced in 2016-2017, 1.0 to1.2 million MT of wastes were produced, which accounted a value of 8,000 crore BDT. This seemed to be an over-estimation, because research made in our laboratory (Akter et al., 2017) calculated that fish cutting wastes averaged around 15%. Apprehending that findings, the country's current fishery production in 2019-20 of 4.23 million MT may have produced market fishery wastes of 0.65 million MT in 2019.

In the retail fish markets, there are also huge quantity of wastes during dressing and cutting of fish for the buyers. Survey conducted by our laboratory nearly a decade ago estimated a 12-15 MT wastes produced everyday by cutting and dressing of fish in the wet fish markets in 4 metropolitan cities, viz., Dhaka, Chattogram, Khulna and Rajshahi (Nowsad, 2015). The quantity might be very high in recent days, because of increasaed quantity of harvest and utilization. The cutting wastes have also valuable use in definite specialty products. For example, a portion of fish cutting wastes, in its simplest form, can be boiled and sieved, and dried and pulverized, to produce crude fish oil and fish meal, and the rest can be converted into fish silage for fish and poultry feeding. But due to lack of a comprehensive fishery wastes management protocol, the country is deprived of getting ample amount of revenues every year. However, through some private initiatives, some of the wastes are now used in fish meal, fish oil, medicine and cosmetic productions. Many of the shrimp industry wastes are exported, but major portion of the fishery wastes are destroyed.

Table 5 Fish market waste in 4 metropolitan cities

Sl	Metropolitan city	No. of fish market	Qty of market wastes (MT/day)	Present use
1	Dhaka	120	12	Partially used in fish meal (FM) oil, scale, etc
2	Chattogram	45	5	A few use in FM
3	Khulna	15	1	No use
4	Rajshahi	17	1	No use
5	Sylhet	21	2	No use
6	Rangpur	13	1	No use
7	Mymensingh	13	0.5	No use
8	Cox's Bazar	7	2	Partially used in FM, oil production
Total		**24.5**		

Source: Abu Hena Basahar, Versetile Sea Resources Ltd. Chittagong (2020)

3.6. Other fishery wastes as discard (non-conventional harvest, non-edible species, spoiled fish, etc.)

There are other forms of fishery waste in the country, obtained and/or discarded during fishing both in inland and marine capture fisheries. These may include spoiled trash fish, non-harvested dead fish while fishing, non-edible fish and invertebrates. Invertebrates include small crabs, mollusks, bivalves, arthropods, octopodes, decapods, sea urchins, jellyfish, etc. from marine /brackish water origin and snails, bivalves, other aquatic invertebrates and insects, etc. from freshwater origin. Non-edible fish include small cuchia (*Monopterus cuchia)*, kumirer khil (*Microphis deocata)*, cheka (*Chaca chaca)*, kan pona (*Aplocheilus panchax)*, neptani (*Ctenops nobilis*), gachua (*Chana gachua*), napit koi (*Badis badis*), etc. Table 6 shows the tentative estimate obtained from the fishermen of the landing center sources of those areas. There are four forms of discards during hauling, viz., freshwater discard, spoiled fish, non-harvested dead fish and very small trash fish, generally accounting for 3%, 2%, 1% and 2% of total capture fishery harvest/discard, respectively. In total, the loss as wastes accounts for 97,322 kg in 2017-18. Collection of these huge wastes in organized way may add a substantial volume to the requirements of raw material in fish meal industry.

Table 6. Non-edible small fish and invertebrates obtained during fishing in 2017-2018*[1]

Sl	Non-edible items	Estimated loss during harvest (kg)					
		River & Estuary	Sundar bans	Beels	Flood plains	Kaptai Lake	Total
Production, MT (2017-18)*[2]		**3,20,598**	**18,225**	**99,197**	**7,68,367**	**10,152**	**12,16,539**
1	FW discard (3%)*[3]	9,617	547	2976	23051	304	36,495
2	Spoiled fish (2%)	6412	365	1984	15,367	203	24,331
3	Non-harvested dead fish (1%)	3206	183	992	7,683	101	12,165
4	Very small trash fish (2%)	6412	365	1984	15,367	203	24,331
Total		**25,647**	**1,460**	**7,936**	**61,468**	**811**	**97,322**

*1 Data taken from the fishermen in the landing centers

*2 FRSS, 2018

*3 FW= Freshwater; freshwater discards constitute small unpopular, non-habituated fish, aquatic invertebrates and insects including snails, bivalves, water snakes, etc.

4. Nutritional Status of Fishery Wastes

4.1. Fish body parts and proportions

Body parts and wastes production vary based on groups or species of fish. Nowsad (2015) studied the proportion of different body parts and wastes in different fish groups and in individual species obtained from wet fish kitchen markets in Bangladesh. Major fish groups are Indian major carp, exotic carp, minor carp, percids including tilapia, snakeheads, catfishes including pangas, clariid and scheilbid catfishes and featherback (Table 7). Wide variations were observed on scales and fins within the groups due to size variation of fish, but skin, intestine, head, frame, and muscles within the group did not vary much.

Table 7. Body parts of different fish groups commonly marketed in Bangladesh

Fish Groups	Variation of different parts of fish body (%)						
	Scale	Fin	Intestine	Skin	Head	Frame	Muscle
Indian major carp	4.20±0.11-4.95±0.05	0.65±0.02-0.81±0.01	5.95±0.05-6.65±0.15	2.80±0-2.93±.03	21.72±0.32-26.65±0.23	7.81±0.57-9.41±0.67	50.42±0.25-55.42±0.08
Exotic carp	1.75±0.01-4.49±0.01	0.70±0.02-1.33±0.03	6.76±0.24-7.60±0.05	3.00±0-3.16±0.03	22.45±0.05-25.38±0.17	10.15±0.56-13.69±0.04	51.46±0.14-54.67±0.23
Minor carp	3.25±0.05	1.10±0	4.43±0.03	3.05±0.05	19.03±0.03	13.69±0.04	55.46±0.15
Percids	4.32±0.03	1.73±0.02	7.55±0.41	3.45±0.05	19.17±0.03	8.20±0.35	55.59±0.09
Catfishes	-	1.95±0.05	4.05±0.05	4.53±0.03	22.6±0.1	8.99±0.55	57.12±0.77
Snakeheads	4.50±0.13	1.88±0.04	3.75±0.05	3.13±0.06	19.6±0.5	6.89±0.67	56.54±1.04
Feather back	5.03±0.03	2.42±0.02	4.78±0.08	11.05±0.05	16.2±0.2	15.01±0.41	46.03±0.78

Source: Nowsad (2015)

On the other hand, when individual fish were assessed for body weight and wastes productions, a clearer picture was obtained. Ten commonly consumed individual fish species (catla *Catla calta*, rui *Labeo rohita*, mrigel *Cirrhinus mrigala*, grass carp *Ctenopharyngodon idella*, silver carp *Hypophthamichthys molitrix*, Thai sarpunti *Puntias gonionatus*, tilapia *Oreochromis niloticus*, shole *Chana striata*, *Thai pangas Pangasianodon hypophthalmus* and chital *Notopterus chitala*, were studied (Nowsad, 2015, Akter et al., 2016, 2017) to assess proportions of different body parts, in order to know quantity of wastes for making fish glue. At least three individual fishes for each species were assessed (Table 8). For a larger fish, flesh contained 45% of the total body weight, with head 24-27%, skeleton 12%, skin 3%, cut off 4% and viscera 12% including egg, milt and liver. On average, the volume of waste (%) varied according to species and size. The larger the fish size, the higher the volume of waste.

Table 8. Wastes proportions in some individual fish species

Species	**Body wt. (g)**	**Fish body weight and wastes proportions (%)**						
		Scale	**Fin**	**Intestine**	**Skin**	**Head**	**Frame**	**Muscle**
Catla	1450±50	4.20±0.1	0.65±0.02	5.95±0.05	2.93±0.03	26.65±0.23	9.41±0.67	50.42±0.25
Rui	1375±25	4.45±0.15	0.69±0.03	6.85±0.29	2.80±0	24.08±0.18	10.26±0.91	50.89±0.62
Mrigel	1100±100	4.95±0.05	0.81±0.01	6.65±0.15	2.65±0.06	21.72±0.32	7.81±0.57	55.42±0.08
Grass carp	1475±25	4.49±0.01	0.71±0.02	7.60±0.05	3.00±0	22.45±0.05	7.09±0.31	54.67±0.23
Silver carp	2400±100	1.75±0.01	1.33±0.03	6.76±0.24	3.16±0.03	25.38±0.17	10.15±0.56	51.46±0.14
Sharpunti	450±0	3.25±0.05	1.10±0	4.43±0.03	3.05±0.05	19.03±0.03	13.69±0.04	55.46±0.15
Tilapia	350±0	4.32±0.03	1.73±0.02	7.55±0.41	3.45±0.05	19.17±0.03	8.20±0.35	55.59±0.09
Shole	840±43	4.37±0.26	1.67±0.31	3.57±0.35	3.34±0.66	18.0±0.72	7.69±0.87	58.35±0.87
Pangas	1000±0	-	1.95±0.05	4.05±0.05	4.53±0.03	22.6±0.1	8.99±0.55	57.12±0.77
Chital	1000±0	5.03±0.03	2.42±0.02	4.78±0.08	11.05±0.05	16.2±0.2	15.01±0.41	46.03±0.78

Source: Nowsad (2015)

The total cutting waste produced by different fishes were also determined, as in Fig. 4 (Nowsad, 2015). Tilapia (*O. niloticus*) produced highest cutting/dressing wastes of 13.25%, followed by grass carp (*C. idela*), mrigal (*C. mrigala*), rui (*L. rohita*), chital (*N. chitala*), catla (*C. catla*), silver carp (*H. molitrix*), sarpunti (*P. gonionatus*) and pangas (*P. hypophthalmus*). The scale-less fish like pangas produced lowest cutting wastes of 6.0%.

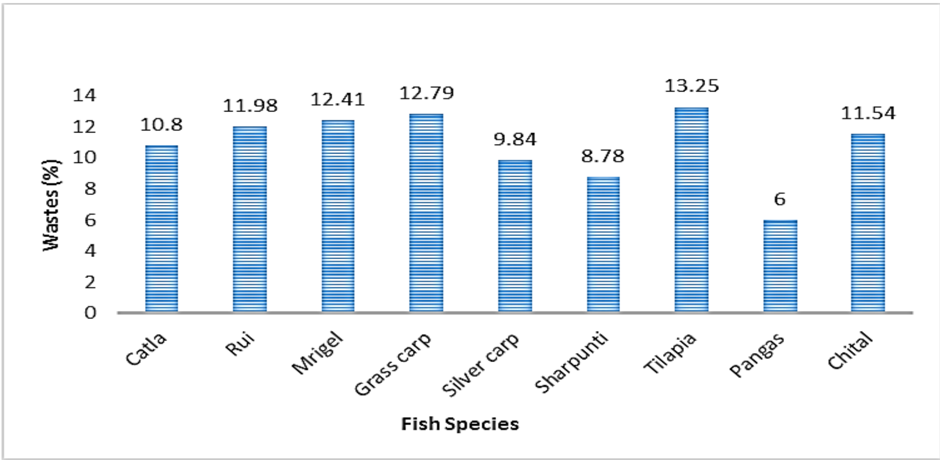

Figure. 4. Fish wastes obtained from 9 major marketable fish of the country (Nowsad, 2015)

4.2. Nutritional composition and values of different shrimp wastes

The proximate and nutrition compositions of different shrimp and fish processing wastes obtained from the processing plants and municipal fish markets in Bangladesh were studied by Nowsad (2009a, 2009b, 2010b, 2015); Khan et al. (2010); Hossain and Nowsad (2015); Islam et al. (2016).

Nutrient contents of different component parts of shrimp wastes were analyzed. Using the extracted protein-rich components from shrimp wastes, several nutritious, tasty and cheaper value-added food products were produced (Nowsad, 2010b, Khan et al., 2010). Shrimp shell waste components were found to have very high nutritional contents (Table 9).

Table 9. Proximate composition of different component parts of shrimp waste

Waste Component	**Composition on dry weight basis**			**pH**	**SPC (CFU/g)*1**
	Protein	Lipid	Mineral		
Thoracic & abdominal shell	48.5±1.15	4.4±0.22	22.7±1.1	7.1±0.1	
Carapace	43.5±1.52	3.8±0.23	19.6±1.0	7.0±0.2	
Telson	50.2±1.87	4.5±0.14	18.2±2.1	7.1±0.1	
Appendages	48.6±2.24	3.8±0.51	20.3±2.3	7.3±0.0	
Antennae	40.7±2.87	3.4±0.67	18.4±1.9	7.2±0.1	
Maxillary case	47.8±1.98	10.5±1.02	14.6±1.5	6.8±0.0	
Head	48.5±3.21	12.8±0.98	15.9±0.9	6.8±0.1	1.1×10^5
SSP*2	47.4±1.74	10.5 ±1.71	19.4 ± 0.6	7.2 ± 0.1	9.2×10^4
Mashed head	-	-	-	-	1.6×10^5
Mashed mixed SS	-	-	-	-	4.3×10^5

*1 Standard plate count was made on dry and paste of head and mixed shrimp shell waste
Source: (Nowsad, 2010b, Khan et al., 2010).

*2SSP= shrimp shell powder

Component parts of shrimp industry wastes were cleaned, washed and dried, both individually and as mixed lot, and pulverized to transform into powders. The powder obtained from mixed lot was termed shrimp shell powder (SSP). Very high levels of protein, ranging from 40 to 50%, were found in the shell component wastes. The contents varied with the lowest in antennae and carapace, and highest in telson. Antennae, which were supposed to have low nutritional content and always thrown outside or grinded for silage in waste processing plants, were found to have 40.7% protein on dry weight basis. The mixed lot of such exclusive wastes (SSP) which are always thrown to garbage, had 47% protein and 10% lipid. Average protein content in the whole shell wastes was 45.2±1.3%. Whole shell waste including head meat had an average lipid content of 4.1±0.5%. Head had the highest lipid content of 12.8%. True shell (carapace and shells) had about 3.4 t0 3.8% lipid. Minerals contents in shrimp wastes in terms of ash were also found to be very high (Table 9). This extremely high level of nutrient found in the shrimp wastes widened the scope of utilization of such valuable nutrients as functional nutritive additive in human food, as explained later.

4.3. Nutritional content in fish offal wastes

In the process of utilization of fish market cutting wastes, particularly fatty viscera in powder fish silage production, Nowsad (2015) and Hossain and Nowsad (2015) determined the proximate and other nutritive components of fish cutting wastes. Mixed fish viscera contained 14.01±0.68% protein, 20.00±1.04% lipid, 4.75±0.64% ash, 60.62±2.15% moisture and 0.62±0.08% nitrogen free extract (NFE). The pH of fish viscera was 6.21±0.07 (Table 10).

Table 10: Proximate composition of silage and its ingredients

Ingredients/Silage	**Composition (%)**				
	Protein	**Lipid**	**Ash**	**Moisture**	**NFE***
Viscera (wet weight basis)	14.01±0.68	20.00±1.04	4.75±0.64	60.62±2.15	0.62±0.08
Viscera (Dry weight basis)	32.38±1.19%	47.10±0.92	10.20±1.10	9.16±1.25	1.15±0.40
Rice bran	9.32±0.06	17.94±0.35	18.67±0.12	9.65±0.14	44.42±2.60
Liquid silage	12.00±0.89	17.26±1.49	3.73±0.81	66.41±3.07	0.60±0.09
Powder silage	20.84±0.12	33.73±0.14	14.05±0.27	10.83±0.19	20.55±0.65

Mean± SD of 8 samples; NFE* (Nitrogen Free Extract) = {100- (protein+ lipid+ ash+ moisture) %}
Source: Hossain and Nowsad, 2015

In other studies (Akter et al., 2016, 2017), some selected fish cutting wastes like scales and skins were subjected to biochemical analysis, in order to prepare fish glue from these parts.

Table 11: Proximate composition of different fish skin and scale

Fish wastes	Proximate Composition (%)*1			
	Moisture	Ash	Protein	Lipid
Major Carp Scale	51.23±0.66	17.56±0.23	28.84±1.29	0.44±0
Tilapia Scale	55.34±0.62	18.72±0.76	22.84±1.36	0.55±0.06
Tilapia Skin	71.73±0.31	3.88±0.44	21.31±1.17	1.55±0.49
Pangas Skin	60.65±0.30	3.58±0.52	24.85±0.99	1 6.98±0.43

*1 Mean± SD of three replicates Quality of glue: Proximate composition of glues
Source: Akter et al., 2016, 2017

Proximate composition study (Table 11) revealed that both fish scales and skins contained high levels of crude protein, from 21% to 28%, but negligible amount of lipid, indicating that freshwater fish scales and skins could be very effectively used in fish glue production, because protein is the main component of glue. Mahboob et al., (2013) found similar proximate composition of common carp scale, as 58.83±1.1% moisture, 27.01±03% protein, 0.75±0.01% fat, 7.96±0.08% ash and silver carp scale as 54.75±0.1% moisture, 28.38±0.3% protein, 0.87±0.01% fat and 10.58±0.11% ash. Muyonga et al., (2004) analyzed proximate composition of tilapia skin and found moisture of 72.6±2.49%, ash 4.24±0.35%, protein 21.30±2.53% and fat 3.85±0.22%. Prommajak and Raviyan (2010) found 60.86±0.65% moisture, 35.83±2.61% crude protein, 2.19±0.64% crude lipid and 0.18±0.08% ash in Thai pangas (*Pangasius bocourti*). So, in all cases protein content is quite high in fish scales and skins.

5. Current Status of Utilization of Fishery Wastes

5.1. Shrimp industry wastes utilization

As mentioned in Table 1 and Table 3, most of the shrimp industry wastes obtained from the processing plants of Khulna are being dried by several private entrepreneurs. These dried shells are collected by private companies as listed (Table 3) and exported to China. Shrimp shell wastes from Chattogram fish processing plants are either used in fish meal industries or disposed to municipal garbage bins or rivers.

Shrimp and prawn shell wastes produced in other processing plants of the country and from fish markets have no organized utilization protocol, programs, and management practices, so mostly dumped in the municipal garbage bin or anywhere outside of the factory premises or fish markets.

5.2. Fish processing industry wastes utilization

A major portion of fish processing wastes from Chittagong or Khulna fish plants are being shifted to fish meal plants nearby to produce fish meal (Table 1). Some processing plants have their ancillary process line of manufacturing fish meal from own factory produced wastes like Masud Fish and Ice Co. A significant portion from other plants is being dumped outside as well.

5.3. Fish cutting wastes utilization

Utilization status of fish cutting wastes obtained in fish markets is very frustrating. Most of the wastes are dumped and disposed to municipal garbage bin throughout the country. A small portion is however, collected by some small enterprises in organized way through agents in Dhaka and Cox's Bazar and processed into fish meal, fish oil or dried scales, etc. (Table 3). Produced fish meal and oil are used in feed company and dried scales are exported to South Korea.

5.4. Other fishery wastes utilization

There are other types of fishery wastes as described in Table 6, produced a handsome bulk quantity (97,322 MT) if accumulated. These are non-edible fishery items, including spoiled trash fish, aquatic invertebrates, dead fish, etc. When ample quantities of such items are produced or landed, they are collected by the poor people, dried in the sun and sold to the fish meal industry. But there are no organized entrepreneurs or collectors for collecting and processing these elements, so are thrown away to the river sides. If these elements are collected in an organized way, the quantity could be much higher than the present incidental harvest or discard (Table 6).

5.5. Quality of the raw material wastes, process and products

Currently, most of the fish dressing and cutting wastes collected from the markets are rotten during collection and transportation to processing centers. In the case of fish meal and fish oil manufacture, these partially rotten wastes are boiled and sundried in open yard, which produce obnoxious bad smell and pollute the local air. There have been complaints from the local inhabitants against the processing of fish wastes in the open place. Since mostly traditional methods are used to extract fish oil and produce fish meal, which seriously lack modern equipment and technical knowhow, the finished fish meal and fish oil products are of low quality and sold at lower price compared to fish meal produced from fresh raw material fish. Both these products are sold and used by fish and poultry feed mills. Because of low quality fish meal and oil obtained from wastes, finished fish and poultry feeds would have lower nutritive values. Therefore, adequate measures should be taken to keep the quality of raw material offal wastes in good quality during collection, transportation and processing and to use appropriate methods and machineries for good quality product manufacture.

6. Innovation in Fish Waste Utilization

6.1. Global innovation in fishery waste utilization

Plazzotta and Manzocco (2019a) reviewed the utilization of seafood wates so far in detail. Based on the review the following utilization is suggested.

a) Globally most seafood waste is currently processed in fish meal plants, where fish meal and fish oil are produced. While fish meal is used as animal feed, pet food, or plant fertilizer due to its rich composition in protein and minerals, fish oil can be exploited for both food and nonfood uses according to its composition. Among food uses, the production of margarine and shortenings is the most common use of fish oil; nonfood applications include production of soap, glycerol, fertilizers, and substrates for fermentations (Ferraro et al., 2010).

b) Skin, scales, fins, and bones deriving from fish waste are used as valuable alternative to meat waste to produce collagen and gelatin. Moreover, with respect to animal gelatin, seafood gelatin presents analogous functional properties, associated to an enhanced digestibility (Woodard et al., 2007).

c) Fish bone is used as an alternative to animal waste to produce biocompatible materials such as hydroxyapatite (Yamamura et al., 2018).

d) The liver and residual flesh of some fishes (cod fish, mackerel) can be an important natural source of polyunsaturated fatty acids (PUFA), which are being used in the production of PUFA concentrates and nutritional supplements. The PUFAs are well known to be associated to numerous biological and physiological functions in the human body (Zuta et al., 2003).

e) Fish wastes are important source of free amino acids, such as taurine and creatine, which are largely used for producing sport drinks, food supplements, infant formulae and drugs (Kang et al., 2009). Free amino acids present different biological activities: for example, taurine is involved in renal functionality and anti-inflammatory activity, while creatine is responsible for skeletal and muscle regeneration and contraction. Although free amino acids are mainly produced by chemical synthesis, due to their negative health effects, a lot of research is being dedicated to the possibility of extracting these amino acids from fish flesh. In particular, raw mussels, fresh clams, and raw fish flesh are particularly rich in taurine, while herring, salmon, and cod are valuable sources of creatine (Ferraro et al., 2010).

f) Crustacean shell wastes (from crabs, shrimps and krill) are the main sources for the extraction of chitin and chitosan. These ubiquitous marine polysaccharides are used in food, pharmaceutical, and health industries. In particular, chitin, chitosan and their oligomers are used in nutraceutical formulation for their role as dietary fibers, in lipid absorption reduction and hypocholesterolemia effect. In the food industry they are used as additives for beverage clarification, as texturing and emulsifying agents, fat mimetic, and to produce edible films. Chitinous materials are also used as antimicrobial agents and in drugs as delivery systems and helpers in wound healing. Other applications include water purification from dyes, pesticides, and phenols and laboratory application as chromatographic separation agents and enzyme immobilizers (Kim et al., 2008; Kumar, 2000).

g) Production of chitinous materials from seafood shell waste is a well-established and profitable process, especially if it includes also the recovery of pigments such as carotenoids (e.g., astaxanthin). Crustacean cells as well represent a major source for the recovery of these compounds, which present interesting characteristics for use in food and medical applications. They are used as natural colorants and powerful antioxidants. Medical uses exploit their protection activity against chemically induced cancers and age-related macular degeneration, as well as their enhancement of the immune system (Sánchez-Machado et al., 2006).

h) Seafood waste is also a very promising source of antifreeze proteins, which prevent fish from freezing and are thus present in fish adapted to very cold sea waters, such as cod. Antifreeze proteins find large applications in frozen foods, low-fat products, cryopreservation, cryosurgery, and aquaculture. In frozen foods they allow lowering the freezing point, thus reducing cellular damage and maintaining texture. Their structuring ability has also been exploited in low-fat ice cream production (Feeney and Yeh, 1998; Ferraro et al., 2010).

i) Aquatic invertebrates as well as the internal organs of fish and the shells of crustaceans constitute natural sources of enzymes. At present, proteases constitute the dominant group of marine enzymes with a commercial value. They mainly include gastric, intestinal, and hepatopancreas proteinases but also nonproteolytic enzymes, such as transglutaminase, lipases, and chitinolytic enzymes. These enzymes present a wide range of well-established applications in food (e.g., extraction of pigments, production of protein hydrolysates, meat tenderization) and nonfood sectors (wastewater treatment, polyester production) (Kim and Dewapriya, 2014).

6.2. Innovation Under Bangladesh Perspective

6.2.1. Wastes in fish meal production for fish, poultry and pet

Although a few fishery offal waste is currently processed in fish meal plants, there are ample scopes to utilize these invaluable resources into fish meal. Fish meal production consists of very simple technology of chopping, boiling and pressing fish waste to separate the solid part - the fish meal, from a liquid phase. The liquid part is centrifuged to obtain the fish oil. Fish meal is used as fish or poultry feed, domestic animal and pet food, as well as fertilizer in the crop field. Fish oil is used in both food and nonfood items.

In Bangladesh, fish meal produced for fish and poultry feeds accounts for a substantial proportion of total dried fish production. Fish meal production in the country was initiated by BFDC in 1980s in small fish meal plants in Potenga, Chittagong, where both fish meal and fish oil were produced from marine underutilized and trash fish with modern machineries, but these plants have long been abandoned due to availability and price of raw material fish. Present fish meal production in the country is not significant due to lack of industrial and underutilized species. The majority of fish meals are of marine origin, although small quantities of very low value freshwater fish and crustaceans are used. There are four main sources of fish meal:

1) Small crabs, crustaceans, fish and squid which cannot be marketed as human food because no demand for them exists.

2) Fresh fish which has deteriorated badly in quality and cannot be sold fresh or dried for human consumption – this often occurs when boats carry insufficient ice to chill their entire catch. In this case higher value fish are iced and lower value fish are sacrificed and sold for fish meal production.

3) Various species of sand eel gobby (*Odontamblyopus rubicundus)*, locally called *Cheuwa*, are used for fish meal production because it has a particularly high protein content. *Cheuwa* is mainly harvested and dried in the south-central coast, mainly in Barisal division.

4) Dried fish which is stored too long without refrigeration becomes discolored and is prone to insect infestation, and cannot be sold for human consumption. If this happens, it is sold for fish meal production.

Consignments of fish and aquatic organisms destined for use in fish meal are mixed with large quantities of salt before drying, and are usually dried on the ground, so heavily contaminated/adulterated with sand and debris. Some are also dried as part of mixed lots containing food fish and separated by sorting after drying on bamboo racks. The value of most fish meals is low compared to that of other dried fish, costing Tk 25-50/kg at wholesale, depending on quality. Quality is partly determined by the ratio of fish to other aquatic organisms, the higher the proportion of fish, the higher the price. *Cheuw*a is more expensive, costing BDT 70-80/kg. The price of *Cheuwa* has increased rapidly in recent years, indicating rising demand and/or constricted supply. *Cheuwa* is also relished by a class of consumers, mainly the southern inhabitants who like riverine sand eel gobbies, as food fish. So, fish meal production often competes with food fish and only market demand and availability determine its fate if it is for fish meal or human food.

Most dried fish used in fishmeal production are sold unprocessed and ground into meal at the point of use (i.e. at the feed mill or farm). Some are sold through major wholesale markets such as Asadganj in Chittagong or Sayedpur of Nilphamari, but the majority is sold directly to buyers (feed mills, large farmers and district and sub-district level feed ingredient wholesalers) by middlemen who collect fish from drying sites, or direct from dried fish producers themselves.

It is difficult to estimate the portion of total catch used to produce dried fish which is ultimately converted to fish meal, but field observations and discussions with informants suggest that it is about 20%.

6.2.2. Fish meal for ruminant

Protein degradation in ruminant stomach is crucial in getting optimum benefit from their proteinaceous diet, particularly to obtain better growth performance while feeding fish meal. Research indicates that ruminal protein degradation of fish meal is affected by processing factors including type and freshness of fish, addition of preservatives, stabilization of fat, type of dryer used, temperature and duration of heating, and the amount of fish soluble added back to the meal (Kaufmann and Lupping, 1982). Therefore, these factors should be considered during manufacture of fish meal, particularly used for ruminant diet.

Johnson and Savage (1987) reported several reasons for variations observed in the quality of fish meal applicable for ruminant. These are: i) meals made from fish scraps contain a higher ash and a lower protein content than meals made from whole fish; ii) fish spoilage due to autolysis, lipolysis, and microbial action results in soft, degraded flesh that coagulates poorly during cooking, causing difficulties during pressing and leading to meals with lower protein and higher fat content; iii) crude protein levels are affected by the amount of stick-water added back to the meal; iv) evaporator temperatures as high as 150^{o}C, used to condense stick-water, may affect protein quality of the whole meal; v) time and temperature used to dry the pressed fish alter cysteine, histidine, lysine, and tryptophan, which are susceptible to destruction during heat treatment; and vi) storage of FM without stabilization of fat leads to fat-protein autoxidation that decreases the solubility, digestibility, and availability of proteins.

Therefore, it is important that the fish meal for ruminant should have low fat, low ash, but high crude protein, produced from non-fatty un-spoiled fresh raw fish.

6.2.3. Chitin and chitosan production

Chitin, a macromolecular linear polymer of anhydro N-acetyl glucosamine (N-Acetyl, 2-Amino 2-Deoxy D-Glucose) found in crustacean shells, has various industrial applications viz., paper, textiles - sizing, dyeing and printing, chromatography, purification of water, effluent treatment, cosmetics, drugs and pharmaceuticals.

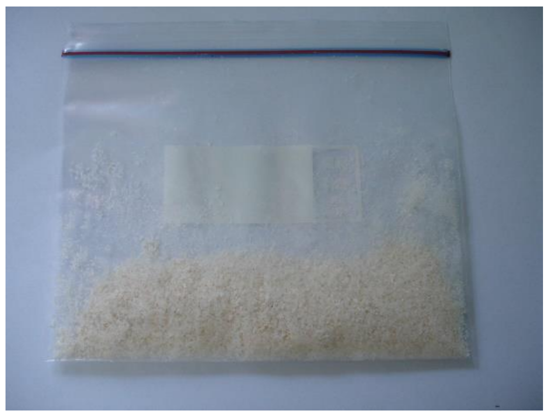

Figure. 5. Laboratory produced chitosan (Islam et al., 2016)

Production method of chitin and chitosan was refined, fine-tuned and field validated in Bangladesh (Nowsad, 2009b). For production of chitin, fresh shells of *Penaeus monodon* and *Macrobrachium rosenbergii* having initial bacterial load of >10^5 CFU/g sample and peroxide values of >10 m mol free iodine liberated /kg of oil were washed with dilute sulphuric acid. Adhered proteins were removed by washing with low strength alkaline solution and then rinsed with water. Crude chitin thus prepared was treated with concentrated hydrochloric acid and purified chitin was obtained after treating with low strength alkali solution. Water soluble chitosan was prepared by performing a deacetylation process using 50% NaOH (w/w) at 100^{o}C for 3-4 hours. Finally, chitosan was washed, dried and ground. Biochemical qualities of crude chitin and chitosan have been given in Table 12. Prepared crude chitin and chitosan had protein contents of 3.3% and 1.6% respectively while lipid content was nil. This was further verified as with no peroxide values found for chitin and chitosan samples (Table 12).

Table 12: Biochemical qualities of *P. monodon* shell and crude chitin and chitosan

Component	Composition (%) on d/w basis				pH	Peroxide value (mmol/kg)	APC (CFU/g)
	Moisture	Protein	Lipid	Ash			
Shell	20.5	48.7	4.4	22.5	7.0	9.2	8.4 x 10^4
Chitin	10.9	3.3	0.0	2.8	7.4	Nil	-
Chitosan	8.2	1.6	0.0	1.5	8.0	Nil	-

Source: Nowsad (2009a)

Figure. 6. Purified chitosan (Islam et al., 2016)

For purification of chitin and chitosan, a series of experiments were conducted to optimize the level of NaOH concentration and time and temperature schedule of demineralization and deproteinization / deacetylation. A high temperature-short time schedule obtained the best quality chitin and chitosan. Quality of chitin and chitosan and their purity were tested by both subjective and objective methods (Table 13). Moisture, ash and crude protein contents in purified chitin and chitosan were 9.6 and 7.3, 1.7 and 1.0 and 1.8 and 0.0 percent respectively. Lipid was nil in both the products. Colour was developed from brownish white in chitin to bright off-white in chitosan. The pH was 7.3 and 7.8 respectively in chitin and chitosan and reflected well with the solubility data in 1% acetic acid, where chitosan was mostly soluble, but chitin did not. Both the products were kept airtight at ambient temperature for 12 months and found in very good quality in terms of solubility, pH and reabsorption ability.

Table 13. Characteristics of purified chitin and chitosan in the laboratory

Attributes	Chitin	Chitosan
Moisture %	9.6	7.3
Ash %	1.7	1.0
Protein %	1.8	0.0
Lipid %	nil	nil
Color	Brownish white	Off white
Solubility in 1% acetic acid	Not soluble	Soluble (99.5%)
PH	7.3	7.8
Reabsorption ability %	8	9
Particle size	25 mesh	65 mesh
Shelf life	12 months	12 months

Source: Nowsad (2009b)

Field validation of chitin and chitosan production

Processes developed for chitin and chitosan were field validated in the shrimp/prawn processing plants and small-scale processors of Khulna and Cox's Bazar (Nowsad 2009a).

Comparative studies between the quality of products from different components of the shell and from different shrimp/prawn species were done. The cost of production and profit analysis done under factory production level suggests that chitin and chitosan could be profitably produced in existing shrimp/prawn processing plants of the country with simple renovation. A leaflet was prepared for the dissemination of research results highlighting the production protocol and application of chitin and chitosan with required renovation and cost-profit analysis of production at factory level.

6.2.4. Preparation of powder fish silage from offal wastes

Generally, fish silage is a liquid product produced from the whole fish or parts of it, to which acids, enzymes or lactic acid-producing bacteria are added, with the liquefaction of the mass provoked by the action of enzymes from the fish. Liquid silage could be dried with feed materials like rice bran, wheat bran, etc. to prepare powder silage. Powder fish silage can be vitally used as a feed supplement in aquaculture to convert nutrients into flesh. A study was conducted to investigate the suitability of using fish market wastes (viscera) as raw material for powder fish silage production. Incorporation of fish silage in fish diets was found to increase body weight gain, total body length, and specific growth rate without any adverse effects on survival and water quality (Hossain and Nowsad, 2015; Nowsad, 2015).

Fish viscera collected from fish markets was blended with an electric blender, formic acid (2, 3, 4 and 5%) was added and the mixture was stirred at room temperature (25-30°C) for complete liquefaction. Then, Na_2CO_3 (1, 2, 3, 4, 5 and 6%) was added to neutralize the pH at 6.0-7.0. To make powder silage and minimize cost, rice bran was added at different proportions (20, 30, 40, and 50%) to see powder effect. The mixture was dried under the sun for two days, ground in an ordinary flour mill, dried by an electric oven at 35^0C for 5-6 hours to adjust moisture at 10-12%. Powder silage was sealed in air-tight polythene packets and appropriately labeled for sale (Fig. 7). Several packets were stored in clean and dry plastic container at room temperature for four months to study the shelf life.

Figure.7. Powdered fish silage for marketing (Hossain and Nowsad, 2015)

Mixed fish viscera contained 14.01±0.68% protein, 20.00±1.04% lipid, 4.75±0.64% ash, 60.62±2.15% moisture and 0.62±0.08% nitrogen free extract (Table 14). The pH of fish viscera was 6.21±0.07. For liquid fish silage production, 4% formic acid was found to act better, which had a pH value of 3.77±0.07. Liquid silage contained 12.00±0.89% protein, 17.26±1.49% lipid, 3.73±0.81% ash, 66.41±3.07% moisture and 0.60±0.09% NFE. For neutralizing liquid fish silage, variable levels of Na_2CO_3 were added. The pH value (6.32±0.01) was better when mixing with 4% Na_2CO_3 (Fig. 8). Cheaper powder silage made with 30% rice bran containing 20.84±0.12% protein, 33.73±0.14% lipid, 14.05±0.27% ash, 10.83±0.19% moisture, 6.61±0.10% crude fiber and 13.94% carbohydrate was found to be better to improve the nutritional quality of the product. The pH value was 6.54±0.01. Protein, lipid, ash, moisture, crude fiber, carbohydrate and pH of stored product reached 20.30±0.13, 32.41±0.16, 13.49±0.33, 10.98±0.28, 6.32±0.07, 16.50 and 6.76±0.09%, respectively (Table 15). Nutritional value and pH of powder fish silage after 4 months were found to be good to be used as a complete fish feed, that could be able to reduce feed cost and enhance aquaculture production.

Table 14: Proximate composition of silage and its ingredients

Ingredients/Silage	Composition (%)				
	Protein	**Lipid**	**Ash**	**Moisture**	**NFE***
Viscera (wet weight basis)	14.01±0.68	20.00±1.04	4.75±0.64	60.62±2.15	0.62±0.08
Viscera (Dry weight basis)	32.38±1.19%	47.10±0.92	10.20±1.10	9.16±1.25	1.15±0.40
Rice bran	9.32±0.06	17.94±0.35	18.67±0.12	9.65±0.14	44.42±2.60
Liquid silage	12.00±0.89	17.26±1.49	3.73±0.81	66.41±3.07	0.60±0.09
Powder silage	20.84±0.12	33.73±0.14	14.05±0.27	10.83±0.19	20.55±0.65

Mean± SD of eight samples; NFE* (Nitrogen Free Extract) = {100- (protein+ lipid+ ash+ moisture) %}

Dry viscera contained an average of 32.38±1.19% protein, 47.10±0.92% lipid, 10.20±1.10% ash, 9.16±1.25% moisture and 1.15±0.40% Nitrogen Free Extract (NFE) (Table 1). Similar results were given by Folador et al. (2006).

Table 15. Change in proximate composition and pH of packaged powder silage during storage

Storage period (month)	Composition (%)						pH
	Protein	**Lipid**	**Ash**	**Moisture**	**Fiber**	**Carbohydrate**	
0	20.84±0.12	33.73±0.14	14.05±0.27	10.83±0.19	6.61±0.10	13.94	6.54±0.01
1	20.70±0.19	33.45±0.31	13.91±0.11	10.87±0.30	6.56±0.08	14.51	6.58±0.03
2	20.61±0.18	33.03±0.28	13.73±0.29	10.84±0.24	6.50±0.08	15.29	6.63±0.02
3	20.43±0.31	32.77±0.35	13.62±0.12	10.92±0.15	6.43±0.13	15.83	6.71±0.06
4	20.30±0.13	32.41±0.16	13.49±0.33	10.98±0.28	6.32±0.07	16.50	6.76±0.09

Mean± SD of three replicates

Shelf-life of powder silage

To observe the quality changes of powder fish silage during storage, proximate composition, pH and physical characteristics were observed for four months. Most of the compositions of packaged powder silage were unchanged during the storage for four months. A slow decrease in protein, ash, crude fiber, and lipid, and a slow increase in carbohydrate and moisture were observed during the storage. The protein content was recorded to be 20.70±0.19, 20.61±0.18, 20.43±0.31 and 20.30±0.13% in the 1st, 2nd, 3rd and 4th month, respectively (Table 6). The data indicated that protein content of powder silage could be made stable for a long time, up to one year without any change in quality. The rate of lipid degradation was slightly higher than protein, ash and fiber. The results indicated the importance of proper packaging that makes powder fish silage nutritious. The pH of powder fish silage after four months of storage remained almost unchanged, indicated that the quality of powder fish silage was almost similar to that of the initial product before packaging.

6.2.5. Waste in fish glue production

Fish glue, a very important value-added adhesive agent, can be made from the heads, bones, and skin of fish, where most of the collagen tissues are found. Attempts were made to prepare fish glue from different parts of fishery wastes, such as from the scales, bones and skin of pangas, major carp and tilapia (Akter et al., 2016; Akter et al., 2017; Nowsad, 2015).

The scales or skin were washed thoroughly in plenty of water, strained through a sieve to remove odor and heated in a heatproof covered container until it boils. The boiled paste was allowed to sim until the scales/ skin turned into a mass of soft viscous mush. Water was allowed to evaporate from the container. The liquor was cooked on low heat for several hours and allowed for 6 to 8 hours for the collagen to dissolve, releasing calcium phosphate into the water. The container was removed from the heat, the scales and skins were completely dissolved, mixture was cooled and kept covered until use. Fish glue was packed in air-tight container with adequate labeling and kept in cool and dry place for further quality analysis.

Figure. 8. Fish glue from tilapia skin (Akter et al., 2017)

A very good looking, attractive colored and appealing flavored fish glue was prepared from all five different wastes samples. Comparing the proximate composition color, pH, specific gravity, yield and flammability among glues, it was found that tilapia skin produced the best quality glue.

6.2.6. Waste in collagen film

Fish skin contains a high amount of collagen. The quality of gelatin from fish skin depends on the habitat temperature of fish and method of extraction. The main advantages of using fish processing waste for gelatin production are the availability of raw material and utilization of processing waste.

Collagen was extracted (Nowsad, 2015) following the method of Kumar et al. (2017). Fish skins were separated from the fillets and cleaned by scraping with a knife manually to remove the meat. The cleaned skins were washed in chilled potable water, frozen and stored at −20°C. The frozen skins were thawed and cut into small pieces of 1 cm^3 and pre-treated with 0.75 M NaCl solution. The ratio of fish skin to NaCl solution was 1:6 (w/v) and duration of extraction was 10 min at 4°C. The NaCl treatment and water washing was repeated twice. The temperature, time of extraction, and the ratio of skin to water were optimized for gelatin extraction. The washed skins were gently stirred with appropriate volume of water and kept in water bath at a desired temperature and duration. After heat extraction, the extracts were cooled and subjected to centrifugation at 10,000 x g at 25°C for 15 min, using refrigerated centrifuge to separate the insoluble material. The supernatant was filtered using Whatman filter paper No.1 and the filtrate was freeze dried to obtain gelatin. The thickness of the solution layer in the drying trays was less than 10 mm. The freeze-dried gelatin was stored in air-tight containers under desiccated conditions till further analysis was carried out.

Figure. 9. SSP for protein fortification in shrimp loaves, cookies and snacks (Khan et al., 2010)

6.2.7. Waste in human food

Various human food products were manufactured from shrimp shell wastes (Nowsad, 2009a). The shrimp waste transported in ice was thoroughly washed with cooled freshwater, kept in ice and used within 20 hours of collection. Products were prepared in two ways: i) ground dough of the shell and meat used directly for product preparation; or ii) different component parts of the wastes were dried at 45°C in an electric oven, powdered as shrimp shell powder (SSP), kept refrigerated and used as nutrition supplement to the shrimp loaves, shrimp crackers and shrimp croquettes.

For shrimp loaves, meat (20%) separated from the prawn/shrimp head was mixed thoroughly with spices (1.5%), salt (1.5%), wheat flour (40%), corn flour (2%), besan (4%), sugar (3%), cow fat block (4%) and water (30%). The dough was shaped and baked in an oven at 180°C for 10 min. In another process, 40% wheat flour, 8% vegetable oil, 1 % salt, 4% sugar, 8% egg, 1% milk powder, 30% water and variable quantities of SSP were thoroughly mixed. After mixing 0.5% yeast, the dough was kept at room temperature for 6 hours for ripening and then baked at 200°C for 12 min. For shrimp crackers, shrimp head-meat and SSP were ground and mixed with flour, spices and seasonings, then shaped into convenient flat bar, steamed, cut into equal pieces and baked in electric oven.

Figure.10. Shrimp cookies added with shrimp shell powder (Khan et al., 2010)

For shrimp croquette, a combination of vegetables (potato, arum (*Colocasia esculenta*), green banana, green papaya and ipomoea), spices (green chili, onion, garlic, turmeric, red pepper, white pepper) and ingredients (salt, wheat flour, egg, sugar, milk powder, bread crumb) were mixed with variable quantity of SSP, shaped, frozen at -25°C and then frozen-stored in sealed polyethylene bag.

The quality of the products was evaluated by subjective sensory analysis, *viz.*, texture (softness/hardness), taste/mouth feel and flavor. Objective analysis included biochemical parameters and aerobic plate count.

Figure. 1. Shrimp loaves (Khan et al., 2010)

Head meat and whole shrimp-waste paste had total bacterial load of 1.6×10^5 and 4.3×10^5 CFU /g sample respectively. Dried powder of different shrimp waste components had a bacterial load of 9.2×10^4 CFU/g sample. Therefore, both raw meat and dried components of the shrimp wastes appeared to be safe for possible use as food additives. Shrimp industry wastes contained very high level of crude proteins and lipids. The antennae and appendages, which apparently have no use except crushing into fertilizer, had as much as 40-46% crude proteins. This finding opened a new avenue of using such neglected shrimp

Figure. 12. Fish croquette (Nowsad, 2009a)

wastes in the food industry to improve nutritional value of various food products. In-vitro digestibility test of dried shrimp antennae and appendages with standard enzyme-mix found almost 90-93% digestibility of such components (Nowsad, 2015). It was therefore suggested that shrimp antennae and appendages can equally be used as food ingredients in human food along with carapace and shell powders. Based on these findings, using such nutritious SSP, various food products like shrimp crackers, shrimp loaves and shrimp croquettes were prepared (Nowsad, 2009a; Khan et al., 2010). It was found that sensory qualities of the products produced with dried SSP were better ($p<0.05$) compared to those added with raw head meat paste. Best flavor development ($p<0.05$) was achieved in products supplemented with antennae and appendages powder.

Table 16. Proximate composition of shrimp crackers, loaves and croquettes

Product	**SSP incorporated (%)**	**Proximate Composition (%)** on dry weight basis		
		Protein	**Lipid**	**Ash**
Shrimp crackers	0 (Control)	6.7 ± 0.56^{a}	30.5 ± 0.37^{a}	14.9 ± 0.13^{a}
	5	8.6 ± 0.47^{b}	32.1 ± 0.61^{a}	15.6 ± 0.29^{a}
	10	9.47 ± 0.66^{c}	33.5 ± 0.15^{ab}	17.1 ± 0.69^{b}
	20	14.39 ± 0.34^{d}	34.7 ± 0.59^{b}	18.3 ± 0.19^{b}
Shrimp loaves	0 (Control)	3.2 ± 0.02^{a}	5.3 ± 0.23^{a}	1.2 ± 0.23^{a}
	5	4.55 ± 0.45^{b}	6.25 ± 0.24^{b}	$1.28\pm.03^{a}$
	10	8.05 ± 0.34^{c}	$9.0\pm.1.01^{c}$	$2.04\pm.03^{a}$
Shrimp croquettes	0 (Control)	4.46 ± 0.56^{a}	3.90 ± 0.37^{a}	17.92 ± 0.13^{a}
	3	5.22 ± 0.66^{b}	4.52 ± 0.61^{a}	18.21 ± 0.19^{a}
	5	7.39 ± 0.37^{bc}	5.99 ± 0.15^{ab}	18.27 ± 0.23^{a}
	10	8.73 ± 0.61^{c}	6.51 ± 0.59^{b}	18.97 ± 0.29^{a}

Different superscripts in the same product for same quality attribute differ significantly ($p<0.05$).

In all preparations incorporated with SSP, protein and lipid contents increased in significant proportion compared to control ($p<0.05$) where no SSP was incorporated (Table 16). The lipid content was high in shrimp crackers due to high level of vegetable oil and hydrolyzed vegetable oils, which were added as an essential part of the recipe to improve crispiness. Ash content was increased slightly due to SSP incorporation, indicating mineral enrichment, that might be very useful from nutritional point of view. Percentages of ash could also be attributed to the presence of some tissues within the shrimp waste residue.

To optimize the level of antennae and appendage powder, products were prepared with 2.5, 5.0, 7 .5 and 10.0% of the powder and were subjected to panel test. All the three products showed better texture and mouth-feel and significantly ($P<0.5$) better flavor at 5.0% of appendage powder. During consumer acceptance tests this level of powder was applied and, in all cases, very good responses from rural, coastal and urban consumers were obtained.

Table 17. Sensory quality of the products incorporated with raw head meat and dried shell powders

Products	Head-meat (raw)			Whole shrimp waste powder			Thoracic & abdominal shell powder			Antennae & appendages powder (SSP)		
	Texture[1]	MF	Flavour	Texture[1]	MF	Flavour	Texture[1]	MF	Flavour	Texture[1]	MF	Flavour
Shrimp loaf	7.3[a]	7.5[a]	7.5[ab]	8.3[b]	8.3[b]	8.2[b]	8.2[b]	8.0[b]	7.6[a]	8.5[b]	8.3[b]	8.8[c]
Shrimp cracker	8.2[b]	7.1[a]	7.4[a]	8.6[b]	8.4[b]	8.2[b]	8.7[c]	8.1[b]	7.5[a]	8.4[b]	8.4[b]	9.0[d]
Shrimp croquette	6.8[a]	8.2[b]	7.0[a]	7.5[a]	8.5[b]	8.3[b]	8.2[b]	8.0[b]	7.8[ab]	8.5[b]	8.4[b]	9.3[d]

[1] Texture was studied differently for 3 different products: for shrimp loaf texture measurement was softness/firmness; for shrimp crackers texture was crispiness; for shrimp croquette texture measurement was chewiness/rubberiness; MF= mouth-feel Different superscripts in the same product for same quality attribute differ significantly ($p<0.05$).

Table 18. Consumer's response (%) toward shrimp loaves, shrimp crackers and shrimp croquettes

Product	TS[1]	Taste	Flavour	Colour	OA
Loaves	1	-	-	-	-
	2	-	-	-	-
	3	8.75±3.4[c]	5.07±2.5[c]	5.46±1.8[c]	3.93±2.6[c]
	4	57.25±3.8[a]	62.75±2.3[a]	51.76±3.0[a]	60.25±3.5[a]
	5	35.50±3.2[b]	33.10±1.7[b]	42.40±1.5[b]	37.60±2.5[b]
Crackers	1	-	-	-	-
	2	-	-	-	-
	3	7.65±3.4[c]	4.27±2.5[c]	5.41±1.8[c]	10.56±2.6[c]
	4	50.25±3.8[a]	60.05±2.3[a]	56.67±3.0[a]	55.45±3.5[a]
	5	35.10±3.2[b]	35.10±1.7[b]	37.34±1.5[b]	32.40±2.5[b]
Croquette	1	-	-	-	-
	2	-	-	-	-
	3	12.45±3.4[c]	14.27±2.5[c]	19.46±1.8[c]	9.93±2.6[c]
	4	58.56±3.8[a]	57.55±2.3[a]	51.76±3.0[a]	55.25±3.5[a]
	5	30.40±3.2[b]	29.56±1.7[b]	30.40±1.5[b]	35.60±2.5[b]

Mean sensory scores of same parameters for a particular product bearing different superscripts differ significantly ($p<0.05$). 1 TS = test score: 1= very bad; 2= bad; 3= average; 4= good; 5= very good; OA= overall acceptability

7. Conclusions and Recommendations

The present review study elucidated the available information on different forms of fishery wastes in the country. Information regarding nutritional status of fishery wastes and current innovations in fish waste utilization were also provided.

Fish and shrimp processing factories produce substantial quantity of wastes in the forms of head, frame, skin, bones, fins, viscera, scales, shells, and appendages. In the retail fish markets, there is also a huge quantity of waste during dressing and cutting of fish. Although presently discarded, these are important organic resources having very valuable use. In its simplest form of utilization, these wastes can be used to produce fish meal for fish feed, that will reduce the overall post-harvest fish loss and will increase the nutritional value of feed. Thus, utilization of these fish wastes may help reduce fish farming cost by improving the quality of fish feed with better FCR values.

However, information is greatly lacking on current fishery wastes production and management in the country, nor any planning and management protocols are available to utilize such huge waste resources, which can add value to the livelihood of the small-scale fishers and processors. Therefore, the present review study conducted country-wide has opened up wider eyes to understand the current production and utilization status and nutritive value of such fish offal wastes, and to recommend actions for their useful utilization.

It has been estimated that Bangladesh produced an ample quantity of fishery offal wastes in 2018-19, in the form of dressing and cutting wastes of about 650,000 MT, along with fish processing plants wastes of 2,024 MT, shrimp processing plant wastes of 19,600 MT and other wastes (like spoiled trash fish, non-harvested dead fish, non-edible fish and aquatic invertebrates, snails, mollusks, crabs, etc.) of about 100,000 MT. Most of the fish processing plants do not process and utilize offal wastes, but dumped outside of the factory premises, with a few exceptions. Some small enterprises use a portion of the offal into fish meal, fish oil, dried fish scale, etc. About 90% of the shrimp shell waste is presently sun dried and exported.

Several private companies have been involved in processing fishery waste, although on limited scales. There is no organized waste collection, processing and utilization protocols or programs. As observed, the collected offal waste was rotten mostly. Currently, collected wastes are being simply boiled in open place and sundried in open yard before crushing into fish meal. In the course of collection, separation and processing, quality is further degraded. Open yard sun drying produces obnoxious odor and pollutes the air and environment. Both technical and logistic supports are required to develop a sustainable environment-friendly fishery wastes valorization program. Therefore, the following recommendations are made for the effective utilization of fishery offal wastes in Bangladesh:

i). Develop and adopt concrete policies for fishery market waste and freezing/filleting factory waste disposal by the government with concerned ministries and departments. Based on policies, adopt adequate laws and regulations for environmentally friendly disposal, collection and utilization of fishery wastes.

ii). Based on policies, laws and regulations, develop specific protocols and program for safe collection and utilization of wastes, specific to each of production and/or valorization.

iii). Develop quality standards for each of the products produced from wastes and monitor those by the appropriate authority, be very strict for surveillance for quality maintenance, since the product quality standards would be different from those prepared from good quality raw material like fresh fish.

iv). Train people involved in wastes collection on both personal and occupational protection, hygiene and safety and for appropriate processing.

v). Encourage and support entrepreneurs and equip them with technical know-how and institutional credit in easy terms for good quality product manufacture.

vi). Adopt "*Total Utilization*" approach in composite in the waste processing plants to utilize all components of waste for effective valorization and minimization in production cost.

vii). Ensure and make available the use of modern environment-friendly machinery, equipment and methodologies to manufacture products from fish market or processing factory wastes.

viii). Adopt hydrolysis technique instead of boiling of waste to reduce off-odor formation during processing.

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Occurrence and Antibiotic Susceptibility of Pathogenic Bacteria Isolated from Diseased Rohu (*Labeo rohita*) in Greater Mymensingh, Bangladesh

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Abstract

In the present study, pathogenic bacteria were isolated from diseased Rohu (*Labeo rohita*) and assessed the antibiotic susceptibility of isolated bacteria. Diseased fish samples were collected from 30 fish farms in the greater Mymensingh region of Bangladesh for the isolation of the pathogenic bacteria. The infected fish exhibited noticeable clinical signs, including loss of balance, excessive mucous secretion, fin and tail erosions, body surface hemorrhages and skin lesions, and enlargement of internal organs. Various selective media were used to isolate bacteria from the infected fish and biochemical tests were conducted to identify these isolated bacteria. The antibiotic sensitivity of the isolated bacteria was determined using a commercial panel of antibiotics. A total of 43 bacterial strains were isolated, including *Aeromonas hydrophila*, *A. sobria*, *Pseudomonas anguilliseptica* and *P. fluorescens.* Among these, *Aeromonas* spp. were identified as the primary pathogens in the diseased fishes. Specifically, *A. hydrophila* constituted 44.19% of the isolates, followed by *A. sobria* at 20.93% and unidentified *Aeromonas* strains at 6.98%. Other isolated bacteria, such as *P. anguliseptica* and *P. fluorescens* were present in smaller percentages in infected Rohu at 13.95% and 9.30%, respectively. Interestingly, the results of antibiotic sensitivity testing revealed that the bacterial isolates were largely resistant to most antibiotics, except for ciprofloxacin and levofloxacin, which showed high sensitivity against all strains of *Aeromonas* spp. and *Pseudomonas* spp.

Keywords: Rohu (Labeo rohita), Aeromonas septicemia, Pseudomonas septicemia, antibiogram

Introduction

The Indian Major carps are the natural inhabitants of the perennial river network of India, Bangladesh and Pakistan and enjoy a wide distribution. Among the Indian Major carps, Rohu (*Labeo rohita*) is one of the most preferred aquaculture fish species with high market price. However, the increasing production of Rohu in aquaculture is hampered by outbreaks of infectious diseases, posing a significant challenge to successful production (Giri *et al.*, 2013; Rashid *et al.*, 2014). Among the different infectious diseases, bacterial diseases are considered the main cause of high mortalities and economic losses in carp fishes.

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Diseases such as bacterial hemorrhagic septicemia and motile Aeromonas septicemia have caused substantial losses in aquaculture (Monir *et al*., 2016). Among the infectious bacterial diseases, *Aeromonas* spp. and *Pseudomonas* spp. have been consistently identified as significant impact on freshwater aquaculture (Giri *et al*., 2013). However, a specific disease condition, characterized by symptoms such as fin rot, redness on the head and swollen abdomen, has led to significant carp fish mortality. This condition has been frequently observed in farms across the Mymensingh region (Rashid *et al*., 2014). *Aeromonas* spp. are significant opportunistic pathogens, often leading to infections following host injury or stress responses (Giri *et al*., 2013; Monir *et al*., 2015). These pathogens can cause a range of infections in humans, including endocarditis, gastroenteritis and septicemia (Janda and Abbott, 2010). In recent years, *Aeromonas* spp. have been responsible for an increasing number of fish diseases, involving strains like *A. caviae* (Thomas *et al*., 2013), *A. veronii* (Chen *et al*., 2019), *A. hydrophila* (Rashid *et al*., 2014) and *A. sobria* (Monir *et al*., 2015). Among these, *A. hydrophila* is traditionally considered the most harmful to aquatic animals, often causing hemorrhagic diseases in farmed fish (Chen *et al*., 2019).

The intensive practice of fish farming has resulted in a widespread use of different antibiotics to treat bacterial diseases in cultured fish. One of the significant diseases is septicemia caused by Aeromonad and Pseudomonad, which is considered a severe condition and is currently addressed with various antimicrobial drugs globally (Wang *et al*., 2019). Liu *et al*. (2017) and Marques *et al.* (2019) have reported that several classes of antibiotics such as tetracyclines, quinolones, and sulfonamides commonly applied in aquaculture. Consequently, the substantial use of antimicrobials in aquaculture settings has been linked to elevated levels of antibiotics resistance in aquatic bacteria, as reported by Daood (2012) and Monir *et al*. (2016). Additionally, the increased antibiotics resistance confer bacterial pathogens additional virulent feature.

Previous studies have isolated the pathogenic bacterium *A. hydrophila* in both indigenous and exotic carps under polyculture conditions (Rashid *et al*., 2014). Saeed (2010) and Monir *et al*. (2016) identified bacteria from eight naturally infected fish species, including Rohu (*Labeo rohita*), Catla (*Labeo catla*), Tarabaim (*Macrognathus aculeatus*), Koi (*Anabas testudineus*), Shing (*Heteropneustes fossilis*), and Magur (*Clarias batracus*) from various areas in the Mymensingh district. Nevertheless, identifying these diseases and their causes are crucial for developing strategies to control and prevent disease incidence in farmed carp fishes, thereby reducing losses for farmers. Therefore, this study aimed to identify the pathogenic bacteria present in skin lesions and internal organs of cultured Rohu and assess their sensitivity to various antibiotics.

Materials and Methods

Sample collection

A total of 180 diseased Rohu fish were sampled from 30 fish farms in the greater Mymensingh region of Bangladesh. At least five affected fish were collected from each farm using cast net. The majority of these diseased fish were retrieved alive and carefully placed in sterile plastic boxes with ice to maintain their freshness. Subsequently, the fish samples were transported to the Fish Disease and Health Management Laboratory of Bangladesh Fisheries Research Institute, Mymensingh.

Isolation of bacteria

Bacteria were isolated from the skin lesions and internal organs of the diseased Rohu. Skin lesions were disinfected using 70% ethanol to remove surface contaminants. Smears from these lesions as well as internal organs were aseptically placed in nutrient broth following the method outlined by Monir *et al*. (2016). The broth was allowed to enrich overnight and was then streaked onto various selective media for *Aeromonas* spp. and *Pseudomonas* spp. These plates were then incubated at 37°C for 24 hours. Individual colonies were chosen and streaked again on new TSA plates to ensure the purity of the cultures. The resulting pure isolated bacteria were cultivated in tryptic soya broth (TSB) and preserved as a glycerol stock at -20°C.

Identification of bacterial pathogens

Bacterial colonies obtained from different culture plates were isolated and streaked onto TSA agar before being incubated overnight at 37°C. The resulting pure isolates were characterized through various assessments, including examination of colonial features, bacterial cell morphology, motility, and a series of biochemical tests. These tests encompassed Gram reaction, catalase activity, and the utilization of glucose, sucrose, and lactose. Additionally, the other tests were also performed such as citrate utilization, indole production, urease activity, hydrogen sulfide (H_2S) production, triple sugar iron (TSI) reactions with gas production, methyl red (MR) test, Voges Proskauer (VP) test and coagulase test. The application of these biochemical tests adhered to the guidelines outlined in Bergey's Manual of Bacteriological Classification to facilitate the identification of the bacteria (John *et al*., 1998).

Determination of antibiogram of bacterial isolates

The disc diffusion method described by Finegold and Martin (1982) was applied to evaluate the susceptibility of bacterial isolates to antibiotics. The isolated bacterial strains were cultured in nutrient agar for 24 hours at 37°C. After that, the colonies of each isolate were fixed to a turbidity standard of 0.5 McFarland (equivalent to 1 x 10^7 CFU/ml) in sterile buffered saline. The bacterial suspension obtained was uniformly distributed over Mueller-Hinton agar (Oxoid). Subsequently, discs containing antibiotics were positioned on the solid medium, followed by an incubation period at 37°C overnight. The resulting clear areas surrounding the discs, known as zones of inhibition were measured, and the antibiotic sensitivity was evaluated based on the diameter of these zones (measured in millimeters). The measurement was taken from the center of the antibiotic disc to the outer edge of the clear area where bacterial growth was stopped. The classification of zone diameters as sensitive, intermediate, or resistant was conducted in accordance with the guidelines provided by the manufacturer.

Results

Clinical pathology and post-mortem findings

Rohu (*Labeo rohita*) that were naturally infected exhibited abnormal physical features such as reddish head and eyes region, external ulcerative lesions marked by hemorrhages, and red discoloration at the bases of fins (Figure 1a-d). Moribund fish were observed displaying unusual swimming behavior near the water surface. Additionally, the infected fish exhibited congestion, and hemorrhaging in internal organs such as the liver (1e), kidney (1f) and spleen.

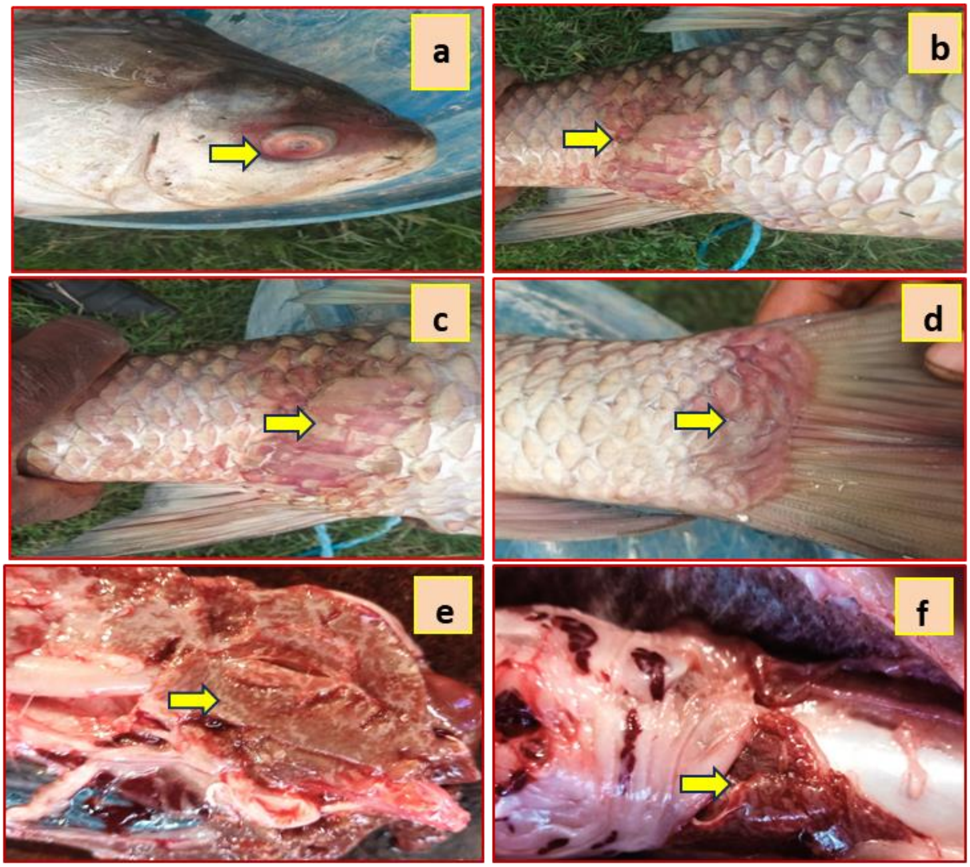

Figure 1. Disease signs and symptoms observed in Rohu (*Labeo rohita*) during sampling. Arrow heads show; (a) collapsed eye with hemorrhages; (b) skin ulcer; (c) remarkable ulcerative skin lesion; (d) erosions at the base of fins and tail, enlargement of liver (e) and kidney (f).

Bacteria isolated from different organs of infected Rohu

A total of 43 bacterial strains were identified from 150 samples taken from diseased Rohu. Table 1 presents the species composition and sources of these isolated bacterial strains. The frequencies of isolation for these 43 strains across various anatomical parts of infected Rohu were as follows: 18 (41.86%) in lesions (skin and fin), 9 (20.93%) in gill, 9 (20.93%) in spleen and 7 (16.30%) in liver. Among the *Aeromonas* species, *A. hydrophila* accounted for 19 (44.19%), *A. sobria* for 9 (20.93%) and 3 (6.98%) strains were unidentified *Aeromonas* spp. In contrast, only two species of *Pseudomonas* were identified in lesions and various organs of diseased Rohu. The distribution of *Pseudomonas anguliseptica* and *P. fluorescens* in infected Rohu was 6 (13.95%) and 4 (9.30%), respectively. However, *Aeromonas hydrophila* emerged as the major pathogen in infected Rohu compared to other bacterial species.

Table 1. Bacteria isolated from different organs of infected Rohu (*Labeo rohita*)

Isolated bacteria	**Distribution (Number & %) of different bacterial stains (n=43) according to site of isolation**				**Total**
	Anatomical parts of infected Rohu				
	Infected area (skin & fin)	**Gill**	**Spleen**	**Liver**	
A. hydrophila	9 (20.93)	5 (11.63)	3 (6.98)	2 (4.65)	19 (44.19)
A. sobria	4 (9.30)	2 (4.65)	1 (2.33)	2 (4.65)	9 (20.93)
Unidentified *Aeromonas* spp.	2 (4.65)	0 (0)	1 (2.33)	0 (0)	3 (6.98)
P. anguliseptica	2 (4.65)	1 (2.33)	1 (2.33)	2 (4.65)	6 (13.95)
P. fluorescens	1 (2.33)	0 (0)	2 (4.65)	1 (2.33)	4 (9.30)
Unidentified *Pseudomonas* spp.	0 (0)	1 (2.33)	1 (2.33)	0 (0)	2 (4.65)
Total	18 (41.86)	9 (20.93)	9 (20.93)	7 (16.30)	43 (100)

Morphological and biochemical tests for bacterial identification

Bacteria such as *Aeromonas hydrophila*, *A. sobria*, *Pseudomonas anguilliseptica* and *P. fluorescens* were isolated from the lesions (skin and fin), gills, spleen, and liver of the infected Rohu (Table 2). The isolated *A. hydrophila* exhibited positive results in motility, oxidase, O-F, VP, catalase, indole, H_2S production, and nitrate reduction tests, while MR and urease production tests were negative. The *A. sobria* strain displayed positive outcomes in motility, oxidase, O-F, catalase, indole, H2S production, and nitrate reduction tests, with negative results in VP, MR and urease production tests. Besides, the isolated strain of *P. anguilliseptica* was identified as an oxidative, Gram-negative rod that is non-fluorescent, with positive results in oxidative and catalase, indole, and MR-VP tests, while H_2S production and nitrate reduction tests showed negative results. *P. fluorescens* isolated from infected Rohu, was characterized as negative results in indole, H_2S, urease, and MR-VP tests, but positive results in catalase and fluorescence tests (Figure 2).

Table 2. Morphological and biochemical characteristics of the isolated bacteria from infected Rohu (*Labeo rohita*)

Test name	***Aeromonas hydrophila***	***A. sobria***	***Psudomonas angulliseptica***	***P. fluorescens***
Gram staining	-ve	-ve	-ve	-ve
Motility	+	+	+	+
Oxidase test	+	+	+	+
O-F test	+	+	O	O
MR test	-	-	d	-
VP test	+	-	+	-
Catalase test	+	+	+	+
Indole test	+	+	+	-
H_2S production	+	d	-	-
Nitrate reduction test	+	+	-	+
Urease production	-	-	+	+
TSI test	A/A	A/A	K/N	K/N
Production of acid from				
Glucose	+	+	+	+
Galactose	d	d	+	+
0/129 test (10 µg & 150 µg)	R	R	R	R

Note: d= variable reaction, O= oxidative, A= acid, K= alkaline, R= resistant, S= sensitive

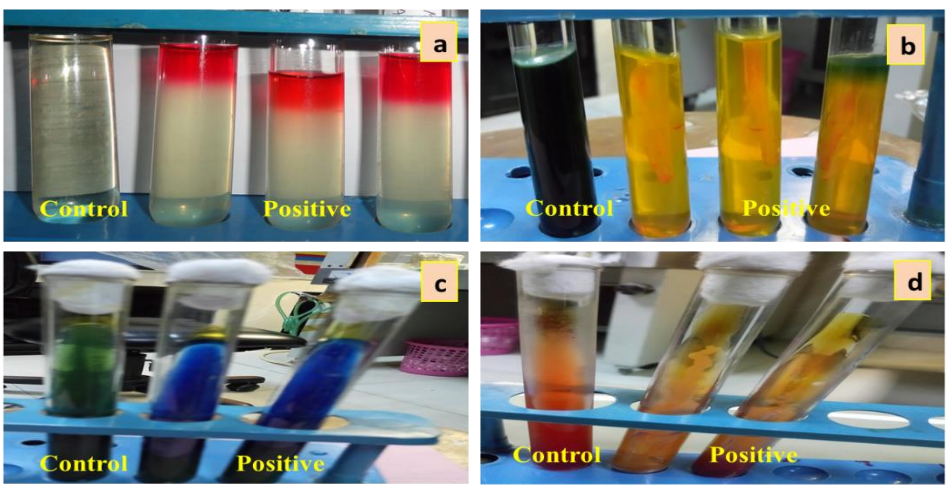

Figure 2. (a) Methyl Red (MR) test; (b) O/F test; (c) Indole test; (d) TSI test showing positive result

Susceptibility to antimicrobial agents in-vitro condition

All the identified bacteria exhibited sensitivity to ciprofloxacin, levofloxacin, azithromycin, and gentamicin. Ciprofloxacin, levofloxacin and azithromycin showed high efficacy against *A. hydrophila*, and *A. sobria* (Table 3). Besides, gentamicin displayed significant effectiveness against *P. anguilliseptica*, while chlortetracycline exhibited a moderate effect against all the isolated bacteria. Ampicillin and penicillin did not show any efficacy against *Aeromonas* spp. and *Pseudomonas* spp. (Figure 3).

Table 3. Antibiotics sensitivity test on isolated bacteria from infected Rohu (*Labeo rohita*)

Antibiotic (Cons/Disc)	***Aeromonas hydrophila***	***A. sobria***	***Psudomonas anguliseptica***
Ciprofloxacin (5µg)	+++	+++	++
Levofloxacin (5µg)	+++	+++	++
Gentamicin (10µg)	++	++	+++
Azithromycin (15µg)	+++	+++	++
Tetracycline (30µg)	+	+	+
Oxytetracycline (10µg)	+	+	+
Chlortetracycline (25µg)	++	++	++
Novobiocine (5µg)	-	-	-
Ampiciline (10µg)	-	-	-
Penicillin (10µg)	-	-	-

Note: no inhibition, +: inhibitory zone between 5 - 12mm, ++: inhibitory zone between 13 – 20 mm. +++: inhibitory zone between 21 - 30 mm above

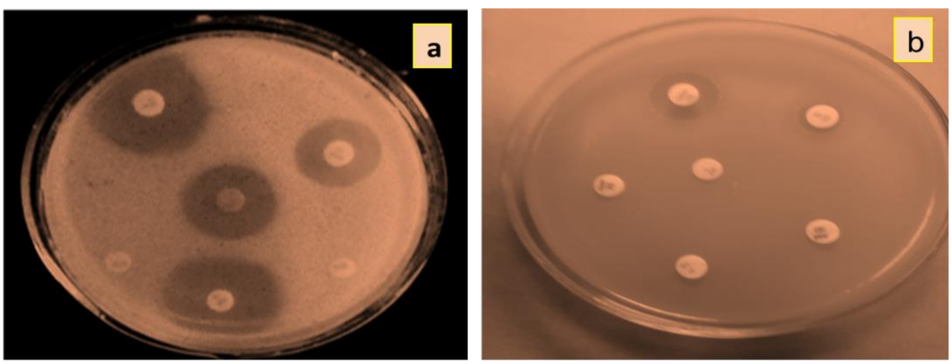

Figure 3. (a) Antibiotic sensitivity; (b) resistant pattern of bacteria isolated from infected Rohu (*Labeo rohita*)

Discussion

Aquaculture is experiencing significant growth in Bangladesh, both in terms of the quantity and diversity of species. Among the Indian Major Carps, Rohu (*L. rohita*) holds a crucial position in Bangladesh's aquaculture. Farmers predominantly cultivate carps in ponds for commercial purposes, yet they encounter various challenges such as diseases stemming from bacterial, viral, and fungal pathogens, which leads to high mortality of Rohu in cultured ponds and farms in greater Mymensingh, Bangladesh. In this study, the clinical signs in infected Rohu were observed such as loss of equilibrium, mucous secretion, skin lesions, hemorrhages, erosion of body and tail, and enlargement of internal organs, accompanied by hemorrhaging. These signs align with the findings reported by Rashid *et al*. (2014). Additionally, observations of congested liver and internal organs in diseased fish were consistent with the study conducted by Monir *et al*. (2016).

The isolated aerobic bacteria could potentially induce skin lesions either through immune suppression of the fish or by contaminating wounds resulting from mechanical injuries. *Aeromonas* spp. and *Pseudomonas* spp. were recognized as commensals on fish skin, and they may trigger opportunistic infections in situations of immune suppression (Janda, 2010; Monir *et al.*, 2016). However, the identified bacteria in this study were *Aeromonas hydrophila*, *A. sobria*, *Pseudomonas anguilliseptica* and *P. fluorescens*. Similar bacterial isolates were documented by Monir *et al.* (2016), Geraldine *et al.* (2020). Mastan, 2013 and Monir *et al*. (2015) noted that within bacterial diseases, motile *Aeromonas* was responsible for significant mortality in carps, leading to severe outbreaks of ulcerative disease in fish across Southeast Asia and other global regions (Anyanwu *et al.*, 2014; Rashid *et al*., 2014; Chen *et al*., 2019). Moreover, Sabur (2006) and Geraldine *et al.* (2020) identified five distinct species within the *Aeromonas* genus from infected Rohu (*L. rohita*), Silver carp (*Hypophthalmichthys molitrix*) and Carpio (*Cyprinus carpio*). *A. hydrophila* was commonly identified in various lesions associated with epizootic ulcerative syndrome (EUS) across diverse fish species (Sarkar and Rashid, 2012). Chowdhury (1998) and Monir *et al.* (2016) isolated and identified of several *Pseudomonas* strains from diseased farmed fish in Bangladesh. Additionally, *P. anguilliseptica* has also been identified as a causative agent of red spot disease, leading to significant mortalities in pond-cultured fishes in Japan (Zhang *et al*., 2009).

In the present study, the highest incidence of bacterial strains, constituting 44%, was observed in lesions affecting the skin and fin. This aligns with findings by Monir *et al*. (2016), who noted the highest isolation rate (40%) of aerobic bacteria from fish skin lesions. Monir *et al.* (2015) highlighted that Gram-negative bacteria are predominantly responsible for causing skin lesions in freshwater fish. Various researchers, including Shewan (2000); Rashid *et al*. (2014); Chen *et al*. (2019) have reported the isolation of different bacteria species from the skin of freshwater fish, such as catfish, with examples like Bacillus species isolated from the skin of warm water fish.

In this investigation, *Aeromonas* sp. and *Pseudomonas* sp. isolates were subjected to antibiotic susceptibility testing using the disk diffusion method for ten antibiotics. The results revealed that all isolates exhibited sensitivity to ciprofloxacin, levofloxacin, azithromycin and gentamicin. However, a majority of the isolates demonstrated resistance or reduced sensitivity to tetracycline, and oxytetracycline. Notably, ciprofloxacin, levofloxacin and azithromycin displayed high effectiveness against both *Aeromonas* sp. and *Pseudomonas* sp., whereas ampicillin and penicillin showed complete resistance. In another studies, Truong *et al.* (2008) and Monir *et al.* (2016) also found that two isolates of *Aeromonas hydrophila* were sensitive to ciprofloxacin and levofloxacin. Besides, the diminished sensitivity to tetracycline, chlortetracycline, and oxytetracycline is attributed to their indiscriminate use in fish culture ponds, coupled with farmers not adhering to recommended dosage, leading to the transfer of resistance genes to the isolated bacterial strains (Monir *et al*., 2016). Additionally, Sahoo and Mukherjee (1997) observed that the tetracycline group has been associated with an increased production of plasmid-mediated resistance in aquatic bacteria, resulting in a higher frequency of new tetracycline-resistant isolates.

Conclusions

The predominant causative agents of bacterial diseases in this species were *Aeromonas* spp. and *Pseudomonas* spp. The emergence of multidrug resistance in *Aeromonas* sp. and other isolates from infected Rohu is likely attributed to the indiscriminate use of antibiotics in fish culture ponds. It is crucial to isolate and identify the causative agents and determine their antimicrobial profiles for effective antimicrobial treatment. However, proactive measures for disease prevention in Rohu should prioritize improved culture practices and health management. This approach aims to ensure optimal yields and the highest quality of products while mitigating the economic impact of bacterial diseases on fish farmers.

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Fish Biodiversity Status of Gojaria Beel - A Perennial Freshwater Wetland of Bangladesh: Conservation and Management Strategies

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Abstract

A comprehensive evaluation of fish diversity and natural distribution is essential for biodiversity conservation and sustainable resource management. An attempt was made to investigate the current fish diversity and conservation status of Gojaria beel, a perennial wetland that is home to a wide variety of faunal and floral species. Data on fish diversity were collected through direct catch observations, focus group discussions and interviews with fisheries stakeholders using semi-structured questionnaire. The results of this study reveal the existence of 51 species belonging to 11 different orders, 19 families and 14 groups, of which 34.62%, 26.92%, 19.23% and 19.23% were commonly available, moderately available, rarely available, and abundantly available, respectively. The majority of the order (44.33%) was made up of Cypriniformes, whereas Beloniformes accounted for the lowest species (0.20%). Among the 14 distinct fish groups, catfish (24%) made up the largest group. At the national level, 15 species (31.92%) are considered threatened (3 species critically endangered, 6 species endangered and 6 species vulnerable), most of which belong to the orders Siluriformes and perciformes. The results of the Margalef richness index (D), Pielou evenness (J'), Brillouin index (HB), Berger-Parker index and Shannon winner diversity (H) varied from 4.93 to 5.00, 0.70 to 0.81, 2.73 to 3.18, 0.14 to 0.27, and 2.74 to 3.18, respectively. In conclusion, this study provides decision-makers with a few fish conservation management options that might serve as a roadmap for the sustainable use of fisheries resources of Gojaria Beel.

Key Words: Fish biodiversity; Gojaria beel; Freswater wetland; Conssrvation; Managent strategies

1. Introduction

Global attention has been drawn and focused to genetic resource conservation and aquatic biodiversity due to its sharp declining in recent decades, notably in Bangladesh (Mou et al. 2023). As one of the largest wetlands in the world with the most abundant fishieries

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resources, the country is known as one of the top producers of inland fisheries in the world. In the 2022–2023, Bangladesh produced 4.75 million tons of fish, placing it 3rd globally in terms of inland open water capture production and 2nd in terms of inland water body growth rate during the previous ten years (DoF 2022, Ullah et al. 2023; Mou et al. 2023). Bangladesh is known for its rich aquatic biodiversity linked to small-scale fisheries (Hossain et al. 2023) while approximately 4.24 million ha of inland water are supported by the haor basins, rivers, beels (perennial water bodies), floodplains, and estuaries (DoF, 2022; Ferdous et al. 2023). Fish living in existing wetlands show extraordinary diversity in terms of size, shape, color, habitat, feeding habits and reproductive behavior (Hossain et al., 2023). The country boasts a plethora of resources and a wide variety of aquatic flora and fauna including more than 260 freshwater fish and 730 marine fish species, as well as other aquatic animals (Hossain et al., 2023). Only 253 native fish species were evaluated by IUCN Bangladesh; 36 of them are migratory, and 113 are located in rivers and floodplains (Pandit et al., 2021). Hence, freshwater fish species and the integrity of their existing habitat are critically threatened, making them the most endangered or critically endangered group of animals in the world (Sarker et al. 2022; Hossain et al. 2023).

The perennial wetland known as "beel" refers to an open-water capture fishery that is regarded as one of the world's most significant ecosystems because of its abundant terrestrial and aquatic biodiversity. This wetland holds water all year round and has the appearance of a tiny, saucer-shaped depression with a static water body and a sizable surface area. In order to feed and grow during the rainy seasons, a large number of finfish and shellfish enter the inundated parts of the beel from the connected rivers and canals (Kamrujjaman & Halder 2022). Conversely, according to the IUCN (2015) ‘beel’ is seen as a supporting agent for the livelihood of many fishermen (Ferdous et al. 2023). With an area of around 114,161 hectares (DoF 2022, Pandit et al. 2021), these permanent wetlands are regarded as one of the preferred natural habitats for Bangladesh's native fish species and provide 2.3% of the country's yearly fish production.

Bangladesh is one of the countries struggling to feed its rapidly growing population and raise living standards for its substandard population. In order to meet this challenge, it is now believed that creating an industrial food production system that can be used both locally and internationally is essential to raising living standards (Kamal et al. 2022). Riverine ecosystems as well as perennial wetlands are essential to the long-term provision of quality food and nutrition, as well as the economic stability of millions of local populations in developing nations (Momi et al. 2021). Basic understanding of species order patterns and visual representations of their existence are crucial for effectively describing the structure and dynamics of ecosystems (Radhika et al., 2023; Sarker et al., 2022). Additionally, this information encourages careful management of natural resources and lessens any negative effects caused by people. Diversity indexes are a mechanism for providing more accurate information than just listing the number of species in a community. Therefore, for the sustainable use of natural resources, biodiversity and its conservation are very crucial.

According to several studies (Aziz et al. 2021; Talukder et al. 2021; Kamal et al. 2022), open water natural fish diversity and productivity are steadily falling, with the exception of a small number of fingerlings stocked and managed water bodies. A survey conducted by the Fish Museum & Biodiversity Centre (FMBC), Bangladesh, during 2009-2010 found more than 100 riverine fish species were under severe threat. In 2015, International Union for Conservation of Nature (IUCN) in Bangladesh assessed 253 inland fish species and found that nearly one third (91 species) are under threat (9 Critically Endangered, 30 Endangered, 25 Vulnerable and 27 Near Threatened). In addition, there were 40 Data Deficient fishes, which might be already extinct. They also assessed crustacean in a separate Red List of 2015 including 141 species. Freshwater fish have suffered over the past few decades as a result of human-caused environmental deterioration, including pollution, urbanization, dam construction, and water diversion for irrigation and power generation (Ullah et al. 2023; Pandit et al. 2021; Rimi et al. 2022). Regrettably, the nation's biodiversity is under danger because of the excessive extraction and use of natural resources, as well as the increasing demand of fish due to country's recent population growth (Sarker et al., 2022).

The analysis of fish abundance and natural distribution is essential for biodiversity conservation, and a thorough understanding of the various management techniques is necessary for optimal fish exploitation (Ullah et al. 2023; Pandit et al. 2022; Ferdous et al. 2023). The fish diversity of wetlands indicates the distribution pattern of various aquatic species in inland water fisheries, ecosystem services, and conservation status. The Gojaria beel is abundant in floral and faunal diversity while a large number of the nearby fishermen rely only on this beel for their livelihood. There have been numerous studies on the status of the fish biodiversity in wetlands, rivers, estuaries, and beels (Ullah et al. 2023; Radhika et al. 2023; Goswami & Singha et al. 2023; Sarker et al. 2022; Boruah et al. 2023; Kamrujjaman & Halder 2022; Sultana et al. 2021), but no such work has been done on the Gojaria beel. In order to support future management attempts, the current study aimed to catalog fish species and provide information on their availability, conservation status, and threats to the aquatic biodiversity of the Gojaria beel under the Mohanganj Upazila of Netrokona district of Bangladesh.

2. Materials and Methods

Study Area

The greatest extent Gojaria Beel is located somewhat to the east of Korachapur Bazar, which is accessible from Mohanganj Upazila to Adarshanagar under the district of Netrokona. Covering an area of about 51 acres, its depth ranges from 70 to 80 ft. which holds water all the year round. The two village communities surrounding the Beel are Borantaor and Korachapur. The southern border of the beel is marked by the renowned Dingapota Haor.

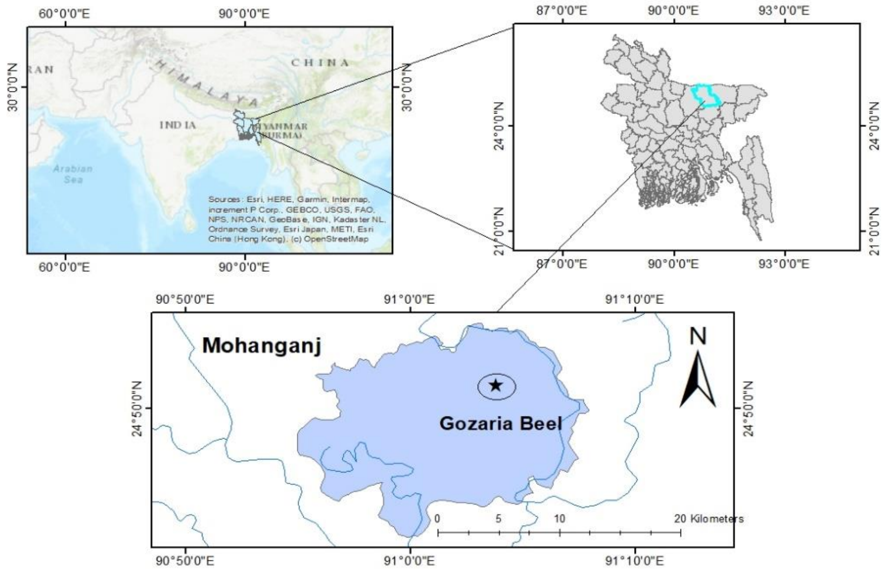

Figure 1: Location of the study area (Gojaria Beel)

Data Collection Method

In order to conduct the study, a wide range of fisheries stakeholders were selected and communicated, including local leaders with knowledge of the biodiversity of Gojaria beel and experienced in fishing, fish trading, and other related activities. A questionnaire was used to conduct face-to-face interviews with 80 fisherman, 10 aratders, and 10 fish traders, with a focus on obtaining data on fish diversity status, the causes of declining fish diversity and conservation measures. Participatory Rural Appraisal (PRA) was used in this study through focus group discussions (FGD) with fishermen and cross-check interviews with key informants. Interviews with the Upazila Fisheries Officer (UFO), educators, community leaders, and representatives of non-governmental organizations allowed for a cross-check of information that was contradictory or requested.

Fish Sample Collection

Fresh and live fish were used to acquire sample data. Direct samples of live and fresh fish were obtained from fishermen at their fishing locations, wholesalers, aratders and retailers fish markets. Local fishermen in the study area use a variety of fishing gear, which varies in terms of target species, size, and efficiency (e.g., seine nets, gill nets, cast nets, hooks, and traps). Every month, samples were collected using the same methods and techniques.

Collected Fish Sample Identification

The fish that were caught were identified based on their main morphological characteristics. The species that were challenging to identify on the spot were then transferred to the Fisheries Biology and Genetics laboratory at Sylhet Agricultural University, where they were maintained in a 5–10% buffered formalin solution. The species was then identified by morphometric and meristic analysis. After IUCN Bangladesh (2015), the taxonomic analysis was done. Nelson (2006) stated that the fish species were needed to be recognized first and subsequently categorized.

Fish Diversity Index

In the present study, the diversity of fishes was calculated by means of Shannon-Weaver diversity index (H′) (Shannon and Weaver, 1949), species richness by Margalef index (d) (Margalef, 1968), evenness by Pielou's index (J′) (Pielou, 1966), and dominance by Simpson index according to the following equations:

Simpson dominance index (C)= $\sum_{i-1}^{s}\left(\frac{ni}{N}\right)^{2}$

Where, ni = number of individuals in the 'each' species

N = total number of individuals

S = total number of species

Shannon-Weiner diversity index (H'): H' =-Sum [pi × log(pi)]

Where, H'=Shannon-Weiner index,

pi=ni/N, ni= no. of indivduals of a species, and N=Total number of individuals.

Margalef's species richness index (d): d = (S-1)/log(N)

Where, S = Total species, N = Total individuals.

Equitability or Pielou's evenness index (J'): J' = H(s)/H(max)

Where, H(s)=The Shannon-Weiner diversity index, and H(max)=The theoretical maximum value for H(s) if all species in the sample were equally abundant.

Berger -Parker dominance (d) =N (max)/N

Where d is the Berger-Parker dominance; N (max) is the number of individuals in the most abundant species, and N is the total number of individuals in the sample

Dominance (D) = $\sum i(ni\ /N)2$

Where n i is the number of individuals of taxon i; and N is the total number of individuals

Brillouin's Index, HB=$\frac{ln(N!)-\sum_i ln(ni!)}{N}$

Where HB is the Brillouin's index; N is the total number of individuals, and n_i is the number of individuals in the i^{th} species.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) software version V25.0 was used for data entry, pre-processing and analyzing the collected data. PAST (Paleontological Statistics) version 2.16 was used to assess biodiversity indices. Mapping of the study area was done by ArcGIS 10.0 software with the help of global positioning system (GPS). Both qualitative and quantitative analysis was done. Finally, data were presented as tabular or graphical formats.

3. Results & Discussions

Fish and Shell Fish Diversity of the Gojaria Beel

In the surveyed and studied wetland-Gojaria beel, a total of 51 faunal species including 49 species of finned fish and 2 species of prawn were recorded. Of the documented species, there were 11 different orders, 19 families and 14 groups (Table 1). This study is consistent with the findings of Talukder et al. (2021), who identified 66 fish species from the Shari-Goyain River in Sylhet. A similar observation was also noted by Chowdhury et al. (2019), who reported 51 indigenous fish species from the Surma River divided into 16 groups. In the Gurukchi River of Gowainghat-Sylhet, Pandit et al. (2020) identified 55 native and 2 exotic fish species, representing 9 orders, 22 families, and 42 genera which were higher than the present study. Sarker et al., 2022 discovered 188 morpho-species from the Sylhet division, of which 176 were finfish and 12 were shellfish, divided into 15 orders and 42 families which is much higher than the present study.

Diversity Status according to Order & Family

Among the orders identified from the Gojaria beels, Cypriniformes accounted for 44.33%, making it the most prevalent order (Figure 2). Siluriformes, Perciformes, synbranchiformes, Clupeiformes, Osteoglossiformes, Beloniformes, Decapoda, Anabantiformes, Tetraodontiformes, and Lepidoptera made up the remaining faunal orders, with their respective contributions being 16.25%, 15.88%, 0.80%, 18.21%, 1.46%, 0.22%, 0.73%, 0.36%, 0.36%, and 1.46%.

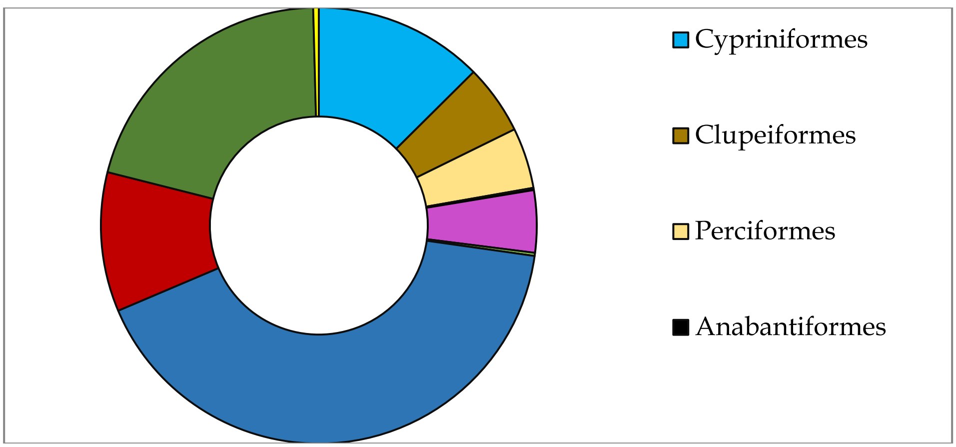

Figure 2: Recorded fish species available in the Gajaria Beel according to different order.

The Cyprinidae (44.25%) family, which belongs to the Cypriniformes order, majority of them with about 19 species. The species that fall under this category are *Labeo rohita, Catla Catla, L. cirrhosis, L. reba, L. calbasu, Cyprinus carpio, Hypophthalmichthys molitrix, Ctenopharyngodon idella, L. gonius, L. nandina, Puntius sophore, Pethia phutunio, Systomus sarana, Amblypharyngodon mola, Osteobrama cotio, and Esomus lineatus*, among several other species.

Table 1: Taxonomic classification and conservation status of recorded fish and shell-fish species of the Gojaria beel, Bangladesh.

Order	Family	Scientific Name	English Name	Common Name	Group	IUCN BD status	IUCN status	present status
Cypriniformes	Cyprinidae	*Labeo rohita*	Rohu	Rui	Carp	LC	LC	MA
	Cyprinidae	Catla Catla	South Asian carp	Catla	Carp	LC	NE	RA
	Cyprinidae	*Cirrhinus cirrhosus*	Mrigal carp	Mrigel	Carp	NT	VU	MA
	Cyprinidae	*Cirrhinus reba*	Reba carp	Lachu	Carp	NT	LC	CA
	Cyprinidae	*Labeo calbasu*	Orange Fin Labeo	Kalibaus	Carp	LC	LC	MA
	Cyprinidae	*Cyprinus carpio*	Common carp	Carpio	Carp	NT	VU	MA
	Cyprinidae	*Hypophthalmichthys molitrix*	Freshwater cyprinid fish	Silver carp	Carp	LC	NT	RA
	Cyprinidae	*Ctenopharyngodon idella*	Ray-finned fishes	Grass carp	Carp	NT	NE	AA
	Cyprinidae	*Labeo gonius*	Kuria labeo	Gonia	Carp and minnows	NT	LC	MA
	Cyprinidae	*Labeo nandina*	Nandi Labeo	Nandina	Carp and minnows	CR	NT	MA
	Cyprinidae	*Pethia ticto*	Ticto barb	Tit punti	Barbs and minnows	VU	LC	MA
	Cyprinidae	*Puntius sophore*	Spotfin swamp barb	Jat punti	Barbs and minnows	LC	LC	AA
	Cyprinidae	*Pethia phutunio*	Spotted sail barb	Phutanio punti	Barbs and minnows	LC	LC	MA
	Cyprinidae	*Systomus sarana*	Olive barb	Shorputi	Barbs and minnows	NT	LC	MA
	Cyprinidae	*Amblypharyngodon mola*	Mola carplet	Mola	Barbs and minnows	LC	LC	AA
	Cyprinidae	*Osteobrama cotio*	Cotio	Dhela	Barbs and minnows	NT	LC	RA
	Cyprinidae	*Esomus lineatus*	Stripped Flying Barb	Darkina	Barbs and minnows	DD	NE	CA
	Cyprinidae	*Securicula gora*	Chela gora	Ghora chela	Barbs and minnows	NT	LC	CA
	Cyprinidae	*Salmostoma acinaces*	Silver razorbelly minnow	Chela	Barbs and minnows	DD	LC	MA
	Cobitidae	*Lepidocephalichthys guntea*	Guntea loach	Gutum	Loaches	LC	LC	MA
Clupeiformes	Clupeidae	*Gudusia chapra*	Indian river shad	Chapila	Clupeids	VU	LC	AA
	Clupeidae	*Corica soborna*	Ganges river sprat	Kachki	Clupeids	LC	LC	RA
	Channidae	*Channa marulius*	Giant snakehead	Gozar	Snakeheads	EN	LC	RA
	Channidae	*Channa striata*	Snakehead murrel	Shol	Snakeheads	LC	LC	CA
	Cobitidae	*Botia dario*	Bengal Loach	Bou Rani	Loaches	EN	LC	CA

Order	Family	Scientific Name	English Name	Common Name	Group	IUCN BD status	IUCN status	present status
Perciformes	Cobitidae	*Botia dayi*	Botya Loach	Maitta Rani	Loaches	EN	NE	MA
	Ambassidae	*Polyura delphis*	Ewelled Nawab	Chanda	Perches	EN	NE	CA
	Ambassidae	*Chanda nama*	Elongate glass perchlet	Lamba chanda	Perches	LC	LC	CA
	Gobiidae	*Glossogobius giuris*	Tank goby	Bele	Mudskippers	LC	LC	CA
	Ambassidae	*Pseudambassis lala*	High fin glassy perchlet	Lal chanda	Perches	LC	LC	MA
Anabantiformes	Osphronemidae	*Trichogaster fasciata*	Banded gourami	Baro kholisha	Perches	LC	LC	CA
Beloniformes	Belonidae	*Xenentodon cancila*	Freshwater garfish	Kankila	Gars	LC	LC	CA
	Hemiramphidae	*Hyporhamphus limbatus*	Congaturi halfbeak	Ekthutia	Gars	LC		MA
Siluriformes	Siluridae	*Wallago attu*	Freshwater shark	Boal	Catfishes	VU	LC	CA
	Siluridae	*Ompok pabo*	Pabo catfish	Pabda	Catfishes	CR	VU	CA
	Pangasiidae	*Pangasius pangasius*	Pungas Catfish	Deshi pangus	Catfishes	EN	NT	RA
	Schilbeidae	*Eutropiichthys vacha*	Batchwa Vacha	Bacha	Catfishes	LC		CA
	Schilbeidae	*Ailia coila*	Gangetic Ailia	Kajuli	Catfishes	LC	NT	RA
	Schilbeidae	*Clupisoma garua*	Garua Bacha	Gharua	Catfish	EN	N E	RA
	Bagridae	*Sperata aor*	Long-whiskered catfish	Air	Catfishes	VU	LC	CA
	Bagridae	*Bagarius bagarius*	Gangetic Goonch	Baga air	Catfishes	CR	NT	RA
	Bagridae	*Mystus bleekeri*	Bleeker's mystus	Gulsha tengra	Catfishes	LC	LC	AA
	Bagridae	*Mystus vittatus*	Asian striped catfish	Tengra	Catfishes	LC	LC	AA
	Bagridae	*Rita rita*	Rita	Rita	Catfishes	EN	LC	MA
Lepidoptera	Nymphalidae	*Neptis jumbah*	Chestnut-Streaked Sailer	Batashi	Catfishes	LC	NE	MA
Synbranchiformes	Mastacembelidae	*Mastacembelus pancalus*	Striped spiny eel	Guchi baim	Eels	LC	LC	RA
	Mastacembelidae	*Mastacembelus armatus*	Tire-track Spinyeel	Baim	Eels	EN	NE	MA
	Synbranchidae	*Monopterus cuchia*	Gangetic mudee	Kuchia	Eels	VU	VU	RA
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	Bronze featherback	Foli	Feathers backs	VU	LC	MA
	Notopteridae	*Chitala chitala*	Humped featherback	Chital	Feathers backs	RA	EN	RA
Tetraodontiformes	Tetraodontidae	*Leiodon cutcutia*	Ocellated puffer fish	Potka	Puffer fish	LC	LC	RA
Decapoda	Soleniceridae	*Solenocera crassicornis*	Red prawn	Gura chingri	Prawns	LC	NE	AA
	Palaeomonidae	Macrobrachium rosenbergii	Giant river prawn	Golda	Prawns	LC	LC	MA

Note: LC – least concern, NT – near threatened, NE – Not evaluated, DD – Data Deficient, VU – vulnerable, EN – endangered, and CR – critically endangered (IUCN Bangladesh, 2015); AA – Abundantly available, CA – Commonly available, MA – Moderately available, RA – Rarely available.

Clupeidae (18.21%) was the second dominating class in the "family basis percentage analysis" based on availability, followed by Channidae (12.38%), Siluridae (9.5%), and Bagridae (4.95%) (Figure 3). Osphronemidae, Ambassidae, Cobitidae, Schilbeidae, Hemiramphidae, Pangasiidae, Nymphalidae, Schilbeidae, Mastacembelidae, Synbranchidae, Notopteridae, Tetraodontidae, and Soleniceridae were among the other families. These results align with the research conducted by Borua et al. (2023), Radhika et al. (2023), Sarker et al. (2022), wherein the authors reported that the Family Cyprinidae exhibited the highest number.

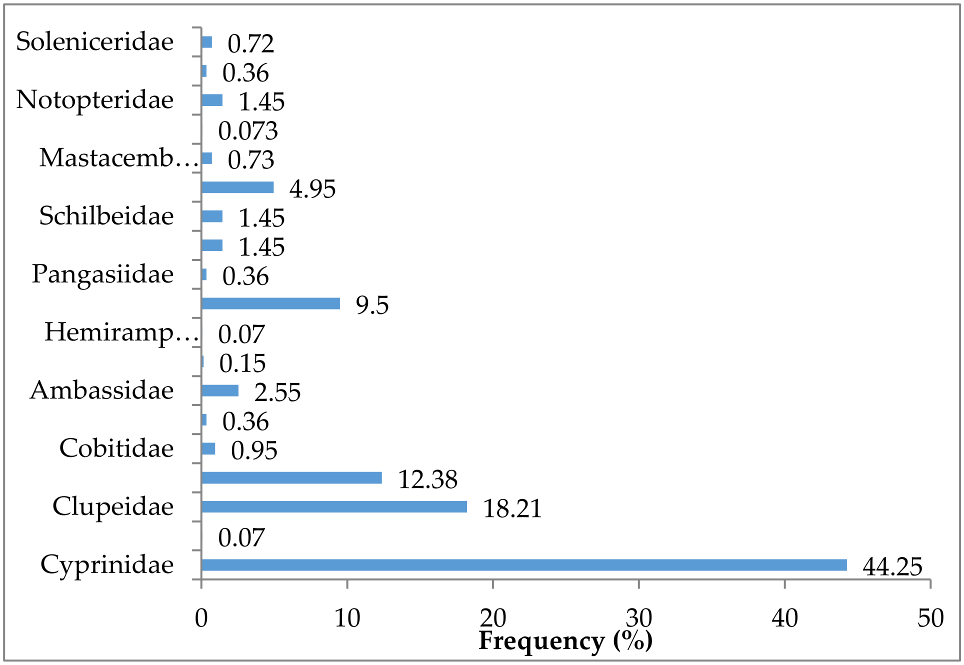

Figure 3: Recorded Fish species available in the Gajaria Beel according to different families.

Distribution of Fish Species according to Groups

Fish identified in this study were divided into 14 main groups: carp, clupeids, featherbacks, pufferfish, prawns, and loaches; perch, snakeheads, catfish, eels, barbs and minnows. According to the identification of 14 different fish groups in the Gojaria beel, catfish make up the largest group (24%), followed by carps (16%), barbs (12%), and minnows (12%) (Figure 4). On the contrary, approximately 4% of all fish species were assessed to be clupeids, carp and minnows, prawns and feather backs, snakeheads and perch, 2% puffer fish and mudskippers, 8% loaches, and 6% eels. A little higher than in the current study; Sarker et al. (2022) categorized the species into 17 major groups that have been recorded from the Sylhet haor Division. Furthermore, the results of this study varied significantly from those of Ferdous et al. (2023), stating that minnows and barbs (20%) were the most common group in the Pilati Beel.

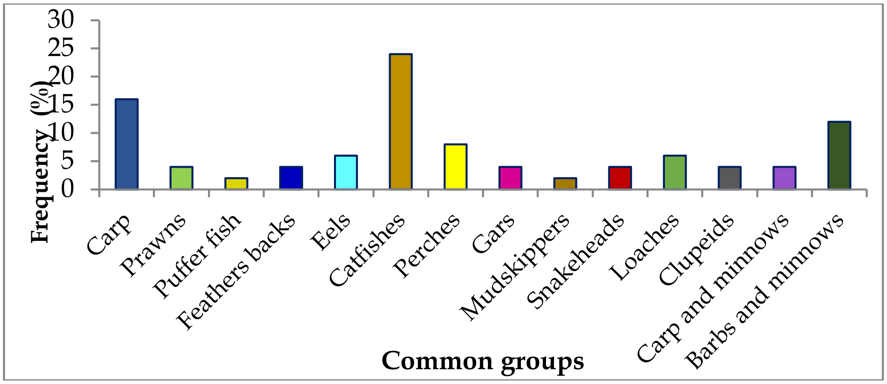

Figure 4. Distribution of major fish groups commonly found in the Gojaria Beel.

Present Status of Identified Fish Species

The availability of fish and shellfish species recorded from Gojaria beel is depicted in Figure 5. According to the result, 34.62% of the fish species were commonly available, followed by 26.92% were moderately available and 19.23% were rarely and abundantly available. However, the results of this study are generally consistent with studies conducted on fish diversity in haor and riverine environments. In Kawadighi haor, Kamal et al. (2022) found that 18% of the species were abundantly available, 20% commonly available, 42% moderately available, and 20% seldom available. Related findings have come from research on fish diversity in the environments of rivers and haors. According to Pandit et al. (2020), fish species that are rarely available (29.82%) were found to be more prevalent in the Gurukchi River than often available (28.07%), moderately available (22.81%), and abundantly available (19.30%) which is almost similar to the present study. In the Pilati beel of Mohanganj, research conducted by Ferdous et al. (2023) reported that 20% of the species were abundantly available, 40% were commonly available, 29.09% were moderately available, and 10.90% were rarely available.

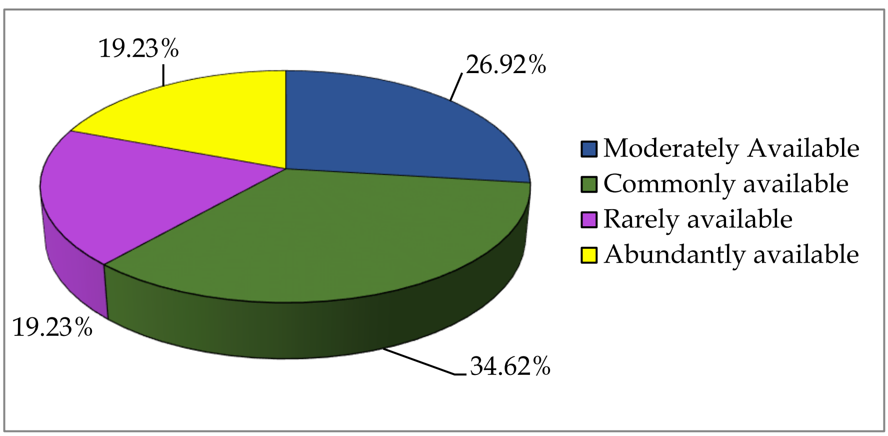

Figure 5. Present status of fish species identified from the Gojaria beel.

Fish documented from the Gojaria beel were divided into 14 main groups: carps, clupeids, featherbacks, pufferfish, prawns, and loaches; perch, snakeheads, catfish, eels, barbs and minnows. Figure 6 summarizes the present status of species according to different fish groups. The results indicated that, in the case of carps, this group represented the higher quantity of species that are moderately available (62.50%). Except for carp and minnows, clupeids and prawn, it was found that commonly available fish species belonged to the other distinct fish groups, such as mudskippers, gars, catfishes etc. On the other hand, the percentage of rarely available fish species was significantly higher in eel fish. Tanguar Haor also contains a large number of nationally threatened and endemic fish species. Among 55 threatened fish taxa, 23 of which are endangered fish species, 17 were found only in Tanguar Haor (Alam et al., 2015). Hussain (2020) found in a recent study that in Tanguar Haor, there were only 67 species captured by local fishermen during the summer season; among those numbers, 11 fish (16%) were Commonly Available Species (CAS), 14 fish (21%) were Moderately Available Species (MAS), 22 fish (33%) were Less Available Species (LAS) and 20 fish (30%) were Rarely Available Species (RAS). Both LAS and RAS can be categorized as vulnerable species: those at risk of becoming endangered within a few years.

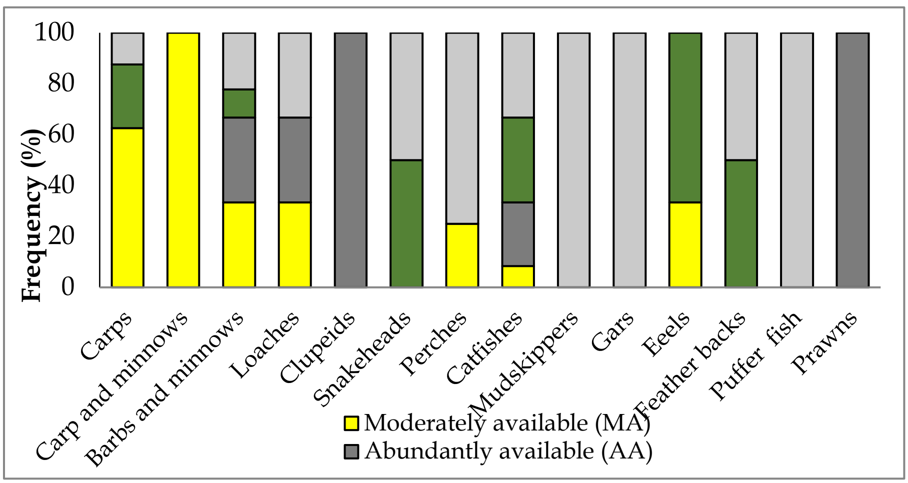

Figure 6. Frequency of occurrence of fish species according to major groups.

Conservation status of recorded fish species

A total of 47 species out of 49 species were compared with the national list (IUCN 2015) and global list, respectively. Of these recorded species, 15 species (31.92%) were considered threatened at a national level and four species listed as VU (8.16%) at a global level (Figure 7). Sarker et al. (2022) highlighted in their study that 26.74% of recorded species were found to be threatened at the national level which relatively lower than the present study.

Among the identified fishes few were found various threat categories, 3 species (6.38%) were identified as critically endangered (CR), 6 species (12.77%) as endangered (EN), and 6 species (12.77%) as vulnerable (VU) at the national level. Similar findings were reported by Ferdous et al. (2023), who revealed that there were 15 fish species were classified as threatened in Malam Beel, of which 6 were considered vulnerable. Most recorded species, both locally (48.94%) and globally (65.30%), were classified as least concern. Higher than the current study, Goswami and Singha (2023) found that 70.96% of fish of the Beki River in Assam were in the least concern category, followed by 9.67% vulnerable, 6.45% endangered, and 9.57% non-threatened.

Additionally, in contrast to global IUCN status, 14.89% of the recorded fishes were classified as near-threatened (NT) and 4.26% as data deficient (DD) (Figure 1). According to Global IUCN status, a few species (16.37%) listed as not-evaluated (NT). This is in line with the study conducted by Momi et al. (2021), stated that 11% of the fish species listed from the Fakirni River do not currently have an assessment.

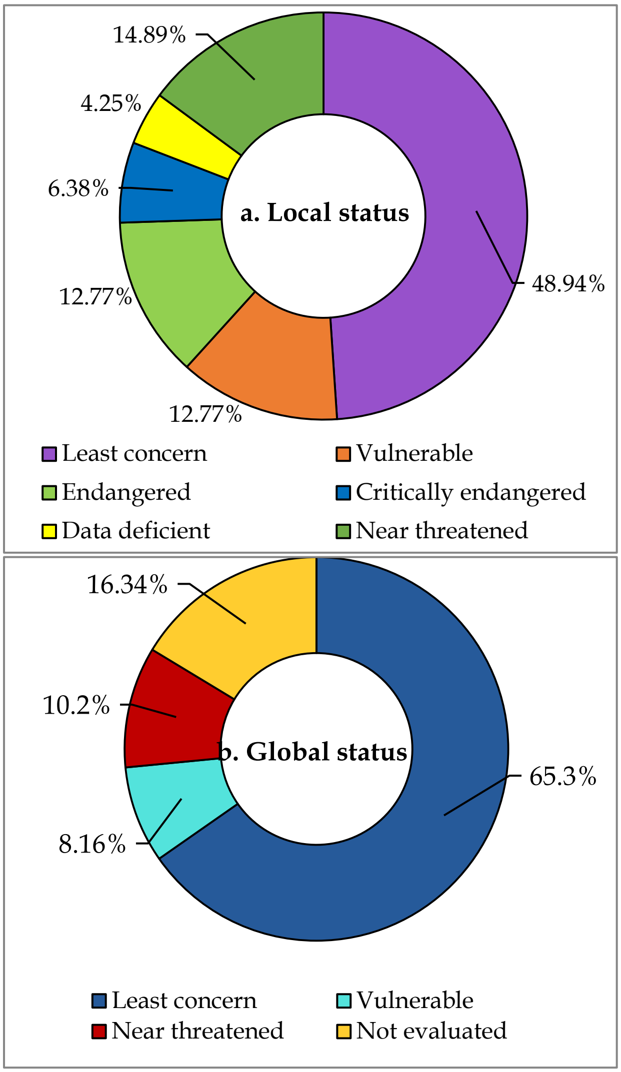

Figure 7. Conservation Status of Fish Species Identified from the Gojaria Beel a. Local conservation status b. Global Conservation Status (IUCN, 2015).

Regarding the endangered category, Figure 8 showed that 18.19% of fish species (*P. pangasius, C. garua, R. rita*) were from the Siluriformes order, while the majority (57.14%) of fish species (*B. dario, B. dayi, P. delphis* and *C. marulius*) belonged to the order Perciformes. Thus, the results diverge significantly from the research cited above. *N. notopterus, C. marulius*, and *M. armatus* were listed as Endangered and *W.o attu* as Vulnerable by IUCN Bangladesh (2015) (Table 1 & Figure 8). Recent research by Islam and Hossain (2019), Sarker et al. (2022) specified that these species have been moved into Least Concern and Endangered due to indicators of population growth and increased prevalence in the haor.

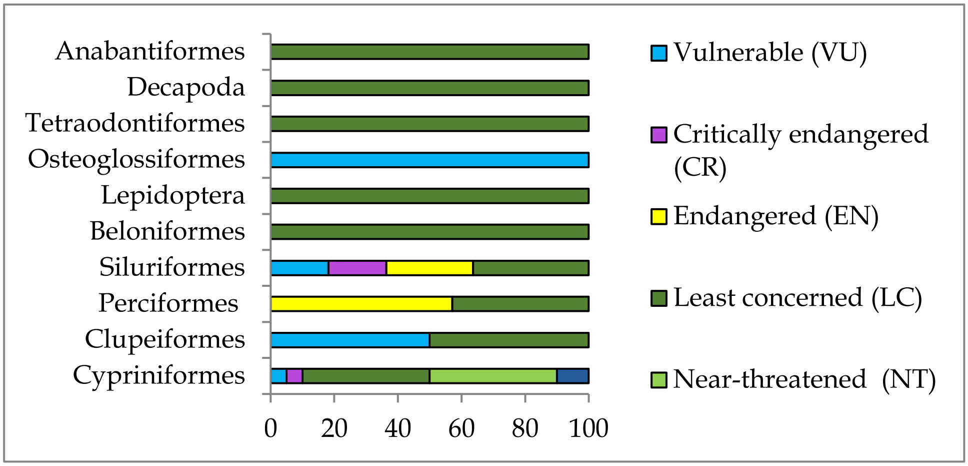

Figure 8. Frequency (%) of the threatened species according to the different orders.

Fish Diversity Indexes

Both dominance and evenness are complementary measurements & this index offers a naturally occurring proportionate dimension of species diversity that is somewhat less affected by species richness (Momi et al. 2020; Kerkhoff, 2010). The dominance index (D) at the Gojaria beel fluctuated from 0.06 in December to 0.12 in February (Figure 9). There were significant differences in the absolute dominance of some fish species. Regarding the evenness index, the month of December exhibited the maximum evenness value of 0.47, ranging from 0.30 to 0.47. The dominance and evenness diversity indexes, therefore, demonstrated a reciprocal relationship. Contrary to the current findings, Momi et al. (2020) reported that a negative association between dominance and diversity conducted at the Fakirni River.

The Berger-Parker index is used to calculate the number of individuals in the dominating taxon to all taxa, even though it is extremely rare in studies of fish diversity from Bangladesh (Moni et al., 2020). Figure 9 illustrated that the highest Berger-Parker index was 0.27, which indicates dominance recorded in February, while the lowest (0.14) was in December (Figure 9).

Distribution of individuals within the current taxonomic group is measured by the "equitability" or Pielou's evenness index (J) (Momi et al. 2020). The present study revealed that December had the highest Pielou's evenness (J) value (0.81) and February had the lowest value (0.70).

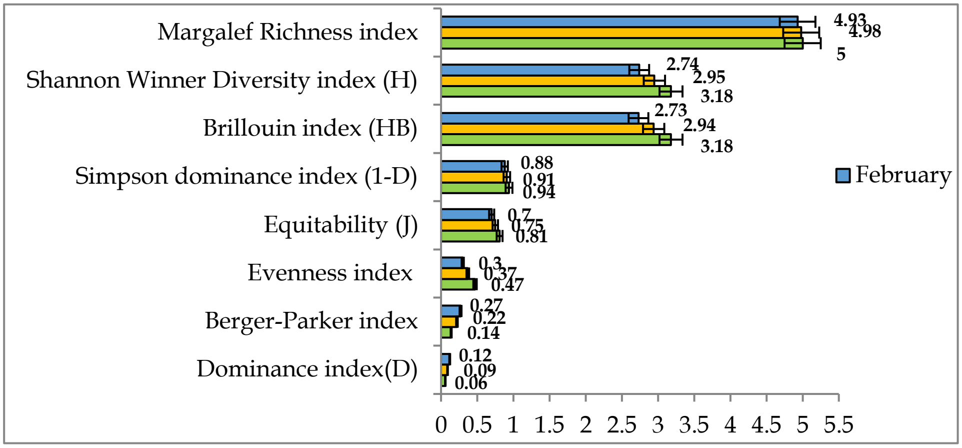

Figure 9: Monthly comparison of evaluated diversity and dominance indices in the Gojaria Beel.

A significant variation was observed in the Brillouin index (HB) value, which varied from 2.73 (in February) to 3.18 (in December). Momi et al. (2020) made a more or less similar observation, reporting that the HB value of Fakirni River was recorded from 1.847 (in June) to 0.481 (in September).

The highest value (3.18) of the Shannon-Weiner index (H), indicating good water quality, was measured in December, while the lowest value (2.74), indicating moderate water quality, was recorded in February. Wilhm and Dorris (1966), Goawami & Singha (2023) stated that the Shannon index (H) value range >3 indicates good water quality, the range from 1.00 to 3.00 indicates moderately polluted water, and the range <1.00 indicates extremely polluted water. More or less similar observation were also reported by Goawami & Singha (2023), where Shannon index of 3.33 at Uttarganakguri, 3.21 at Nizdamaka, and 3.11 at Gobardhana indicate good diversity while 2.98 at (Safakama), 2.97 at (Dumnighat) and 2.88 at (Madulijar) sampling sites indicated moderately polluted water.

The Margalef Richness Index (D) showed that the highest value of richness (5.00) was recorded during December, and the lowest value (4.93) was recorded during February. A similar study conducted at the Pilati beel by Ferdous et al. (2023) where the margalef richness index varied between 5.67 (February) and 5.95 (January) which is higher than the present study.

The Simpson index showed the probability that two randomly selected individuals of the same species would live in the same habitat. A low Simpson index value equals high diversity, whereas low diversity is correlated with a high index value (Goswami & Singha 2023). Throughout the study, the highest Simpson index value (0.94) was recorded during December, indicating lower fish diversity, while the lowest value (0.88) was recorded during February, indicating greater fish diversity.

The results of the Margalef richness index (D), equitability or Pielou evenness (J'), and Shannon winner diversity (H) varied from 4.93 to 5.00, 0.70 to 0.81, 2.74 to 3.18, respectively. The findings revealed that December had the highest fish fauna, with the most fish species identified, while February had the lowest recorded species. Corresponding to the results of the present study, Ferdousy et al. (2023) results for H', J', and C' showed that February had the greatest quantity of fish fauna since the greatest number of fish species were discovered during this period. Similar to our study, Das et al. (2022) reported that the values of C', J', and D' in the Shari Goyain River, varied from 0.244 (January) to 0.294 (November), 3.430 (December) to 2.325 (March), and 0.508 (November) to 0.561 (March), respectively. The values of the Margalef's richness (d), Pielou's evenness (J), and Shannon-Weaver diversity (H) indices were reported by Kamal et al., 2022, as follows: 2.98, 7.72, and 0.67 in Hawagulaia; 2.97, 7.52, and 0.67 in Patasingra; and 2.61, 7.30, and 0.59 in Salkatua beel.

Fishing Gears Used to Catch Fish

Adjacent to the Gojaria Beel, fishermen utilize a variety of fishing gear to catch different species of fish. Table 2 lists the fishing gear they were used during the study period. Though most fishermen use nets to collect their fish, fishermen around the Gojaria Beel used all of the aforementioned fishing gear. They employed current jal, khona jal, and ber jal as their primary net and trap materials. In the Chalan beel and Ashura beel, respectively, Sultana and Islam (2016) and Ferdoushi et al. (2018) recorded 28 different types of fishing devices which is much higher than the present study. It is reported that in Hakaluki haor the fishermen used five different types of fishing nets, three types of fishing traps, two types of hooks and lines, and one type of metal/stainless harpoon. This information collected on fishing practices and gears can be utilized to understand their effects on fishing and biodiversity (Hussain, 2021).

Table 2: Recorded fishing gears operated in Gojaria beel during the study period

Name of the beel	Fishing gear type	Local name	Duration of net operation	No. of fishermen for operation	Fish catching periods	Species Caught
Gojaria Beel	Seine net	Ber Jal	1-1.30 hrs	30-35	December -April	Rui, catla, mrigel, kalibaush, puti, silver carp, grass carp, mohashol, mola, dhela, gutum, gozar, shol, meni, tengra, bele, foli, icha, chapila, chanda, chitol
		Khona Jal	30 min			
		Chhota Jal	1-1.30 hrs			
	Caste net	Uthar jal	1hr			
		Jhaki/Koiya jal	30 min			
	Gill net	Current Jal	1-1.30 hrs			

Major Threats to the Fish Diversity

Numerous factors, both natural and man-made, have an impact on fish species diversity both directly and indirectly. A factor raising the danger of fish and other aquatic life extinction is the employment of destructive fishing gear and the dewatering of wetlands during the dry season. These types of fishing gear allow fishermen to easily catch fish eggs and fry them. According to 88.2%, 77%, and 72.5% of the respondents, respectively, the main dangers were fishing and dewatering with poison, dewatering rivers for irrigation, and gathering fry and brood fish during the breeding season. Furthermore, factors affecting fish biodiversity were found to include the use of illicit or destructive fishing gear, the unrestricted use of pesticides, insecticides, and chemical fertilizers on agricultural lands, and the construction of infrastructure for development purposes. Of the respondents, these issues were reported by 60%, 44.6%, 45.5%, and 47.5% of them.

Management MeasuresManagement Measures	Percentage of respondents
Prohibition of undersized and overfishing, using illegal fishing gear	77.8%
Prohibition of the use of monofilament nets and control over net mesh size	68.2%
Proclamation designating a portion or the entirety of a haor as a “fish sanctuary” and the idea of a “beel nursery	45.6%
Limitations on completely drying out water bodies and regular dredging of silted water	80.0%
Initiating catch restrictions to conserve the threatened fish species	65.0%
Using eco-friendly fishing technologies for the monitoring, controlling and surveillance of protected areas and threatened species	49.1%
Controlling on the extensive use of inorganic fertilizers and pesticides	72.8%
Establishment of ecosystem-based management strategies for the beel	66.9%

Conclusion

Documenting the existing fish biodiversity and its environment following the thorough survey and study is essential to adapt to the changing conditions of the world since the studies frequently uncover species variability. The present study and investigation into the fish biodiversity of Gojaria beel is sheding light on essential facts of its present status, conservation necessities, and strategies for management. The identification of 51 fish species across diverse orders, families, and groups underscores the ecological richness of this particular beel wetland. The prevalence of Cypriniformes and the prominence of catfish offer crucial insights into ecological dynamics of the beel. Concurrently, the classification of 31.92% of species as threatened and endangered at the national level, particularly within the Siluriformes and Perciformes orders, underscores the vulnerability of this ecosystem to both anthropogenic and natural stressors. Overfishing, habitat degradation and the use of destructive fishing gears are among the primary anthropogenic stressors identified. Natural factors such as high drought proneness further exacerbate the challenges faced by the fish species in the beel. In response to these challenges, present study advocates for a multifaceted approach to conservation including habitat restoration, sustainable fishing practices, and community engagement. These measures can serve as a valuable roadmap for decision-makers, aiding in the formulation and implementation of policies to ensure the long-term ecological resilience and sustainable utilization of Gojaria beel's fisheries and genetic resources. Additionally, several management strategies for fish conservation have been promoted; they could act as a guide for the sustainable exploitation of fisheries resources in an effort to protect these waterbodies . As we navigate the complexities of the changing world, safeguarding the biodiversity of this beel wetland is not just a regional imperative but a global responsibility, ensuring the continued vitality of ecosystems and the livelihoods hey engage and support.

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Impact of Agroecology in the Agricultural Activities of Chittagong Hill Tract (CHT) for Improving Local Food Production and Livelihoods in Bangladesh

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Abstract

The Chittagong Hill Tract (CHT) is situated in southeastern Bangladesh possess an area of 13,295 sq. km. distributed in three hill districts of Khagrachari, Rangamati and Bandarban remains behind in comparison to other parts of the country in development indicators, such as poverty, income, food security, health, and education, and in access to roads, infrastructure, electricity, and credit facilities. The nature and factors contributing to food and nutrition security in CHT are more complex than those in the plains because of the harsh biophysical environment, poor accessibility, and weak market infrastructure. This paper is based on the final assessment of different agro-interventions to 2,300 hill families of 5 upa-zilas of 3 hill districts in Bangladesh during 2018-2021. A total of 2,300 farmers (Family) involved in the agroecology program. Traditional agricultural system of jhum cultivation is not sustainable due to population pressure, reduction of fallow period and soil degradation. The paper analysis the major causes of resource destruction and also the opportunity and challenges exist to address the food security in CHT. Few smart food crops are also mentioned to address the improvement of livelihoods and food security of the hill people. Prolonged conflict of land tenure and settlement of plain land people should need to be addressed adequately. Modern agro-ecological technology with quality seeds, horticultural improvement, raising nursery and tree plantation, proper market and value chain development may improve the livelihoods and food security situation of CHT.

Keywords: Agro-ecology, Indigenous community, Crop production, Agro-interventions, Jhum, Soil degradation

Introduction

The challenges to ending hunger, food insecurity and all forms of malnutrition keep growing globally. In 2021, hunger affected 278 million people in Africa, 425 million in Asia and 56.5 million in Latin America and the Caribbean, i.e. 20.2, 9.1 and 8.6 percent of the population, respectively. While most of the world's undernourished people live in Asia, Africa is the region where the prevalence is highest (FAO, IFAD, UNICEF, WFP

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and WHO 2022). Agriculture remained the driving force behind the economic growth of Bangladesh and has a strategic function because it is the main food supplier for a huge people of the country. Majority of rural people in the CHT are involved with agriculture (Khan et al. 2002, FAO 2019), and hence land is the prime source for them (Nayak 2014). Over 50% of the annual net income of all CHT households comes from different agriculture related sources (Haque et al. 2021a). Food and cash incomes are generated by at least one agricultural related activity. Agricultural activities include ploughing lands, shifting cultivation, paid wage labor, livestock and poultry rearing, tree nurseries, fruit gardening, fishing and making agriculture implements (Ahammad and Stacey 2016). Land suitable for intensive field crop cultivation is less than 5 percent of the total area (Haque et al. 2021a). The traditional agricultural economy is based on growing paddy and other crops in the valley bottoms. The utilization of hill slopes by shifting cultivation is locally known as jhum. The main farming systems in mountain areas are upland jhum cultivation, plough land farming system, homestead cultivation system, horticulture farming system, fruit and tree crop farming system, mixed orchard farming system, vegetable farming system, fringe-land farming system, forestry farming system, wood production (Teak and Gamar) farming system, rubber plantation, agar plantation, non-wood production system (Broom grass- *Thysanolaena maxima*, bamboos), domestic animal production system (livestock and poultry), and aquaculture fish farming systems etc. Barua et al. (2015) showed that 55.4% households harvest single crop, 26.3% households harvest double crops, 10.8% households harvest triple crops in a year and only 7.5% households practiced jhum cultivation in the study area.

Agriculture can be seen as a significant example which the resilience of terrestrial ecosystems should be considered (Haque et al. 2021b). The organic matter (elements carbon and nitrogen) in soil, which is supposed to be recharged by multiple plants, is the main source of nutrients for crop growth. At the same time, intensive agriculture practices in response to global food demand and shortages involves the removal of weeds and the application of fertilizers to increase food production. However, as a result of agricultural intensification and the application of herbicides to control weeds, fertilizers to accelerate and increase crop growth and pesticides to control insects, plant biodiversity is reduced as is the supply of organic matter to replenish soil nutrients and prevent run-off. This leads to a reduction in soil fertility and productivity, particularly jhum fields in the hilly terrains. Consequently, more sustainable agricultural practices may consider and estimate the resilience of the land and monitor and balance the input and output of organic matter. Without implementing excellent agricultural practices, the balance of the agroecosystem will be affected. Agriculture has advanced better than it used to be in the old days; with improved practices it has supplied large volumes of food to global markets. However, resource-intensive practices and high-external input in agriculture have resulted in water scarcities, deforestation, soil depletion, and biodiversity loss along with other effects. One of the most efficient solutions to halt the negative effects of agriculture on the environment is the implementation of Agroecology.

Agroecology can be defined as the study of applying the most efficient ecological processes to agricultural production systems (Silici, 2014). It is similar to sustainable farming, a scientific framework integrating human socio-economic systems and ecological concepts into agricultural operations.

It is a technique of sustainable farming that focuses on utilizing natural resources comprehensively without letting them be susceptible to damage. Agroecology seeks to optimize the relationships and interactions between animals, plants, people, and the environment while addressing social issues for a fair and sustainable food system. It is very different from other approaches to achieving sustainable development because it is based on territorial and bottom-up processes. It combines science with traditional, practical, and local farmers knowledge. Agroecology seeks to transform agricultural systems by addressing the root cause of the problems in an integrated way and providing effective and long-term solutions. Though it may seem stressful and time-consuming, it adds a lot of benefits to the farmer, the crops, the environment, the health, and the safety of the people.

The soil must be healthy and improved to grow healthy crops, making the growth and production of crops efficient. Implementing agroecology practices boosts the economy of a country or region because there will be a massive reduction in the application of outputs like pesticides and chemical fertilizers. It also recognizes and accepts the multi-functional aspects of agriculture, local, and indigenous practices and knowledge. So, with agroecology, farming is not only improved, but there are also benefits to the social, cultural, and environmental aspects of life. Producing food by implementing agroecology will result in enough food to feed the ever-increasing population of a community. The good thing about agroecology is that it does not achieve short-term benefits but rather long-term goals. It involves using efficient processes that reduce the inputs of industrial products and their adverse effects. The methods used in agroecology are the effective use of water, better seeds, planting density, design, and efficient use of farm chemicals. These processes reduce the negative effects of agriculture on the environment and improve efficiency. In addition to the transformation of food and agricultural systems to sustainable agriculture on a large scale and achieving zero-hunger, the principles of agroecology developed are diversity, synergy, co-creation, and sharing of knowledge, efficiency, resilience, recycling, human and social values, responsible governance, culture and food traditions, and circular and solidarity economy.

Since a number of Sustainable Development Goals (SDGs) are closely related to food and nutrition security in the CHT and the success of SDGs is depending with the success of food and nutrition security (Rasul and Tripura 2016). Achieving food and nutrition security has direct and indirect implications for achieving other SDG goals and targets. Ensuring healthy lives may depend on achieving food and nutrition security. A failure to ensure food and nutrition security in the CHT, Bangladesh would imperil the region's other targets of SDGs such as ending poverty, ensuring healthy lives, achieving gender equality, and reducing inequalities as well as adaptation and mitigation of climate change (Rasul 2015).

Caritas Bangladesh (CB) has been implemented a "*Promotion of Agro-ecology practices in the Chittagong Hill Tracts" (PAEP* project in CHT) areas, where the direct beneficiaries of the project are 2,300 families (11,000 people, whom 50% of the beneficiaries are women) coming from ethnic and Bengali communities from 100 villages, 14 Unions and 5 upazilas of three hill districts. A baseline survey, midterm review and a final evaluation was carried out in an aim to document the improving food security and resilience to climate change of the vulnerable populations of the project beneficiaries.

Materials and Methods

Caritas Bangladesh (CB) has been implemented a "*Promotion of Agroecology practices in the Chittagong Hill Tracts" (PAEP* project in CHT) areas, where the direct beneficiaries of the project are 2,300 families (11,000 people, whom 50% of the beneficiaries are women) coming from ethnic and Bengali communities from 100 villages, 14 unions and 5 upazilas of three hill districts. Data were collected through Focus Group Discussion (FGD), In-depth Interview (IDI) with beneficiaries and concerned stakeholders. Relevant literatures were reviewed like Project Proposal, reports, peer reviewed journal articles for the study.

Results and discussion

Among the 2,300 participants in 5 upa-zilas (sub-district), 830 participants implement organic farming followed by livestock and poultry (800 participants) and multi-storied horticulture garden by 300 participants (Table 1).

Table 1. Participants (number) implementing the agroecology interventions in CHT by Caritas

Agro-interventions	**Lama**	**Alikadam**	**Thanchi**	**Manikchari**	**Rajsthali**	**Total**
Organic Farming	150	235	48	230	167	830
Livestock & poultry	176	241	33	191	159	800
Upgrade Jhum cultivation	30	50	40	10	20	150
Multi-storied horticulture garden	50	80	40	70	60	300
Women corner	02	02	02	02	02	10
Nursery	02	02	02	02	02	10
Fisheries	40	40	35	45	40	200
Honey bee rearing	07	12	8	10	09	46

Among the agro-interventions, highest monthly income (1,896/-) was for organic farming in Lama upazila followed by 1,459/- in Alikadam and the lowest in Rajasthali (430/-) (Table 2). The farmers monthly income for different agro-interventions vary from area to area (Table 2). Farmers in Manikchari monthly earned 3,095/- jhum cultivation followed by 1,084/- in Rajasthali. Among the all agro-interventions, farmers earned highest

(16,417/-) from nursery in Lama followed by 1,283/- in Rajasthali. Among all the interventions, women corner earned the highest 11,531/- in Manikchari and the lowest (3,053/-) in Thanchi (Table 2).

Table 2. Farmer's monthly income (Taka) from the agroecology interventions in five upazilas

Agro-interventions	Lama	Alikadam	Thanchi	Manikchari	Rajasthali
Organic Farming	1,896/-	1,459/-	520/-	1,176/-	430/-
Livestock & poultry	3,060/-	6,099/-	2,227/-	5,221/-	6,429/-
Jhum cultivation	777/-	430/-	642/-	3,095/-	1,084/-
Multi-storied Horticulture Garden	720/-	464/-	138/-	1,385/-	527/-
Women corner	3,072/-	4,010/-	3,053/-	11,531/-	5,645/-
Nursery	16,417/-	1,192/-	375/-	613/-	1,283/-
Fisheries	150/-	200/-	06/-	194/-	443/-
Honey bee rearing	125/-	18/-	12/-	142/-	13/-

Vermicompost preparation and application in agroecological interventions are one of the most common and popular technology among the farmers. Out of the 2,300 farmers, 1,398 farmers involved in compost preparation and selling to others and applied in agricultural and forest crops and multi-storied horticulture garden. During January 2018-June 2021, about 282,095 kg compost was prepared of which 231,306 kg compost were used (Table 3).

Table 3. Component wise beneficiaries involved for vermicompost production information (from January 2018 to June 2021)

Component	**Target**	**Involved**	**Compost pit**	**Production (kg)**	**Used (kg)**	**Sell (kg)**	**Stock (kg)**	**Sell warm (kg)**
Upgrade Jhum	150	100	87	22,628	21,192	23	1,413	1
Multi Storied Horticulture Garden	300	244	305	46,392	42,467	413	3,512	5
Organic farming	830	710	1,040	148,586	126,92 1	12,529	9,136	55
Livestock	800	297	402	60,889	37,847	16,780	6,262	40
Nursery	10	7	6	2,450	1,890	0	560	0
Women Corner	10	2	2	130	20	30	80	0
Fish Culture	200	38	38	1,020	969	0	51	0
Total	2,300	1,398	1,880	282,095	231,306	29,775	21,014	101

Balancing food security and ecosystem health

Balancing the food security in hill regions of Bangladesh is one of the important and demanding issues now-a-days. Keeping the ecosystem health balancing and food security, crop varieties and diversity is important. Caritas Bangladesh provides a number of different varieties and species for different agro-interventions (Table 4).

Table 4. Caritas supported agro-interventions and used crop varieties and species

Sl. No.	Agro-interventions	Crop varieties and species
1	Organic Farming	Rice varieties of Boro, Aus and Aman, seasonal summer and winter vegetables, spices crops, cash crops like ginger, turmeric, taro, yam, maize, sugarcane and potato
2	Livestock & poultry	Goat, pig, sheep and small indigenous poultry birds like duck, hen with seasonal summer and winter vegetables.
3	Jhum	Indigenous paddy varieties, maize, sesame, taro, yam, chilli, cotton, pumpkin, wax gourd, beans, marpha, chinal and eggplants.
4	Multi-storied horticulture garden	Mango varieties- BARI 4, Haribanghya, Amrapoli, Rangui, banana, guava, pineapple, jackfruit, coconut, betel nuts, kajubadam, litchi, teak, gamar, bamboo, beans, eggplants, chilli
5	Nursery	Fruit seedlings and saplings: Mango varieties, amloki, papaya, guava, jujuba, lemon, litchi, olive, bay leaf etc. Timber species: Arjun, teak, also summer and winter vegetables
6	Fisheries	Rohu, catla, mrigal, tilapia, common carp, black carp, mirror carp, bighead carp, grass carp, silver carp, Thai sharpunti, and small Indigenous species.

Improving livelihoods and conservation through Agroforestry

Caritas Bangladesh has given attention on food security and improving livelihoods at the expense of maintaining healthy agro-forestry ecosystems. The number of tree seedlings supplied to the beneficiaries during 2018-2021 by Caritas are shown in Table 5. A total of 57,749 seedlings & saplings of 45 fruit and timber tree species and varieties were distributed among the CB participated farmers (Table 5). Farmers interested for fruit seedlings rather than timber species, however, some are interested for long rotation timber tree species. They are realizing the drawbacks of deforestation and the climate change impacts in hill regions. They are interested to reforest the available areas adjacent to their homesteads and crop fields.

Table 5. The number and survival percentage of tree seedlings supplied to the beneficiaries during 2018-2021

Sl. No.	Species/ Variety local Name	Botanical name	Lama		Ali Kadam		Thanchi		Rajasthali		Manikchari	
			No.	Survival %	No.	Survival %	No.	Surviva l%	No.	Surviv al %	No.	Survival %
1	Aam	*Mangifera indica* var. BARI 4	-	-	85	76	280	93	-	-	-	-
2	Aam-Haribangya	*Mangifera indica* var. Haribangya	-	-	-	-	-	-	86	95	-	-
3	Aam-Ranguye	*Mangifera indica* var. Ranguye	-	-	-	-	-	-	1,440	94	-	-
4	Aam-Amrapali	*Mangifera indica* var. Amrapali	1,052	85	1829	89	-	-	1,335	97	2285	89
5	Amloki	*Phyllanthus emblica*	-	-	60	83	-	-	-	-	282	90
6	Amra	*Spondias purpurea*	678	85	235	81	160	86	35	97	96	89
7	Arjun	*Terminalia arjuna*	--	-			120	97	200	97	-	-
8	Ata	*Annona reticulata*	-	-	225	84	-	-	-	-	-	-
9	Bahera	*Terminalia bellerica*	-	-	-	-	-	-	188	97	79	86
10	Bamboo	*Bambusa vulgaris*	250	50	1600	22	1600	95	1,020	96	-	-
11	Banana (sucker)	*Musa sapientum*	660	95	-	-	-	-	-	-	-	-
12	Bel	*Aegle marmelos*	300	77	-	-	80	93	370	95	762	122
13	Chalta	*Dillenia indica*	-	-	84	86	-	-	-	-	-	-
14	Champa	*Michelia champaca*	-	-	-	-	160	93	-	-	201	86
15	Chapalish	*Artocarpus chama*	-	-	-	-	-	-	-	-	150	88
16	Garjan	*Dipterocarp us turbinatus*	100	95	400	88	40	93	-	-	208	87
17	Grape fruit	*Vitis vinifera*	-	-	196	82	480	94	-	-	55	87
18	Hartaki	*Terminalia chebula*	-	-	-	-	120	94	180	97	92	86
19	Jalpai	*Elaeocarpus tectorius*	-	-	-	-	400	94			78	85
20	Kalo jam	*Syzygium cumini*	-	-	130	96	-	-	-	-	115	85

Sl. No.	Species/ Variety local Name	Botanical name	Lama		Ali Kadam		Thanchi		Rajasthali		Manikchari	
			No.	Survival %	No.	Survival %	No.	Surviva 1%	No.	Surviv al %	No.	Survival %
21	Latkon	*Baccaurea ramiflora*	-	-	275	84	-	-	291	91	443	87
22	Lemon	*Citrus aurantifolia*	750	83	800	88	560	93	172	100	86	224
23	Litchi	*Litchi chinensis*	-	-	1039	82	360	89	-	-	-	-
24	Litchi	*Litchi chinensis var. Bombay*	-	-	-	-	-	-	277	92	-	-
25	Litchi	*Litchi chinensis var. China-3*	-	-	-	-	-	-	654	92	1,135	89
26	Lukloki	*Flacourtia jangomus*	200	81	12	75	-	-	363	91	12	83
27	Mahagony	*Swietenia macrophylla*	500	87	1280	91	160	98	-	-	92	85
28	Malta-Bari-1	*Citrus reticulata var. BARI-1*	350	75	330	78	640	89	616	84	1,048	92
29	Narikel-Sapling	*Cocos nucifera*	400	80	232	92	160	98	80	99	443	90
30	Neem	*Azadirachta indica*	250	85	160	94	80	96	223	97	116	86
31	Olive-Local	*Elaeocarpus tectorius var.* local	700	90	474	87	-	-	-	-	-	
32	Orange	*Citrus reticulata*	-	-	-	-	-	-	1,220	82	55	89
33	Tal	*Borassus flabellifer*	7	100	-	-	-	-	-	-	-	-
34	Papaya	*Carica papaya*	664	82	1540	86	-	-	-	-	920	88
35	Pepper	*Capsicum annum*			331	91	-	-	-	-		
36	Peyara-Guava	*Psidium guajava*	1,150	85	153	95	120	93	874	89	687	99
37	Pineapple	*Ananus comosus*	-	-	-	-	800	95	-	-	-	-
38	Kul/Boroi - Apple	*Ziziphus mauritiana var.* Apple	-	-	133	83	560	92	713	84		
39	Kul/Boroi - BAU	*Ziziphus mauritiana var.* BAU	-	-	48	79	-	-	104	84	700	86
40	Safeda	*Manilkara zapota*	50	90	96	89	280	89	220	88	196	89
41	Sajna	*Moringa oleifera*	900	79	-	-	-	-	-	-	90	89

Sl. No.	Species/ Variety local Name	Botanical name	Lama		Ali Kadam		Thanchi		Rajasthali		Manikchari	
			No.	Survival %	No.	Survival %	No.	Surviva l%	No.	Surviv al%	No.	Survival %
42	Sharifa-Local	*Annona squamosa*	100	76	-	-	-	-	-	-	-	-
43	Supari-Betel nut	*Areca catechu*	1,214	90	450	93	610	94			1698	89
44	Tej pata	*Cinnamomum tamala*	350	87	548	82	160	87	466	97	811	86
45	Tentul-Tamarind	*Tamarindus indica*	-	-	800	81	320	91	272	95	639	89
	Total		**57,749**									

Community Reserve and Village Common Forests (VCFs) in CHT

Village Common Forest (VCF) in CHT are mostly small (20-120 ha), consisting of naturally grown or regenerated vegetation (Jashimuddin and Inoue, 2012). The VCF are managed, protected and utilized by indigenous village communities under the leadership of the Mauza headman or village ‘‘karbaris’’or by educational or religious institutions, or a committee formed by leaders from one or more villages. VCF have set a standard model for the protection of biodiversity, environment and natural resources in CHT (Roy, 2000; Tiwari, 2003; Halim et al.,2007; Islam et al.,2009; AF, 2010). Village Common Forest is a natural forest other than the government forest around the households of the ethnic communities and managed to fulfil their daily demands (Jashimuddin and Inoue, 2012). Although the entire area of the CHT was covered with dense forest in the early l9th century; now most of the area has been denuded and covered with some scattered trees and shrub (Kamruzzaman et. al., 2018; Jannat et al. 2018). Evolving community-managed VCF in the CHT is a direct result of resource constraints caused by deforestation and the prevention of entry into and use of the resources of the newly acquired reserved forests (which were promptly declared as off limits to local people). These constraints led local communities to devise newer and more sustainable modes of the natural resource management. One such innovation, drawing upon indigenous traditional methods of forest fallow and jhum cultivation (shifting cultivation), gave birth to the VCF during the first quarter of the 20th century (Rasul, 2007; Baten et al., 2009). CB has supplied 1,548 seedlings of 39 tree (including timber, fruit, ornamental, spices etc.) species in Longdon Community Reserve at Alikadam, Bandarban (Table 6). The average survival percent of the seedlings is 78%.

Table 6. Seedlings supplied to the Longdon community reserve, Alikadam, Bandarban

No.	Local name	Botanical name	Uses	Seedling No.	Survival %
1	Safeda	*Manilkara zapota*	Fruit	9	89
2	Rangan phul	*Ixora coccinea*	Ornamental	10	60
3	Sil koroi	*Albizia procera*	Timber	30	77
4	Kala koroi	*Albizia lebbeck*	Timber	20	60

No.	Local name	Botanical name	Uses	Seedling No.	Survival %
5	Ata	*Annona squamosa*	Fruit	5	100
6	Pitraj	*Aphanamixis polystachya*	Timber	20	70
7	Betel nut	*Areca catechu*		50	88
8	Chapalish	*Artocarpus chama*	Timber, Fruit	85	76
9	Kanthal	*Artocarpus heterophyllus*	Fruit, Timber	50	64
10	Latkon	*Baccuera ramiflora*	Fruit	10	80
11	Kanjal Bhadi	*Bischofia javanica*	Tree, Fodder	40	75
12	Tal	*Borassus flabellifer*	Fruit, Timber	100	82
13	Palash	*Butea monosperma*	Timber, Ornamental	20	70
14	Tezpata	*Cinnamomum tamala*	Spices	10	90
15	Lemon	*Citrus aurantifolia*	Fruit	90	94
16	Malta	*Citrus sinensis*	Fruit	70	89
17	Orange	*Citrus reticulata*	Fruit	20	70
18	Coconut	*Cocos nucifera*	Fruit, Timber	25	88
19	Krishnachura	*Delonix regia*	Ornamental, Fuelwood	60	70
20	Chalta	*Dillenia indica*	Fruit, Timber	50	82
21	Gab (Deshi)	*Diospyros malabarica*	Fruit, Timber	30	77
22	Garjan	*Dipterocarpus turbinatus*	Timber	30	83
23	Gamar	*Gmelina arborea*	Timber	30	73
24	Jarul	*Lagerstroemia speciosa*	Timber	80	85
25	Aam	*Mangifera indica*	Fruit, Timber	25	72
26	Mango Bari-4	*Mangifera indica var. Bari 4*	Fruit	9	89
27	Nageshwar	*Mesua ferrea*	Ornamental, Timber	20	60
28	Champa phul	*Michelia champaca*	Timber	110	82
29	Bakul	*Mimusops elengi*	Ornamental, Timber	90	80
30	Amloki	*Phyllanthus emblica*	Medicinal	45	82
31	Peyara	*Psidium guyava*	Fruit	10	70
32	Thai Amra	*Spondias purpurea*	Fruit	5	100
33	Mahagoni	*Swietenia macrophylla*	Timber	110	88

No.	Local name	Botanical name	Uses	Seedling No.	Survival %
34	Tentul	*Tamarindus indica*	Fruit, Timber	35	76
35	Arjun	*Terminalia arjuna*	Medicinal, Timber	15	73
36	Bahera	*Terminalia bellerica*	Medicinal, Timber	65	78
37	Kat badam	*Terminalia catappa*	Ornamental, Timber	5	80
38	Haritoki	*Terminalia chebula*	Medicinal, Timber	55	82
39	Boroi	*Ziziphus mauritiana*	Fruit	5	60
				1,548	**78**

Protection and production of local seeds

A total of 10 seeds banks and reserve (5 at Sub-district level and 5 at Para level) has established to help the farmers for preserving the quality seeds of local variety (Rice-Aus, Amon, Boro, sesame, chilly, Maize, long bean, French bean, etc.) of crops. Beneficiaries get seed from seed banks before planting their land. Seed banks make the farmers autonomous in seed preservation and use in their fields. Farmers exchanged seeds from seed banks with others. Different varieties of seeds preserved in the seed bank. A total of 180 community people gets local seeds from office level seed bank. 97 farmers exchange seeds from office level seed bank. Seeds also exchanged to other community members in the nearest villagers. 198 community beneficiaries got the seed from local para seed bank. 113 beneficiaries exchange seed to para level seed Bank. High yielding variety seeds are available in the seed bank and have easy access among the community people. According to the information from the field, the germination rate was found 80%-90%. The crop production was also good from the seeds of seed bank. The initiative benefitted the farmers and reduces the dependency of seeds from multinational seed traders.

Conclusion and recommendations

Positive agro-ecological, socio-economic, and environmental impact was found at the end of the project at five upazilas in CHT. Overall crop production and income of the beneficiaries are increased. An especial impact observed on women empowerment and entrepreneurship. Most important gain of the project is knowledge development and awareness raising among the beneficiaries. The cost of crop production reduced due to incorporation of new technologies. Market linkage and liaise also developed. The food security is inevitably ensured because of organic farming, cultivation of local crop variety, fruits and fishes. The ecosystem balance is also maintained as indigenous species with diversified varieties are provided. The minor but not avoidable impact observed, many fallow lands are now utilized by the beneficiaries for cultivating crops, plants and fishes. Many farmers are using their lands for mix culture rather than mono culture. Thus, many unproductive lands or a little productive land are now converted into a productive one.

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Cultivation of Non-rice Cereal Crops in Bangladesh: Wheat and Maize - A Review

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Abstract

This paper examines the trend of cultivation of wheat and maize, the two major non-rice cereal crops grown in Bangladesh, over the past five decades since the country became independent. This period is divided into three sub-periods: 1972-1985, 1986-1999, and 2000-2021 to identify the key moments of how the opportunities as well as constraints played out in shaping the trend of cultivation of these two crops. Wheat was promoted as a staple food crop besides the main staple cereal, rice, through the Green Revolution that started at the beginning of the 1970s. Both wheat cropped area and production rose rapidly during 1972-1985 due to introduction of modern varieties of wheat and extension support provided to wheat growers. Subsequently, the mission approach to wheat cultivation was lost and its cultivation entered a period of decline resulting in decrease of domestic wheat production. Maize, in contrast, for long was a marginal crop. Its cultivation dramatically expanded during 2000-2021, in which the private sector played the major role through the introduction of high-yielding hybrid varieties. Maize has now emerged as the second-most grain crop after rice. Given that wheat is a food staple with rising demand, the paper explores policy options to support revitalization of wheat cultivation in Bangladesh.

Keywords: Non-rice cereal crops in Bangladesh; Cultivation of wheat and maize; A review

Introduction

Cereal crops other than rice traditionally grown in Bangladesh include wheat, maize, barley, millets, sorghum, buckwheat and oat. Among these crops wheat and maize are the major non-rice cereal crops which together contributed 12.2 percent to production of total cereals in 2020-2021. In Bangladesh, the Green Revolution (GR) is associated mainly with the introduction of high-yielding varieties of rice that led to rapid increase in production of rice, the major cereal crop vital for national food security. But to a lesser extent, it also promoted the introduction of high-yielding varieties of wheat, the other staple food, promoted by the Green Revolution in India, Pakistan and elsewhere in the developing world. At the dawn of independence rice was the only major foodgrain crop grown in Bangladesh. Cultivation of wheat was insignificant and centered on low-yielding degenerated local varieties. As a result, wheat production was low and didn't have a meaningful contribution to national food security. Despite having negligible share in the total output of foodgrains, it was a remarkable decision of the Government at that time to shift the focus of the GR on wheat, too, to bring about dietary diversity as well as

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strengthening of national food security. This policy focuses produced dividends in subsequent years through popularzing cultivation of wheat and its rapid expansion throughout the country.

Similarly, the cultivation of maize was more insignificant and sporadic than wheat was in the early 1970s. But beginning in the 2000s, maize production started rising dramatically and within a decade it displaced wheat from its status of the second-ranking grain crop in Bangladesh. Unlike wheat, the private sector played the lead role in transforming maize production in Bangladesh. Interestingly, the period of decline of wheat production is marked by the rise of maize production. This paper discusses how the cultivation of these two crops evolved since independence and how their relative contribution to total grain production changed with important consequences for national food production. In doing so, it divides the entire 1972 - 2021 into three sub-periods: 1972-1985, 1986-1999, and 2000-2021 to get a better perspective of the processes that drove production of these two non-rice cereal crops during this period.

Wheat

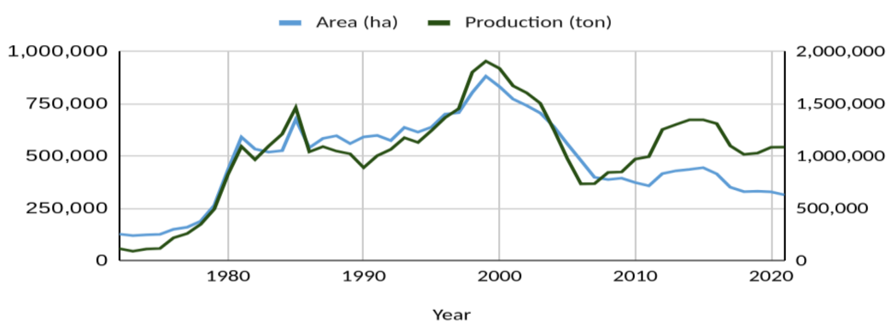
Research and Development efforts to improve wheat production began during the East Pakistan period when the first contact was established with the International Maize and Wheat Center (CIMMYT). In 1965 a kilogram each of Sonora 64 and Penjamo 62 were sent to East Pakistan from West Pakistan. These varieties yielded almost five times the provincial average wheat yield and matured more rapidly than the local wheats. On the basis of these results 160 kg of seed was sent for testing in the 1966-67 season. These trials were also impressive. The CIMMYT representative in West Pakistan visited these sites in 1968 and provided some initial technical assistance to the scientists. The next year the CIMMYT representative, along with West Pakistani wheat breeders, sent a collection of 265 promising Mexican lines to be tested. The same year the first Mexican variety was released to farmers - based on 1212 tonnes of Penjamo 62. (Pray and Anderson, 1985). At the beginning of independence, the Government of Bangladesh faced persistent and serious food deficits that forced the government to import large quantities of food. Because then wheat was cheaper than rice in world markets and also concessionary food aid sales, the preference in food imports was for wheat. As wheat imports rose and consumption of wheat-based food products increased, the government was exploring options to expand domestic wheat production.

The first systematic national research program was launched in 1971, shortly after independence, with the initiation of the "Accelerated Wheat Research Program." Since resources for new areas of agricultural research were very limited in Bangladesh at the time, this programme continued for five years with extremely modest resources. By 1973-74, considerably more interest in wheat cultivation existed among Bangladeshi decision-makers. In particular, Dr. Kazi M. Badruddoza, the new leader of agricultural research in Bangladesh, saw the potential benefits that wheat production could have for his country. Each year, when the late Dr. Glenn Anderson, then associate director of the CIMMYT wheat program, and Dr. Eugene Saari, CIMMYT Asian regional wheat representative, visited Bangladesh in February to see the wheat crop, Dr. Badruddoza would arrange meetings with key officials in the Ministries of Agriculture and Planning to discuss the potential for wheat production in Bangladesh. By 1974-75, research data confirmed the potential for wheat production in Bangladesh, and the stage was set for the take-off in wheat production (CIMMYT, 1982).

A key decision that the government took was to import 4,000 tonnes of Mexican varieties from India and Mexico in 1975/76, and wheat production was firmly launched (CIMMYT 1982). The variety Sonalika, developed in India from advanced CIMMYT wheat germplasm and released in 1974, became popular with wheat growers. With its optimum planting date between November 15 and 30, crop duration of 100-104 days, 3-4 tillers per plant, 30-35 spikelets per spike, 1000-grain weight of 48-52 g and yield potential of 3.2 - 3.5 tonnes/ha, the variety Sonalika set the stage for rapid progress in expanding wheat production in Bangladesh.

Of the 600,000 ha planted to wheat in 1980-81, it was estimated that about 96 percent was seeded to high-yielding wheat varieties. The variety Sonalika was dominant, covering roughly 68 percent of the high-yielding variety (HYV) area. Next in importance was the Mexican variety Inia 66, seeded to 10 percent of the HYV area, followed by the varieties Pavon 76 (5 percent), Jupateco 73 (5 percent), Tanori 71 (4 percent), and an assortment of others (8 percent) (CIMMYT 1982). The Government also adopted favourable policy including input support to encourage farmers to grow wheat. As a result, wheat area rapidly expanded from 127,259 hectares (ha) in 1972 to 591,216 ha in 1981 and the average national wheat yield was more than doubled from 0.904 t/ha in 1972 to 1.85 t/ha in 1981.

Figure 1: Trend of wheat area and production in Bangladesh 1972-2021



At a National Symposium organized in December 1983 to mark the Ten-Year Anniversary of the Bangladesh Agricultural Research Council, Dr. Kazi M.Badruddoza termed the developments in wheat production as a "wheat revolution" noting that average yields have more than doubled and total wheat production increased more than 16-fold during a decade (BARC, 1983).

Despite its high yielding potential, Sonalika became susceptible to leaf rust and *Helminthosporium* leaf blotch diseases. It was gradually displaced by high-yielding varieties developed by the national Wheat Research Centre (WRC) - Doel, Balaka 71 released in 1979; Ananda, Kanchan, Barkat, and Akbar in 1983. At the beginning of the

1990s, 89 percent of wheat growers used the newest varieties, Kanchan and Akbar. Farmers' adoption of high-yielding varieties was reflected in the trend of wheat cultivation during the period 1972-1985, which witnessed rapid expansion of wheat area and dramatic increase in wheat production (Figure 1 and Table 1). Between 1972 and 1985, cropped area under wheat increased from 127,259 hectares (ha) to 676,125 ha with an average of 324,344 ha (shown on the left vertical axis) and production soared from 115,012 tonnes to 1.463 million tonnes with an average of 600,430 tonnes

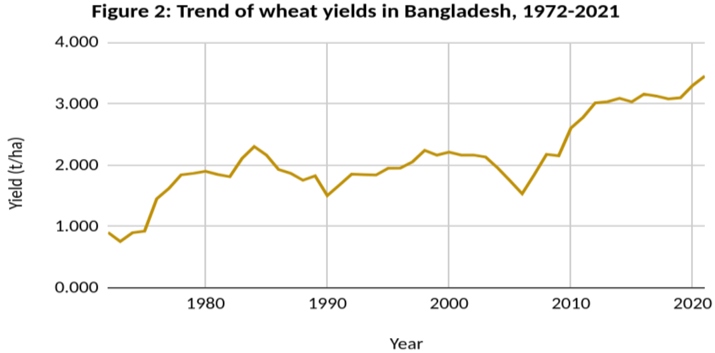
(shown on the right vertical axis). This period witnessed the highest annual growth rate at 16.9 percent for cropped area and 27.0 percent for production. Rapid increase was reflected in the high coefficient of variation (CV) values - 64.5% for area and 81.3% for production (Table 1). The high CV values during this period were due to considerable year-to-year variation in area and production. Average wheat yield during this period was 1.60 t/ha which increased from 0.90 t/ha to 2.16 t/ha at 8.60 percent annually (Figure 2). In 1985, the share of wheat in national production of total cereals increased from 0.8 percent in 1972 to 8.7 percent in 1985.

Table 1. Trend of area, production and yield of wheat in Bangladesh over 1972 - 2021 disaggregated by periods: 1972-1985, 1986-1999, 2000-2021

	Area (ha)			Production (tonne)			Yield (t/ha)		
Period	Mean	CV %	Annual growth rate, %	Mean	CV %	Annual growth rate, %	Mean	CV %	Annual growth rate, %
Wheat									
1972-1985	324,344	64.5	16.90	600,430.0	81.3	27.00	1.60	32.7	8.60
1986-1999	645,335	15.1	3.00	1,231,985.0	24.6	4.60	1.89	9.9	1.50
2000-2021	474,854	33.6	-4.00	1,175,771.0	25.9	-1.00	2.58	22.4	3.10
Maize									
1972-1985	2,221	30.9	-3.85	1,812	36.1	-4.34	0.81	9.0	-0.52
1986-1999	3,102	13.7	-0.71	2,993	12.4	0.00	0.97	11.7	0.71
2000-2021	228,732	74.2	19.2	1,700,693	87.4	86.0	6.23	29.3	5.10

Source of data: Bangladesh Bureau of Statistics (BBS), Yearbook of Agricultural Statistics, from 2000 to 2021; FAOSTAT for the period from 1972-1985 to 1999

Figure 2: Trend of wheat yields in Bangladesh, 1972-2021



Subsequently, the variety Aghrani developed in 1987 came as a replacement for Kanchan. However, one of the major shortcomings of these varieties was their susceptibility in varying degrees to leaf rust diseases. Despite the presence in the pipeline of several promising new varieties with improved traits (Protiva, BARI Gom 19, BARI Gom 20, BARI Gom 21), beginning in the latter half of the 1980s, the momentum in wheat cultivation was lost and a negative trend emerged. Wheat area decreased from the high of 676,125 ha in 1985 to 639, 000 ha in 1995 and average national yield declined from 2.165 t/ha in 1985 to 1.948 t/ha in 1995 (Figure 1 and 2). The declining trend of wheat area was reversed in 1996, but the trend persisted in production; the yield level of 1985 was recovered in 1999. As a result, annual growth rate in the wheat area dwindled to 3.0 percent during 1986 - 1999. Wheat production during this period increased at 4.6 percent annually. Annual yield growth decreased to 1.5 percent (Table 1).

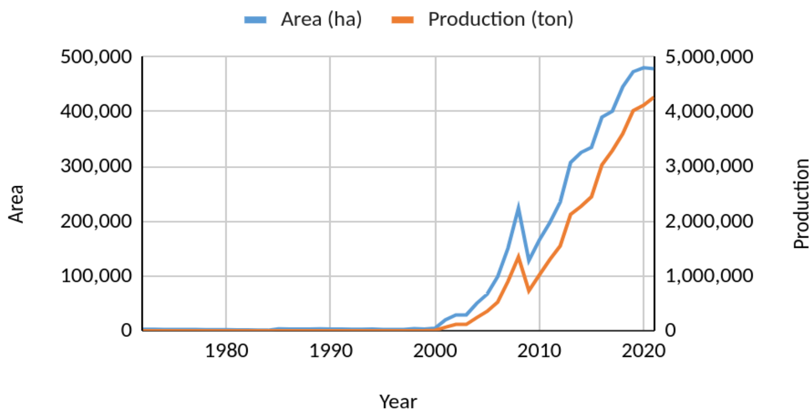
The key driver of this phenomenon was the change in Government's policy. At the height of the Green Revolution in the mid-1980s, the GoB's policy shifted to achieving self-sufficiency in food production which meant increasing rice production through expansion of cultivation of Boro rice across all land types including lands where farmers preferred growing wheat in the cool winter season. The incentives provided to expanding Boro rice cultivation were also discriminating against wheat. When the incentives provided to make wheat attractive to farmers were withdrawn, the crop had to compete for land with other winter season crops - Boro rice, potato, vegetable crops and maize. Because of government subsidies provided to chemical fertilizers and irrigation equipment, many farmers saw cultivation of Boro Rice was financially more attractive and switched to growing Boro rice instead of wheat in the Rabi season. Gradually wheat cultivation was pushed to less productive marginal areas. The theory that was put forward to explain decline of wheat production was the rise in average temperatures and shortening of the duration of the winter season due to climate change often resulting in prevalence of higher than optimum temperature during the flowering and grain filling stages of wheat crop growth. But the impact of climate change was equally applicable to all crops grown in the Rabi season and not only to wheat.

Beginning in 2000, the declining trend of wheat cultivation became irreversible. During this period maize emerged as the new competitor of rice. Many farmers in the traditional wheat growing areas began cultivation of maize in the Rabi season. Wheat area decreased from 882,224 ha in 1999 to 314,732 ha in 2021 and production fell from the highest 1.91 million tonnes in 1999 to 1.085 million tonnes in 2021. Over the period 2000-2021, the annual decrease recorded was 4.0 percent for wheat area and 1.0 percent for wheat production. Modest decline in production relative to cropped area was reflected in increase of productivity. Wheat yields during the period continued increasing at 3.1 percent annually with the highest yield 3.45 tonnes/ha achieved in 2021. Varieties developed and released during this period (Sufi, Bijoy, Pradip, BARI Gom25, BARI Gom 26, BARI Gom 27, BARI Gom 28, BARI Gom 29, BARI Gom 30, BARI Gom 33; WMRI Gom 1, WMRI Gom 2, WMRI 3) with yield potentials in the range 4.0 to 5.0 tonnes/ha, improved tolerance to diseases and terminal heat stress have contributed to sustaining upward trend in yield growth of wheat.

Maize

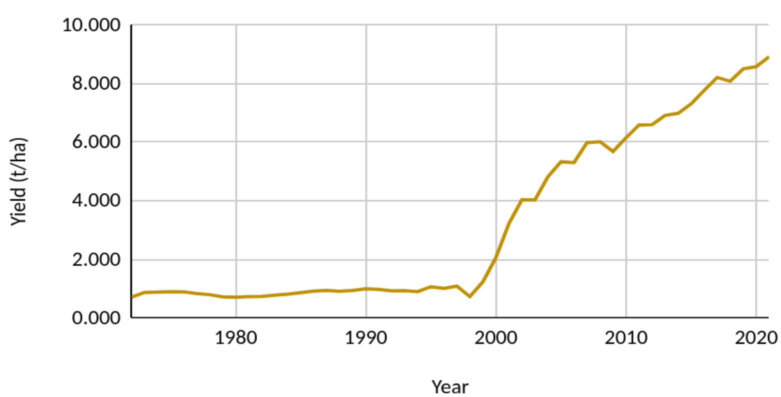
Maize wasn't a significant grain crop until the beginning of the 1990s. Its cultivation was limited mostly in Chittagong hill tract areas. Area planted to maize varied from 2,800 ha in 1972 to 3,772 ha in 1985 and widely fluctuated; annual growth rate of maize area was negative 3.85 percent for this period (Table 1 and Figure 3).

Figure 3: Trend of maize area and production in Bangladesh, 1972-2021



Research and Development efforts to improve maize yields were launched after independence at the Bangladesh Agricultural Research Institute (BARI) in 1976. Those efforts led to development and release of the first two high-yielding open pollinated variety (OPV) of maize in 1986 - Bornali (BM-1), Suvra (BM-2) followed by release of six other OPVs - Khaibhutta (BM-3) and Mohar in 1991; BARI Bhutta-5 and BARI Bhutta-6 in 1998; BARI Mishtibhutta-1 and BARI Bhutta - 7 in 2002. Those varieties (Shuvra, Barnali, Khoibhutta, Mohor and others) had yield potentials in the range 5.5 - 7.5 t/ha. At that time OP was given preference over hybrids because of convenience for seed multiplication.

Figure 4: Trend of maize yields in Bangladesh, 1972-2021



Introduction of those early varieties for commercial cultivation led to a slow increase of maize yields from 0.925 t/ha in 1986 to 1.235 t/ha in 1999 at 0.7 percent annually over 1986-1999 (Table 1). Apart from breeding improved varieties, agronomic approaches such as testing maize-based cropping systems in large scale on farm demonstrations were conducted by BARI, BRRI, and the Department of Agricultural Extension and the most profitable maize-based systems were promoted to popularize maize cultivation throughout the country. But progress in expansion of maize cultivation was slow because of poor demand for maize. In Bangladesh, maize grains aren't directly consumed by humans as food rather used as livestock fodder and feed. The emergence of the private sector in agriculture in input supply, seed production and supply, crop breeding and seed multiplication; expansion of agribusiness and agro-based enterprise development since the beginning of the 1990s set the stage for revolution in maize production beginning in 2000. This process got a major boost from the USAID-supported Agro-based Industries and Technology Development Project (ATDP) during 1995 - 2005. Through the project many commercial firms and business operations/entrepreneurs centered on poultry, shrimp and fishes were established that created large demand for maize grains for use as feed (Evaluation of ATDP Project, 2005).

Introduction of hybrid maize varieties by the private sector seed companies since 1997 with yield potentials in the range of 10 -11 t/ha fostered dynamic growth in maize cultivation. Many farmers adopted maize cultivation because it increased their incomes as well as profitability relative to wheat growing. The Government also encouraged maize cultivation to improve financial security of smallholder farmers. Major players in the private sector in modernizing maize cultivation in Bangladesh include BRAC, ACI Ltd. and Lal Teer Seed Ltd. In the public sector, BARI developed the first hybrid maize variety "Pioneer hybrid 3056" which was released in 1998. Between 2000 and 2022, BARI and the Bangladesh Wheat and Maize Research Institute (BWMRI) have developed 20 hybrid maize varieties using introduced as well as locally developed inbred lines with yield potentials as high as 12.5 t/ha (BWMRI Annual Report, 2021-20220). Because of constraints in rapid multiplication, seeds of hybrid maize varieties developed in the public sector were made available to maize growers more slowly than those introduced by the private sector.

Rapid spread of cultivation of hybrid varieties led to dramatic increase of maize cropped area from 4,855 ha in 2000 to 478,217 ha in 2020 at an annual growth rate of 20.3 percent (Table 1 and Figure 1). Production soared from 10,000 tonnes in 2000 to 4.116 million tonnes in 2020 at an annual growth rate of 19.2 percent (Table 1). Average national yield of maize increased from 2.06 t/ha in 2000 to 8.91 t/ha in 2020 at 5.10 percent annually during this period (Figure 4). Maize, as a gain crop, displaced wheat from its second-ranking status both in cropped area and production. In 1985 wheat contributed 8.7 percent and maize 0.02 percent to total annual grain production in Bangladesh (calculated using data from Yearbook of Agricultural Statistics, BBS, 1999).

After the lapse of 35 years the size of the relative contribution of these crops to total annual grain production flipped with the share of wheat dwindling to 2.53 percent and that of maize rising to 9.61 percent in 2020. The upward trend of maize cultivation is set to continue (Figure 3). Growth in maize production is expected to continue at such rates in response to rising demand for poultry, dairy and fish feed. The annual varietal gains at 5.10 percent indicates considerable untapped potential for increasing maize productivity in future.

Policy implications: wheat versus maize in domestic production

In Bangladesh, national food security is traditionally centered on grain cereals that people directly consume as food - rice and wheat. Maize, despite being the second most important grain crop now, isn't directly consumed as a staple food. About 90 percent of harvested maize is used as livestock and fish feed while some is used to make starch, flour and processed food such as corn cereal. Wheat grain processed into flour (atta), on the other hand, is directly eaten and, therefore, contributes to national food security in the same way as rice does.

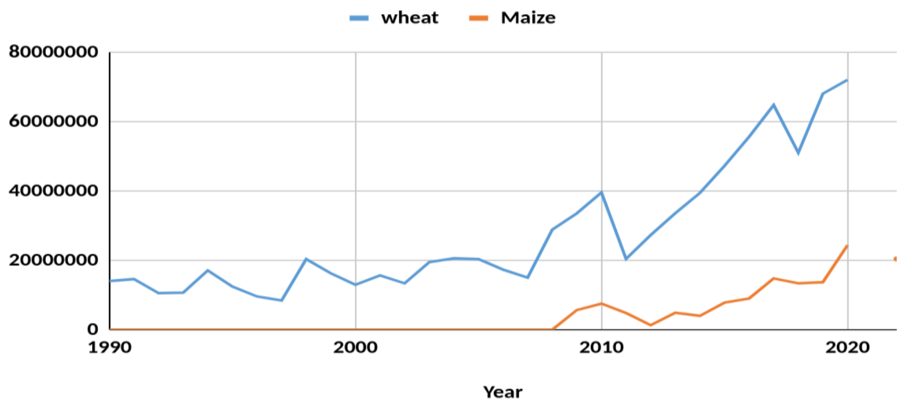
Based on this consideration, in the early years after independence, the government's food production policy emphasized increasing production of both rice and wheat taking advantage of high-yielding varieties developed in the wake of the Green Revolution. Besides the existing Rice Research Institute, a new research facility dedicated to wheat research - Wheat Research Centre - was built in Nashipur, Dinajpur. The incentives in the form of price support for inputs (fertilizer, seed, and irrigation equipment and fuel) that the Government provided benefitted not only rice production but also wheat production. As a result, the growth in wheat production was dramatic and in the mid-1980s its share in total domestic foodgrain production rose from less than 1.0 percent to 8.7 percent.

As domestic wheat production increased, the popularity of wheat flour-based food (roti, chapati, naan and other processed food) also increased. People's diet preferences gradually shifted creating demand for wheat. But, as stated above, when the focus of Government's policy shifted to achieving self-sufficiency in food through rapidly expanding rice cultivation in the Boro season and the targeted support for wheat cultivation discontinued, domestic wheat production took a downturn in the backdrop of rising demand for wheat. Wheat is also used as a feed ingredient in the poultry, aquaculture, and cattle feed industries. In industrial use, specific types of animal feed contain approximately five percent wheat and wheat bran. Sometimes the feed industry uses wheat bran and rice bran alternatively. Cattle farmers also feed wheat bran separately (United States Department of Agriculture, Grain and Feed Update, 23 August 2023).

According to FAO, Consumption of wheat flour products has tripled since 2000 and currently it accounts for about 10 percent of the total average calories' intake. As national wheat production was declining, the role of imports was on the rise to close the gap between supply and demand. As evident from Figure 5, annual import of wheat increased from 1.339 million tonnes in 1990 to 7.2 million tonnes in 2020 (USDA, Production, Supply and Distribution Online, accessed 8 January 2024). Imports cover 80 percent of the country's wheat requirements (FAO, GIEWS, accessed 28 December 2023). Domestic production covers about 20 percent of the demand. Wheat, at present, accounts for about

15 percent of the staple cereals consumed in Bangladesh. Reliance on commercial imports in large quantities to meet the demand for wheat isn't risk free because global trade in wheat is sensitive to unforeseen external shocks. Some examples are temporary ban on exports by wheat exporting countries or disruptions in global supply chain due to sanctions or other barriers. The ongoing Russia-Ukraine war is a case in point. The Russian Federation and Ukraine together account for approximately 25 percent of Bangladesh's total wheat imports. In such cases, it may not be possible to import the target amount to cover the shortfall in requirements and the deficit may cause wheat prices to rise. In Bangladesh, prices of wheat flour were at least 70 percent above their year-earlier levels as of January 2023, due to a considerable slowdown in imports in 2022 (FAO, 2023).

Figure 5. Import of wheat and maize, tonne (1990 - 2022)



Contrary to wheat, maize cultivation in Bangladesh is set on a growth trajectory. Despite a dramatic increase in domestic maize production, there is still a shortfall to meet the growing demand for maize. As a result, since 2009 maize is also being imported to cover the deficit in annual requirement of maize. But maize imports are rising less quickly and there is opportunity to increase domestic maize production at a faster rate to reduce dependence on imports.

But given the current trend in wheat cultivation, Government's targeted support is needed to recover wheat production from decline and make it profitable for farmers much in the same way cultivation of Aus rice is being promoted now. It is important because the demand for wheat will continue rising. If the shortfall is not bridged by increasing domestic production, wheat imports will keep rising, placing a burden on the country's foreign exchange reserves. This can be done by accelerating diffusion of new generation high-yielding heat-tolerant varieties through rapid seed multiplication; bringing less favorable lands in southern areas under wheat cultivation through introduction of salinity tolerant varieties and accelerating farm mechanization. There are still considerable genetic and agronomic potentials for revitalizing wheat production in Bangladesh as evident from impressive yield growth of wheat at 3.1 percent annually during 2000 - 2021 compared with stagnant yield growth of Boro rice at 0.6 percent during the same period. Appropriate policy support is needed to alleviate other constraints.

Conclusion

Over the past five decades cultivation of wheat and maize, the two major non-rice cereals, in Bangladesh evolved in two different directions. At the beginning, wheat cultivation expanded rapidly due to research and extension support as well as incentives to farmers provided by the Government. Later when the incentives were withdrawn and cultivation of Boro rice in wheat growing areas was expanded, wheat cultivation entered a period of decline. Wheat growing also faced competition with other winter season crops such as potato and vegetables. In contrast to wheat, maize cultivation recorded a dramatic expansion mainly owing to the introduction of high-yielding hybrid varieties of maize by the private sector. Despite its dwindling share in total annual production of cereals, wheat is still the second most important food staple because maize is used mainly as feed and its use as food is insignificant. Therefore, there is a need for revitalization of wheat cultivation in Bangladesh to reduce dependence on commercial imports of wheat in large volumes.

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Research-Extension Linkage Strategy of Agricultural Universities in Bangladesh: *prospects and challenges in technology development and transfer*

M Zulfikar Rahman[1*]

Abstract

Agricultural research system of Bangladesh is highly efficient. Both research organizations and the universities have generated contemporary technologies to address the challenge of climate change as well as increasing demand of ever-increasing population of Bangladesh. There is untapped potential in agriculture which may lead to food self-sufficiency and even export of some crops. Many of the technologies didn't reach to farmers due to weak linkages among stakeholders such as research, extension, education and farmers. This paper described potentials of education system which is underutilized in dissemination of technologies. Some of the old universities have adequate facilities for packaging and dissemination of the technologies to the extension agencies through training of trainers and lead farmers. Such facilities should be utilized to harness potential of agriculture in Bangladesh. It is recommended that a representative from university extension education be included in National Agricultural Technology Coordination Committee (NATCC) to share the research results of agricultural universities and utilize their services for training of extension officers. The Technology Transfer and Monitoring Unit of Bangladesh Agricultural Research Council may engage university extension center in developing technological packages and utilize their services for arranging training. Similarly, all NARS (National Agricultural Research System) institute should share their technologies with extension education center to develop technological packages.

Key words: Research extension linkage, agricultural university, technology development and transfer

Introduction

A*gricultural innovation systems (AIS)* is a network of actors or organizations, and individuals, together with supporting institutions and policies in the agricultural and related sectors, that brings existing or new products, processes, and forms of organization into social and economic use. Policies and institutions (formal and informal) shape the way that these actors interact, generate, share and use knowledge, as well as jointly learn. As agriculture increasingly involves complex interactions of environmental and socio-economic factors with stakeholders at multiple levels, innovation needs an AIS

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perspective. The AIS comprises four components: research and education; bridging institutions; business and enterprise; and the enabling environment.

The AIS entails explicitly the integration of various institutions and their possible roles towards achieving a sustainable agricultural development in a country. The overall supports needed from policy environments are also shown as integral part of the process. In making the learning and networking environment capable enough, the universities, research organizations and extension/advisory service providers have been playing their informal roles to boost agricultural production in the country. But, due to the absence of appropriate linkages among these institutions the real benefits of the integrated system approach could not be accrued appropriately.

In South Asian countries, the universities are engaged in teaching and research for professional development and practical application of the theories for problem-solving (Dongol, 2004). In USA, the Land-Grant College Act of 1862, Act of the U.S. Congress that provided grants of land to states to finance the establishment of colleges specializing in “agriculture and the mechanic arts.” Each state is granted 12,140 hectares for each of its congressional seats. Due it’s policy coverage, the land-grant university provided readily available, research-based programs and educational resources with the goal of improving the lives of the individuals, families, and communities within the state.

State Agricultural Universities in India (similar concept as Land-grant universities of the United States) are state funded autonomous organizations responsible for agricultural research, extension and education. Their establishment is a crucial landmark in strengthening agricultural extension education system in India (Meena et al., 2013). As the context of universities varies across a country, an extension education is likely to evolve at a local level accordingly, being responsive to the needs of the agricultural community. This kind of adaptation at the local level drives the future of extension education at national level. For example, integration of adaptive research in universities who formerly emphasized basic research, coordinating and facilitating agricultural community activities, paid or unpaid technical advice and services in farmer’s issues, etc. may help universities specialize based on market demand. There will be differences among the universities, however, attributes like a result-driven, science-based, efficient use of public funds and suitable delivery mechanism relevant to customers and producers should distinguish the national extension system in the future. The result of this transition will be seen in all universities across the world, as the access of people to universities will increase from few to many. However, universities in developing countries face additional responsibilities could be summarized in following of the three points.

- The most distinctive feature of the modern agricultural university around the world is its integrated program of teaching, research and extension.
- In addition to the traditional function like teaching and research, the extension which is emerged as the provision of educational service and program to the people, and remained outside the boundary of the campus, is now generally accepted as one of the main functions of an agricultural college or university.

- A comprehensive example of this system is found in the land grant institution of the US, which was established after the Morill Act 1862, providing at least one university-level institution in each state. The trilogy role of teaching, research and extension are the characteristics of these land grant institutions of the United Nations, which are considered the world's most extensive educational program beyond the boundaries of their campus in the form of field extension activities for farmers, homemakers and youth.

Private and public universities other than land-grant universities also offer outreach programs to enhance the socio-economic status of the rural population. Many states of the US have established Rural Development Centers (RDC) who works for extension outreach independent of the land grant universities. The extension has a comparative advantage in aiding rural development by creating a link between technical assistance provided by land grant universities, research and community services through local government officers (Schutjer, 1991). In countries like Nigeria, according to the need of local government, the national agricultural research system has been developed into specialized universities and faculties of agricultural crops and veterinary, research institutes and experimental stations for generating agricultural innovation aiming rural development (Adesiji et al., 2010).

In Bangladesh, the agricultural universities are under the Ministry of Education which has no direct linkages with the Ministry of Agriculture resulting in a poor linkage and weak coordination with agricultural extension and research systems. And possibly, we also lack adequate information and understanding about the potential research-extension and education linkages. Thus, the paper seeks the main aim to explore the linkages of higher educational institutes with research and extension towards achieving a sustainable agriculture growth and development in the country. Specifically, it envisages looking into the matters of existing situation of linkages and their strength and weaknesses, future potentialities and suggestions for developing sustainable linkages and way forward in developing and transferring the agricultural technologies.

Present state of research extension linkage in relation to Agricultural and Science & Technology Universities

Linkage implies the communication and working relationship established between two or more organizations pursuing commonly shared objectives in order to have regular contact and improved productivity. It is evident that manpower training is the primary mission of higher education institutes. However, in addition to their primary function, they are expected to play a developmental role by establishing linkages with public, private and non-government organizations engaged in agricultural and rural development and with farming communities. Popularly, the agricultural universities are established with three major missions: *education, research and extension*.

There are six public agricultural universities and nine other public universities where there is agriculture department and award degree in the field of agriculture. These are:

Agriculture Universities

- Bangladesh Agricultural University (BAU)
- Sher-e-Bangla Agricultural University (SAU)

- Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU)
- Khulna Agricultural University (KAU)
- *Sylhet Agricultural University* (*SAU*)
- Chittagong Veterinary and Animal Sciences University (CVASU)

Other universities having department of agriculture that offer degrees in agriculture

- Patuakhali Science and Technology *University* (PSTU)
- Hajee Mohammad Danesh Science & Technology University (HSTU)
- Rajshahi University (RU)
- Khulna University (KU)
- Noakhali Science and Technology University (NSTU)
- Bangabandhu Sheikh Mujibur Rahman Science and Technology University (BSMRSTU)
- Bangamata Sheikh Fojilatunnesa Mujib Science & Technology University (BSFMSTU)

The faculty members in the above universities are engaged in teaching as well as guiding students for their research for the partial fulfilment of degrees. In addition, teachers have been taking independent research projects funded by different donor agencies on specific issues. So far, 28 development partners provided grants to the Bangladesh Agricultural University (BAU, 2023). Such a research program is coordinated by the Bangladesh Agricultural University Research System (BAURES) and generated more than 100 technologies which are contributing to sustainable food production in Bangladesh. More specifically, the Crop science sector has generated 36 technologies, veterinary science 14, animal husbandry 30, agricultural engineering 28 and fisheries sector 28. The technologies generated by BAU are transferred to the neighboring farmers through involving them either directly in the research projects or through group approach. Such engagement helps in validating the effectiveness of technologies. To facilitate dissemination of technologies BAU has established an Extension Centre (BAUEC) in 1976. At the same time, BAU has established Graduate Training Institute (GTI) to train newly recruited cadre officers as well as others on agricultural development and technologies.

The BAUEC established 43 Farmers' Associations with farmers from the neighboring areas to work jointly with BAU research teams. In each association, there are 40 members, one from each household. The members are either male or female. They help in establishing pilot research plots under the guidance of researchers. The researchers provide them with necessary inputs and information on production and crop management technologies (https://bauec.bau.edu.bd/). Apart from that, BAU has its Graduate Training Institute (GTI) to facilitate training for their graduates and others in the allied fields. This assists in developing technical skills to the graduates and ultimately serves towards better advisory services in the field of agriculture. It may be mentioned here that many of the technologies didn't reach the farmers beyond Mymensingh only because there is a gap between university research and agricultural extension.

SAU has also its research system in place. It is designated as SAURES. It coordinates research undertaken by different disciplines and also provide necessary support for dissemination of technologies through arranging training to farmers, agricultural professionals and helps in establishing linkages with national extension services, research organizations, NGOs and other universities as well.

SAU also disseminate information on technologies through publishing a newsletter on extension activities undertaken by the Outreach Program and produces extension materials for teaching rural farmers (http://www.sau.edu.bd/offices/outreach).

BSMRAU has developed 77 improved varieties of vegetables, cereals, pulses, fruits and flowers which are commercially cultivated by the farmers who received training from BSMRAU due to their high yield and nutritional potentials (https://bsmrau.edu.bd/dres/varieties-released/). It may be mentioned here that BSMRAU has an outreach center, which was established in 1985 for disseminating knowledge and skill to the farmers on the technologies generated by the BSMRAU through training and on-farm activities at farm levels (https://bsmrau.edu.bd/doutreach/). Adoption of technologies generated by BSMRAU would have been more if there were formal linkages between BSMRAU and the DAE.

CVASU offers degrees in Veterinary Medicine, Food Science and Technology, and Fisheries. The CVASU has three campuses, main campus is in Chattogram city, farm-based campus situated in Hathazari, Chattogram and a marine research station in Cox's Bazar. CVASU also has a pet hospital at Purbachal, Dhaka and a research vessel at Kaptai Lake, Rangamati, Chittagong Hill Tracts. CVASU has an anatomy museum and a fisheries museum. CVASU faculties have developed over 100 technologies which are published in national and international journals. They received research grants from UGC, Ministry of Science and Technology, World Bank, collaborative projects with different universities of Sweden, USA and UK, and BARC. For dissemination of technologies, they offer training courses or arrange customized training for the GO and NGO Officers and staff as per their requirements. Arannayk Foundation, a not-for-profit organization utilized the services of CVASU for training livestock service providers developed through a project supported by the World Bank (Arannayk Foundation, 2016).

PSTU has also a Department of Agriculture and a Department of Animal Science and Veterinary Medicine. They have also generated some agricultural technologies through their collaborative research funded by different donor agencies and UGC. Arannayk Foundation also utilized the services of Animal Science and Veterinary Medicine to develop livestock service providers during 2014-16 (Arannayk Foundation, 2016).

Other universities have also developed either some improved crop varieties or technologies for improvement of crop production and protection but most of them didn't reach to farmers due to lack of proper research, education and extension linkages. Though BAU has a strong set up for extension education, there is no formal linkage between education and extension. Some of the activities of BAU have made tremendous contribution in the country. For example, BAU has established a Germplasm Center of fruit trees which is second largest in the world. It was established through a project supported by Swiss Agency for Development and Cooperation (SDC). The project started in 1991 (International Tropical Fruits Network, 2011) to centralize germplasms and develop propagation protocol of different fruit tree grafts for supplying quality planting materials to the farmers through NGOs. Though it started with one hectare of land, now it is spread over 33 ha of land. The germplasm has 163 varieties of mango, 39 varieties of guava, 25 varieties of litchi, 48 varieties of citrus, 94 accessions of jackfruit, 67 species of minor fruits, 31 species of exotic fruits from 19 countries including 97 species of medicinal plants. BAU has released 32 varieties of fruits in the country from this center. This germplasm center is one of the main quality planting materials distribution centre in the country. The center has become the center of excellence that provides training on quality fruit tree planting materials production and management, a learning center of fruit tree management and a demonstration site for local and exotic fruit trees and their management (TFNet, 2011).

BAU has also contributed in developing national nursery guidelines in the country for production and maintenance of quality planting materials. Ministry of Agriculture has published the guidelines through a Gazette (Nursery Guidelines 2008). The nursery guidelines have recognized the contribution of BAU in production of foundation materials and distribution to the farming communities through Department of Agriculture.

Similarly, the fisheries faculty of BAU has the largest fish museum and biodiversity center in the country. Established in 2009, it contains germplasm of riverine fish resources of the country which helps in both in-situ and ex-situ conservation. There is a lake of 3 ha, 16 experimental ponds and about 100 small ponds under the faculty of fisheries. Those waterbodies serve as repository for quality brood supplying in the country (BAU, 2017). There is scope for maximizing use of facilities of the fisheries department of BAU. Research, extension and education departments should work together for full utilization of resources.

Role of extension education in packaging technologies

Scientists develop technologies using their scientific knowledge. When a scientist presents the technology, the farmers or even the extension officers might not understand it clearly. Scientific language is different from language of farmers or extension workers. So, it is necessary to translate science language to local language which is understandable to an extension worker. The role of extension education is to develop technological packages and provide training to the extension workers for clear understanding of the technologies and subsequent dissemination to the farmers. In other words, the extension education targets training of trainer (ToT). For bridging the gap between research, education and extension, Bangladesh Academy of Agriculture (BAAG) has undertaken a project for dissemination of technologies generated through financial support of Krishi Gobeshona Foundation by the agricultural universities, research organizations, NGOs and other agencies (BAAG, 2021). BAAG engaged communication specialists to develop technological packages of crops, fisheries and livestock and arranged ToT for the DAE and lead farmers. It appears that such collaborative project has helped establishing linkages among research, extension and education (Annual Report of BAAG, 2023).

The lessons learned from the project may be summarized (Figure 1) as follows:

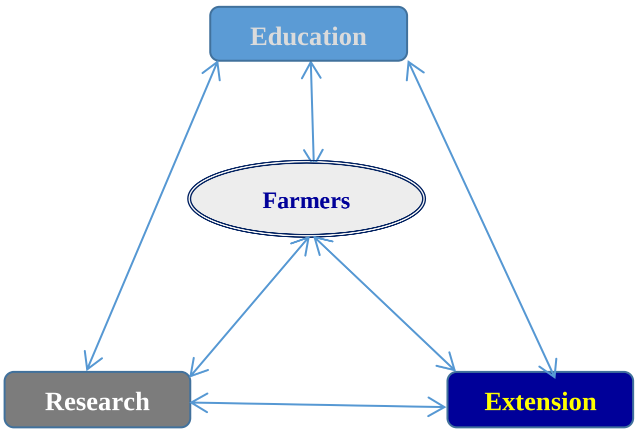

Figure 1: Linkage model of education with producer, research and extension.

Technologies generated either by the universities or research institute must be shared with extension education department of universities. The role of the universities would be packaging the technologies which should be validated by the farmers as well as researchers and extension agencies. Once the technological packages are finalized, training should be arranged by the education extension or other agencies involved in training. It is also necessary to include representative of extension education in the National Agricultural Technology Coordination Committee (NATCC).

Conclusion and way forward

It is necessary to have an assessment of technology transfer situation in agricultural research. The study provided information about technologies generated by different organizations and their adoption by the farmers. Critical analysis of the gap in dissemination of technologies and discussion with the farmers revealed the reasons for low adoption. Project implemented by BAAG suggests that the gap is due to weak linkages among the stakeholders.

Based on the experience, it is recommended that a professional platform should be developed to consolidate technologies generated by agricultural universities. The technologies should be screened to find out the mature one. BAUEC may take initiatives in leading the platform. A representative from the extension education platform may be included in the NATCC, the platform for screening agricultural technologies and guiding extension agencies for adoption of technologies. The Technology Transfer Unit of BARC should work closely with BAUEC in developing technological package and arrange ToT for extension officers and lead farmers. Similarly, all NARS institute should be encouraged to utilize the services of BAUEC to develop technological packages suitable for extension officers and lead farmers. It is envisaged that such collaboration will strengthen linkages among research, education and extension.

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Articles dealing with the past activities, present status and future guidelines in one or more disciplines of agriculture will get priority. Original research works, both fundamental and applied will also receive priority. The articles, in addition to being on research results, should preferably be on policy, management, advancement and frontier issues of research, extension and economic aspects.

The topics will cover current and future scenarios for improvement of sustainability of the fragile eco-system, food security, natural resource management, input distribution & management, nutrition, agribusiness, climatic risk management, human resource development and economic implications of rapid globalization obtaining since the recent past. The retrospects and prospects of agricultural improvement *vis-à-vis* the constraints hindering progress of agricultural development etc, are burning topics needing elaborate analysis and synthesis for the policy makers , teachers, researches, extensonists, service providers, marketing agents, NGOs and private sector entrepreneurs.

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   2. Ali, M.S., S.A. Khan and A.R. Chowduary, 1998. Production of rice in the changing climatic condition of Bangladesh. Bangladesh Agriculture: 1(1): 9-13.
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   5. Rahman, S.1987. Water stress in potato. In: Annual Report, Bangladesh Agric, Res. Institute, Gazipur, Pp. 170-190.
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