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Extinction of cultural rites and ritual of an ethnic group: Insider's view of Oraon community

Sarawat Rashid[1*] and Bablu Lakra[2]

[1] Rural Development Academy (RDA), Bogura, Bangladesh.

[2] Gram Bikash Kendra (GBK), Parbatipur, Dinajpur, Bangladesh.

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***Corresponding Email:**
sarawat.rashid@gmail.com

ABSTRACT

This study examines the present cultural condition of the Oraon community in Bangladesh and investigates how these conditions have affected their traditional rites and rituals. The Oraon are an ethnic minority primarily residing in the Barind region of north-western Bangladesh, where villages are ethnically and religiously diverse, including Muslims, Hindus, Christians, and Buddhists, but are predominantly Bengali Muslim. As a result, the socio-cultural sphere is largely shaped by majority culture, which has contributed to the gradual erosion of Oraon cultural practices. The objectives of this qualitative study were twofold: (i) to explore the features and attributes of Oraon history and culture through which they define themselves as a distinct community in the Barind region, and (ii) to examine their cultural rites and rituals, including the reasons for their gradual extinction, from an emic perspective. Data were collected through interviews and observations within the community. The study found that sustained contact with other societies and technological advancement are perceived by community members as the main causes of cultural erosion. Although government and non-governmental organizations have implemented various programs to support ethnic communities, these initiatives remain insufficient to halt the decline of traditional practices. The findings contribute to a deeper understanding of the processes influencing cultural change among minority communities and highlight the importance of preserving indigenous rites and rituals.

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Introduction

Bangladesh is often perceived as a culturally homogeneous nation dominated by Bengali identity; however, ethnically and linguistically the country is highly diverse. Alongside the Bengali majority, numerous ethnic communities maintain distinct languages, belief systems, cultural practices, and historical identities (van Schendel, 2009). Anthropologically, these communities are not simply "minorities"; they occupy a socially and politically marginal position in relation to the dominant ethnic and religious majority, and their cultural practices are embedded in broader power structures and historical processes (Bourdieu, 1998; Foucault, 1978).

According to the Population and Housing Census 2022, Bangladesh has a total population of 165,158,616, of which 1,650,159

people (approximately 1.00%) belong to ethnic communities, comprising 824,751 males and 825,408 females (Bangladesh Bureau of Statistics [BBS], 2022). These communities are primarily associated with minority religions, including Christianity, Hinduism, Buddhism, and indigenous belief systems (ibid.).

However, scholars and indigenous activists believe that the number of ethnic people may be underestimated because of limitations in definitions and census methods (Roy & Deshwara, 2022).

Among the ethnic communities living in the plains, the Oraons constitute a significant group. The 2022 BBS census records 85,846 Oraons, who are concentrated in the Barind region of north-western Bangladesh, particularly in Rangpur, Dinajpur, Bogura, Rajshahi, Naogaon, and Chapai Nawabganj districts (ibid.). Historical census data indicate that the Oraon population was only 11,296 in 1991 (BBS, 1991), highlighting demographic growth and improved recognition. Despite their presence, Oraons remain a numerical minority in villages dominated by Bengali Muslims, which influences their cultural expression and social integration.

The Barind region has ethnically mixed villages, but the culture of the majority often dominates, influencing moral values, social norms, and public rituals (Abed, 2006). This dominance is not neutral; it puts minority groups like the Oraons in a position where they must struggle to maintain their identity and cultural practices (Bourdieu, 1998). As a result, Oraon cultural rites and rituals—such as religious ceremonies and seasonal festivals—are increasingly at risk. Factors such as economic pressures, social exclusion, and conversion to Christianity, Hinduism, Buddhism, or Islam have changed traditional practices, leading to a gradual loss of cultural traditions.

From a theoretical perspective, the disappearance of Oraon rites can be seen as a result of structural inequality and cultural dominance. According to Gramsci, dominant groups decide what culture and behavior are considered acceptable, often devaluing minority practices. Foucault's idea of power/knowledge shows how social institutions control behavior and set moral rules, affecting which rituals continue or disappear (Bourdieu, 1998; Foucault, 1978). Using this perspective, the study examines not only which cultural practices are fading but also why and how this happens within wider social power structures.

Despite the presence of several ethnic groups in the Barind region, research has largely focused on the Santal community, which forms the largest population. Studies on the Oraons are limited, particularly concerning ritual transformation, identity negotiation, and cultural survival in plain land contexts (Kamal et al., 2007). By adopting an insider's perspective, this study investigates how Oraons experience, interpret, and negotiate the erosion of their cultural rites and rituals. It contributes to anthropological knowledge on the effects of majority dominance, religious conversion, and structural marginalization on the survival of minority cultural traditions in Bangladesh.

Significance of the study

The Barind region is a significant area for understanding the conditions of some of Bangladesh's most underdeveloped and marginalized ethnic communities. Compared with their peers in the Chittagong Hill Tracts (CHTs) and the broader Bengali society, ethnic groups in Barind face greater socio-economic and cultural challenges. Despite efforts by various government and non-governmental organizations to support these communities, their quality of life continues to deteriorate.

While previous studies have highlighted the marginalization and socio-economic challenges of ethnic communities in Bangladesh, there is limited research on the specific issue of cultural extinction. Understanding how and why traditional Oraon rites and rituals are disappearing is essential to addressing broader questions of identity, cultural preservation, and minority rights. This study builds on the introduction by linking the socio-cultural marginalization of the Oraons to the structural and anthropological processes affecting their cultural practices.

Objectives of the study

i] To examine the features and attributes of Oraon history and culture through which the community defines itself as a distinct ethnic group in the Barind region.

ii] To explore the Oraon's cultural rites and rituals and investigate the reasons for their gradual extinction from an emic perspective (insider's view).

Methods of the study

This research primarily relies on qualitative data collection methods conducted among the Oraon community in the Barind region, complemented by a review of historical and secondary literature on the Oraons. An emic approach (insider's perspective) was prioritized to understand cultural practices from the viewpoint of community members.

The research team consisted of an anthropologist and an Oraon community member. Focus group discussions (FGDs) were conducted with both male and female participants from different age groups to address the study objectives. Data were collected in 2018 from the following locations:

- Bilpara, Ghoraghat, Dinajpur – 18 households
- Doihara, Gobindaganj, Gaibandha – 26 households
- Udaypur, Gopalpur Union, Mithapukur, Rangpur – 39 households

This methodological approach allowed the researchers to explore the dynamics of cultural change, identify factors contributing to the erosion of traditional rites, and capture the community's own explanations and experiences, thereby directly linking the field data to the anthropological perspective outlined in the introduction.

The Oraons of the study area: Historical and cultural profile

The Oraons belong to the Dravidian linguistic group and traditionally speak the *Kurukh* language, classified as a North Dravidian language. In Bangladesh, many also speak *Sadri* and Bengali due to prolonged interaction with neighboring communities (Islam, 2014; SIL Bangladesh, 2011). The Oraons (also called *Kurukh*) are an ethno-linguistic group primarily concentrated in eastern India, although they are now spread across several South Asian regions, including Bihar, Jharkhand, Chhattisgarh, West Bengal, Odisha, Assam, Tripura, and neighboring countries such as Nepal, Bhutan, and Bangladesh (Joshua Project, n.d.).

The precise timing of the Oraons' migration to Bangladesh is debated; however, ethnographic research suggests significant settlement in the Barind region occurred during the British colonial period (1765–1947), often for labor in agriculture, clearing forests, and working in tea estates and railway stations (Islam, 2014, 2023). Today, the Oraons are recognized as a culturally distinct minority in Bangladesh, maintaining their own social organization, ritual practices, and linguistic expressions, even while interacting with the broader Bengali society (Islam, 2014).

Historically, agriculture was the primary livelihood of the Oraons, supplemented by forest-related labor and employment during the colonial period. Many continue to work as landless agricultural laborers in the Barind region (Islam, 2014, 2023).

According to Roy (2004), the origins and traditions of the Oraons point to South India. A linguistic connection exists between *Kurukh* and Tamil. Roy (2004) suggests that the Oraons once occupied territories from the north bank of the Krishna river to the Vindhya mountains in south India and settled in the fertile valleys of the Narmada river in north India. Due to overpopulation, external pressures, or other reasons, the Oraons migrated from south India to north India (ibid.).

Oraon informants indicate that the Oraons in Bangladesh's Barind migrated from Ranchi (Jharkhand forest tract) and Nagpur (locally called Chota Nagpur). A few also trace their origins to south India, the Indus Valley civilization, or north India. During British rule, the Oraons settled in Barind as tenants or sharecroppers under local Zamindars (Islam, 2014, 2023).

The name 'Oraon'

The Oraons are known by several names. According to Hahn (1986), the term "Oraon" is seldom used by the people themselves. Terms such as *Kurukh* and Oraon are used to refer to them (Koonathan, 1999:104). Roy (2004) notes that Hindus originally called them *Uraon, Raonaput*, or *Orawan*, which eventually became "Oraon." The Oraons refer to themselves as *Kurux, Kurukh, Kuruxar,* or *Kurukhar*. The term *Kurukh* is derived from *Karakh*, the name of a mythical king, and *Kurukh* thus means "people from the community of King *Karakh*" (Roy, 2004:10–17).

Language: *Kurukh and Sadri/Khatoya*

The Oraons speak *Kurukh* or *Sadri* as their mother tongue. *Kurukh* belongs to the Dravidian linguistic group, which includes Tamil, Malayalam, Kannada, Telugu, Koragu, Tulu, Toda, and Kota languages (ibid.:18).

Sadri is a mixture of several Indian languages, including Hindi, Urdu, Bengali, and Arabic, which the Oraons adopted through historical interactions (Tirkey, 1999). Approximately 60–70% of Oraons, especially the younger generation, speak *Sadri* rather than *Kurukh* (Roy, 2004).

Kurukh has no known written literature. The Oraons believe they once had a script, but it was lost during historical crises (Hahn, 1906/1996). Christian missionaries have attempted to write in Oraon languages using English and Bengali alphabets.

Political organization

An Oraon village council is called *Padda Panch*, the lowest administrative tier of traditional political organization. Each village has a council of five members, also referred to as village-*Panch* or *Panchayat*. The *Padda Panch* is highly respected, placed next to *Dharmes* (Oraon Sun-God), as the highest earthly authority among the Oraons.

The council maintains peace, enforces moral and social codes, and resolves disputes, including family property issues, marriage law violations, assaults, and witchcraft cases. Punishments range from fines to excommunication in serious cases. The *Padda Panch* also oversees community activities, such as school openings, wall construction, or government visits (Dhan, 1967; Roy, 2004; Tirkey, 1980, 1999).

Religion and belief

The Oraons believe in one supreme god, *Dharmes* or *Biri Belas* (Sun-King or Sun-God), whose color is white. Sacrificial offerings to *Dharmes* include a white fowl or goat, an egg, water, and white rice beer (*Dharia*). The Oraons perform *Danda-Kattna* as the greatest sacrifice, reflecting a monotheistic understanding of God (Roy, 1972, 2004; Tirkey, 1980, 1999).

Totem clans

The Oraon community is divided into numerous totemic clans, named after birds, animals, plants, materials, or objects. S. C. Roy (2004:195) identifies 68 totemic clans: 43 animals, 19 plants, two minerals, two places, and two split totems. Oraons are patrilineal, and clan names (*gotras*) are inherited from the father.

Family

Males are the heads of Oraon families. Economic crises and landlessness have led to a shift from joint to nuclear families. Single-member families, including widows and divorced individuals, are also common.

Oraon women play a crucial role in household and economic activities. They work in fields, earn wages as daily laborers, manage household chores, care for children and the elderly, and produce *Haria* (rice beer) a culturally specific practice that contributes to Oraon identity.

Marriage

Marriage occurs in adulthood and signifies the fullness of life. Infant marriage is strictly prohibited. The Oraons generally practice monogamy and view marriage as fulfilling the will of *Dharmes*. They believe that marriage enables procreation, extends the community, and satisfies divine will (Tirkey, 1980, 1989; Roy, 1972, 2004).

Inheritance of land and property

Customarily, women are excluded from inheriting land and property. When a father dies, property is divided among surviving sons. This is

because daughters live with their husbands after marriage. In modern times, influenced by the broader Bengali Muslim community, daughters may inherit property if there are no sons.

Economy and occupation

Agriculture was traditionally the main economic activity, supplemented by fishing, crafts, and cattle rising. Occupations such as weaving, basket-making, tanning, and blacksmithing are considered below Oraon dignity. While Oraons are not traditionally traders, they do sell and borrow goods (Roy, 2004; Tirkey, 1989, 1999).

Dress, food and dwelling

Traditionally, Oraon men wore *Nengti* (loincloth), and women wore *Fota* (two pieces of cloth). Today, men typically wear shirts, trousers, *Lungis*, or vests, while women wear *Sarees*, *Salwar*, and *Kameez*.

Bhat (cooked rice) is the staple food. Oraons eat fish, meat, vegetables, lentils, and milk products such as *Chhana, Doi,* and *Makhan. Kichuri* and *Panta Bhat* are popular dishes. *Haria* is a traditional drink produced by women, consumed during festivals and ceremonies.

Oraon dwellings are made of thick mud walls, with roofs of corrugated iron or straw thatch, and bamboo or wooden windows and doors. The inner compound contains multiple structures, including kitchens, cattle sheds, and storage rooms.

Festivals

Oraons celebrate several annual festivals, although economic hardship has reduced the number of celebrations. Some festivals are at risk of extinction or transformation.

Fagua: Celebrated at the end of February or early March, *Fagua* is a symbolic hunting and New Year festival. Before hunting, Oraons perform *Danda-Kattna* and build a straw hut to be set on fire after the hunt. Food production resumes only after the festival.

Sarhul: A spring festival celebrated in late March or early April when *Sal* trees blossom. It involves a symbolic marriage between the village chief (*Pradhan*) and his wife, representing the union of earth and sky. Work and consumption of new fruits and leaves are avoided until the festival is completed.

Karam: Celebrated on *Ekadoshi* of Bhadro (August–September) after paddy transplantation. The ritual involves installing three *Karam* tree branches at the village *Akhra* (dancing ground) and listening to the legend of *Karam* from an elder.

Sohorae: A cattle festival in Karthik (November) after harvest. Houses are cleaned, lamps are lit, and cattle are bathed and anointed. A fowl is sacrificed, and a feast is held. Food is eaten only after feeding the cattle. *Haria* is consumed throughout the night. Oraons have distinct songs performed during festivals and ceremonies, narrating their history and migration.

Insider's view on changing the traditional culture

The Oraons have faced many interruptions, conflicts, and confrontations throughout their history. According to the literature, they had a relatively prosperous life in earlier habitats during their migrations, including in South India, North India, and their settlement in Chota Nagpur (Singh, 2019; Tiwari, 2020). They lived off nature and the products they produced from the land. The objects and materials they collected from forests and rivers significantly supported their livelihood. In all their settlements, they were self-sufficient. However, their lifestyle was impacted by overpopulation, natural calamities, and the intervention of the *Dikus* (powerful outsiders), including Hindus, Muslims, and the British. These powerful outsiders created challenges for them in terms of livelihood and socio-cultural life (Patel, 2017).

After the independence of Bangladesh in 1971, the Oraon community perceived an upsurge of Bengali nationalism that led to discriminatory practices against minorities, which they maintain are still reflected in government policies favoring the Bengali Muslim majority. The Oraons are considered minorities or subaltern groups who remain socially, politically, and economically marginalized within dominant power structures in Bangladesh (Spivak, 1988).

According to the community, their languages are in danger due to a lack of use in primary and higher education. Ethnic people rarely have the opportunity to use their mother tongues in schools, colleges, and universities. Moreover, none of these indigenous languages are included in academic curricula, closing the scope for them to continue studying their mother tongue.

The Oraon community has identified several important factors that have contributed to cultural change over time. These changes have not occurred suddenly; rather, they have developed gradually through continuous interaction with social, economic, and technological forces.

Contact with other societies

Contact between different societies is one of the most significant causes of cultural change. When the Oraons interact with neighboring communities, dominant social groups, and wider national institutions, cultural diffusion and acculturation take place. Through this interaction, ideas, values, customs, and behaviors are exchanged. As a result, both societies experience change, although the impact is often stronger on minority or subaltern communities like the Oraons.

- **Technological evolution:** Technological change has played a major role in transforming Oraon culture. Developments in production technology have altered traditional livelihoods and work patterns. Modern communication systems have changed the way information is shared and social relationships are maintained. Improvements in transportation have increased mobility and contact with urban areas and mainstream society. These changes have affected daily life, social practices, and traditional cultural expressions.
- **Adoption of new customs and practices:** The Oraon community does not adopt all new customs automatically. New practices are accepted under specific conditions. First, a new custom is more likely to be adopted if it is considered socially desirable and useful in everyday life. Second, it must not directly conflict with existing customs that are still meaningful and valued by the community. When new practices align with traditional values or offer clear benefits, they are more easily integrated into Oraon cultural life.
- **Nature of cultural change:** Not all cultural changes have the same level of importance. Some changes are adopted because they are necessary for survival, such as those related to livelihood, health, or security. Other changes are accepted to meet socially acquired needs, which are not essential for survival but are important for social status, convenience, or integration with the wider society. Periods of crisis—such as economic hardship, displacement, or social pressure—often accelerate cultural change and make communities more open to adaptation.

Conclusion

Cultural change is cumulative in nature. Over time, many new elements are added to culture, while only a few older elements are completely lost. Once a change becomes established and is defined as a social necessity, it often creates new needs. These new needs encourage further changes, leading to a chain reaction of cultural transformation. In this way, cultural change becomes an ongoing and interconnected process rather than a single event.

Although the government of Bangladesh has introduced development policies for ethnic communities, these policies are generally culture-oriented and well-addressed in principle. However, the effectiveness of such policies depends on how well they recognize the lived cultural realities of communities like the Oraons and supports their ability to adapt while preserving their cultural identity.

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Prospects of solar-powered drip irrigation system for sustainable crop production in Bangladesh

Md. Arif Hossain Jewel[1*], Md. Ferdous Hossain Khan[2], Israt Jahan Jany[3], Md. Abdul Kader[2]

[1] Department of Agricultural Engineering, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

[2] Rural Development Academy (RDA), Bogura-5842, Bangladesh

[3] Department of Agricultural Marketing, Ministry of Agriculture, Bangladesh

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***Corresponding Email:**
arifjewel@sau.edu.bd

ABSTRACT

Efficient irrigation techniques can help to achieve the goal of improving crop yields and maximizing water usage in smart agriculture. Drip irrigation systems operate under pressure and utilize pumps to maintain the necessary pressure levels and make them effective particularly in water-scarce regions. The integration of solar-powered pumping systems with drip irrigation presents a promising strategy that provides the dual benefits of reduced energy and water consumption along with enhanced agricultural productivity and environmental sustainability. This study examines the design intricacies of solar-powered drip irrigation systems as a sustainable solution for agricultural water management in Bangladesh by emphasizing the combination of renewable energy as a progressive alternative to traditional irrigation practices. Key components of the system including photovoltaic panels, energy accessibility, crop water requirements, solar pumps, and drip lines were studied to improve overall system performance. The economic analysis of solar-powered drip irrigation system was also assessed and found to be acceptable for vegetable cultivation in Bangladesh. Therefore, this study emphasizes the importance of integrating solar energy with drip irrigation to promote sustainable agricultural practices and improve water efficiency, particularly in Bangladesh.

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Introduction

Bangladesh ranked as the 8th most populous country globally with a density approximately 1,265 per km^2 and faces a rapid decrease in arable land due to urbanization and climatic pressures (World Bank, 2023). Projections indicate that Bangladesh's population will reach approximately 191 million by 2031, 216 million by 2051, and 223 million by 2061 (BBS, 2015). Despite this challenge, Bangladesh has remarkably increased agricultural productivity by 3.54 percent annually over the last two decades, laying the groundwork for its national and economic success. Agricultural land occupies about 70% of the country's total land area, totaling roughly 9.1 million hectares. Of this, around 59.2% is arable, 6.5% is used for permanent crops, and 4.6% is for meadows and pastures (FAO, 2015). However, urban and

peri-urban expansion has led to a reduction in overall cropland area, though crop intensification has increased significantly. In Bangladesh, the agriculture sector contributes around 12% to the GDP and serves as the cornerstone of the economy, playing a crucial role in poverty reduction, ensuring food security, and employing 41% of the total labor force (World Bank, 2021). Irrigation, a vital component, has been instrumental in advancing Bangladesh's agriculture and promoting food security, poverty alleviation, and crop diversification. While surface water was traditionally the primary irrigation source, many rivers now dry out, leading to a gradual decline in surface water irrigation. Groundwater has become the primary source, meeting over 80% of the agricultural water demand, with irrigation land area increasing from 7,056 to 7,685 thousand hectares between 2011 and 2018 (BBS, 2021). The relationship between irrigation by different equipment and sources of irrigation water used in Bangladesh illustrated in Figure 1.

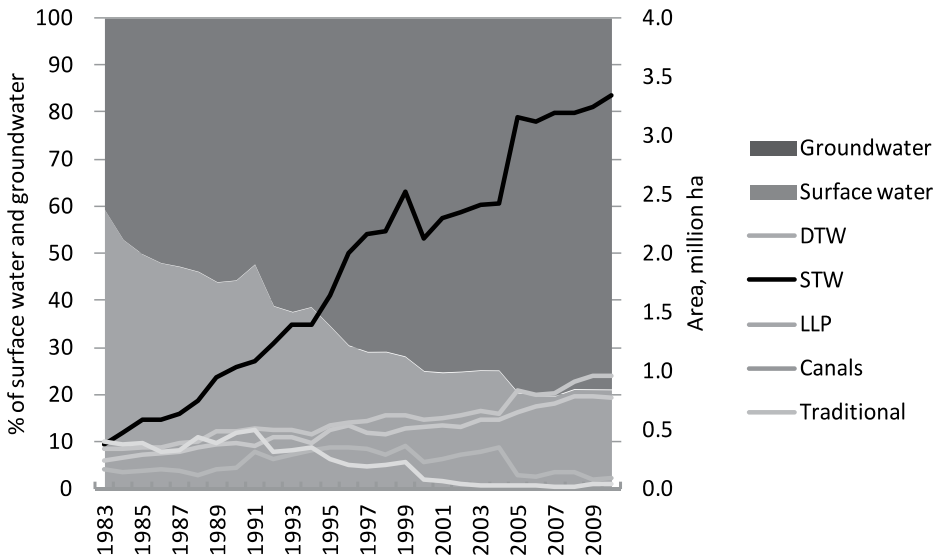

Figure 1. Irrigation by different equipment and sources of water [adopted from CSIRO (2014)]

Challenges faced in traditional irrigation systems

Irrigation involves artificially supplying water to plants using various man-made structures like pipes, sprinklers, and channels. There are two main types: gravity-powered and pressure-driven irrigation. Surface irrigation methods including basin, bordered, uncontrolled flooding, and furrows are commonly used, along with sprinkler and drip/trickle irrigation. Each method has an advantages and disadvantages, depending on factors like soil type, topography, crop type, climate, and water availability and quality (Rai et al., 2017). Traditional irrigation systems like basin, bordered, uncontrolled flooding, and furrow irrigation have drawbacks such as waterlogging and uneven water distribution, requiring significant human and cattle labor and resulting in lower efficiency. As for example, furrow irrigation is associated with inefficiencies such as deep percolation, runoff, and leading to significant water loss (Islam et al., 2024; Setu et al., 2023). The poor performance of traditional surface irrigation systems often leads to crop wilting, with potential water use extending beyond the irrigated area (Teshome et al., 2018). They (2018) also noted that traditional surface irrigation channels suffer from low conveyance efficiency due to high losses and long paths.

Global renewable energy scenarios

Renewable energy is derived from natural sources like sunlight and wind, which replenish more quickly than they are used. In contrast, fossil fuels such as coal, oil, and gas are finite resources that take hundreds of millions of years to form. The combustion of fossil fuels for energy generation releases harmful greenhouse gases (GHGs), whereas generating renewable energy results in significantly lower emissions. Shifting from fossil fuels, which contribute significantly to emissions, to renewable energy is crucial for addressing the climate crisis. Previously, nuclear energy and traditional biomass (like fuelwood, charcoal, and organic waste) were considered renewable energy sources. However, the traditional use of biomass contributes to household air pollution, and nuclear energy and its waste produce radioactivity. Consequently, they are now excluded from modern renewable energy sources. Renewable energy currently makes up approximately 14.4% of global energy consumption, including 9.9% of heat energy, 3.7% of fuel, and 30% of global electricity generation (World Energy, 2023). Fossil fuels account for the majority of global electricity production (61%) followed by renewable energy (30%), and nuclear power (9%). Among renewable energy sources, hydropower comprises 15.1%, wind power 7.2%, solar power 4.9%, and bioenergy and geothermal power 2.7% (World Energy, 2023).

Renewable energy status in Bangladesh

Renewable energy generation in Bangladesh currently stands at approximately 1,200 MW, as depicted in Table 1. Solar energy constitutes the predominant share at 80.6%, with hydropower following at 19%. Other renewable sources contribute minimally and offer limited potential for future expansion. The government of Bangladesh is actively advancing renewable energy production. In 2014, the Sustainable and Renewable Energy Development Authority (SREDA) was established to foster renewable energy adoption and enhance energy efficiency. Despite the Renewable Energy Policy of 2008 aiming for 5% and 10% of total electricity to be generated from renewable sources by 2015 and 2020, progress toward these targets has been lacking. The Power System Master Plan 2016 has set a revised goal of 10% (4000 MW) by 2041. Currently, renewable sources contribute 4.6% of the power supply, with solar energy accounting for 80% of this share. To meet the Sustainable Development Goal (SDG) 7 target, which is overseen by Sreda in 2024, the renewable energy output must escalate to 10% (2000 MW) by 2030. Presently, renewable sources generate 1,200 MW of electricity, a figure projected to surpass 5,000 MW by 2030.

Table 1. Status of power by different renewable sources in Bangladesh

Energy source	Off grid (MW)	On-grid (MW)	Total (MW)	Share (%)
Solar	366.79	601.69	968.48	80.54
Wind	2.00	0.90	2.90	0.24
Hydropower	-	230.00	230.00	19.13
Biogas to electricity	0.69	-	0.69	0.06
Biomass to electricity	0.40	-	0.40	0.03
Total	369.16	825.48	1202.47	100.00

Source: SREDA (2024)

The government has recently initiated a program to generate 500 MW of solar-based electricity for the national grid, as shown in Table 2. The private sector has been identified as an essential partner in this program. The main components of this initiative include 150 MW for solar irrigation, 28 MW for solar mini-grids, 135 MW for a solar park, 20 MW for solar rooftops, and 160 MW for the electrification of social sectors (such as health centers, educational institutions, religious establishments, and railway stations) (MPEMR, 2020).

Table 2. Solar power installations in Bangladesh

Type of installation	Numbers	Power (MWp)*
Solar irrigation	2,973	55.1
Solar drinking water	116	0.1
Solar park	50	135.0
Solar rooftop	238	77.5
Solar rooftop (Net metering)	2,053	85.5
Solar minigrid	28	5.8
Solar nanogrid	2	0.001
Solar charging station	14	0.3
Solar home system	6,037,689	263.6
Solar street light	297,691	17.1
Total	6,340,854	499.165

* Megawatt-peak

Source: SREDA (2024)

Solar energy serves as an ideal, eco-friendly power source in Bangladesh, applicable for various purposes such as solar irrigation pump (SIP), solar drying, running small agricultural machinery, and powering solar home systems (Hossain, 2023). Presently, Bangladesh operates around 6,000 solar pumps, totaling 176.38 MW in capacity. SIP covers an area of 16,524 hectares (0.31%) (Hossain, 2023). Notably, governmental bodies have installed 3,627 SIPs with a combined capacity of 57.9 MWp, detailed in Table 3. IDCOL offers financial and technical assistance to promote solar irrigation pumps. Multiple governmental organizations like BARI, BADC, DAE, BARD, RDA, REB, DU, BUET, and BAU are actively involved in expanding the utilization of solar irrigation pumps. Furthermore, enterprises and NGOs including Rahimafrooz, Electro Solar, Super Star, Gazi, Nusra, Grameen Shakti and RDF are engaged in marketing and supporting the operation of these pumps and solar panels. The Government of Bangladesh (GoB) has enacted the Grid Integration Guidelines-2020 (Net Metering) to facilitate the sale and purchase of electricity generated by SIPs to/from BREB.

Table 3. Organization wise installed solar irrigation pump

Name of organization	No. of SIP	Power (MWp)
BADC	682	5.8
BMDA	792	4.4
IDCOL	1619	44.9
BRRI	9	0.0
BARI	37	0.1
BREB	349	2.3
BARD	9	0.1
RDA	25	0.3
DAE	105	0.1
Total	3627	58.0

Source: SREDA (2024)

The main objective of this study is to analyze the prospect of solar powered drip irrigation in the context of Bangladesh. The specific objectives of the study are:

i. To analyze the various design components of a solar power-based drip irrigation system; and
ii. To calculate the cost and return of investment based on secondary data.

Methodology

This study was conducted on the basis of primary as well as secondary information. Primary data are collected through direct visit to institutions, face to face conversation and key informant interviews (KIIs) with relevant people. The pertinent secondary information was collected from relevant articles, relevant literature review, different position papers, latest annual reports and surveys published by different organizations, and action plans of the government. One case study reported in (Hossain et al., 2022) was presented for analyzing benefit cost ratio of about 1 ha land for tomato, brinjal, watermelon and chili cultivation using solar powered drip irrigation in Patuakhali, Barguna, and Bhola districts of Bangladesh.

Results and discussions

Solar powered drip irrigation as sustainable solution

Farmers primarily utilize diesel and electricity-powered pumps for groundwater extraction in irrigation. Recent statistics indicate that out of 1.57 million irrigation pumps operational in the country, 80% rely on diesel while the remaining 20% are electricity-operated (Islam & Hossain, 2022). Due to the predominant use of diesel-run pumps, Bangladesh finds itself importing approximately 1.06 million tons of diesel annually (BADC, 2020). To mitigate this dependency, the government subsidizes diesel for irrigation, incurring an annual expenditure of around Tk 23 thousand crore, thus adding strain to Bangladesh's economy. Introducing solar irrigation pumps (SIPs) could alleviate this burden, potentially saving approximately $3.2 million annually by substituting diesel with renewable solar energy (BADC, 2020). Bangladesh contends with an energy shortfall of about 800 MW (BBS, 2022), particularly during the Boro season, the peak irrigation period. Despite having a total electricity generation capacity of approximately 22,482 MW in 2021-22, fuel supply constraints limited maximum generation to 14,782 MW (BBS, 2022). Natural gas and oil are the primary sources of electricity, contributing 61.4% and 24.7% of the nation's total power, respectively (Islam & Hossain, 2022). However, these sources are deemed unsustainable and vulnerable due to dwindling reserves of natural gas and fluctuations in oil prices on the global market. Consequently, the government aims to generate around 20% of its total power from renewable sources by 2030 (BPDB, 2020). Additionally, Bangladesh targets generating a minimum of 150 MW of electricity from SIPs by 2020 (SREDA, 2020). This goal seems achievable given the average daily bright sunshine hours ranging from 6 to 9, as depicted in Fig. 2 which is a crucial factor for the viability of SIPs (Rofiqul Islam et al., 2008; Shariar et al., 2011). Furthermore, the country experiences an average solar radiation availability ranging between 4 and 6.5 kW/m^2/day (Hossain et al., 2015; Islam & Hossain, 2022).

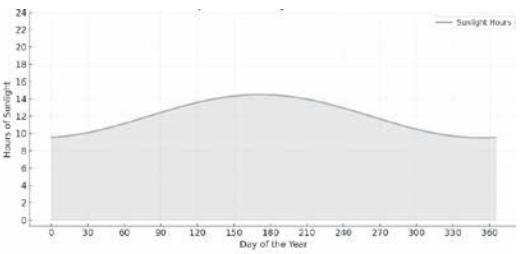

Figure 2. Daily sunshine hour over the year in Bangladesh

Drip/trickle irrigation

Drip irrigation by delivering water directly to the plant roots, reduces water usage compared to conventional irrigation techniques for the same crop. This system employs a series of pipes and valves equipped with drippers or emitters strategically placed at the root zone of each plant. Water is distributed across the field through filters, driplines, and emitters, as depicted in Figure 3.

Figure 3. Block diagram of drip irrigation system supplying source to field

Drip irrigation is renowned for its remarkable water efficiency, which is calculated by the ratio of absorbed water to total water utilized. Previous research indicates that drip irrigation can achieve over 95% water efficiency, whereas flood irrigation is typically only 40-50% efficient (Narayanamoorthy, 2004; Van der Kooij et al., 2013). It can curtail water wastage by 30-50% compared to surface irrigation. In certain instances, particularly in India, it has slashed water wastage by 30-60% while boosting crop yields by 20-50% (Doan, 2017; Van der Kooij et al., 2013). Despite being well-documented and validated for their effectiveness, drip irrigation

systems are not as widely embraced as more conventional methods like flood and surface irrigation. This is partly due to the initial investment costs, despite the fact that the return on investment is typically achieved within a reasonable timeframe. For instance, the return on investment in drip irrigation is estimated to occur within the first year for crops such as bananas and grapes in India (Narayanamoorthy, 2004).

Basic components and principles of solar-powered drip irrigation

Solar-powered drip irrigation relies on several key elements, including photovoltaic (PV) or solar panels, a controller or inverter, a pump/motor, a water reservoir, and drip irrigation components like filters, driplines, and emitters. The interconnected PV or solar panels harness sunlight, converting it into direct current (DC) electricity. This energy is then directed to the solar water pump via a controller. In certain setups, an inverter takes the place of the controller to accommodate solar pumps utilizing alternating current (AC). Figure 4 illustrates a standard configuration of solar-powered drip irrigation.

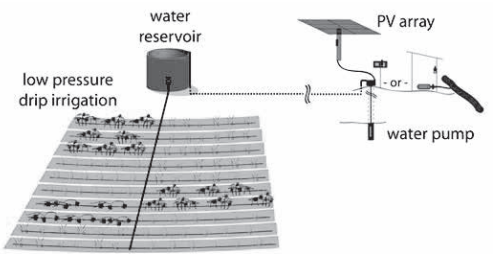

Figure 4. Solar powered drip irrigation system for vegetable production [Adopted from Ahmed & Fernando (2017)]

The pump capacity and solar panels' number will depend on irrigation requirement of crops and all the head losses of the system. The cost of solar panel is a vital part of the total investment for a typical drip irrigation project, covering about 40-45% of the total cost.

Solar powered drip irrigation system design

This section outlines the entirety of the design process for a solar-powered drip irrigation system. Key components of the design include determining crop water needs, planning the layout of the drip irrigation system, designing the pumping system, and configuring the photovoltaic (PV) system.

Calculation of water requirement for the system

Designing an efficient drip irrigation system requires knowledge of the peak crop water requirement. This requirement can be determined by estimating crop evapotranspiration (ET). The water needs of crops depend on factors such as the type of plant, the surface area covered by the plant, and the rate of evapotranspiration. The water requirement for each plant is calculated, and the total water requirement for the entire area is estimated based on the per-plant water requirement and the total number of plants. The highest crop water requirement during any growing season is used for system design. The daily water requirement for fully grown plants can be calculated as follows:

$$V = ET_o \times K_c \times A \times W_p \quad (1)$$

where is volume of water required (L), is reference crop evapotranspiration ($mmday^{-1}$), is crop coefficient, is area occupied by a plant (row to row spacing plant to plant spacing) (m^2), and is wetting fraction (varies from 0.2 for wide spaced crops and 1.0 for close spaced crops).

Crop evapotranspiration (ET_0) is influenced by meteorological factors as well as management and environmental conditions (Allen et al., 1998). The FAO Penman-Monteith method to calculate crop evapotranspiration. Initially, is calculated for various months of the year, reflecting the standard growing conditions of the crop. The FAO Penman-Monteith formula is presented as follows:

$$ET_o = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (2)$$

where R_n is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m^{-2} day^{-1}), T is mean daily air temperature at 2 m height (°C), U_2 is wind speed at 2 m height ($m\ s^{-1}$), e_s is saturation vapor pressure (kPa), e_a is actual vapor pressure (kPa), ($e_s - e_a$) is saturation vapor pressure deficit (kPa), Δ is slope of vapor

pressure curve (kPa°C^{-1}), and y is psychrometric constant (kPa°C^{-1}).

The net volume of water, V_n to be applied as follows:

$$V_n = V - R_e \times A \times W_p \qquad (3)$$

where R_e is effective rainfall (mm).

Daily operating hours, T of the system can be calculated using following equation.

$$T = \frac{V_n}{N_e \times N_p \times q} \qquad (4)$$

where N_e is number of emitters per plant, N_p is number of plants, and q is emitter discharge (Lh^{-1}).

Pumping system design

The Hazen-Williams equation, as proposed by Miller (1990), can be utilized to calculate head losses in the pipe network of a drip irrigation system. The head loss equation is expressed as follows:

$$H_L = \frac{10.67 Q^{1.852} L}{C^{1.852} d^{4.8704}} \qquad (5)$$

where H_L is head loss (m), L is length of pipe (m), Q is volumetric flow rate (m3/s), C is pipe roughness coefficient, and d is pipe inside diameter (m). When selecting an appropriate pump, factors such as the volume of water to be pumped, the required pressure, pressure losses in all components, and the efficiencies of subcomponents like the motor and pump must be considered. The size of the pump for a solar-powered drip irrigation system in a specific area depends on the energy needed to operate the drip system at a specific pressure (Pande et al., 2003).

If motor and pump efficiencies are known, the power required for the motor to run pump is calculated by the formula given in Eq. (6).

$$P = \frac{Q \times H}{3960 \times motor\ and\ pump\ efficiency} \qquad (6)$$

where is motor horsepower, is discharge (GPM), and is pumping head (feet).

Photovoltaics (PV) design

Given the high initial cost, a flawless design and installation are crucial for ensuring a PV system is cost-effective (Cuadros et al., 2004; Gajic et al., 2013). Cuadros et al. (2004) designed a PV system to power a drip irrigation system for an olive orchard. Based on these studies, a PV system can be designed. According to Alamsyah et al. (2003), the size of the PV array is determined by Eq. (7).

$$A_{PV} = \frac{E_H}{H_{avg} \eta_{pv} \eta_l T_{CF}} \qquad (7)$$

where is the required area of PV array in m^2, is the required hydraulic energy including pumping system losses (kWhday $^{-1}$), is the average daily global irradiation (kWhm^{-2} day^{-1}), is the efficiency of PV panel (%), is the efficiency of inverter (%), and is the temperature correction factor. Finally, the peak power of PV generator can be found using following Eq. (8).

$$P_{PV} = A_{pv} I_p \eta_{pv} \qquad (8)$$

where is PV peak power (W) and is peak solar irradiance. The selection of photovoltaic panels is based on the power requirement. Multiple PV panels can be used, with series-parallel connections to meet the voltage and current specifications of the inverter.

Optimization of solar energy

Proper calculation is needed to find out optimum tilt angle for solar panel since the position of the sun varies throughout the day, month and location on earth. The tilt angle optimization helps to maximize the solar panel output by realizing different positions of the sun. There are costly and sophisticated maximum power point tracking devices which help to position solar panels automatically based on sun position. Since cost is an important factor for investment, available optimum tilt angle data in Bangladesh for manual setting may be helpful. The following optimum tilt angles may be observed across the country at an average for different months of the year in Bangladesh as shown in Figure 5 (Ahmed & Fernando, 2017).

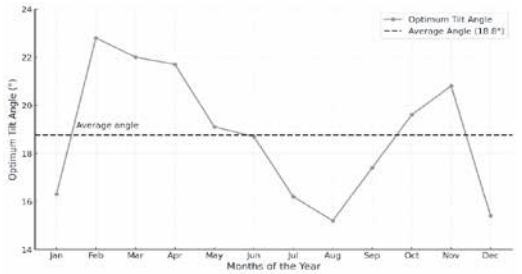

Figure 5. Variation of optimum tilt angle around the year in Bangladesh

On the other hand, dust on solar panels isn't so good. It turns into hardened mud through prolonged moisture exposure is even worse. Both of these situations impede sunlight from reaching solar cell. Simple spray and light brushing are helpful to keep panel clean. Moreover, the amount of sunlight that reaches solar panels directly affect its energy production. It is important to regularly trim trees and shrubs around panels to prevent shading that can help ensure maximum time at full sun exposure for optimal performance.

Financial analysis

A solar pump comprised of 1.3 kW photovoltaic panel and 0.9 kW centrifugal pump with 180 L/min discharge capacity is considered for economic analysis. The command area of the solar pump is about 1.6 ha. The service life of solar panel and DC motor is assumed 20 years and 5 years, respectively. An economic analysis of such considerations can be found in Hossain et al. (2022).

Table 4. Investment cost components of solar pump

Power	Cost of panel ($)	Cost of pump with DC motor ($)	Installation cost ($)	Fittings cost ($)	Total cost ($)
Panel:1300 Wp Motor: 910 W	514.80	270.00	36.00	120.00	940.80

The total investment cost is about $940.80. Other costs such as fixed cost, variable cost, operating cost, and life cycle cost (LCC) are calculated about $167.90, $155.70, $323.60, and $1588.00, respectively. Total cultivation cost which includes fixed cost, input cost, and irrigation cost is calculated for tomato, brinjal, watermelon and chili using drip irrigation by solar pump. The input cost includes land preparation cost, fertilizer cost, seed cost, insecticide and pesticide cost, and labor cost. On the other hand, irrigation costs include pipes, tank and other fitting.

Table 5. Costs of different vegetables cultivation using solar powered drip irrigation

Crop	Fixed cost ($/ha)	Input cost ($/ha)	Irrigation cost ($/ha)	Total variable cost ($/ha)	Total cultivation cost ($/ha)
Tomato	73.99	1142.78	961.61	2104.39	2178.38
Brinjal		3890.24	1215.66	5105.90	5179.89
Watermelon		1184.98	711.36	1896.34	1970.32
Chilli		3942.52	1130.98	5073.49	5147.48

The gross return and benefit cost ratio (BCR) of different vegetables can be calculated as follows in Table 6.

Table 6. Gross return of different vegetables cultivation using solar powered drip irrigation

Crop	Yield (t/ha)	Selling price ($/t)	Total price ($/ha)	Gross return ($/ha) = Total price - Total cultivation cost	Benefit cost ratio (BCR)
Tomato	44.29	122.04	5405.15	3226.77	1.48
Brinjal	47.71	300.00	14313	9133.11	1.76
Watermelon	44.69	148.44	6633.78	4663.46	2.37
Chilli	12.50	960.00	12000	6852.52	1.33

In case of benefit cost ratio for watermelon gives highest BCR than other crops. It could be stated that the selection of suitable crops with solar powered drip irrigation is more important than conventional practice.

Future implications

Solar-powered drip irrigation system has the potential to long-term reduction of water and energy consumption in irrigation sector. Furthermore, this system allows farming in water scarce areas and absence of electricity, thereby enhancing sustainability. However, cost involvement should be studied for installation costs, pump costs, and irrigation costs due to the large variability depending on location. In addition, subsidies from the government may play a great role in the economic viability of solar-powered drip irrigation systems for rural community in Bangladesh. Business model approach having share both government and owner can be a sustainable solution in the long run. There is still substantial work needed to ensure the accuracy and validity of this system using statistical analysis, probability, and mathematical modeling. A complete sensitivity analysis of each variable is necessary to the decision making and ability for variations in installation of the system. Extensive experimental trials under real-world conditions are also necessary to confirm performance, crop yield benefits, and resource use efficiency. Addressing these economic, technical, and research gaps will be crucial for scaling solar-powered drip irrigation as a sustainable solution for Bangladesh's agricultural sector.

Conclusion

This study delves into the fusion of drip irrigation and photovoltaic systems in the context of Bangladesh. Solar-powered drip irrigation is recognized as a viable method for dispensing water in orchards and high-value crops. It holds promises for enhancing yield, water efficiency, and productivity, while simultaneously cutting down on expenses and energy usage. Furthermore, it ensures stability in energy provision and environmental conservation, contributing to the long-standing goal of reducing water and energy consumption in irrigation. Additionally, it facilitates agricultural activities in regions plagued by water scarcity and lacking electricity, often characteristic of developing nations, thereby fostering sustainability. The system design is customized to match peak water requirements and is applicable to various crops. The economic analysis was found acceptable using solar powered drip irrigation system for vegetable cultivation in Bangladesh. There exists a natural synergy between crop water needs and solar energy availability which can reliably meet crop water demands throughout the year by leveraging available sunlight hours.

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Impact of conserving river water by rubber dam in Barind area of Bangladesh using mathematical models

Md. Tarikul Islam[1*], Chowdhury Sarwar Jahan[2], Khondaker Emamul Haque[2], Md. Amirul Islam[1], Md. Atiqur Rahman[1]

[1] Institute of Water Modelling (IWM), Dhaka, Bangladesh

[2] Department of Geology and Mining, University of Rajshahi, Bangladesh

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***Corresponding Email:**
mti@iwmbd.org

ABSTRACT

The drought-prone Barind area in northwest region of Bangladesh, is a water scarce area where annual average precipitation varies from 1,275 mm to 2,080 mm and irrigation depends mainly on groundwater due to limited availability of surface water in dry season. The availability of surface water is also very limited in this area. Due to groundwater abstraction at high rate and low recharge rate, groundwater is declining at an alarming rate in this area. Due to very limited water in the Mahananda river during dry season, only a small area adjacent the river is irrigated using river water by low lift pumps (LLPs) and most of the area is irrigated using groundwater. As an opportunity for enhancing the use of surface water for irrigation, it was planned to construct rubber dam on the Mahananda river for conserving additional water and use in irrigation. As a part of the feasibility study of this rubber dam, the study has been carried out for assessing river flow under different options, backwater effect and volume of water storage and the impact of groundwater. Here, the 1-D river flow model has been developed using MIKE-11 mathematical modelling software which comprises of rainfall-runoff and hydro-dynamic models. The main objective of the study was to investigate impact rubber dam on groundwater, agriculture and environment in surrounding area of Barind area. The study shows that due to river water conservation, surrounding area is getting benefits for agriculture, fisheries, environment, social and groundwater recharge. As a result of raised ponding water level (12.50 mPWD) in the river, the groundwater loss from the aquifer to river will be less and the recharge of aquifer will be more. Due to availability of additional conserved water, it will be possible to irrigate about 7,400 ha land instead of present 3,245 ha, and also helps to maintain the minimum water level at 12.50 mPWD in place of 11.00 mPWD. So, rubber dam is a better alternative for enhancing groundwater recharge at a large scale and reducing the declining trend as well as protecting the environment of Barind area.

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Introduction

Globally, the shortage of water even for drinking and domestic purposes have identified as the principal challenge for livelihood of inhabitants. The recurrent shortage of water has posed several impacts on economic, social, environmental and hygienic, etc. (Takara & Ikebuchi, 1997; Sajjan et al., 2002). Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. More than half the world's wetlands have disappeared. Agriculture consumes more water than any other source and wastes much of that through inefficiencies. Climate change is altering patterns of weather and water around the world, causing shortages and droughts in some areas and floods in others. So, time has come to conserve rain/surface water or harvesting rain water. For example, the construction of rubber dams on Luoyang River basin in China has changed the regional groundwater flow system tremendously after its construction in 2000. The main replenishment of this dam to groundwater has changed from vertical seepage to lateral one (Dong et al., 2014).

In Bangladesh, farmers primarily depend on groundwater for irrigation purposes during the dry period due to low flow in the perennial rivers and lack of storage facility (Krupnik et al., 2017). The contribution of groundwater to irrigation has increased from 41% in 1982-83 to 77% in 2006-07, and surface water has declined accordingly (Dey et al., 2017; Shahid, 2008; Shahid & Behrawan, 2008).

Seasonal variations produce irregularities in surface water availability. Additionally, 95% of the surface water in the river system comes from sources outside of the nation (Ahmad et al., 2001) resulting uncertainty of surface water availability. As an example, in 1990, surface water availability varied from 3,710 Mm3 in the dry months to 111,250 Mm3 in the rainy months (BBS, 2013). As a result, seasonal water shortages occur based on how long the monsoon lasts. The primary sources of drinking water, hand tubewells (HTWs) and dug wells, are challenged due to thousands of deep tubewells (DTWs) which are mostly installed and maintained by the Barind Multipurpose Development Authority (BMDA) and shallow tubewells (STWs) operated by private owners for agricultural purposes over the dry months. The availability of surface water in this area, especially during dry season is very limited.

Moreover, the Barind area has irrigation system mostly depend on groundwater due to its limited surface water source. Previous studies show that groundwater level (GWL) in the study area has declined substantially during last couple of decades causing threat to the sustainability of its use for irrigation. The share of groundwater to total irrigated area is 77% in 2007-08 (BBS, 2009), and its sustainability became in risk in coming decades (Karim et al., 1990; Simonovic, 1997) in terms of quantity and quality in major parts of country, and northwestern part in particular. Aziz et al. (2015) noted that groundwater is depleting all over the Barind area and groundwater recharge is coming less in comparison to its overexploitation due to rising demand for agriculture over the past decades (Adham et al., 2010; Islam et al., 2009, 2010, 2014, 2015; IWM 2023; Shahid 2011). During dry season, most of the ponds and *Kharies* (canals) have become derelict creating shortage of surface water in both domestic and livestock populations (IWM, 2006, 2012). The operation of thousands of DTWs of the BMDA – only organization responsible for irrigation water supply in the area, and STWs of private ownership for irrigation during dry season creates problems for operation of HTWs and dug wells, which are the main source of drinking water. Thus, the continuous lowering trend of GWL indicates non-sustainable situation with its declining trend over decades.

The elevation of the Barind area varies from 9.00 mPWD in Naogaon to 47.0 mPWD in the Nachole-Niamatpur area (IWM, 2006). Figure 1 illustrates the digital elevation map (DEM) of Barind area, and its central part is uneven and comparatively high. The rainfall in this area is comparatively lower than that of the country average amount, yearly rainfall varies from 1,000 mm to 1,400 mm, and the average rainfall from November to April only fluctuates from 12 mm to 20 mm (IWM, 2012).

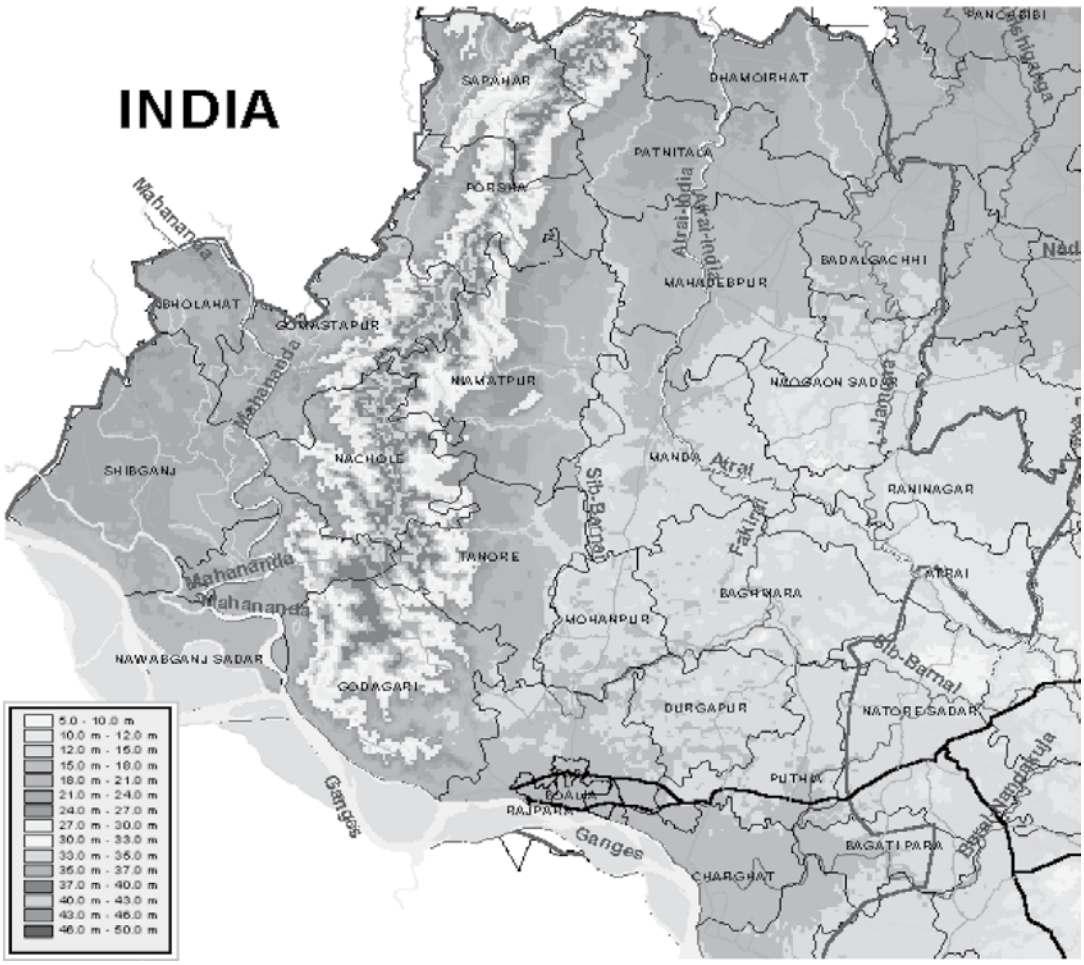

Figure 1. Location map of Barind area along with digital elevation map.

The major rivers which flow in and around the Barind area are the Ganges, Mahananda, Atrai, Sib-Barnai, Punarbhaba and some others are of perennial nature. The Mahananda is the trans-boundary river which originates from two tributaries namely the Mahananda – originate from West Bengal (India), and entering into Bholahat Upazila of Chapai Nawabganj district, and the Punarbhaba originating from Panchagarh district, and near Dinajpur, it enters into West Bengal (India). Finally, the Mahananda and Punarbhaba rivers meet at Mokarrampur of Chapai Nawabganj district and flows as the Mahananda and ultimately falls into the Ganges at Godagari Upazila. Total catchment area of the river before joining the Ganges is about 12,700 km^2, out of which about 5,120 km^2 is located in Bangladesh and rest of is within India. The low-lying floodplain area of the Mahananda river catchment is located mostly in Chapai Nawabganj and partly in Godagari Upazila of Rajshahi district with an area of around 1,420 km^2 which is mostly prone to flood, and likely has potential for irrigation from the available Mahananda river water. The river-aquifer interaction study shows that, groundwater outflow from Barind area aquifer to the Ganges river is around 0.29 Mm^3/km varies from 0.20 Mm^3 to 0.45 Mm^3, and remarked that the river maintains some reasonable surface water level due to out flow of groundwater from aquifer (Islam, 2009). The Mahananda, Punarbhaba and Pagla river system have shown in Figure 2.

Before starting of groundwater-based irrigation project in late nineties of last century in the Barind area, only rainfed *Aman* rice was cultivated, but at present different types of crops including fruits are grown round the year due to available groundwater-based irrigation initiatives of BMDA since 1990 (Asaduzzaman, 2023). As a result, the area has turned into granaries and its socio-economic condition of the neglected farmers has changed (ibid.). Nearly 43 LLPs have operated for lifting surface water for irrigation from Mahananda (from Mokarrampur to Godagari), but the flow is very limited during dry season and decreasing day by day. At present, the irrigation area coverage in dry season covers around 4,200 ha of land on both bank of river Mahananda (IWM, 2015), where out of the total 43 LLPs, 36 LLP schemes are located at upstream of the rubber dam, irrigates about 3,250 ha of land on both banks of the river.

Before the construction of rubber dam, the dry season flow in Mahananda river is declining and during the last five years, 80% dependable dry season flow is found to vary in the range of 1.50 to 3.00 m^3/sec (IWM, 2015). On the other hand, the GWL is declining day by day due to overexploitation for irrigation purposes and insufficient recharge due to very low permeability. It is very important to conserve the surface water in the river for irrigation purposes as well as for improving the groundwater situation. So, for meeting the increasing demand and reducing the lowering trend of GWL, it is very much urgent to frame effective measure for use of surface water for enhancing ground water supplies.

This paper highlights the impact of conserving surface water by means of rubber dam for improving the groundwater situation in Barind area. It also highlights the benefit in agriculture and socio-environment condition of the area. The main objective is to see the impact of rubber dam for enhancing groundwater at large scale.

Figure 2. Mahananda, Punarbhaba and Pagla river system

Approach and methodology

In present study, the necessary data i.e. river water level and flow, river cross sections and topographic data, alignment of bank line, suspended sediment, GWL, rainfall etc. have been collected both from primary as well as secondary sources, mainly from Bangladesh Water Development Board (BWDB), Bangladesh Meteorological Department (BMD), Water Resources Planning Organization (WARPO), Barind Multipurpose Development Authority (BMDA), Department of Agricultural Extension (DAE) and Institute of Water Modelling (IWM). After processing and quality checking of the collected data, 1-D river flow model has developed for assessing the water availability as well as to investigate the impact of backwater afflux, and 2-D model for investigating morphological stability. The social and environmental impact has also investigated to observe the overall impact of rubber dam construction on the river Mahananda. The schematic diagram of the approach & methodology followed in the study is shown in Figure 3.

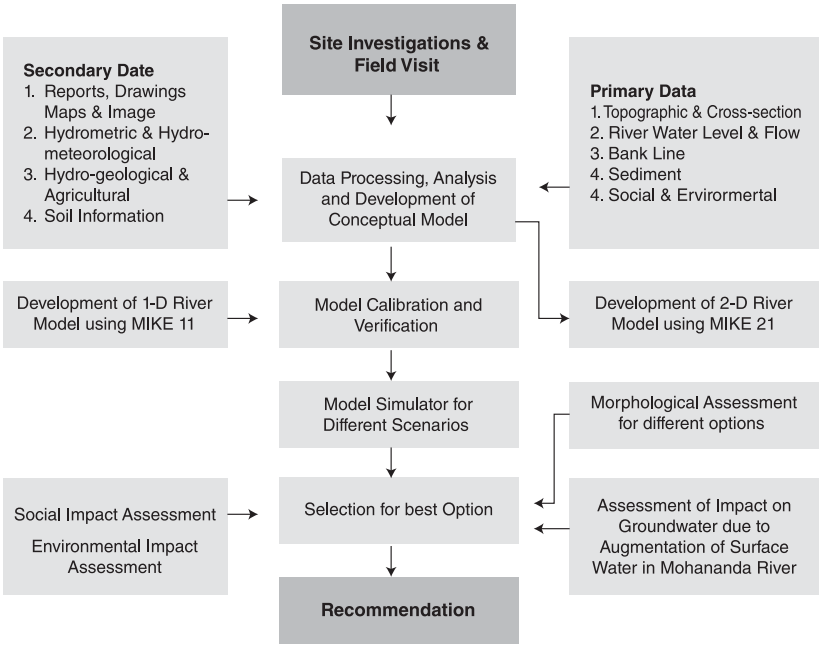

Figure 3. Schematic diagram of study approach

1-D River Flow Model

In present study, the river flow model has been developed for assessing river flow under different options, assessment of backwater effect and assessing the possible volume water storage by the rubber dam. Another objective of this model was to generate boundaries for the 2-D morphological model. The 1-D river flow model has developed using MIKE-11 mathematical modelling software of DHI. This model comprises of rainfall-runoff and hydro-dynamic models. In present study, the hydro-dynamic model covered the Ganges river from Panka Narayanpur to Hardinge bridge, the Mahananda river from Rohanpur to confluence with the Ganges and Pagla river from Binodpur up to confluence of the river Mahananda, and rivers included in the model has shown in Figure 4. The model has used four boundaries, out of which

three are at upstream boundary and one is at downstream boundary. The upstream boundaries have been defined by time series river flow or discharge data and the downstream boundary has been defined by time series water level data. The discharge time series has generated using rating curves, and details of the boundaries has given in Table 1.

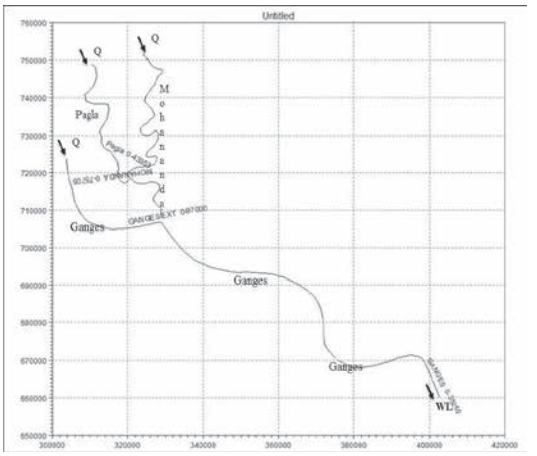

Figure 4. Schematized river system of the 1-D River Flow Model

Table 1. List of boundary stations of the rivers in the study area

Sl. No.	River name	Chainage (m)	Station/location	Source
1	Mahananda	0.00	Near border	Generated discharge of Mokarrampur
2	Pagla	0.00	Near Binodpur	Continuous flow=0.50 m3/sec
3	The Ganges	0.00	Near border (Panka Narayanpur)	Generated discharge of H. Bridge used with 5% reduction and 2.5 hours lead time.
4	The Ganges	35,250.00	Hardinge Bridge	WL, BWDB

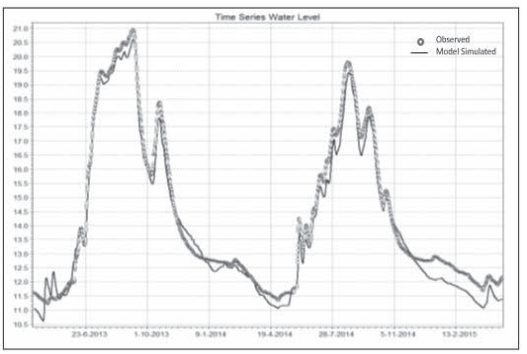

Figure 5. Comparison against WL at Chapai Nawabganj on the river Mahananda

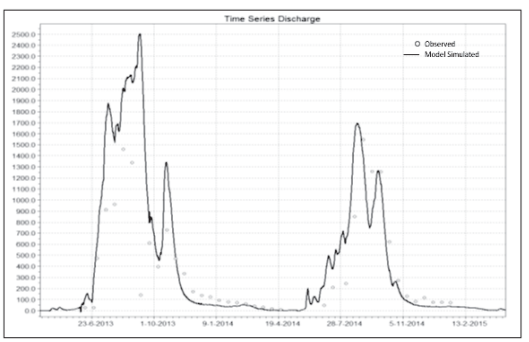

Figure 6. Comparison against discharge at Chapai Nawabganj on the river Mahananda

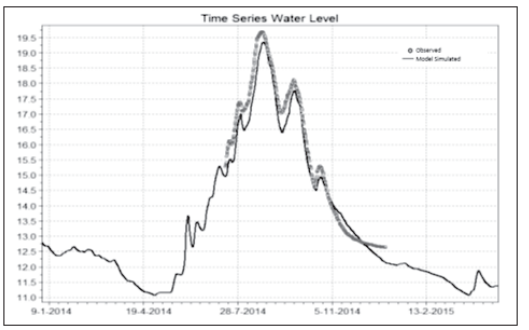

Figure 7. Comparison against WL at Char Mohonpur on Mahananda

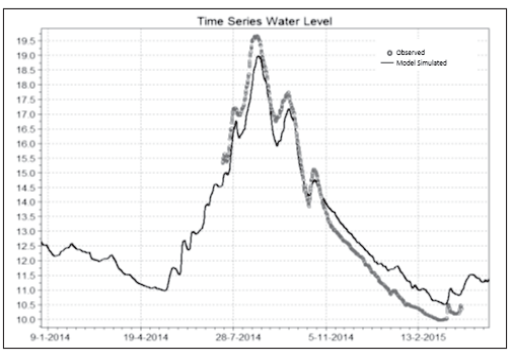

Figure 8. Comparison against WL at Sultanganj on the river Mohananda

The model has been calibrated against the river water level and river-flow or discharge data at several Chapai Nawabganj, Mohonpur and Sultanganj on the Mahananda river. Comparison plots of both water level and discharge are shown in Figures 5-8. From calibration plots it appears that matching model simulated result with the observed data is quite good in both the cases of water level as well as discharge. So, in all cases of calibration against water level and discharge is quite satisfactory both at Chapai Nawabganj and Sultanganj.

Application of the developed model

For assessing the opportunity of surface water irrigation by conserving water through construction of a rubber dam on Mahananda river and necessary river dredging, several options were developed. During the development of the options, emphasis was given to determine the viability of irrigation expansion under each option, followed by impact evaluation on options and other related issues. Total four options were developed for investigating the impact using the model which are:

i. **Option-0:** Under this option, the model was simulated for the design hydrological year 2010-2011 with no intervention and considering the abstraction for of present 43 LLPs.

i. **Option-1:** Under this option, the model was simulated for the design hydrological year 2010-2011 with Rubber Dam and considering the abstraction of present and proposed LLPs but no dredging.

i. **Option-2:** Under this option, the model was simulated for the design hydrological year 2010-2011 with Rubber Dam and considering the abstraction of present and proposed LLPs with dredging of hump.

i. **Option-3:** Under this option, the model was simulated for the design hydrological year 2010-2011 with Rubber Dam and considering the abstraction of present and proposed LLPs with dredging of hump.

2-D morphological model

Two-dimensional model has been developed and applied to obtain a clear understanding of prevailing and probable hydro-morphological condition of the Mahananda river as well as the impact of the engineering intervention i.e. rubber dam and dredging. The model has been applied to assess the suitability of dredging, suitability of the location of the rubber dam, probable changes of the Mahananda river, bank erosion, etc. The model domain covers a major part of Mahananda river, a small part of Pagla river near the confluence of Pagla and Mahananda river and a part of the Ganges river including the confluence of Mahananda and the Ganges. Figure 9 shows the domain of the two-dimensional (2-D) model.

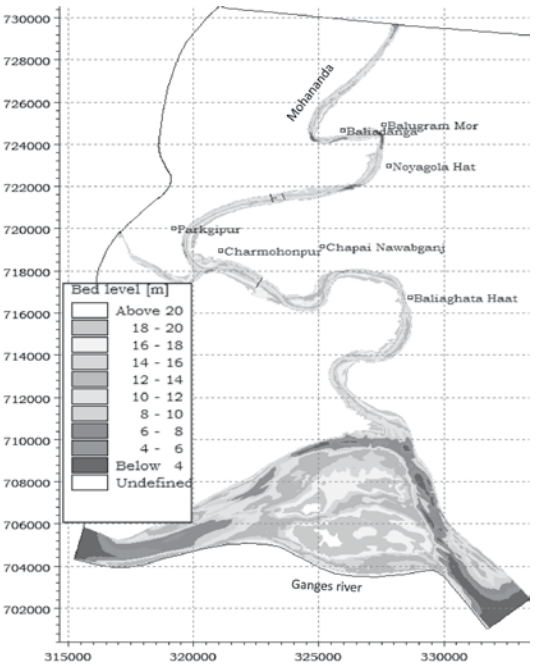

Figure 9. Domain of Two-dimensional model

Selection of design year

It is very important to select the design hydrological year for simulating the hypothetical options evaluation of any irrigation or structure related project. As the lowest water level or flow in the Mahananda river will dominate the irrigation coverage of the area dependable on it, the yearly lowest water level was considered for frequency analysis as well as to determine the design hydrological year.

Considering the yearly minimum water level for the duration of October 1980 - April 2015, frequency analysis has performed using the Gumble method (Al-Mashidani, 1978). The water level for different return periods, the matching year as well as the corresponding WL is shown in Table 2. Under the present study, five-year return period has been chosen for determining the representative design year. A review of the yearly minimum water level at Chapai Nawabganj station shows that in years such as 1989, 1993, 1995 and 2011, and minimum water level at Chapai Nawabganj reached very near to 1 in 5-year water level i.e. 11.65 mPWD. It has also been noticed that

there is a declining trend of minimum water level at Chapai Nawabganj, and in 2013, it is the historical minimum water level (Figure 10). Considering the statistical analysis as well as trend of minimum water level variation, 2010-11 has selected as the representative year for irrigation development. Impact of water abstraction on water level both at upstream and downstream has evaluated during the period of 2010-11.

Table 2. Water level at different return period

Return Period	WL mPWD	Year	Corresponding WL mPWD
2.00	12.12	1996	12.11
2.33	12.04	1983	12.05
5.00	11.65	1990	11.65
10.00	11.33	2010	11.38
25.00	10.93	2013	11.23

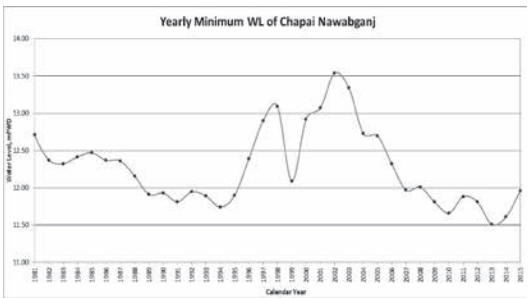

Figure 10. Yearly minimum water level of Mahananda river

Minimum allowable water at upstream of rubber dam

It is necessary to set a minimum allowable water level in Mahananda river below which no water should be abstracted for sustainability of the river to ensure fishery, aquatic environment and navigation. Review of the yearly minimum WL at Chapai Nawabganj shows that since 1980, it is observed that there is a decreasing trend of minimum WL at Chapai Nawabganj and it varies from 11.51mPWD to 13.54mPWD. Considering the variation of yearly minimum WL, river cross section, variation of the river thalweg, minimum fishery requirement etc. the minimum allowable WL at 12.50 mPWD was set below which no water should be abstracted from the river. The long profile of the Mahananda river is shown in Figure 11.

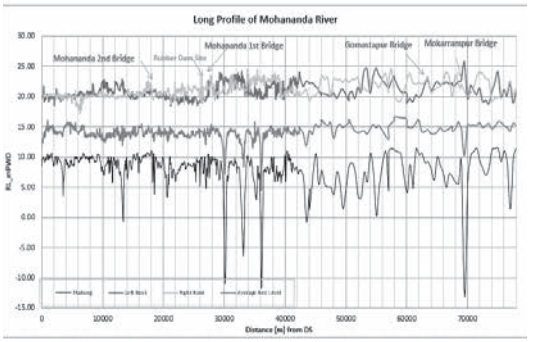

Figure 11. Long profile of Mahananda river

In Bangladesh, the agricultural sector is the primary user of water for rice production being the main economic activity, and 90% of all food grains produced in the country are produced from rice, which has farmed on 75% of all cultivated land (BADC, 2013). The *Aus*, *Aman*, and *Boro* are three elementary seasonal varieties of rice cultivated in Bangladesh, where *Aus* is pre-monsoon, rainfed, and generally yields little; *Boro* is irrigated and produces significant yields of rice from January to June; and *Aman* (a variety of rain feed rice variety) is cultivated during the monsoon season and yields less. Over past 20 years, *Boro* rice production has increased because of its relatively higher yield potential in comparison to *Aus* and *Aman* (Talukder et al., 2008). The widespread abstraction of groundwater has major factor in high rise in *Boro* production. Currently, irrigation occupies up to 80% of groundwater, of which *Boro* uses 73% mostly (Rahman & Ahmed, 2008). There are also adverse consequences of groundwater irrigation, among them rising costs of energy, declining GWLs in highly irrigated zones of the country, and resulting overall groundwater quality. Considering the crucial condition and its vulnerable role in the area, groundwater should have imperative to guarantee both its quantity and quality. Thus, it is critical to recognize the problems and difficulties associated with groundwater use and to assess the available alternatives for its environmentally friendly management.

Results and discussions

Due to construction of rubber dam at the downstream of 'Birsrestho Sahid Jahangir' road bridge, there will be numerous positive impacts on irrigation coverage at both side of the river, reducing the natural loss of groundwater, enhancing groundwater recharge and reducing declining trend of groundwater level, fisheries development and socio-environmental benefit. The impact of conserving water in the Mahananda on irrigation, groundwater and fisheries are described below:

Impact on irrigation coverage

The project envisages irrigation development by conserving water in the Mahananda river by constructing a rubber dam near downstream of *Bir Shirsto Jahagir Setu* (Bridge) and dredging of the Mahananda river. Different options have been considered and evaluated with the rubber dam. The dam and subsequent river dredging have intended to conserve river water during the dry season for agricultural and domestic use. The model has simulated for all the options and evaluated to assess impacts on different issues e.g. expansion of irrigation coverage, impact on downstream existing LLPs, back water effect, change of river morphology etc. After simulation and evaluation of the different options, option-2 has been identified as the most feasible option.

The hydrograph of river water level along with the irrigation coverage at present (Option-0) and project (Option-2) is shown in Figure 12. From the analysis of the figure, it is clear that at present condition, the minimum water level falls upto 11.0 mPWD but the minimum ponding water level will be around 12.50 mPWD due to construction of the dam. As a result of this, it will be possible to irrigate around 7,400 ha land during dry season where only 3,245 ha land is being irrigated presently using the river water.

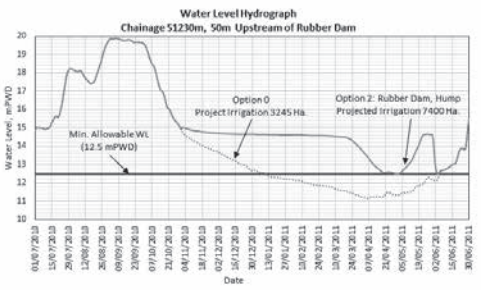

Figure 12. Water level hydrograph of Mahananda river

Impact on groundwater

The impact on groundwater due to rubber dam on the Mohananda river has been assessed based on comparison between river water level and existing GWL. To visualize the impact of rubber dam on groundwater, a comparison has been analyzed for river water level and GWL from the groundwater observation well GT-7066013 which is adjacent to the Mahananda river, and is shown in Figure 13.

From the analysis of the figure, it is observed that at base condition (option-0), river water level always remains below the GWL for the period for 2nd week of October to last of June. As a result, the aquifer loses groundwater to river. On the other hand, due to conserving surface water in the river by means of rubber dam (option-2), river water level remains above the GWL for most of the time in a year except only for few days of April and May during dry season. As a result, the aquifer gains water from river and helps for enhancing groundwater recharge in the aquifer and ultimately helps for reducing the declining trend of GWL. At the same time, some part of the irrigated water has infiltrated into the aquifer systems from the agricultural land which is irrigated using the conserved water in the river, also help for enhancing the groundwater recharge.

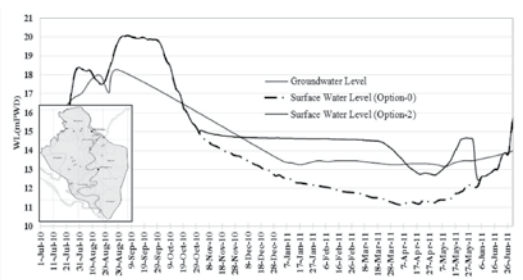

Figure 13. Comparison of river water level and groundwater level

Impact on fisheries

From the questionnaire survey, FGD, KII and public consultant, it has been assessed that many of the surrounding ponds and waterbodies become dry especially due to use of water from them for irrigation purposes. Due to conservation of water in the river, around 20% of these ponds or water bodies will be saved. As a result

of this intervention, fish habitat will be protected in this area and different vulnerable fish species will be protected which ultimately will enhance the production of capture fisheries.

Conclusions and recommendations

From the study results, the following concluding remarks may be made:

- Barind area is a water scarce area where the availability of surface water is very limited. Due to higher abstraction rate of groundwater for irrigation and low recharge, the groundwater level is declining at an alarming rate. The construction of rubber dam on the Mahananda river will help for conserving a considerable amount of surface water. Due to this conserved water, the surrounding area will be benefited for agriculture, fisheries, environment and groundwater recharge.
- Due to raised minimum water level (12.50 mPWD) in the river, the loss of groundwater from aquifer to river will be very negligible. On the other hand, additional recharge of groundwater will occur from the river to aquifer occurrence of higher river water level than groundwater level, which ultimately will help for reducing the declining trend of groundwater level of this area.
- As a result of conserving additional water in the river, it will be possible to irrigate around 7,400 ha land instead 3,245 ha.
- For protecting the environment and reducing the declining groundwater trend of this area, it is very urgent to enhance the groundwater recharge at a large scale and to maximize the use of surface water for irrigation and this is possible by means of conserving surface water in the river by construction of rubber dam.
- It is recommended to conserve surface water in the river by constructing rubber dam on the river flowing through the Barind area for protecting the environment and enhancing groundwater recharge at large scale.

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Quantifying gender-based disparities in Dhaka district: A GIS-based Sopher Index Analysis of literacy and employment inequities

Abu Tanvir Mohammad Tazrian[1*], Bibi Hafsa[1], Khandakar Hasan Mahmud[1], Abu Nayeem Mohammad Ekram[2]

[1] Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka, Bangladesh

[2] Barishal Cadet College, Babuganj, Barishal, Bangladesh

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***Corresponding Email:**
tazrian.48@geography-juniv.edu.bd

ABSTRACT

This study examines gender-based disparities in literacy and employment across the Dhaka district, providing a quantitative basis for targeted policy interventions. Utilizing data on male and female literacy and employment rates from various Upazilas, the Sopher Index was applied to calculate disparity indices. Geographic Information System (GIS) mapping further visualized these disparities spatially, revealing clusters of high and low disparity across regions. The methodology encompassed data collection, processing, index calculation, GIS visualization, and validation, followed by detailed interpretation of results. Findings indicate significant gender inequality in specific Upazilas, notably Keraniganj (employment disparity index of 1.3626) and Dhamrai (literacy disparity index of 0.1792), where gaps are most pronounced. These insights underscore the need for phased policy interventions: short-term strategies to enhance educational access for women, mid-term initiatives for skill development and local economic opportunities, and long-term structural reforms including data-driven policy planning via GIS. This study not only establishes a robust analytical framework for assessing gender disparities but also provides a strong groundwork for policies addressing socio-economic inequities across the Dhaka district, fostering balanced and inclusive development.

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Introduction

Dhaka district, the central hub of Bangladesh for administration and economic activities, stands out for a myriad of contrasts. With its sprawling metropolitan hub, the Dhaka Metropolitan Area (DMA) is teeming with rapid urbanization, comprising a large number of industries and an exceptional concentration of educational institutions. This hub is truly dynamic in terms of economic opportunities and infrastructure that together breed higher literacy and a greater degree of employment. A cluster of Upazilas beyond the city limits, namely Dhamrai, Dohar, Keraniganj, Nawabganj, and Savar, depict a different scenario. Further out in the peri-urban and rural areas, jagged socio-economic disparities highlight an acute problem faced by women in gaining access to education and formal work opportunities.

The multidimensional gender divide in Dhaka draws its roots from socio-cultural expectations and economic limitations, reflecting an uneven spread of resources. Traditional views, for example, favor male education in rural Upazilas, while limited access to schools and vocational training within their vicinity further hinders educational opportunities for girls, thus affecting female literacy and future job opportunities. Employment disparities are also high: while the garment industry in Savar offers substantial opportunities for women, Dohar and Keraniganj-with their agricultural sectors and small-scale industries-do not. As a result, women often fall into informal, unpaid labor, reinforcing economic dependence and further entrenching gender inequality.

These challenges that require a more detailed understanding of the spatial patterns of gender-based disparities. Aggregate data often mask regional disparities in socio-economic indicators, making it difficult for policy planners to identify and address high disparity areas. GIS mapping provides a gateway to visualizing these disparities using the Sopher Index, which is a measure of socioeconomic inequality between demographic groups. GIS mapping enables the identification of clustering of high or low gender disparity, thereby allowing focused policy intervention.

The present study, therefore, focuses on analyzing and quantifying gender-based disparities in literacy and employment within the Dhaka district. The present research assesses the level of disparity between males and females and generates spatial visualizations of the inequalities in the existing setup to present actionable evidence for decision-makers to formulate effective policies. This will pinpoint those Upazilas where interventions are urgently needed and thus provide a basis for formulating phased development strategies with a view to attaining gender equity. In this context, improvement in the access to education for girls, which is planned for the short run, is followed by skill development and economic inclusion in the mid-term. The long-term recommendations include gender-sensitive policy implementation and integration of GIS within regional planning as a standard tool that can contribute to balanced and inclusive development in the Dhaka district.

Literature review

The regional disparity issue has long constituted a focus of socio-economic research, with many developing countries still characterized by highly uneven distributions of resources, educational access, and job opportunities. Regional disparity in most cases is driven by the urban-rural divide, sociocultural norms, and institutional constraints that hinder specific demographic groups from accessing education and employment opportunities. Added to this, inequalities between men and women in Bangladesh further reduce the ability of women to access economic and educational resources. According to Kabeer (2005), the patriarchal structures in South Asia, significantly reinforce gender disparities, with female labor participation often constrained by societal expectations and poor access to education.

The segregation of gender in the employment scenario of Bangladesh is not unlike the general trend in South Asia, where female workforce participation is limited by certain structural and cultural factors. As also reiterated by Bairagi (2017), social expectations related to domestic responsibilities and marriage remain a strong factor affecting women's employment in rural and peri-urban areas. While Bangladesh has, in fact, been making positive steps towards improving female labor participation—in garment manufacturing, for example—these have largely taken root within urban areas. Some of the most relevant factors pertain to the selected area of Dhaka district: while such industrialized Upazilas as Savar display higher levels of employment opportunities for women, other areas, such as Dohar and Nawabganj, remain more traditional and agricultural in nature.

Another important determinant of socio-economic disparity in the region relates to educational inequality. For example, Islam and Azad (2019) discussed how in some rural settings of Bangladesh, boys are often given priority to education, while girls are commonly subjected

to early marriage, household chores, and a lack of facilities which hinder their attainment of proper education. In such regions, the attitudes that have become gendered in relation to education encourage inequalities in literacy within successive generations. Nath and Chowdhury (2018) showed a smaller gap within DMA and a greater gap in peripheral Upazilas because of infrastructural and socio-cultural barriers. With such estimates, the Sopher Index has been helpful in measuring the magnitude of gender inequality and has provided a nuanced understanding of socio-economic disparity. Hasan et al., (2020) explained the same issue in detail.

Study area

The Dhaka district, encompassing the urban core of the DMA and five peripheral Upazilas, namely Dhamrai, Dohar, Keraniganj, Nawabganj, and Savar, represents an ideal microcosm to study regional inequalities within Bangladesh. The location falls within latitudes 23°30' to 24°10' North and longitudes 89°50' to 90°30' East. The district bounded on the north by Mirzapur, Kaliakair and Gazipur Sadar, on the south by Sadarpur, Sreenagar and Narayanganj, on the east by Kaliganj and Rupganj, and on the west by Saturia, Manikganj and Singair. DMA is a densely metropolitan area that presents more job opportunities, better infrastructures and higher attainment rates of education. This, however, stands in contrast to the rural Upazilas of the district.

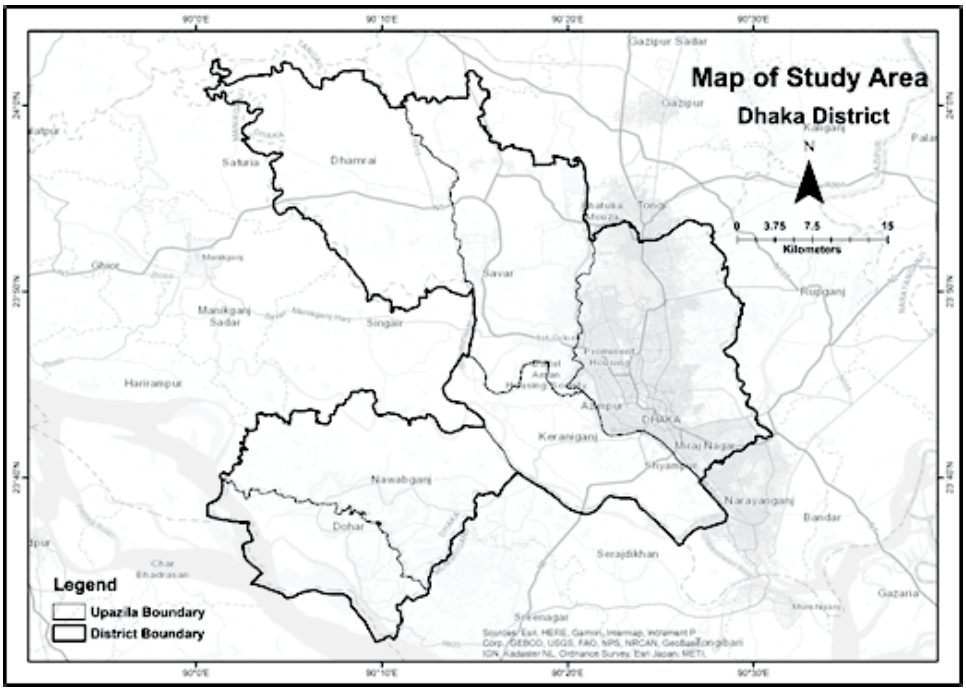

Figure 1. Map of study area

Each Upazila has a distinct socio-economic profile: Dhamrai is predominantly agricultural, with limited industrial activities, resulting in fewer formal employment opportunities for women. Dohar and Nawabganj, similarly rural, face challenges in female literacy due to socio-cultural norms that prioritize male education and restrict girls' schooling. Savar hosts significant industrial zones, notably in the garment sector, offering employment to both genders, though wage disparities and job hierarchies favor men. Keraniganj, a peri-urban

region, embodies a mix of traditional and industrial characteristics, presenting unique socio-economic dynamics that impact gender disparities. These varying profiles make Dhaka district a compelling case for assessing regional and gender-based disparities through the Sopher Index (Bangladesh Bureau of Statistics, 2021; Islam & Azad, 2019).

Data and methodology

This study employs a mixed-method approach by integrating literature review, Sopher Index calculation, and GIS visualization. A comprehensive literature review was carried out to contextualize the regional and gender disparities observed within Dhaka district. The relevant socio-economic disparity indicators identified included male and female employment rates and literacy rates.

$$D = \log\left(\frac{X2}{X1}\right) + \log\left(\frac{100 - X1}{100 - X2}\right)$$

The *Sopher Index* formula is as follows:
where X2 is the percentage for males in employment or literacy and X1 is the percentage for females. The formula is appropriate because it captures the difference between male and female indicators proportionally, which is particularly useful in socioeconomically diverse regions.

This study follows a structured methodology to analyze gender disparities, which is illustrated in Figure 1 below. Each step is detailed to ensure a clear understanding of the approach.

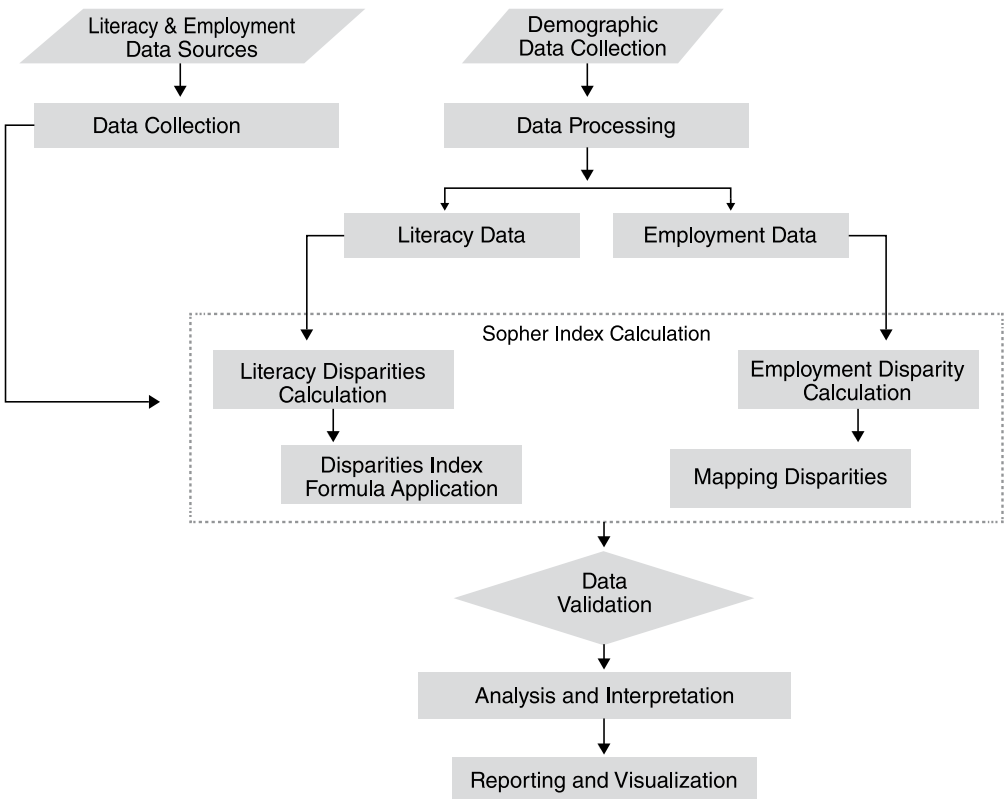

Figure 2. Methodology flowchart for analyzing gender disparity in Dhaka district

This flowchart outlines the entire research process from data collection to reporting and visualization, including the Sopher Index calculation.

2. **Data collection:** Literacy and employment data were sourced from government reports

and surveys, covering both male and female indicators for each Upazila.

3. **Data processing:** The collected data were cleaned and organized for accuracy and consistency in preparation for analysis.
4. **Sopher Index calculation:** This calculation measures the gender-based disparity in both literacy and employment
5. **GIS mapping and visualization:** GIS tools were used to map the disparity indices across the Dhaka district, providing a spatial representation of the gender gaps.
6. **Data validation:** The results were validated through cross-checking with source documents and internal consistency checks to ensure accuracy, followed by detailed analysis and interpretation of disparity trends in each Upazila.
7. **Reporting and visualization:** The findings were visualized using graphs and maps for clarity and to support the policy recommendations.

Figures 3 and 4 present baseline gender differences in literacy and employment across the Upazilas in Dhaka district using dumbbell charts, where male and female values are shown as two points connected by a line to emphasize the size of the gap. Here, Male and female literacy rates are generally closer together across Upazilas, indicating comparatively smaller gender gaps in literacy.

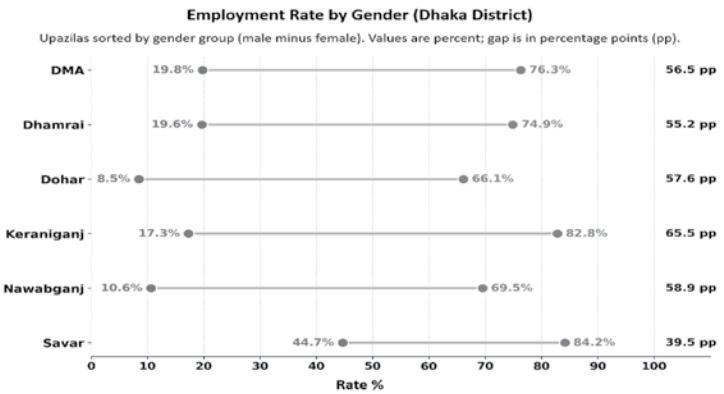

Figure 3. Dumbbell chart of literacy rates by gender across Upazilas in Dhaka District

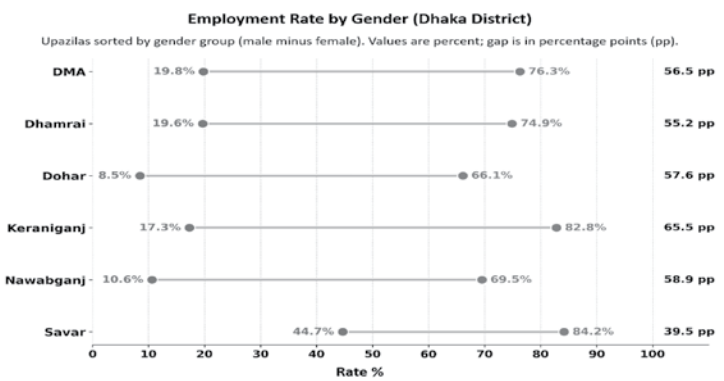

Figure 4. Dumbbell chart of employment rates by gender across Upazilas in Dhaka district

Here, Male and female employment rates are farther apart in several Upazilas, indicating a much stronger gender gap in employment (e.g., Keraniganj shows a large separation consistent with a high disparity index).

On the whole, the images indicate that the

gender disparity is higher in the employment area rather than literacy in the district. This is significant in that it means that even in the areas where the level of literacy amongst women is approaching that of men, it is not being reflected in the labor market. Thus the restricting factors are probably more related to work constraint like mobility and safety, unpaid care load, social expectations as well as work related issues of women like occupational discrimination and the limited choice of work that is socially acceptable.

The charts are also useful to explain various trends by Upazila: areas with small literacy gaps and big employment gaps refer to a problem of conversion (education is not becoming jobs opportunities amongst women), whereas areas with bigger gaps in both imply more disadvantage that is compounding. You strengthen the analysis when you compute the disparity index (Sopher Index) and plot it in GIS as this indicates whether the high disparity is geographically clustered or not. Such a spatial pattern is what makes the findings useful in terms of policy: it informs decision-makers where the interventions are to be considered a priority, not only that the disparity exists.

Calculation

The following tables show the regional disparity calculation of literacy and employment rates in Dhaka district.

Table 1. Literacy disparity index across Upazilas in Dhaka district

Sl. No.	Upazila	Male literacy (%) X2	Female literacy (%) X1	Log (X2/X1)	Log (100-X1/ 100-X1)	Disparity index, D= Log (X2/ X1)+ Log (100-X1/100-X1)
1	DMA	86.66	83.08	0.0183	0.1032	0.1216
2	Dhamrai	73.98	65.30	0.0542	0.1250	0.1792
3	Dohar	75.07	75.23	-0.0009	-0.0028	-0.0037
4	Keraniganj	80.94	76.50	0.0245	0.0909	0.1154
5	Nawabganj	77.09	74.66	0.0139	0.0438	0.0577
6	Savar	85.18	80.37	0.0252	0.1221	0.1473

Table 2. Employment disparity index across Upazilas in Dhaka district

Sl. No.	Upazila	Male employment (%) X2	Female employment (%) X1	Log (X2/X1)	Log (100-X1/ 100-X1)	Disparity index, D= Log (X2/ X1)+ Log (100-X1/100-X1)
1	DMA	76.30	19.78	0.5863	0.5295	1.1158
2	Dhamrai	74.88	19.64	0.0581	0.5050	1.0862
3	Dohar	66.11	8.47	0.8928	0.4315	1.3239
4	Keraniganj	82.80	17.28	0.6805	0.6821	1.3626
5	Nawabganj	69.52	10.64	0.8152	0.4671	1.2823
6	Savar	84.16	44.66	0.2752	0.5432	0.8185

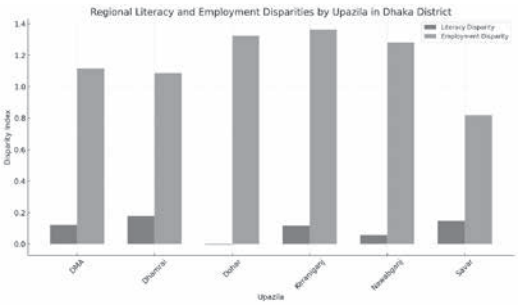

Figure 5. Regional literacy and employment disparities by Upazilas

Figure 4 presents a grouped bar chart for literacy and employment disparities across Upazilas, highlighting both indices side-by-side. This visualization clearly shows the comparative levels of disparity, with Keraniganj having the highest employment disparity and Dhamrai showing significant literacy disparity.

Analysis of literacy disparity

Literacy disparity in Dhaka district shows a distinct trend: Dhamrai has recorded the highest gender gap of 0.1792 out of all areas, primarily as a result of the socio-cultural factors about the education of males. Cultural norms and financial constraints, along with practical barriers such as the distance to schools in suburban areas like Dhamrai, contribute to relatively lower female literacy. Banu (2019), indicates that families in rural Bangladesh often consider women's education less important, which in turn negatively affects women's literacy.

In Dohar, however, the Sopher Index for literacy disparity is close to zero (-0.0037), thereby implying near parity between the male and female literacy rates. This indicates that local efforts at making education inclusive for both genders might be paying dividends, although continued support will be required to consolidate these gains.

Upazilas like Savar and Keraniganj have moderate disparities in literacy, reflecting the general trend of urban areas performing better compared with their rural counterparts, though they face some gender-based challenges in access to education. Figure 2 illustrates these visually, as well, with dark shading representing areas like Dhamrai where disparity is more significant.

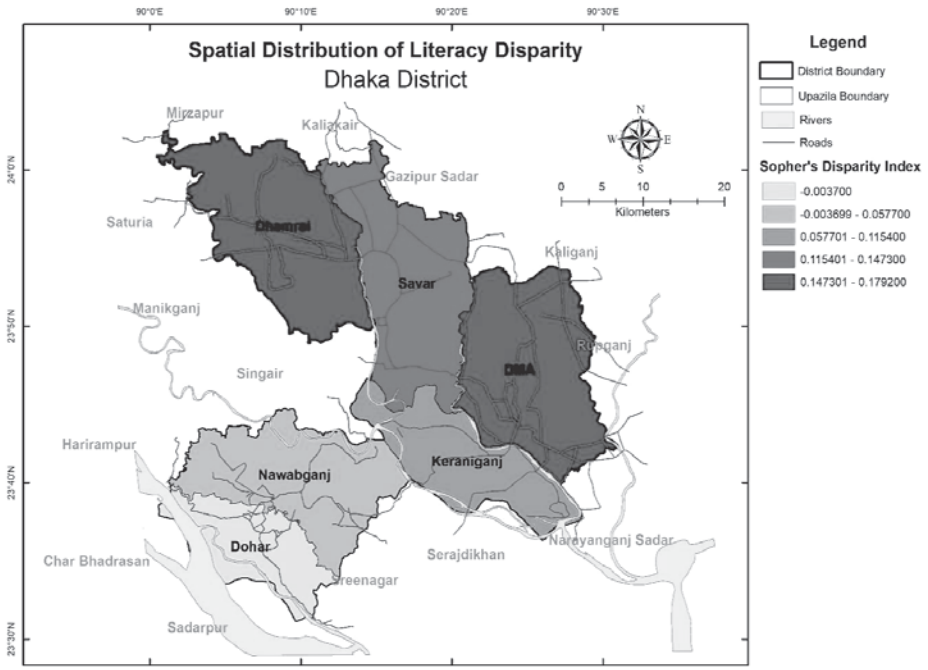

Figure 6. Spatial distribution of literacy disparity in Dhaka district

This map visualizes the calculated literacy disparity index across the Upazilas of Dhaka, highlighting areas with high and low gender disparity in literacy rates. The darker regions indicate higher literacy disparities, providing a quick view of areas that require targeted educational interventions.

Analysis of employment disparity

The Sopher Index presents substantial gender disparities in employment within the Dhaka district. Keraniganj exhibits the highest value of employment disparity, 1.3626, demonstrating the socio-cultural constraints on female labor participation within this peri-urban area. Moreover, limited industrialization in Keraniganj suggests that there is little change in the dominance of males in job opportunities, especially in the building and manufacturing sectors, where societal expectations tend to bypass women.

In contrast, Savar, hosting a number of garment industries, represents the lowest employment disparity with an index of 0.8185. This low index can thus be related to the fact that in the garment industry, which requires female labor, formal employment opportunities opened up for females in the normally male-dominated job market. However, even in Savar, wage disparities based on one's gender and restricted career growth for women still exist to reflect the broader challenges of gender equity in Bangladesh's labor market (Rahman et al., 2020).

It is observed that the incidence of the rural Upazilas like Dohar and Nawabganj has higher incidence, reflected by the value of the indices as 1.3239 and 1.2823, respectively. In these places, traditional norms and limited diversification in the economy contribute to fewer opportunities for women in the formal employment sector. This supports the finding of Hossain (2021), who found that in rural Bangladesh, women are mainly engaged in unpaid or informal work, which negates effective financial empowerment and perpetuates gender inequality.

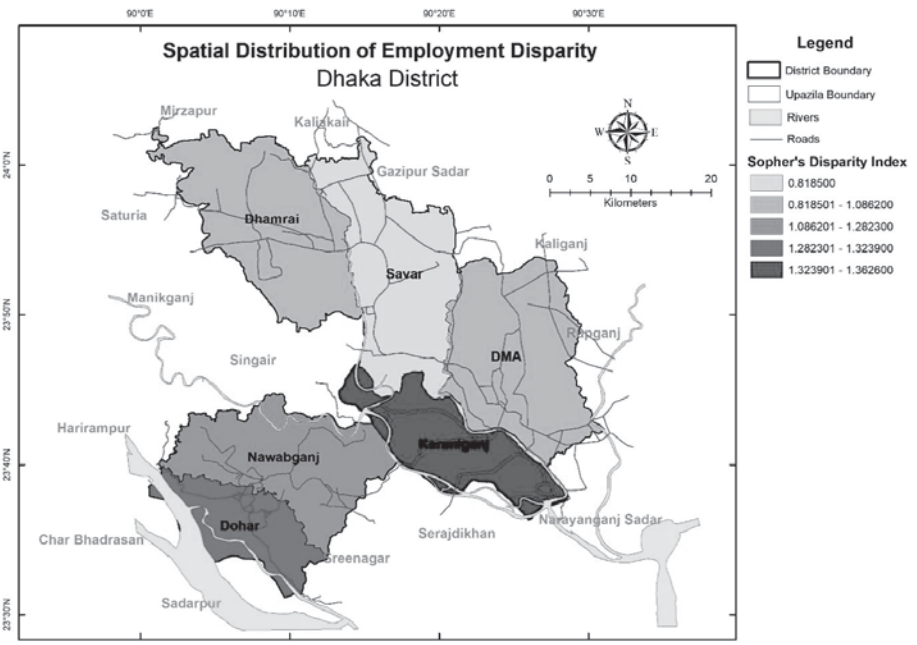

Figure 7. Spatial distribution of employment disparity in Dhaka district

This map represents employment disparity, with darker shades showing regions with significant gaps between male and female employment rates. This visualization allows

policymakers to identify Upazilas with critical gender gaps in employment, guiding them toward areas needing workforce interventions.

The GIS-generated employment disparity maps provides a visual representation of these findings, highlighting regions like Keraniganj and Dohar with dark shades, indicating high disparity. This spatial analysis underscores the need for localized policy interventions that consider the unique socio-cultural contexts of each Upazila.

Implications and policy recommendations

The findings from this study highlight significant gender-based disparities in employment and literacy across the Dhaka district, with notable regional differences influenced by socio-cultural and economic factors. High employment disparity in Keraniganj and literacy disparity in Dhamrai suggest the need for tailored policy interventions that address these local challenges.

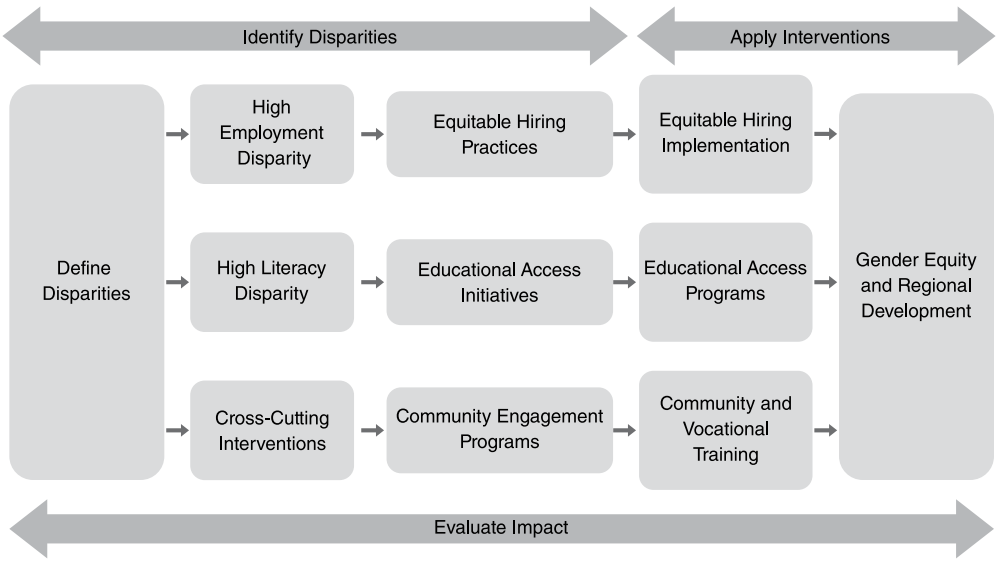

Figure 8. Policy implications flowchart for gender disparity intervention

This flowchart illustrates targeted policy interventions for high employment and literacy disparity areas, along with cross-cutting interventions for community engagement and vocational training.

- High employment disparity: Focus on implementing equitable hiring practices in regions with significant employment disparity to encourage gender balance in the workforce.
- High literacy disparity: Improve educational access through educational access initiatives, such as scholarships and infrastructure improvements, in high-literacy disparity areas.
- Cross-cutting interventions: Broader programs like community engagement programs and vocational training are designed to shift societal norms and equip women with employable skills.
- Outcome: The ultimate objective is Gender Equity and Regional Development, with each intervention contributing toward balanced socio-economic growth in Dhaka district.

The analysis of gender disparities in literacy and employment across the Dhaka district contributes to multiple domains of knowledge and skills. In the 1950s, Benjamin Bloom and his colleagues identified three educational domains—cognitive, psychomotor, and affective—that encompass different facets of learning and skill development. The *cognitive domain* involves knowledge acquisition and intellectual skill-building, essential for understanding concepts and recalling information (Bloom, 1956). The *psychomotor domain,* defined by Simpson (1972), relates to physical skills and

coordination, refined through practice and measured by precision and technique. The *affective domain,* described by Krathwohl et al. (1973), pertains to emotional responses and attitudes. This study on gender disparities in Dhaka district contributes across these domains, enhancing theoretical understanding, practical skill application, and socio-emotional awareness, as outlined in Table 3.

Table 3. Domain based contributions

Domain	Contribution
Cognitive	- Provides a quantitative understanding of gender disparities in literacy and employment through the application of the Sopher Index. - Enhances knowledge on spatial patterns of gender inequality, guiding targeted interventions.
Psychomotor	- Involves the practical application of GIS and data analysis tools for mapping disparities, requiring technical skills in data processing, index calculation, and spatial visualization. - Develops precision in data handling and geographic analysis, supporting skills in geospatial research.
Affective	- Encourages awareness of socio-economic challenges faced by women in different Upazilas, fostering empathy and commitment to gender equity. - Highlights the importance of equitable socio-economic development, potentially inspiring policy initiatives for inclusive growth.

Policy recommendations

To effectively address gender disparities in literacy and employment across Dhaka district, it is essential to adopt a phased approach. Short-term actions focus on immediate, foundational changes, mid-term efforts aim at sustainable growth and community engagement, while long-term strategies target structural and policy transformations for lasting impact.

Short-term recommendations (1-2 Years)

i. Promote gender-inclusive employment policies: Encourage industries in high-disparity areas like Keraniganj to adopt inclusive hiring practices through government incentives, such as tax breaks, in order to create equitable workplaces.
ii. Expand educational access and retention for girls: Initiate scholarship programs and improve basic school infrastructure in high-disparity Upazilas like Dhamrai to ensure more girls attend and stay in school, thereby reducing gender gaps in literacy and school completion.
iii. Community engagement and cultural sensitization: Organize community workshops involving local leaders and influencers to promote gender equality, encouraging families to support female education and employment, and to challenge norms that restrict women's public and economic participation.

Mid-term recommendations (2-5 Years)

i. Targeted economic development programs: Establish local industries and cooperatives in high-disparity Upazilas, such as Dhamrai and Nawabganj, to create job opportunities for women and reduce dependency on male-dominated sectors with particular attention to safe and decent working conditions.
ii. Expand skill development programs for women: Implement vocational training programs tailored for women in high-disparity areas to enhance employability and income potential, fostering economic independence, and linking training with local labor market demand.
iii. Enhance data collection and monitoring: Develop a framework to collect and monitor socio-economic data at the Upazila level, focusing on female employment, literacy, health, and income. This will allow for periodic updates to the Sopher Index, enabling a dynamic approach to policy adjustments, and

helping policymakers evaluate the impact of interventions over time.

Long-term recommendations (5+ Years)

i. **Utilize GIS for policy planning:** Institutionalize GIS-based spatial analysis as a tool for identifying high and low disparity clusters. This allows local governments to plan targeted interventions, such as establishing educational facilities or vocational training centers in underserved areas, and to prioritize resource allocation based on spatial evidence.

ii. **Institutionalize gender-inclusive policies in employment and education:** Implement gender-inclusive policies across sectors, ensuring sustainable opportunities for women in formal employment and continuous support for female education in rural areas, including enforcement mechanisms and accountability frameworks.

iii. **Regular impact evaluation and policy refinement:** Conduct regular assessments at the district and Upazila levels to evaluate the effectiveness of implemented policies, ensuring adjustments based on evolving socio-economic trends and disparities.

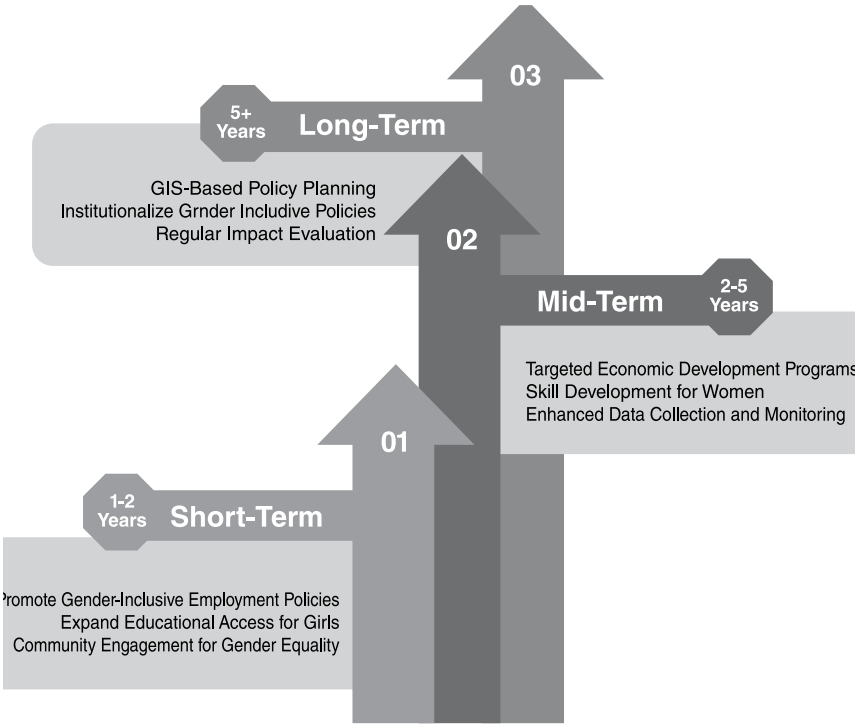

Figure 9. Timeline of policy recommendations for addressing gender disparities in Dhaka district

Conclusion

This discussion covered disparities in gender-based employment and literacies across Upazilas using the Sopher Index and GIS visualization. From the results, it can be represented that even though Dhaka is the capital city and a magnet for economic growth, disparities are still evident, particularly in peri-urban and rural areas. The high level of disparity in Keraniganj employment and the high disparity in Dhamrai literacy indicate that even to this day, deeply entrenched socio-cultural norms and an insufficient infrastructure burden women and limit their access to education and formal employment.

The GIS maps, therefore, act powerfully to visualize these inequalities, hence helping policymakers to point out areas where targeted interventions may be performed. This spatial

analysis identifies the fact that the Dhaka district, similar to many urban regions of developing countries, is internally differentiated in terms of socioeconomic inequalities that demand region-specific policy approaches.

The present study contributes to the fast-growing literature on regional disparities and gender inequality in Bangladesh, as it puts forward an all-inclusive, data-driven approach toward the measurement and visualization of disparity. Future studies could extend this by integrating other indicators that might be available, such as health outcomes or income disparity, and longitudinal analysis in order to observe temporal trends. After all, a decrease in these inequalities requires cooperation among government authorities, NGOs, community leaders, and local businessmen to ensure an inclusive and equitable environment for all residents within the district of Dhaka.

Concomitant policy measures alongside community participation can bring the Dhaka district closer to achieving gender equity and subsequently securing the foundational pillar of sustainable development and social harmony. The district will, therefore, ensure that an enabling environment is created in which all individuals-regardless of sex or address-can rise to their full potential by responding efficaciously to needs manifesting at the level of each Upazila.

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Temporal analysis of land use and land cover changes: A study of Kurigram Sadar Upazila, Bangladesh

Mritunjoy Mojumder[1*], Shehan Tawsif[2], Md. Saazid Bin Saif[2] Md. Abu Bakkar Siddique[3] Md. Iftekher Islam[4]

[1] Department of Geography and Environment, National University, Gazipur-1704, Bangladesh.

[2] Department of Geography and Environmental Studies, University of Rajshahi, Rajshahi 6206, Bangladesh

[3] Office of the Deputy Commissioner, Kurigram, Ministry of Public Administration, Government of the People's Republic of Bangladesh

[4] Department of Zoology, National University, Gazipur-1704, Bangladesh

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***Corresponding Email:**
mritunjoy.mojumder@nu.ac.bd

ABSTRACT

This study analyzes the spatial trends of Land Use and Land Cover (LULC) in Kurigram Sadar Upazila, Bangladesh, during the last four decades (1990–2021). The maps of LULC were established from satellite data of the USGS Earth Explorer by conducting unsupervised classification of five classes (i.e., agricultural land, barren land, vegetation, settlement, and water bodies). Spatial analysis using GIS and remote sensing (RS) techniques confirmed profound transformations, with agricultural land decreasing sharply from 26,199.99 acres in 1990 to 20,930.31 acres in 2021, representing a reduction of 5,269.68 acres over the last four decades. At the same time simultaneous expansion of settlement areas from 7,894.32 acres in 1990 to 16,293.65 acres in 2021, an increase of 8,399.33 acres, which is double in the same period, driven largely by rapid urbanization and environmental change. The study revealed that agricultural land drastically decreased by around 20.11%, while settlement areas increased by over 106% between 1990 and 2021, which demonstrates intensive anthropogenic pressure. Vegetation cover and water bodies have exhibited significant fluctuations over the study period, raising concerns about the ecological sustainability of the region. Based on the Cellular Automata (CA)-Markov Chain model, future LULC scenarios are predicted for 2071 and 2121. The study predicts that if these current changes continue, then agricultural land will rapidly decline by 84.99% by 2121, resulting in severe socio-economic and ecological consequences. Moreover, integrated land management strategies, sustainable agriculture practices, and proactive environmental conservation policies are urgently needed to balance development in Kurigram Sadar Upazila and neighboring regions.

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Introduction

In recent decades, the spatial-temporal changes of land use and land cover (LULC) have significantly transformed the physical terrain to human living patterns. LULC change is a critical environmental event that is affected by natural processes and human factors (Getaneh et al., 2024; Islam et al., 2024). In the context of Bangladesh, a densely populated country with rapidly changing hydro-geomorphological conditions and rapid socio-economic development is taken place rapidly, understanding about LULC patterns is very important for development planning, sustainable development, disaster risk reduction and resource management (Abdullah et al., 2019; Islam et al., 2024; Polash et al., 2023).

Several research efforts have contributed to the debate on LULC change detection and its subsequent social and environmental implications throughout Bangladesh. Rahman et al. (2017) employed the CA-ANN model to model LULC dynamics in coastal areas. Although they utilized ArcGIS tools for evaluating patterns of transformation, they did not specifically examine the link between LULC trends and livelihood impacts (Rahman et al., 2017). Hasan et al. (2023) highlighted that LULC change caused livelihood disruptions; their research did not include long-term changes, and it was a pure methodological forecast of the future using a GIS framework. Other research studies that combined mobile data with satellite data to achieve similar goals were undertaken by Dewan and Yamaguchi (2009) in Dhaka, which dealt with the urban land use and failed to cover the rural change dynamics or future land use modeling required for the development of land use patterns. They estimated the loss of LULC due to coastal erosion and displacement risk. Adnan et al. (2020) utilized the Markov chain modeling to link land use and flood hazards to poverty effects. But it did not provide much analysis of the socio-economic impacts in terms of agricultural livelihoods or settlement transitions. Another investigation by Gazi et al. (2023) revealed the role of socioeconomic factors of LULC change in coastal districts; their study could not project future LULC changes nor include policy implications. Rahman and Esha (2022) projected LULC change by CA-ANN in Bagerhat, but the study ignored public policy and resource dependency aspects (McClelland et al., 2017). Although Rahman et al. (2009) used geo-information technology for monitoring change in two case studies, they did not overcome the gap of inter-decadal transitions and their correlation to socio-economic adaptation in such vulnerable rural zones from Kurigram. Najmuddin et al. (2017) analysis of regional land use scenarios in Afghanistan's river basin provides useful lessons on how socio-economic transitions are processed, though not entirely into dynamics and policy contexts comparable with Bangladesh's floodplains.

Elsewhere in the urban setting, Rahman et al., (2018) investigated the influence of rural-urban migration on land use change in the Dhaka metropolitan area using GIS, but excluded public policy responses or rural agriculture switching. Alam and Ahamed (2022) identified the susceptible agricultural lands (farmlands) based on fuzzy logic but did not have a predictive LULC modeling and policy-making tool. Kafy et al. (2021) found that LULC was associated with land surface temperature, without considering socio-economic impacts or policy adaptations. Hossain and Rahman (2024) utilized NDVI-based classification to predict LULC, but they did not address human-centered results or governance factors. In a related estuarine context, Hoque et al. (2020) employed ecosystem models to forecast changes in ecosystem services but not livelihood impacts and local management compatibility. Finally, Rai et al. (2017) simulated LULC dynamics from 1930 to 2015 on a macro-level, but this approach has not been applied to infer one-scale predictions and the interaction with socio-economics in rural Bangladesh.

Therefore, the present research identifies a clear gap in thematic and methodology approaches by using remote sensing and GIS-based time series analysis to map the changes in LULC. While most LULC studies in Bangladesh emphasize

mapping physical changes and projecting scenarios through remote sensing and GIS (Hasan et al., 2023; Hossain and Rahman, 2024; Rahman et al., 2017), they often overlook governance and policy implications This study aims to document LULC change patterns in Kurigram Sadar Upazila for different periods (1990, 2001, 2011, 2021) and to analyze the trend of the changes and forecast LULC changes using remote sensing analysis. However, the novelty of the present study lies in connecting spatio-temporal LULC changes with prediction. It fills a significant gap in the literature regarding the LULC of Kurigram Sadar and opens a new window into the necessity of the public policy for urban planning, land use planning, and enhancing the adaptation capabilities of government authorities for future planning in the study area.

Methods

Study area

This study focuses on Kurigram Sadar Upazila, which is a sub-district of the Kurigram district located in the northern part of Bangladesh. Geographically, the Upazila is located between 25°45' and 25°58' N latitudes and between 89°32' and 89°50' E longitudes, and it is a total of 276.43 square kilometers (Salam & Kiron, 2023). Historically, it comprises one Paurasava (municipality) and eight Union Parishads (councils) and is the standard unit of local government area in the country for the purpose of development of people and transparency of local government it has been used as a District Thana. The relative location of Kurigram Sadar Upazila is Ulipur in Kurigram district to the south, Dhubri district of Assam state (India) to the east, Rajarhat Upazila to the west, and Fulbari and Nageshwari upazilas in Kurigram district to the north of Kurigram Sadar upazila. Kurigram Sadar has a population of about 361,408, which is 1,447 people per km^2 (BBS, 2022). Local people are mostly dependent on agriculture, fishing, and local trading for their living. There are lots of rivers that control the hydrological situation of the area and are complemented with its branches (Dharla, Dudhkumar), and the Brahmaputra River is one of them (Khan & Rahman, 2024; Rahman et al., 2023). The rivers exert much influence on land-use, cropping intensity, and settlement pattern, particularly in terms of recurring seasonal inundation (Uddin et al., 2019). The landscape of the region is covered with alluvial floodplain, which is rich in agricultural production; however, it faces high risk due to climate induced risks and erosion induced displacement (Hossain et al., 2024; Hosenuzzaman et al., 2024; Islam et al., 2023)

The present-day Kurigram developed from its 20 Ganjs (market places) (Islam, 2020). Kurigram Sub-division was formed under Rangpur district in 1874, and it was turned into a district in 1984. Kurigram Municipality was formed in 1972. Bangladesh's urbanization rate rose from 19.8% in 1990 to 40.5% in 2023, reflecting significant growth as the country rapidly urbanized over three decades (World Bank, 2024). As a result, the district center has also changed rapidly over the last four decades. Kurigram Sadar Upazila serves as the city center of Kurigram district and has experienced significant changes that have impacted the LULC in the area (Joya et al., 2023; Rahman et al., 2022). Kurigram Sadar Upazila is also environmentally important due to its physical characteristics. Located in the northern part of Bangladesh, several rivers flow through the center of Kurigram (Hasan & Khan, 2024; Hossain et al., 2023). As the study area, LULC changes in Kurigram Sadar Upazila can represent the real scenario of LULC changes in Bangladesh's urban and suburban areas. Moreover, these suburban areas can help project future scenarios based on the present rate of change (BBS, 2022; Islam et al., 2021).

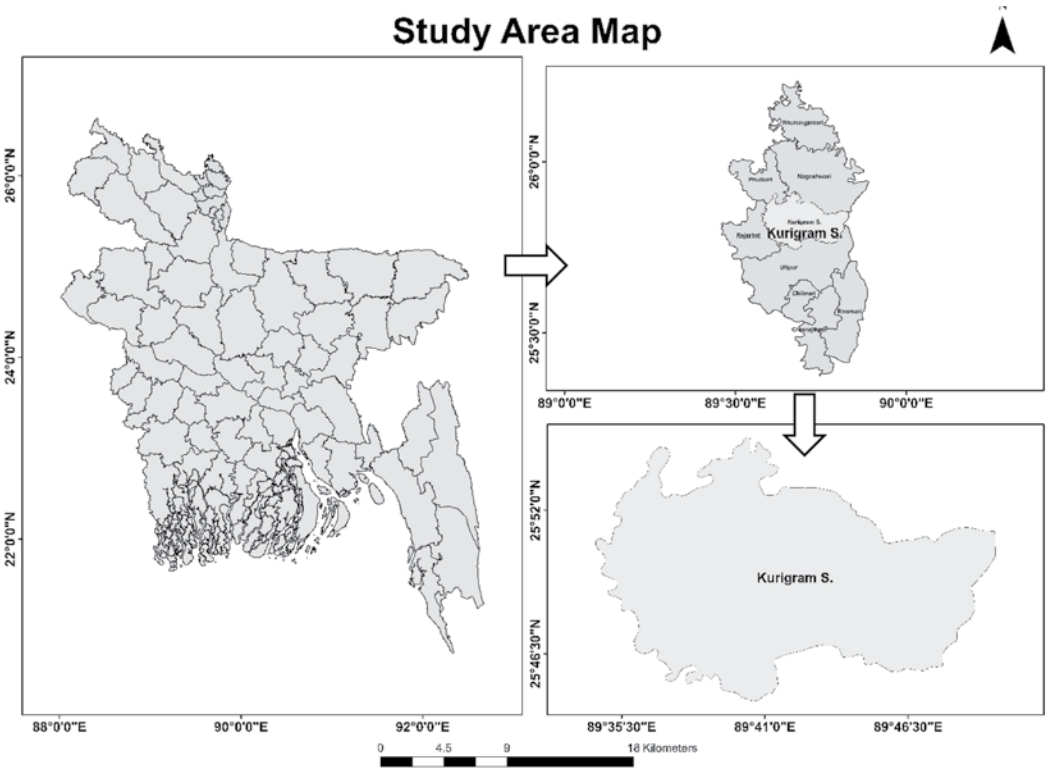

Figure 1. Study area map of Kurigram Sadar Upazila

Satellite image and spatial data

This study employed an **unsupervised** classification technique. This method enables more accurate and efficient categorization of land cover types by leveraging the strengths of an unsupervised approach (Ahmed et al., 2024; Uddin & Rahman, 2023). In this study, satellite image analysis combined with GIS-based techniques was used to evaluate LULC changes in Kurigram Sadar Upazila. Cloud-free, seasonally consistent satellite images for the years 1990, 2001, 2011, and 2021 were obtained from the USGS Earth Explorer platform. These images were selected to ensure temporal consistency and minimize atmospheric distortions (Chander et al., 2009). To understand how Kurigram Sadar Upazila's landscape has shifted and how those shifts affect people's lives, this study combined maps, numbers, and on-the-ground stories. This study first pre-processed satellite images from 1990, 2001, 2011, and 2021, then fed those images into the unsupervised Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm to sort the pixels into distinct classes (Jensen, 2015; Turner et al., 2007). Using the ArcGIS software, the analysts calculated how many acres belonged to each class for every year, producing a clear picture of land extent from 1990 to 2021 (Jensen, 2015). All images have been taken from the post-monsoon season (October-November) to ensure temporal consistency and comparability. The post-monsoon period was selected because it follows the monsoon rains, allowing for better assessment of permanently and seasonally waterlogged areas. Cloud-free, seasonally consistent satellite images for the years 1990, 2001, 2011, and 2021 were obtained from the USGS Earth Explorer platform and Google Earth. These images were selected to ensure temporal consistency and minimize atmospheric distortions (Chander et al., 2009). In addition to satellite data, spatial

boundary layers, including district and Upazila, were collected from the Bangladesh Bureau of Statistics (BBS) and the Local Government Engineering Department (LGED) websites. The analysis then created a transition matrix that showed gains and losses, and charted the results; the steady loss of farmland and the rise of settlements stood out (Lu et al., 2004).

The satellite imagery was classified into five major LULC categories, including agricultural land, barren land, settlement, vegetation, and water bodies. These categories were chosen based on their relevance to urban growth in the study region. To verify and enhance the classification results, field visits were conducted in Kurigram Sadar. These ground surveys provided ground truth data, which is essential for validating satellite-based classifications. Furthermore, relevant secondary data were gathered from both governmental and non-governmental organizations, such as the Bangladesh Water Development Board (BWDB), scientific journals, statistical yearbooks, published research, and official project reports.

Image processing

The data obtained were pre-processed by the standard procedures of geometric and radiometric correction before classification. An Unsupervised ISODATA algorithm was used to divide the land surface into five LULC classes: agricultural land, vegetation, barren land, settlement, and water bodies (Abdullah et al., 2019; Jensen, 2015; Uddin & Rahman, 2023). The Area of each class was identified and change detection was done over across the selected years to see how land transformation occurred (Hossain et al., 2024; Islam et al., 2024; Lu et al., 2024).

Radiometric normalization was applied to all images from the same set, in order to account for intra-set variability of sensors' calibration and atmospheric conditions at different dates (Islam & Hassan, 2024). This process included:

- Dark object subtraction (DOS): Intended to reduce the effect of atmospheric scattering, it seeks for the darkest pixels and applies an adjustment in all bands accordingly (Chen et al., 2024).
- Haze reduction: Improve image clarity by reduce atmospheric haze.

These post-processing adjustments maintain the reflectance values consistent throughout all images making the comparison over time right. Therefore, temporal LULC was valid and reliable for accurately monitoring the effect of settlement growth (Du et al., 2025; Hossain et al., 2024).

Accuracy assessment

Accuracy assessment is a vital step in remote sensing-based land cover/land use analysis, as it indicates the point to which the classified image matches actual ground conditions (Chen et al., 2024; Islam & Rahman, 2023; Janssen, 1994). Accuracy assessment to assess the accuracy and reliability of the LULC classification, a thorough accuracy assessment was performed by using four standard metrics: overall accuracy, user's accuracy, product's accuracy and Kappa coefficient (Jamei, 2022). It was based on confusion matrices, relating land cover classes which were classified to the reference data that obtained from field visits and high-resolution imagery in Google Earth Pro which can be considered a real ground truth. Ground truth data were acquired from field visit to Kurigram Sada Upazila where it became possible to directly observe the real land cover/use during acquisition. The ground visit observation along with reference satellite imagery increased the reliability and repeatability of validation. Classification with accuracy above 85% is generally acceptable according to the common criteria of classification, more than 70% is accepted (Chen & Wang, 2024; Islam & Rahman, 2023; Maxwell et al., 2021). The classification accuracy was evaluated by kappa coefficient, user accuracy and producer accuracy for every land use and land cover class. The kappa coefficient value ranges from 0.82 to 0.93 for Landsat images which shows that there is strong agreement (Hassan et al., 2024; Uddin & Islam, 2023). User's accuracy reflects the likelihood that a pixel assigned to a specific category accurately corresponds to that category in reality (Chen et al., 2024; Maxwell & Melchior, 2022). In this

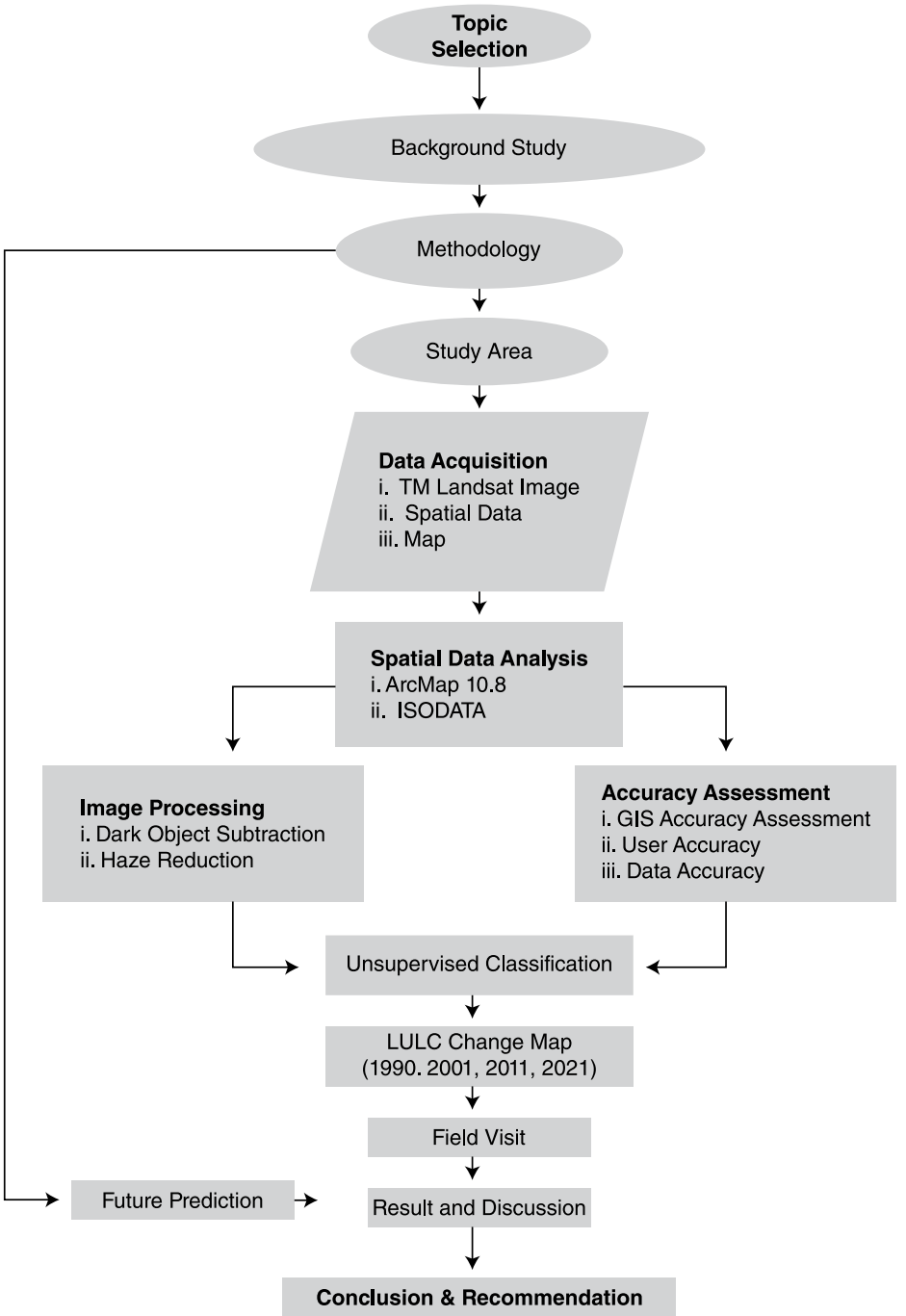

Figure 2. Methodological Framework

analysis, the user's accuracy ranges from 85.37% to 94.65% showing that the class represented on the map is accurate. Producer's accuracy denotes the likelihood that a ground pixel is accurately categorized. The study found that the producer's accuracy is 82.25%, the lowest of the four images, and the producer's accuracy is 92.13%, the highest of the five images. This range of values shows that the mapped ground feature is of high quality (Chen & Wang, 2024; Islam & Rahman, 2023).

Field visit

Field visits were made to a number of identified areas to validate the classified maps. These visits were primarily aimed at validating data from ground observations against satellite observations (Hasan et al., 2024; Islam & Rahman, 2023). The satellite imagery was classified into five major LULC categories, such as agricultural land, barren land, settlement, vegetation, and water body. The ground truthing was conducted with the help of residents & administration data sources from field visits to confirm that features visible on the ground were classified correctly as land cover categories in the image (Chen & Wang, 2024; Uddin & Islam, 2023).

Future prediction

A Cellular Automata (CA)- Markov Chain model was used to predict future LULC scenarios for 2071 and 2121. The observed land cover changes between 1990 and 2021 were applied to predict the probability of transition for the future. This hybrid method develops more accurate LULC prediction through the combination of CA, which present these changes spatially and Markov Chain analysis that predicts the rate of shift (Fitawok & Mumtaz 2023; MDPI Future Scenarios, 2022; Lu et al., 2019; Tariq & Mumtaz, 2023)

Results and discussions

LULC of Kurigram Sadar Upazila

Agriculture was the major land use class in Kurigram Sadar Upazila in 1990, covering an area of 26,199.99 acres, followed by vegetation (17,903.34 acres) and water body (9,993.56 acres), which are shown in Table 1. The settlement site covered 7,894.32 acres with a sparsely populated rural cover, and barren land took 6,010.77 acres of it. The spatial distribution of LULC classes for 1990 is shown in Figure 3, while Figure 4 depicts the bar diagram of each category. The high proportion of agriculture and vegetation indicates a viable agro-ecological base at that time. These results are consistent with a similar pattern in other regions, such as Rajshahi district, which is dominated by agriculture and vegetation that covered more than 60% of the total land in 1990 (Rahman et al., 2017). This dominance is an indication of a pre-urbanization agrarian economy in which the use of the land was for the growing of crops and for natural vegetation, and where there was little man-made infrastructure development.

By 2001, agricultural land cover was also practically unchanged at 26,047.95 acres. Vegetation slightly increased to 18,773.55 acres. But the settlement area was reduced even slightly to 7,275.93 acres and Barren Land was also slightly down to 5,203.88 acres. Surprisingly, the Water Body occupied 10,698.37 acres. A map of LULC in 2001 is shown in Figure 3; by comparison, Figure 4 indicates the percentage change that occurred between classes. While the intensity of farmland land-use is the most dominating one, it was observed that the increase in the water bodies can be associated with temporal inundation patterns, as usual in floodplain areas of northern Bangladesh. A similar pattern of trends was detected in the Rangpur district during that same period, with marginal expansion of agricultural areas but an increment on water and vegetative land due to hydrological changes and afforestation projects (Alam & Uddin, 2020).

In 2011, a substantial transformation occurred when agriculture expanded to 34,078.84 acres, the maximum area in all the years under study. Vegetation fell drastically to 13,074.91 acres, and Settlement declined to 5,991.03 acres. Water Body increased almost marginally to 10,633.96 acres, while Barren Land decreased to 4,221.60 acres. Figure 3 shows the LULC distribution for 2011, and Figure 4 shows the

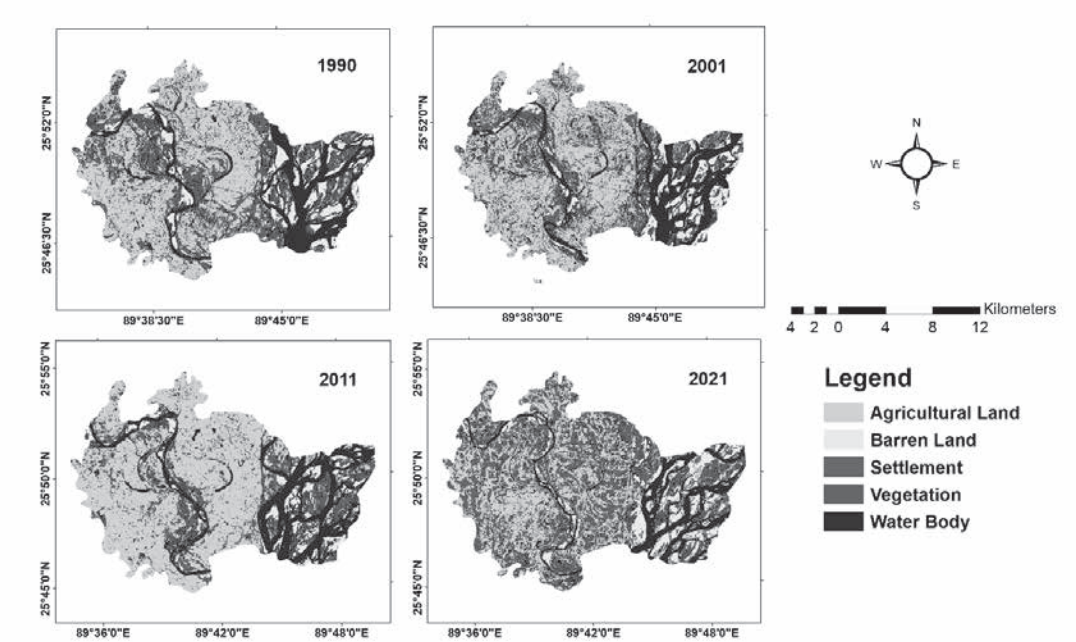

Figure 3. Kurigram Sadar LULC 1990 to 2021

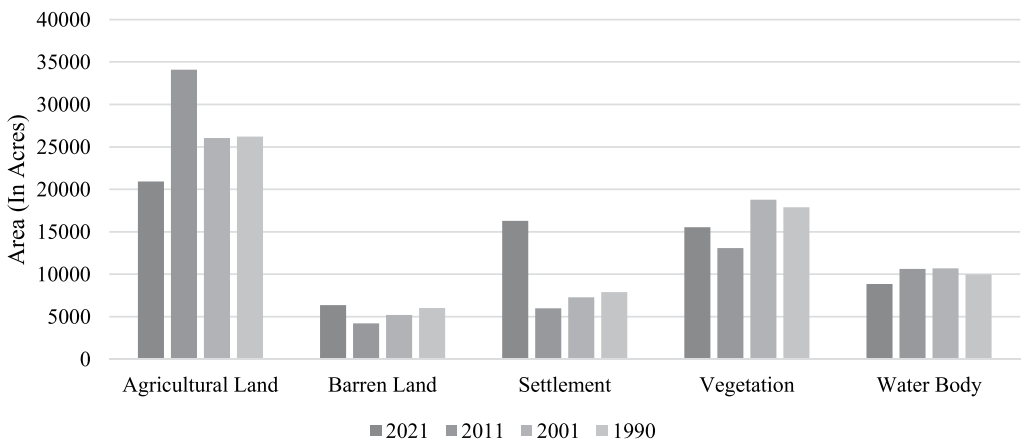

Figure 4. Kurigram Sadar LULC 1990 to 2021 Diagram

Table 1. Analysis of LULC data from 1990 to 2021 for Kurigram Sadar Upazila

Land use land cover (LULC)	1990	2001	2011	2021	LULC change (+/-)
Agriculture	26199.99	26047.95	34078.84	20930.31	-20.11%
Barren Land	6010.77	5203.88	4221.60	6366.37	5.92%
Settlement	7894.32	7275.93	5991.03	16293.65	106.40%
Vegetation	17903.34	18773.55	13074.91	15541.60	-13.20%
Water Body	9993.56	10698.37	10633.96	8864.15	-11.30%

class distribution presented in graphic form. The dramatic rise in agriculture could be ascribed to the encroachment of cropland at the expense of vegetated land, driven by population pressure and intensified food production. The Mymensingh district in the same period witnessed the same phenomenon of transformation of vegetative land to croplands under economic intensification and availability of agricultural subsidies (Parvin et al., 2024).

During 2021, Settlement observed an all-time high with a total of 16,293.65 acres, which was more than double the 2011 figure. Following the decrease to 20,930.31 acres, the Vegetation restored to 15,541.60 acres. Water Body decreased to 8,864.15 acres, and Barren Land increased to 6,366.37 acres. The spatial distribution of LULC in 2021 is presented in Figure 3, and the corresponding bar chart of the categories is shown in Figure 4. The increase in settlement extent reflects high levels of urbanization and infrastructural expansion, aligning with national trends of peri-urban change. These changes are similar to those which were reported in the Gazipur district, where the same types of LULC shifts, agriculture-settlement, were reported due to industrial expansion and unregulated urban sprawl (Hossen et al., 2022).

The spatio-temporal LULC from 1990 to 2021 of Kurigram Sadar Upazila (Fig. 3 and Fig. 4) reports substantial changes in all of the most important land classes. Settlements in particular expanded by an increase of 106.40%, from 7,894.32 acres in 1990 to 16,293.65 acres in 2021. The rapid growth of cities reflects increasing population density and housing development. Our findings were also in line with the results of Ahmed et al. (2020), who reported that the geographical expansion of settlement increased by 95% over the period between 1990 and 2020, which signifies a common trend of rapid urban sprawl associated with both migration and economic development (ibid.). Agricultural land, on the other hand, decreased by about 20.11% from 26,199.99 acres to 20,930.31 acres. This reduction may indicate higher pressure on arable land due to built-up expansion and declining soil fertility or flood threats in low-lying areas. A comparable reduction was recorded in the case of agriculture in Narayanganj district, almost 18%, because of the rapid industrialization (Islam & Hassan, 2017). The percentage decrease of vegetative coverage was observed to be 13.20 due to deforestation, unplanned development, and river bank erosion commonly found in the Northern region of Bangladesh. There was about 11.30% decline in the water body area, which could be due to climatic factors, river morphological changes, or encroachment for the settlements.

Instead, barren land experienced a slight increase by 5.92%, which could be related to land degradation or temporary clearings waiting for urban or industrial use. Rahman et al. (2022) in the case of Jamalpur, where the fallow land is increasing in response to the seasonal cultivation gaps and has free access to land. Overall, these spatio-temporal changes (Fig. 3) illustrate an urban-bound pattern of transformation, characterised by a progressive conversion of natural and rural landscapes to a built environment. This observed trend, which is in line with other floodplain areas in Bangladesh, calls for immediate policy measures such as prudent land use planning and environmental protection.

LULC change prediction

Forecasting these patterns over the future, the percentage alteration in the decade 1990-2071 can be approximated from the Figure 5. Farmlands should decrease by approximately 52.54% by 2071 compared to how much they occupied in 1990, an enormous decrease of agricultural lands with tremendous impacts on food production and countryside economies. Non-agricultural lands must increase by as much as almost 15.48% by 2071, a slow incremental addition of non-productive lands. Settlement zones will spread significantly, by about 277.91% between the years 1990 and 2071, the broad time frame highlighting the ubiquity of urbanization. Vegetation cover will likely decrease by about 34.49% during the same period, indicating growing pressure on natural functioning. Water bodies are projected to decline by approximately 29.52% by 2071, and issues of water resource availability and aquatic ecosystem health are being raised.

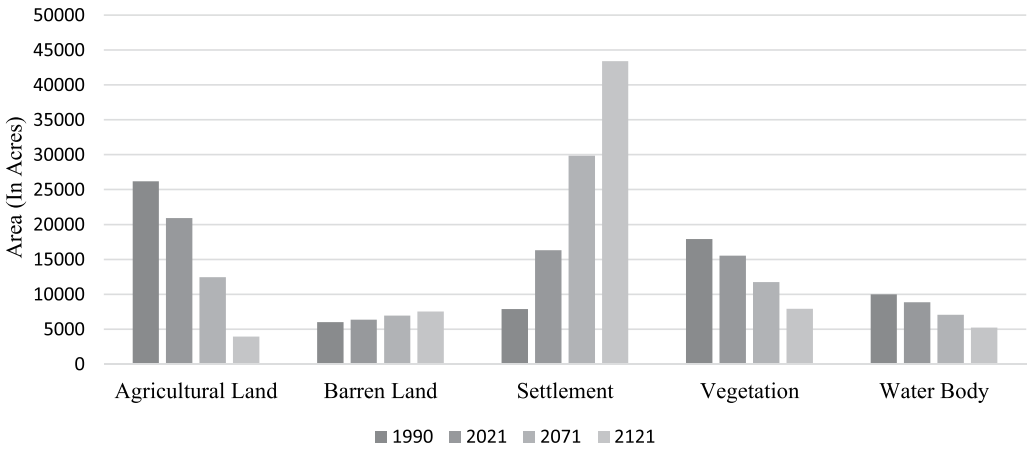

Figure 5. Future Prediction of Kurigram Sadar Upazila LULC

Table 2. Analysis of future LULC data from 1990 to 2021 for Kurigram Sadar Upazila

Land use land cover (LULC)	1990	2001	2011	2021	2071	2121
Agriculture	26199.99	26047.95	34078.84	20930.31	12430.82	3931.39
Barren land	6010.77	5203.88	4221.60	6366.37	6939.91	7513.45
Settlement	7894.32	7275.93	5991.03	16293.65	29840.95	43388.26
Vegetation	17903.34	18773.55	13074.91	15541.60	11732.33	7923.07
Water body	9993.56	10698.37	10633.96	8864.15	7042.54	5220.92

Looking ahead even more, by 2121, the transformation is even greater Agricultural land is projected to decrease by as much as 84.99% from its 1990 level, which would mean that traditional agricultural landscapes would no longer exist in the area. It is expected that barren land will grow by about 25.00%, which is a sure sign that the environment is getting worse without any action being taken to mitigate it. By 2121, the settlement area could be as much as 449.49% bigger than it was in 1990. This would completely change how the Kurigram Sadar Upazila land is used. Vegetation will decline significantly by as much as 55.76%, posing a serious risk to biodiversity, climate control, and ecological balance. Water bodies will also be reduced by as much as 47.74%, an impact that would adversely affect water organisms and the consumption of fresh water by mankind. The bar graph of comparison shows graphically how, decade by decade, agricultural land, vegetation, and water bodies reduce steadily, while showing a steady and steep increase in settlement. The graphical trend indicates that if trends go unchecked, by the end of the 21st century, urban expansion will emerge as the number one land use category, remaking the environment and socio-economic landscape of Kurigram Sadar Upazila in a fundamentally different way. Though, Rahman and Sultana (2020) revealed that LULC change over the last 30 years in Kurigram Sadar Upazila has been identified as a key issue that calls for urgent action of integrated and sustainable land management at different levels. Therefore, serious interventions in sustainable land management, environmental conservation, and smart city planning are warranted to reconcile growth with environmental coherence and to provide for the region's future stability.

Conclusion and recommendations

LULC change over the last 30 years in Kurigram Sadar Upazila has been changed in different perspectives. Planning of agricultural lands should be undertaken as a comprehensive activity for ensuring conservation of agricultural land, so that its productive areas can be reserved for food production and no farmland can be lost to unplanned settlements. Infrastructure for mitigation of riverbanks erosion, improved flood management system, is also needed to mitigate the effects of water body fluctuation and river erosion on livelihoods and land resources. In addition to this, active initiatives like afforestation, plantation at the community level, and awareness campaigns for new and sustainable agricultural technologies to restore ecological balance to the field need to be intensified. The monitoring using GIS and RS technologies must be institutionalized for their provision of real-time data for develop real time monitoring system and policy-informed decision making and early intervention against environmental degradation. Strengthening of local governance structures, increasing public awareness, and involvement of the local community in land management decisions are necessary steps towards the achievement of sustainable development objectives in Kurigram Sadar.

LULC changes in Kurigram Sadar Upazila reflect ongoing socio-environmental transformations in the rural areas. The decline of agricultural land and increase of settlements, and the shifting of water bodies indicate a decline in ecological balance of the study area. If these changing trends continue, this district's agricultural base eco-friendly livelihoods would be affected in the near future. However, a proper sustainable land use plan, environmental conservation, and adaptive livelihood strategies can build a resilient future. Thus, this study provides valuable insights for sustainable land management that integrates eco-friendly development with environmental protection.

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Design and development of a low-cost water purifier using terracotta filter disc

Nabila Azhar Ridhy[1], Shoriful Islam[2*], Md. Zainul Abedin[2]

[1] SAFAL for Integrated Water Resources Management, Uttaran, Dhaka-1209, Bangladesh

[2] Department of Farm Structure and Environmental Engineering, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

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***Corresponding Email:**
shoriful.ae@gmail.com

ABSTRACT

This study designed and developed a low-cost water purifier using a terracotta filter disc (Terafil) and evaluated its performance in treating groundwater. Conducted at Bangladesh Agricultural University, the filter was tested using water samples from three locations in a residential area. The average input concentrations of iron, calcium, magnesium, chloride, total dissolved solids (TDS), and bicarbonate were 1.54, 19.23, 5.82, 8.17, 55, and 1.80 ppm, respectively, with an electrical conductivity (EC) of 133 µS/cm and a pH of 6.95. After filtration, these values reduced to 0.22, 6.42, 2.92, 2.99, 22, and 0.63 ppm, respectively, with EC and pH at 73 µS/cm and 6.77. The filter demonstrated removal efficiencies of 86.03% for iron, 66.61% for calcium, 49.80% for magnesium, 63.27% for chloride, 58.88% for TDS, 64.81% for bicarbonate, and 50.19% for EC. All treated parameters fell within World Health Organization (WHO) permissible limits. The unit was constructed for BDT 1,285.00 per unit and can supply 20–30 liters of potable water daily, demonstrating its potential as an affordable, effective solution for communities lacking access to safe drinking water.

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Introduction

Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and transportation. Clean drinking water is essential to human and other life forms. Need to safe drinking water has improved steadily and substantially over the last decades in almost every part of the world (Hutton & Chase, 2017). There is a clear correlation between access to safe water and GDP per capita. However, some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability. A recent report suggests that by 2030, in some developing regions of the world, water demand will exceed supply by 50% (He et al., 2021). Approximately 70% of freshwater is consumed by agriculture (Ingrao et al., 2023) and it is the natural resource that is the most extracted at the global level. Excessive freshwater consumption can be responsible for a scarcity in the circulation rate, which occurs when the freshwater demand exceeds its availability. Hence, water

consumption needs to be optimised in all human activities, given the increasing freshwater scarcity due to climate changes and to the annual net increase in the human population of 81,000,000. Freshwater plays many important roles in daily life for example, agriculture is responsible for nearly 70% of that withdrawal volume, and it is therefore, the most water-intensive sector. This puts emphasis upon the urgent need of transitioning towards more sustainable agricultural and food-production/consumption systems.

In Bangladesh, there is an abundance of water, but scarcity of safe drinking water is the reality at present. Nearly one fourth of the population has no access to safe drinking water (Abedin et al., 2014). Being a low-lying deltaic country of exceptionally dense population, Bangladesh is susceptible to a variety of environmental stresses and natural disasters; these stresses can intensify the difficulties accessing potable water. The main issues surrounding water quality are microbial pathogens, arsenic (As) in groundwater and salinity (Sultan et al., 2025). Arsenic is not only a great threat; nowadays iron, hardness, turbidity, dissolved solids are becoming a great threat. High levels of iron are widespread, with approximately 40% of the population exposed to more than the Bangladesh limit of 1.0 ppm (Hasan et al., 2019; Khan et al., 2024; Shafiquzzaman, 2017) manganese (Mn. The situation is even worse for manganese, which has health impacts: more than 60% of the population consumes drinking water above the Bangladesh limit of 0.1 ppm, and approximately one third of the population drinks water exceeding the less stringent WHO Guideline Value of 0.4 ppm (Rahman et al., 2021). Mines can produce a variety of Fe pollution problem in groundwater (Barnes & Clarke, 1964; Emrich & Merritt, 1969; Liu et al., 2022). Coal mining in Appalachia has degraded both the surface and ground water. During mining, ground water is drained from the rocks and the pyrite associated with the coal beds is exposed to air. Oxidation of the pyrite produces high iron ana sulfate concentration and a low pH in the water. Some of this polluted water flows directly into nearby streams and some moves into the ground-water system. When the latter occurs, the iron concentration can increase up to several hundred mg/1 and the sulfates to over one thousand mg/1. Unfortunately, in most cases the cessation of mining does not stop the ground-water pollution, and it can take many decades before the ground water again becomes usable. A detailed study of the effects of coal mining on ground water was conducted in the Toms Run drainage basin in northwestern Pennsylvania where coal mining and oil and gas well drilling have occurred for almost 100 years. The rocks of Mississippian and Pennsylvanian Age produce a multiaquifer system–three major aquifers separated by siltstone and shale beds (aquitatdes. Concentrations of nitrate in rainwater of up to 5.0 ppm have been observed in industrial areas (Mamun & Sharif, 2024)commercial stations of untreated water for domestic uses, private wells of residences for households, and private wells for agricultural uses—were found to be in the 16–380 mg/L range. Drinking water from all commercial treated water stations has lower nitrate levels, based on the WHO standard of 50 mg/L. In contrast, almost 33% of commercial stations with untreated water (used only for domestic purposes. In rural areas, concentrations are somewhat lower. The toxicity of nitrate to humans is mainly attributable to its reduction to nitrite. The major biological effect of nitrite in humans is its involvement in the oxidation of normal Hb to metHb, which is unable to transport oxygen to the tissues (Huong et al., 2020; Pittman, 2011). It is found that gastrointestinal infections may cause met Hb formation through the nitric oxide pathway (Belzer & Krasowski, 2024)a form of hemoglobin that cannot bind oxygen. While there are some rare congenital causes of methemoglobinemia, most cases are acquired from the effects of specific drugs or environmental exposures. In this retrospective study, we analyzed a large data set of whole blood samples analyzed for methemoglobin at an academic medical center in Midwestern United States that provides both pediatric and adult services. For a 14 year timeframe (May 2009- June 2023. High nitrate concentration,

above 100 ppm, is an important cause of metHb formation and that breastfeeding is protective in exposed populations (Shaban et al., 2023a). However, gastrointestinal infection is a very important contributor (Shaban et al., 2023b).

Exposure to extreme pH values results in irritation to the eyes, skin, and mucous membranes (Hwang et al., 2022). Eye irritation and exacerbation of skin disorders have been associated with pH values greater than 11. In addition, solutions of pH 10–12.5 have been reported to cause hair fibers to swell. In sensitive individuals, gastrointestinal irritation may also occur. Exposure to low pH values can also result in similar effects. Below pH 4, redness and irritation of the eyes have been reported, the severity of which increases with decreasing pH. Below pH 2.5, damage to the epithelium is irreversible and extensive (Kolle et al., 2017; Lim et al., 2014). In addition, because pH can affect the degree of corrosion of metals as well as disinfection efficiency, it may have an indirect effect on health (Salam et al., 2024). Most surface water sources and many underground sources contain harmful micro-organisms and other harmful substances (contaminants) that must be removed from the water to acceptable levels to make the water fit for domestic use. There are many different types of micro-organisms and other substances that may have health effects on consumers who drink untreated water. These treatment processes are very costly and sometimes rural people cannot afford the cost. Equipments are not available in all areas and its maintenance cost is also very high. So, there is a need of low-cost water filtration device which can reduce pH level, turbidity, remove iron, and reduce total dissolve solids and hardness in drinking water. Considering the need of a low-cost filtration evince for our country Terracotta filter is especially useful when the water is rich in sediments, suspended particles, iron and certain microorganisms cause water borne diseases. The Terracotta water filter aims that it is able to significantly reduce pH level, turbidity, iron, total dissolve solids and hardness in drinking water. The study was carried out the following objectives:

a. To design and develop a potable water purifier using Terracotta filter disc, and
b. To evaluate the performance of the developed water purifier unit.

Materials and methods

Design consideration for the terracotta filter

The following points were mostly taken into consideration for designing the water filter; (i) proper size of sand, (ii) fineness Modulus of sand, (iii) diameter and height of terracotta filter disc, (iv) simplicity in construction of the unit, (v) ease in functional operation, (vi) simple technology with locally available materials of construction, (vii) different parts of the machine should be simple as so that it can be made in local workshop, (viii) it should be easy to repair and maintain, (ix) the cost of the purifier must be within the people's capacity, (x) it should be light and easy to operate.

Materials used to build water filter

A very simple design was made by locally available low-cost materials. Materials required to construct this filter were procured from local market. Most of the parts of the unit were designed and fabricated in the lab of the Department of Farm Structure and Environmental Engineering, Bangladesh Agricultural University, Mymensingh. The major materials required for this filter was: (i) terracotta filter disc, (ii) plastic container, (iii) strainer, and (iv) tap.

Development of the terracotta disc water filter

To produce the terracotta water filter disc, there is a need for a mixture of ordinary pottery clay, river sand, and wood sawdust without using any chemicals. In order to create a porous terracotta disc, the mixture's dough is burned at a high temperature in a wood or coal fired furnace. Figure 1 (a) shows a terracotta filter disc before and Figure 1 (b) after burning, making it hardened and ready for filtration. Through the sintering process, the wood particles are blistered and clay particles are sintered in the region of the sand particles, leaving spherical large pores

in between. These pores are not associated with each other but alienated by very skinny clay walls, which are semi-permeable in nature. The skinny clay walls contain large numbers of ultra-fine vessel openings. A set of pores are linked by these ultra-fine vessels only. The average diameter of the vessel openings is a sub-micron size. During the filtration process, water flows from one pore to another pore through the vessel openings by pressure of water over the disc. The pores inside the disc always work like micro-reservoirs of filtered water.

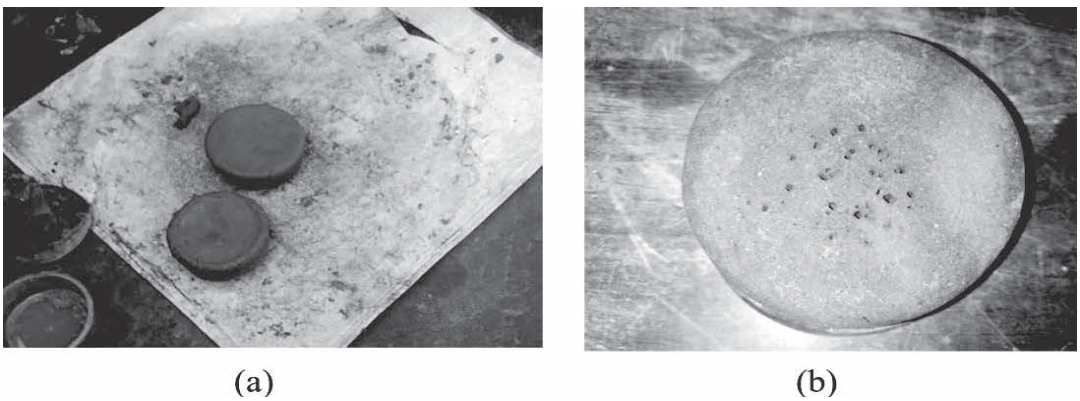

Figure 1. (a) Terracotta filter disc before burning, (b) Filter disc ready to use after burning

Almost all suspended particles cannot enter into the vessels while opening of the vessels are in sub-micron; thus, sediments and impurities deposited on top of the disc throughout filtration. Therefore, the core of Terracotta disc is by no means congested. A schematic diagram of a terracotta filter presented in Figure 2(a), illustrating its structural components and filtration setup and Figure 2(b) depicts the developed plastic container equipped with an outlet tap, which likely serves as a storage unit for the filtered water, facilitating easy access and dispensing.

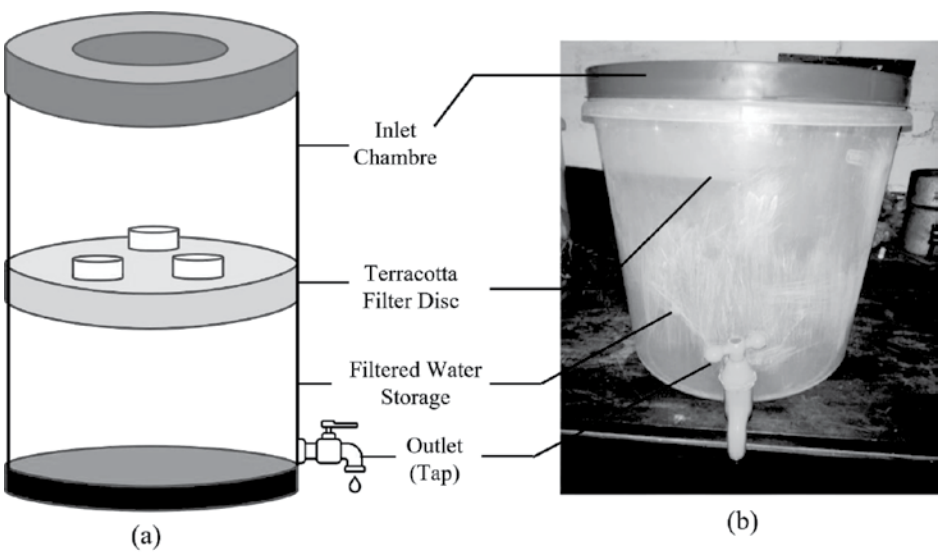

Figure 2. (a) Schematic arrangement of a terracotta filter, (b) Plastic container with outlet tap

Working principles of terracotta filter

The quality of water should be analyzed before installation of terracotta filter. A high range of pH, iron, manganese, chloride, calcium, bicarbonate, TDS and electric conductivity was found in the study area. So, development and installation of Terracotta filter can be useful for the collected samples.

During filtration process, water flows from one pore to another pore through the capillary openings by pressure of raw water over the terracotta disc. The pores inside the Terracotta disc always work like micro-reservoirs of filtered water. Since opening of the capillaries ae in sub-micron, almost all suspended particles and microbes cannot enter into the capillaries; hence sediments and impurities are deposited on top of the terracotta disc during filtration. Therefore, the core of Terracotta disc is never clogged unlike white ceramic candle during filtration. The terracotta is activated during sintering process and the clay is negatively charged. Soluble ion and some heavy metals present in aw water is also removed by ion-exchange and adsorption process. The soluble iron is always precipitated on the top surface of the terracotta. These impurities/ sediments are cleaned from top surface of terracotta periodically.

Collection of the sample

In order to test the performance of the designed unit, contaminated water sample were collected from three selected locations of Bangladesh Agricultural University residential area.

Results and discussions

Initial quality parameter of the water sample

The quality parameter of the water sample and the initial values of the sample are shown in the following Table 1.

Table 1. Quality parameter and the initial average values of sample

Quality parameter	Initial values
Iron concentration (ppm)	1.541
pH level	6.95
Magnesium level (ppm)	5.832
Chloride level (ppm)	7.997
TDS (ppm)	55
Bicarbonate level (ppm)	1.8
EC (µS/cm)	145

Sieve analysis

By using sieve shaking machine Fineness modulus, co-efficient of uniformity, co-efficient of curvature, Average diameter and gradation curve was prepared. Sieve analysis data is in the following Table 2.

Table 2. Fineness modulus of sand

Sieve size	Opening, mm	Wt. of sand retained	% wt. of sand retained	Cumulative % retained	% Passing
#4	4.76	0	0	0	100
#8	2.36	92	9.2	9.2	90.8
#16	1.19	836	83.6	92.8	7.2
#30	0.595	72	7.2	100	0
#50	0.297	0	0	100	0
#100	0.149	0	0	100	0
Pan	-	0	0	-	-

Fineness modulus of sand = 402/100 = 4.02

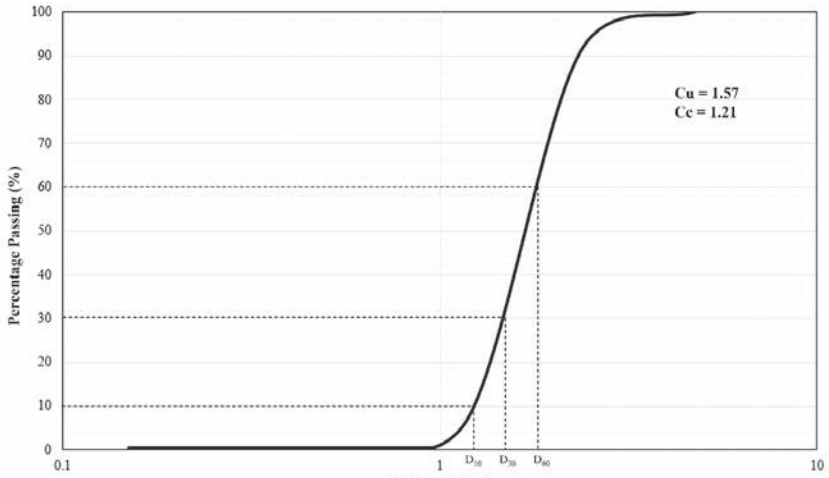

Figure 3. Gradation curve of used sand

The gradation curve for the sand particle (Figure 3), we have found the value of D_{10}, D_{30} and D_{60} are 0.23, 0.51 and 0.93 mm respectively.

Co-efficient of uniformity

The uniformity of a soil is expressed qualitatively by the uniformity coefficient, C_u, given by, $C_u = D_{60}/D_{10.}$ where, D_{60} = particle size such that 60% of the soil is finer than the size, D_{10} = particle size such that 10% of the soil is finer than the size. The larger the numerical value of C_u the more is the range of particles soils with a value of C_u less than 2 are uniform soils. Sands with a value of C_u of 6 or more are well graded. In this study the co-efficient of uniformity of the sample was 1.57.

Co-efficient of curvature

The general shape of the particle size distribution is described co-efficient known as co-efficient of curvature (C_C), given by, $C_C = (D_{30})^2/ (D_{60} \times D_{10})$. where, D_{30} = particle size such that 30% of the soil is finer than the size. For a well grated soil the value of the Cc lies between 1 and 3. In this experiment the Cc of the sample was 1.21.

Performance evaluation of the developed filter

Table 3. Performance of the developed terracotta filter

Quality parameters	Output values	Recommended safe limit	Source
Iron concentration (ppm)	0.215	0.3	WHO
pH level	6.77	6.5 - 8.5	WHO
Magnesium level (ppm)	2.920	Up to 50	DWI, WHO
Chloride level (ppm)	2.999	250	WHO
TDS (ppm)	22.00	500	WHO
Bicarbonate level (ppm)	0.633	Up to 300	US (EPA)
EC (µS/cm)	66.50	400	WHO

The Table 3 shows the results of the water quality analysis show that the developed terracotta water purifier effectively reduced key contaminants within recommended limits. Iron concentration was reduced to 0.215 ppm, below the WHO threshold of 0.3 ppm. The pH level, magnesium, chloride, and TDS were well within their respective recommended limits by WHO, drinking water inspectorate (DWI), and environmental protection agency (EPA).

Additionally, the EC was found to be 66.50 µS/cm, considerably lower than the WHO limit of 400 µS/cm, indicating effective filtration.

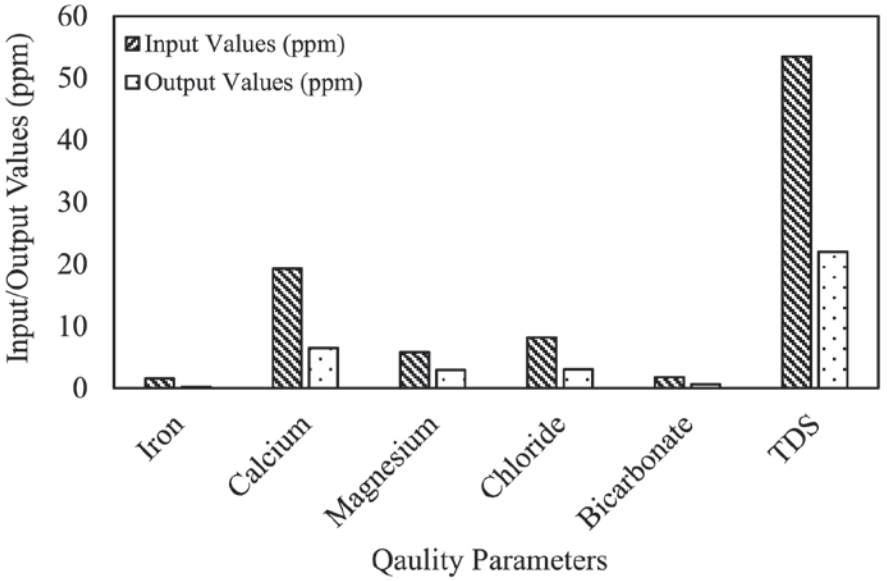

Figure 4. Comparison of the performance in removing particles from water samples

A comparative evaluation of key water quality parameters before and after filtration through the developed terracotta disc filter showed in Figure 4. The data demonstrate a substantial reduction in all measured contaminants. Iron concentration decreased from 1.541 ppm to 0.215 ppm, achieving the highest removal efficiency of 86.03%. This exceptional performance aligns with studies on ceramic filters, where iron removal primarily occurs via oxidation and subsequent physical filtration of precipitated ferric hydroxide on the filter surface (Ali et al., 2021). Calcium and magnesium levels, indicative of water hardness, were reduced from 19.238 ppm to 6.423 ppm (66.61% efficiency) and from 5.817 ppm to 2.920 ppm (49.80% efficiency), respectively. The lower removal efficiency for magnesium compared to calcium may be attributed to its higher solubility and smaller ionic radius, making it less susceptible to adsorption and ion-exchange processes within the clay matrix (Dey et al., 2025; Oyanedel-Craver & Smith, 2008; Sepehr et al., 2013)grog (previously fired clay.

Chloride and bicarbonate ions showed significant reductions from 8.166 ppm to 2.999 ppm (63.27% efficiency) and from 1.80 ppm to 0.633 ppm (64.81% efficiency), respectively. The removal of these anions is likely facilitated by the negatively charged clay particles in the sintered terracotta, which can attract and retain positively charged complexes, though anion removal mechanisms in ceramic filters can be less straightforward and may involve pore size exclusion and surface interactions (Bielefeldt et al., 2009; Zereffa & Desalegn, 2019)but the treatment efficiency decreased with subsequent batches of spiked water. Silver concentrations in the effluent water ranged from 0.04 – 1.75ppb. Subsequent experiments that utilized feed water without a bacterial spike yielded 103–105CFU/mL bacteria in the effluent. Immediately after recoating four of the filters with a colloidal silver solution, the effluent silver concentrations increased to 36 – 45ppb and bacterial disinfection efficiencies were 3.8–4.5log. The treatment effectiveness decreased to 0.2 – 2.5log after loading multiple batches of highly contaminated water.

In subsequent loading of clean water, the effluent water contained <20–41CFU/mL in two of the filters. This indicates that the silver had some benefit to reducing bacterial contamination by the filter. In general these POU filters were found to be effective, but showed loss of effectiveness with time and indicated a release of microbes into subsequent volumes of water passed through the system. Metal oxide ceramic is getting more attention in current times due to their unique pore structures, hydrophilic surfaces, high chemical, thermal and mechanical stabilities which offer avenues for application in water treatment. This paper presents the results of an experimental study on the effects of different ratios of clay, grog, sawdust and bone char on efficiency of ceramic composite water filters. Filter of different designs were developed from clay (50, 60, 70, 75 and 80. TDS, an aggregate measure of inorganic salts, dropped from 53.50 ppm to 22.0 ppm, corresponding to a 58.88% removal efficiency. This reduction is consistent with the combined removal of the individual ions and confirms the filter's ability to lower overall mineralization.

The performance of the terracotta filter is comparable to other low-cost ceramic filtration technologies documented in literature. For instance, studies on fired clay candles have reported iron removal efficiencies of 70-90% (Apea et al., 2023; Bulta & Micheal, 2019; Stubbé et al., 2016) and TDS reductions of 40-60% (Sobsey et al., 2008), which brackets the efficiencies observed in this study. The superior iron removal is particularly noteworthy for regions like Bangladesh, where groundwater iron contamination is prevalent. The mechanism is a combination of physical sieving through sub-micron pores and adsorption onto the active clay surfaces, a process well-described for porous ceramic water filters (Ciawi & Khoiruddin, 2024) rural areas, and remote locations. In the absence of centralized water treatment systems, point-of-use (POU. Overall, the terracotta filter proved highly effective in improving the physicochemical quality of water, bringing all tested parameters within WHO permissible limits and validating its potential as a robust, low-cost point-of-use water treatment solution.

Maintenance and re-installation of terracotta filter

Rate of filtration is dependent upon turbidity and pressure of raw water as well as diameter of Terracotta disc inside the filter. The filtrates clog the top surface of the Terracotta over time during use and hence reduce the flow rate. Therefore, scrubbing or cleaning the top surface of the Terracotta disc with a soft nylon brush or coir or similar abrasive materials or by water jet is necessary to remove the sediments and open the new pores for rejuvenation of filtration process. The thickness of the Terracotta keeps reducing its top surface; however, quality of filtered water is not altered during entire life of Terracotta. Plastic container and strainer of the filter need to be replaced frequently.

Analysis of cost

Users feel so interest for the cost when new technology is introduced. So, cost analysis is so important for new technology. The total cost of the filter was determined by adding the cost of the materials used to build the filter. The cost of the developed terracotta water filter was estimated and it was BDT 1,285.00 shown in Table 4. This filter is capable to supply 20-30 liters with 1-4 liter per hour rate of filtration.

Table 4. Cost of materials and total cost of the filter

Name of component	Materials used	Size/ specification	Quantity	Cost (BDT)
Container	Plastic	15 and 20 liters (capacity)	2 pcs	500
Sand	Sand	0.8-2mm size	1 cft	50
Total cost	-	-	-	1285

Name of component	Materials used	Size/ specification	Quantity	Cost (BDT)
Saw dust	wood	-	5 kg	100
Pottery clay	Clay	-	5kg	50
Tap	plastic	0.75 cm (dia)	1pcs	60
Strainer	plastic	4cm (dia)	1pcs	25
Labor cost	-	-	-	500
Total cost	-	-	-	1285

Conclusions

This study successfully designed and developed a low-cost water purifier using a terracotta filter disc (Terafil). The filter demonstrated significant effectiveness in treating contaminated groundwater, achieving substantial reductions in key physicochemical parameters. Notably, iron concentration was reduced by 86.03% (from 1.541 ppm to 0.215 ppm), calcium by 66.61% (from 19.238 ppm to 6.423 ppm), and TDS by 58.88% (from 53.50 ppm to 22.0 ppm). All treated water parameters—including pH (6.77), EC (73 μS/cm), chloride (2.999 ppm), magnesium (2.920 ppm), and bicarbonate (0.633 ppm), fell within the permissible limits set by the WHO, confirming the filter's compliance with health and safety standards for potable water. The low manufacturing cost of BDT 1,285.00 and a daily production capacity of 20–30 liters underscore the economic viability and practical utility of the system for households in resource-limited settings. Its straightforward maintenance requiring only periodic cleaning of the disc surface and the durable nature of the sintered terracotta ensure long-term reliability and user-friendly operation. This research highlights the importance of accessible, affordable, and locally sustainable water treatment technologies. By utilizing readily available materials such as clay, sand, and sawdust, the Terafil filter presents a scalable and community-adaptable solution to address persistent challenges in water quality management, particularly in regions like Bangladesh where access to safe drinking water remains a critical public health issue.

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Authors' contributions

NAR conceptualized the study and carried out the experimental procedures. SI was responsible for data analysis, data visualization and wrote the original draft of the manuscript. MZA supervised the research work and contributed to data analysis, reviewing and editing the manuscript.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to institutional policy but are available from the corresponding author on reasonable request.

Declarations

Ethics declaration: Not applicable. Consent to participate declaration: Not applicable. Consent to publish declaration: Not applicable.

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Intercropping of cereals with mulberry and its impact on silkworm biology and farmer's income

Faruque Ahmed[1*], Md. Shoriful Islam[2], Md. Iftekher Islam[3], Md. Mostafizur Rahman[4], Md. Dulal Ali Mollah[4] and Md. Aftab Uddin[1]

[1] Bangladesh Sericulture Research and Training Institute (BSRTI), Rajshahi, Bangladesh

[2] Krishi Karigori College, Sirajganj, Bangladesh.

[3] Department of Zoology, National University, Gazipur, Bangladesh

[4] Department of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh

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***Corresponding Email:**
moistfaruk@gmail.com

ABSTRACT

*Mutual cultivation of mulberry (**Morus** spp.) and cereals would be a special and cost-effective cropping pattern for sericulture sector. The study focused on intercropping of cereals with mulberry garden to enhance the crop diversity, productivity and better economy of sericulture. Three types of crop combinations a) sole mulberry, b) mulberry + wheat and c) mulberry + rice were used with three replications. The results revealed that the leaf productivity of mulberry plant was greater in sole mulberry garden followed by the mutual cultivation of wheat and mulberry. Moreover, the biochemical properties of mulberry leaves, especially moisture, total chlorophyll, protein, total Sugar, reducing Sugar and minerals, were comparatively greater with better biological properties of silkworm and silk cocoon production for mulberry + wheat crop combination. At the same time, the post-harvest physiochemical properties of soil like pH, organic matter, nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron and copper were comparatively better for the intercropping soil of mulberry + wheat with maximum benefit: cost ratio (1.95) followed by the mulberry + rice (1.82) and sole mulberry (1,69) respectively. The findings of our study suggested that wheat would be a better option of intercropping with mulberry gardens for better leaf qualities, soil improvement, silk cocoon productivity, and sericulture economy for sloe mulberry growing farmers.*

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Introduction

Intercropping is a pioneering and defensible agricultural practice involving synchronized cultivation of two or more diverse crop species within the same field or growing area in a judiciously strategic and spatially planned method. This agricultural practice originated along with ideologies of polyculture; thereby, various flora species are deliberately and purposefully grown together, in contrast to the predictable culture formulation that trusts the special cultivation of a single crop in a given area. The intercropping

pattern desires to exploit the proficient use of accessible resources, including sunlight, water, nutrients, and space, to enhance global production and biological flexibility. By harnessing the balancing exchanges between the parallel crops, intercropping offers numerous profits far beyond those attainable in finished monoculture schemes (Mao et al., 2015). The mutual growth of varied crop species can lead to a supplementary capable use of resources, as different plants often have diverse root assemblies and nutrient supplies, effectively decreasing competition for crucial elements in the soil and resulting in enhanced crop yield and production. Additionally, confident crop mixtures display a mutualistic association, where one species might offer provision or defence to an alternative, prominent to a synergetic influence that improves inclusive production (Jensen et al., 2006).

Sericulture is profoundly embedded in the culture and practice of Bangladesh, which is awarded a salubrious climate. It is outstanding for its low investment, quick and high returns, and further providing self-employment opportunities. The industry is also gorgeous, predominantly for small and marginal farmers, mainly because of its regular source of income. Mulberry leaf, the sole food for the silkworm *Bombyx mori* L., contributes to around 38.20% of successful cocoon production. However, Bangladesh is the world's most densely populated country and a prominent land mass. Per capita land availability is < 0.05 ha and is slowly decreasing. The scope to expand mulberry cropping in the new land is limited. Bangladesh's population is also increasing at 1.22% year-1 (BBS, 2022), and cropping intensity has already reached 1.9% on average (DAE, 2018). Malnutrition is also among the highest in the world, with six million children estimated to be chronically undernourished. In our country, the continually aggregated need for food, clothing, and shelter from inadequate land due to sky-speeded escalation in the human population has forced man to change the means for swelling the economic incomes from a unit land area.

Due to limited land savings and competition with other crops, sericulture is moving towards keen antagonism. Consequently, it is vital to pledge the parallelism between agriculture and sericulture to uphold fusion reactions. Traditionally, most farmers who are involved with sericulture have constant land holdings and recline capitally upon family labour and facile tools; they neither accept gambling nor have ample land, so the cropping system is prolonged. By raising other minute-time crops, the sericulture farmer earns additional income from cultivation intercrops (Ahasn et al., 1989). The perpetual increasing need for food, clothing, and shelter from the insufficient land for skyscraping the increasing population has made it compulsory for man to leap the earnings for swell the financial benefit from dimension area of the land. In this interpretation, intercropping and multi-cropping are the carefully enforceable options that capitally accentuate land extension and crop diversification.

The cultivation of mulberry is a significant component of the financial stability and success of sericulture, and it would be more worthwhile if short-term crops were intercropped than as a single crop (Ramamurthy et al., 2006). In this context, multi-cropping and intercropping are economically viable replacements that mainly emphasize the diversification of crops and intensification of land use. Crop diversification and intercropping assist farmers in feast risk and diminishing their dependence on a single crop, deterring them from market instabilities and probable income losses. This modification of income sources can improve the overall economic flexibility of rural communities and subsidize local food safety (Gebru, 2015). Intercropping of short-duration pulses, viz., green gram, black gram, horse gram, soybean, cowpea, etc., in mulberry gardens conserves soil fertility and assists not only in increasing leaf yield, grain and fodder yields additionally bulk organic matter (Babu & Dandin, 2009). Intercropping of saffron with mulberry yielded a quality mulberry leaf from the same field where saffron was cultivated alone to generate work as well as a good deal of

returns to farmers during the lean period when there are no operations related to saffron cultivation (Kaur et al., 2002). Recently, other studies also recommend that medicinal plants like Aloe barbadense, Asparagus racemosus, and Acorus calamus can be successfully intercropped with mulberry (Madhusudan et al., 2015). Field crop intercropping in the mulberry garden is one of the economic techniques by which productivity and net returns per unit of land area can be increased (Rajegowda et al., 2020).

Cereals, especially rice and wheat, are the basic food demand in Bangladesh. My previous study observed the effect of pulses and vegetable intercropping in mulberry gardens on sericulture productivity and economic return. However, the impact of cereal intercropping on the mulberry garden was not estimated. That is why the present study was undertaken to know the feasibility of growing mulberry and suitable cereal intercrops to improve the economic returns per unit area of land so that sericulture farmers become economically more benefited and crop diversification will be ensured. Intercropping cereals with mulberry was expected to be a more economical and sustainable sericulture practice for sole mulberry-growing farmers.

Materials and methods

Location

This study was conducted at three locations namely, farmer's field of Paba, Rajshahi (AEZ-26), farmer's field of Bholahat, Chapainawbganj (AEZ-11 and AEZ-26) and research field of BSRTI (24^0 22' 29" North and 88^0 37' 3.84" East), Rajshahi (AEZ-10 and AEZ-11) respectively for three consecutive years during 2021-2023.

Mulberry plantation system

This experiment was executed in a paired row-high bush mulberry plantation system maintaining standard space between plant-to-plant (61cm × 61cm), line-to-line (92 cm × 92 cm), and row-to-row (183 cm × 183 cm). Intercrops were buried in lines between the rows, maintaining the standard spacing for the individual cereal crops.

Mulberry garden management

In the experiment field, all the cultural practices like top cutting, pruning, fertilization, irrigation, digging cum weeding, and disease-pest control were executed as per requisite. Each experimental treatment was used individually in a definite farmer's field according to the farmer's realization after pruning the field. Intercrop was harvested depending on the maturity of the particular cereals.

Experimental design

This study was laid out in a randomized complete block design (RCBD) with three replications.

Treatments

The treatments of the study were as follows:

1. T_0 = Sole mulberry (Control)
2. T_1 = Mulberry + Wheat and
3. T_2 = Mulberry + Rice

Measurement of soil properties

Haber et al. (1909) reported that the soil pH was realized in deionizer water using a soil: water ratio of 1:5 by using the glass electrode method. Heanes (1984) reported that soil organic C was also determined by chromic acid digestion and spectrophotometric analysis. Organic carbon's beneficial per cent value determined soil organic matter content with the conventional Van-Bemmelen's factor of 1.724 (Piper, 1950). Distilling the soil with an alkaline potassium permanganate solution was used to determine the nitrogen content of the soil sample (Subbiah & Asija, 1956). The concentrate was noticed in 20 ml of 2% boric acid solution with methyl red and bromocresol green indicator and titrated with 0.02 N sulphuric acid (H_2SO_4) (Podder et al., 2012).

The soil available K was extracted with 1N NH_4OAC and calculated by an atomic absorption spectrometer (Biswas et al., 2012). A spectrophotometer executed the soil's available phosphorus (P) at a wavelength of 890 nm. As the Olsen method, the soil sample was extracted with 0.5 M $NaHCO_3$, similar to Huq and Alam (2005). Zn in the soil sample was determined by an atomic absorption spectrophotometer (AAS) after extracting with DTPA Soltanpour and Workman (1979).

Table 1. Average of initial physical and chemical properties of the experimental soil

pH	OM (%)	N (%)	P (kg/ha)	K (me/ 100 g soil)	Ca (me/ 100 g soil)	Mg (me/ 100 g soil)	Zn (ppm)	Fe (ppm)	Cu (ppm)
8.07	1.06	0.07	12.13	0.26	28.21	2.78	2.05	2.60	0.47

Here, OM = Organic matter, N = Nitrogen, P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Zn = Zinc, Fe = Iron and Cu = Cupper.

Recorded growth and yield parameters

In this study, several growth and yield parameters viz: total leaf number per branch, leaf present per branch, total branch height per plant (cm), length of most extended shoot (cm), total shoot weight per plant (g), node per meter, 10 leaves area per plant (cm^2), total leaf weight per plant (g) and leaf yield (mt) per hectare per crop were recorded after 90 days of pruning followed by the respective procedure.

Analysis of leaf quality

The mulberry leaf specimens at the individual exaltation of the plant (head, central, and base) were gathered in paper bags at 75 DAP (days after pruning), and combined leaf samples were shaped. The moisture (%) was visualized by Vijayan et al. (1996), total chlorophyll content Hiscox and Israelstam (1979) using the spectrophotometer and were estimation using the standard formulae (Arnon, 1949), total mineral (%) AOAC (1980), protein (%) Kjeldahl's method (Wong, 1923), total Sugar and reducing Sugar (%) consistent with the Miller (1972) and Loomis and Shull (1937) gimmick and approach.

Recorded silkworm rearing attributes

The leaves from mulberry were fed to silkworms, and silk contributed characters, namely, weight of ten matured larvae (g), single cocoon weight (g), single shell weight, cocoon shell ratio, highest filament length (m), renditta, yield of cocoon (kg) /100 dfls (disease-free laying eggs) and economics of mulberry leaf production with intercrops were also recorded during the study period.

Economics

The prices of inputs were used at the time of their use, and selling prices of the seeds based on prevailing market rates at the time of harvest were taken into account.

Net returns

The net profit/ha was calculated by deducting the cost of cultivation/ha from gross returns/ha.

Benefit-cost ratio

The following formula was used:

$$\text{B: C ratio} = \frac{Net\ returns\ (US\ \$\ /ha)}{Cost\ of\ cultivation\ (US\ \$\ /ha}$$

Statistical analysis

The growth and yield contributing characters were analyzed using the Genstat 12.1th end for Windows (Lawes Agricultural Trust, UK). A one-way ANOVA was performed to detect differences for each parameter among the treatments. The results are shown as figures from Sigma Plot 12.5 versions. The leaf quality, silkworm rearing performance, soil properties, and economy were statistically analyzed, and mean values were evaluated using the DMRT test using the Statistic-10 software.

Results

Effect of cereals intercropping on growth and yield performances of mulberry

Branch number per plant

The branch number per plant of mulberry was significantly higher ($P \leq 0.001$) by the different kinds of cereal intercropped with mulberry (Table 2). Nevertheless, the highest number of branches per plant was found at 12.50 for sole mulberry (T_0) growing, followed by T_1 (12.18), and the lowest number of branches was recorded in T_2 (11.78) (Table 2 and Figure 1).

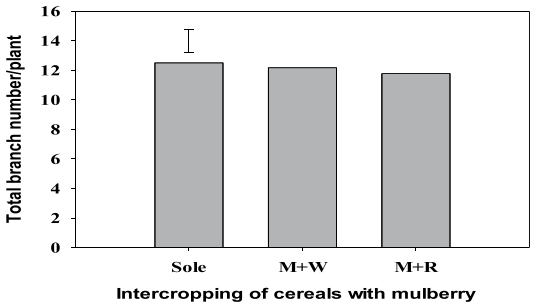

Figure 1: Branch number per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control) T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Total leaf number per plant

A significantly higher total leaf number per plant of mulberry was recorded in sole mulberry (T_0) 1360.62, which was on par with mulberry intercropped with cereals, followed by the T_1 (1327.26). Similarly, the lowest numbers of leaves were identified in T_2 (1303.02) (Table 2 and Figure 2).

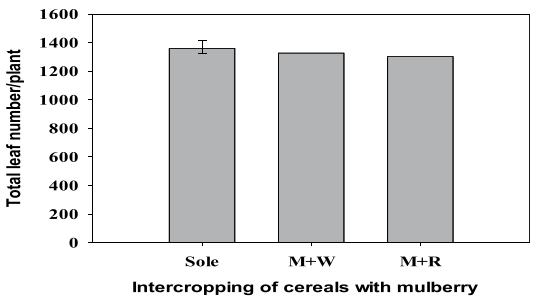

Figure 2: Total leaf number per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control) T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Total branches height/plant (cm)

The trend was highly significant (P ≤ 0.001) audited for total branch height per plant (cm) in mulberry through various types of cereals intercropped with mulberry (Table 2). The recorded maximum branch height per plant was 960.41 cm in sole mulberry (T_0), followed by T_1 (946.47 cm) and T_2 (933.92 cm), respectively (Table 2 and Figure 3).

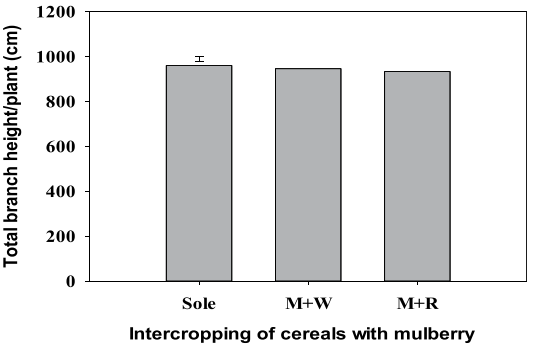

Figure 3. Total branch height per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control) T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Nodes per meter per plant

The intercropping of cereals in a mulberry garden had a highly significant (P ≤ 0.001) effect on nodes per meter of mulberry (Table 2). Nonetheless, the maximum number of nodes per meter was found to be 24.85 for sole mulberry (T_0), trailed by T_1 (23.98), while significantly least was found in T_2 (23.69) (Table 2 and Figure 4).

Table 2. Significance levels from the analysis of variance for the main effects of growth and yield parameters among various intercropped cereals with mulberry

Source of variation	Branch number/ plant	Total leaf number/ Plant	Total branch height per plant (cm)	Node per meter per plant	Length of longest shoot (cm)	Leaf present/ Branch	10 Leaf area (cm) per plant	Total leaf weight per plant (g)	Total shoot weight per plant (g)	Total leaf yield/ ha/ year (mt)
Treatments	***	***	***	***	***	***	***	***	***	***

Where, ns,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

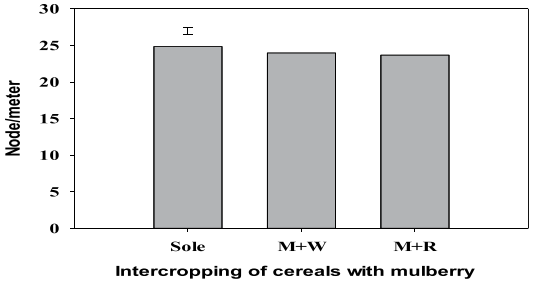

Figure 4. Nodes per meter per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control) T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Length of longest shoot

The length of the most extended shoot of the mulberry plant significantly (P ≤ 0.01) differed by the cereals intercropped in the mulberry garden (Table 2). However, the recorded highest length of the most extended shoot was 133.52 cm in the sole mulberry (T_0) plant, followed by the T_1 (132.55 cm), while the least length of the most extended shoot was (130.78 cm) for the T_2 crop combination (Table 2; Fig. 5).

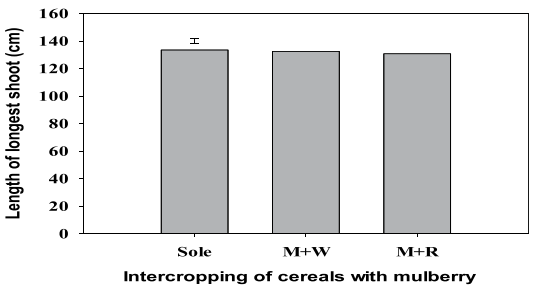

Figure 5: The length of the longest shoot for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.01) for various treatment interactions. Where, T0 = Sole mulberry (Control), T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Leaf present per branch

The presence of mulberry leaves per branch was markedly (P ≤ 0.001) differed for the cereals intercropped in the mulberry garden (Table 2). The obtained maximum leaves were 24.45 for sole mulberry (T_0), whereas the minimum leaves per branch were 22.55 in the T_2 crop combination. However, in the case of the T_1 crop combination, the leaves per branch were 23.58 (Table 2 and Figure 6).

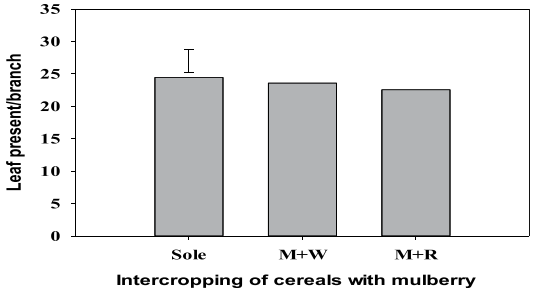

Figure 6. Leaf present per branch for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control), T1 = Mulberry + Wheat, T2 = Mulberry + Rice

10 leaves area (cm^2) per plant

The highly significant (P ≤ 0.001) trend was found for 10 leaf areas of the mulberry plant among the various cereals intercropped with mulberry (Table 2). However, the recorded highest ten leaves area per plant was 621.48 cm^2 for sole mulberry (T_0), followed by the crop combinations of T_1 (609.20 cm^2) and T_2 (565.22 cm^2) (Table 2 and Figure 7)

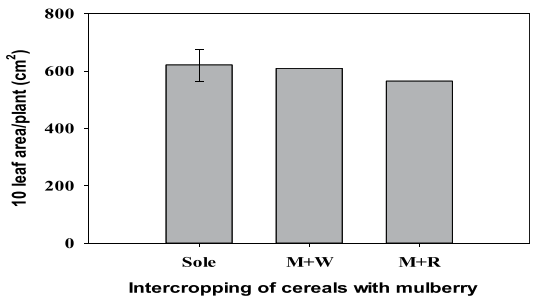

Figure 7. Leaves area per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control), T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Total leaf weight (g) per plant

The total leaf weight per plant of mulberry was statistically (P ≤ 0.001) differed by the cereals intercropped with mulberry plants (Table 2). The obtained maximum total leaf weight per plant was 938.20 g for the sole mulberry (T_0) plant, noticed by the T_1 (911.29 g) and T_2 (905.11 g), respectively (Table 2 and Figure 8).

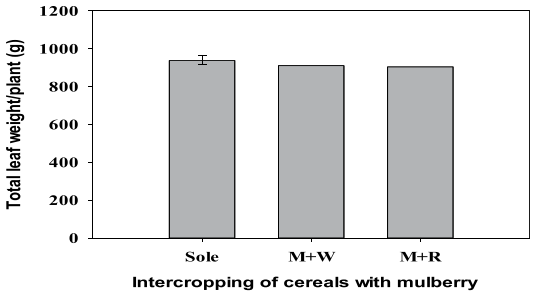

Figure 8. Total leaf weight per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control), T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Total shoot weight (g) per plant

A highly significant trend was found for the total shoot weight per plant of mulberry (P ≤ 0.001) due to cereals intercropping in the mulberry garden (Table 2). However, the maximum total shoot weight per plant was 434.32 g for the cultivation of sole mulberry (T_0), followed by the T_1 (416.91g) and T_2 (406.73g) crop combinations, respectively (Table 2 and Figure 9).

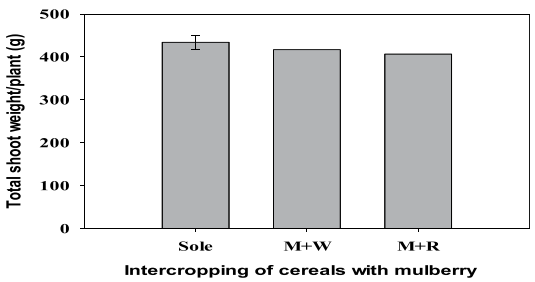

Figure 9. Total shoot weight per plant for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control), T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Total leaf yield/crop (mt)

The leaf yield of the mulberry plant was significantly (P ≤ 0.001) varied among the various cereals intercropped crop combinations (Table 2). Among the three intercropped combinations, the highest total leaf yield per hectare per crop was 11.26 MT for sole mulberry (T_0), and the lowest leaf yield was 10.97 MT for the T_1 combination. However, the leaf yield for crop combination of T_2 was 11.17 MT per hectare/crop (Table 2 and Figure 10).

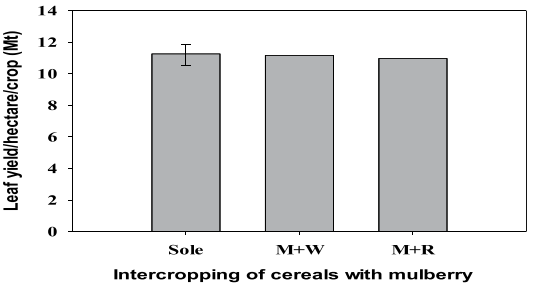

Figure 10. Total leaf yield per hectare per year for several treatments of mulberry intercropped with cereals. Vertical bars represent LSD (P ≤ 0.001) for various treatment interactions. Where, T0 = Sole mulberry (Control), T1 = Mulberry + Wheat, T2 = Mulberry + Rice

Performance of intercropping on mulberry leaf quality

Intercropping of cereals in mulberry gardens had a significant impact on mulberry leaf quality. Among the three crop combinations the obtained greater moisture, total chlorophyll, crude protein, total Sugar, reducing Sugar and mineral were (75.20 %), (38.54), (20.56 %), (6.43%), (4.16%) and (12.72%) respectively for the combination of T_1 (Mulberry + Wheat) followed by the T_2 (Mulberry + Rice) and T_0 (Sole mulberry) respectively.

In the case of Rice, the moisture, total chlorophyll, crude protein, total Sugar, reducing Sugar and mineral were 74.80%, 38.34, 20.25%, 6.25%, 4.09% and 12.50%, respectively. The marked lowest moisture (73.87%), total chlorophyll (38.08), crude protein (20.12%), total sugar (6.21%), reducing sugar (4.05%), and mineral (12.42%) respectively for sole mulberry (T_0).

However, the moisture and reducing sugar % were statistically similar for all the crop combinations. Interestingly, the total chlorophyll and mineral content were statistically similar for the intercropping of wheat and rice, respectively, except for sole mulberry (Table 3).

Table 3. Average leaf quality performances of different cereals intercropped with mulberry field

Treatments	Moisture (%)	Total chlorophyll (SPAD value)	Protein (%)	Total sugar (%)	Reducing sugar (%)	Mineral (%)
T_0	73.87 a	38.08 b	20.12 b	6.21 b	4.05 a	12.42 b
T_1	75.20 a	38.54 a	20.56 a	6.43 a	4.16 a	12.72 a
T_2	74.80 a	38.34 a	20.25 b	6.25 b	4.09 a	12.50 ab

Here, T_0 = Sole mulberry (Control) T_1 = Mulberry + Wheat, T_2 = Mulberry + Rice

Intercropping effect on silkworm rearing attributes

The rearing performance of silkworms was statistically differed due to feed on cereals intercropped mulberry leaf. Significantly greater silkworm rearing performance viz: weight of 15 larvae (53.74 g), single cocoon weight (32.49 g), shell weight (0.22 g), cocoon shell ratio (19.81), highest filament length (984.45 m), renditta (11.09) and cocoon productivity/100 dfls (70.60 kg) respectively were obtained due to feed on of wheat intercropped mulberry leaf.

The silkworm rearing performance due to feeding on rice intercropped mulberry leaves was weight of 15 larvae (52.98 g), single cocoon weight (32.37 g), shell weight (0.21 g), cocoon shell ratio (19.28), highest filament length (970.02 m), renditta (11.50) and cocoon productivity/100 dfls (70.35 kg) respectively followed by the feed on sole mulberry leaf.

In the same way, low-quality silkworm rearing performance viz: weight of 15 larvae (52.76 g), single cocoon weight (31.84 g), shell weight (0.21 g), cocoon shell ratio (19.09), highest filament length (949.23 m), renditta (12.08) and cocoon productivity/100 dfls (65.77 kg) respectively were obtained due to feed on sole mulberry leaf. However, the weight of 15 Larvae, single cocoon weight, shell weight, highest filament length and cocoon productivity/100 dfls of the mulberry + wheat combination were statistically similar to the crop combination of mulberry + rice (Table 4).

Table 4. Average silkworm rearing performances of different cereals intercropped with mulberry field

Treatments	Weight of 15 larvae (g)	Single cocoon weight(g)	Shell weight (g)	Cocoon shell ratio	Highest filament length (m)	Rendita	Cocoon productivity/100 dfls (kg)
T_0	52.76 b	31.84 a	0.21 a	19.09 b	949.23 b	12.08 a	65.77 b
T_1	53.74 a	32.49 a	0.22 a	19.81 a	984.45 a	11.09 c	70.60 a
T_2	52.98 ab	32.37 a	0.21 a	19.28 b	970.02 a	11.50 b	70.35 a

Here, T_0 = Sole mulberry (Control) T_1 = Mulberry + Wheat, T_2 = Mulberry + Rice

Intercropping effect on soil properties

The average post-harvest soil properties of the mulberry garden differed due to cereals intercropped with mulberry. Before intercropping in the mulberry garden, the recorded average initial soil properties were soil pH (8.07), organic matter contents (1.10%), N (0.06%), P (12.33 kg/ha), K (0.27 me/100g soil), Ca (28.03 me/100 g soil), Mg (2.86 me/100 g soil), Zn (2.01 ppm), Fe (2.65 ppm) and Cu (0.45 ppm) respectively (Table 1). After intercrops harvest, the recorded average post-harvest soil properties of the mulberry garden were soil pH (7.98), organic matter contents (1.27%), N (0.08%), P (14.19 kg/ha), K (0.18 me/100g soil), Ca (27.26 me/100 g soil), Mg (3.20 me/100 g soil), Zn (2.93 ppm), Fe (3.25 ppm) and Cu (0.50 ppm) respectively.

The recorded soil properties ranged for cereals intercropped mulberry garden were, soil

pH (7.96-8.0), organic matter (1.24-1.31%), N (0.07-0.08%), P (13.09-14.88 kg/ha), K (0.17-0.20 me/100g soil), Ca (26.29-28.17 me/100 g soil), Mg (2.72-3.87 me/100 g soil), Zn (2.57-3.13 ppm) respectively (Table 5). However, the obtained highest organic matter (1.31%), N (0.08%), P (14.88 kg/ha), Ca (28.17 me/100 g soil), Mg (3.87 me/100 g soil), Fe (3.72 ppm) and Cu (0.53 ppm) respectively for the crop combination of T_1 (mulberry + Wheat) except K (0.20 me/100g soil), Zn (3.13 ppm), Fe (3.04 ppm) and Cu (0.50 ppm) respectively followed by the crop combinations of T_2 (mulberry+ rice) and T_0 (Sole mulberry).

The recorded least soil pH (7.96), OM (1.24%), and Ca (26.29 me/100 g soil) were in T_2 treatments besides N (0.07%), P (13.09 kg/ha), K (0.17 me/100g soil), Mg (2.72 me/100 g soil), Zn (2.57 ppm), Fe (2.99 ppm) and Cu (0.48 ppm) were in T_0 (Table 5).

Table 5. Average post-harvest soil properties of different cereals intercropped with mulberry field

Treatments	pH	OM (%)	N (%)	P (kg/ha)	K (me/ 100 g soil)	Ca (me/ 100 g soil)	Mg (me/ 100 g soil)	Zn (ppm)	Fe (ppm)	Cu (ppm)
T_0	7.98 a	1.27 a	0.07 a	13.09 b	0.17 b	27.31 b	2.72 c	2.57 b	2.99 b	0.48 b
T_1	8.0 a	1.31 a	0.08 a	14.88 a	0.18 ab	28.17 a	3.87 a	3.08 a	3.04 b	0.50 ab
T_2	7.96 a	1.24 a	0.08 a	14.60 a	0.20 a	26.29 c	3.00 b	3.13 a	3.72 a	0.53 a
Average	7.98	1.27	0.08	14.19	0.18	27.26	3.20	2.93	3.25	0.50

Here, T_0 = Sole mulberry (Control) T_1 = Mulberry + Wheat, T_2 = Mulberry + Rice, OM= Organic matter, N = Nitrogen, P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Zn = Zinc, Fe = Iron and Cu = Copper

Effect of cereal intercropping with mulberry garden on mulberry leaf and cereals productivity

The leaf productivity of mulberry plants was statistically similar to the intercropping of cereals in mulberry gardens. However, the highest mulberry leaf yield was 11.26 t/ha/crop for the sole mulberry garden, followed by the second highest leaf yield, 11.17 t ha-1/crop, due to intercropping of wheat in the mulberry garden. However, the productivity of intercrops (wheat and rice) statistically differed statistically differed between them. For the two types of intercrops, the recorded greater productivity was 3.44 t/ha/crop for intercropped wheat, and the productivity of rice was 2.20 t/ha/crop (Table 6).

Table 6. Productivity of mulberry leaf and intercropped cereals in mulberry garden

Treatments	Mulberry leaf yield (t/ha/crop)	Yield of intercrops (t/ha/crop)
T_0	11.26a	-
T_1	11.17a	3.44a
T_2	10.97a	2.20b

Here, T_0 = Sole mulberry (Control), T_1 = Mulberry + Wheat, T_2 = Mulberry + Rice

Effect of cereal intercropping on mulberry economy

Total cost of cultivation (INR./ha/crop)

The total cost of cultivation was more in mulberry + rice intercropping (INR 1,29,900 Tk/ha/crop), noticed by mulberry + wheat (INR 1,29,200 Tk/ha/crop) intercropping, in the period it was lowest in sole mulberry cultivation (96,500 Tk/ha/crop) (Table 7).

Net returns (INR./ha/crop)

The acquired gross margin differed from INR. 162,700 Tk/ha/crop to INR. 251,311 Tk/ha/

crop. The greater value of gross margin of INR. 2,51,311 Tk/ha/crop was picked up for mulberry + wheat intercropping keep to mulberry + rice (INR. 236,409) intercropping, and the least was found in sole mulberry cultivation (INR. 162,700 Tk/ha/crop) (Table 7).

Benefit-cost ratio

The greater benefit-cost ratio was 1.95 for the intercropped wheat with mulberry, followed by the sole mulberry and intercropped mulberry + rice. However, the benefit-cost ratio for the mulberry + rice crop combination was 1.82, and the lowest was noticed in sole mulberry (1.69) (Table 7).

Table 7. Economics of mulberry leaf production with cereal intercrops

Treatments	Gross returns (Tk/ha)			Cost of cultivation (Tk/ha)				Net returns (Tk/ha)	B: C ratio
	Amount of cocoon	Amount of intercrops	Total amount	Mulberry	Silkworm rearing	Intercrops	Total		
T_0	259200	0	259200	46500	50000	0	96500	162700	1.69
T_1	276011	104500	380511	46500	50000	32700	129200	251311	1.95
T_2	270109	96200	366309	46500	50000	33400	129900	236409	1.82

Here, T_0 = Sole mulberry (Control) T_1 = Mulberry + Wheat, T_2 = Mulberry + Rice

Discussion

Cereal intercropping effect with mulberry garden on mulberry plant and cereals crops productivity

Intercropping of cereals with mulberry garden had a significant impact on plant growth and yield of mulberry. The obtained average leaf yield was greater in sole mulberry (11.26 Mt/ha/crop) compared to rest of the intercropping treatments may be due to increasing number of branches per plant (12.50), total leaf number per plant (1360.62), total branch height per plant (960.41cm), node per meter (24.85), length of the most extended shoot (133.52 cm), leaf present per branch (24.45), 10 leaves area per plant (621.48cm^2), total leaf weight per plant (938.20 g) and total shoot weight per plant (434.32g) followed by the T_1 and T_2 crop combinations respectively. These findings were associated with the previous findings of Vishaka et al. (2017). They reported that in sole mulberry at 60 days after pruning compared to other intercropping treatments, the growth parameters viz: plant height (159.43 cm), number of branches per plant (13.31), number of leaves per plant (121.81), which attributed to the increasing leaf yield of 5.81 Mt/ha/crop was significantly higher. The lack of competition from the intercrops for different materials in sole mulberry may cause it. Additionally, with the non-significant impact of allied cereal intercrops (like Wheat and Rice), the yield contributing parameters and leaf yield becomes greater than the other intercrops treatments, which were linked with Vishaka et al. (2017). Similarly, in our previous study the growth and leaf yield parameters of mulberry plant was comparatively better in sole mulberry garden than the others crop combinations (Islam et al., 2022). Due to an uncompetitive lot of attempts and non-significant sequelae of related intercrops, the growth parameters over and above leaf yield were higher in sole mulberry treatment than in the other treatments.

This study may be due to the absence of crop competition from the intercrops for essential plant nutrients, which was confirmed by the previous findings of Vishaka et al. (2017). They found that due to the absence of abundant efforts and the non-significant effect of supplementary intercrops, the growth parameters and leaf yield were greater in sole mulberry than in the other intercrop combinations. However, among the other two intercrops next to sole mulberry (T_0), the maximum leaf yield was 11.17 MT/ha/crop in mulberry + Wheat (T_1), followed by the leaf yield (10.97 MT/ha/crop) of mulberry + Rice

(T_2) with better growth and yield contributing characters would be varied growth nature, nutrients requirements as well as root placement of Wheat in the soil.

Similarly, the wheat production is also 36.05% greater than the intercropped Rice, which may be due to the differential canopy height, position of the root in the soil, and growth nature, as well as nutrient requirements between the mulberry plant and cereals intercrops, might be varied, resulting in the wheat production was greater than the rice production. Furthermore, intercropping of Wheat might improve the diversity and abundance of soil microorganisms as well as enhance the soil humus, improve the availability of nutrients in the soil and provide a favourable soil environment for microbial growth compared to the rice intercropped which was lined with Li et al. (2022). They reported that intercropping improves the diversity and richness of soil microorganisms in farmland, promotes soil humus, increases soil-available phosphorus content and provides a suitable environment for microbial growth.

Cereals intercropping effect on leaf quality of mulberry

Intercropping cereal in the mulberry garden positively impacted the improvement of the leaf quality of the mulberry plant. Among the intercropped of rice and wheat, the leaf qualities viz: moisture (1.33%), total chlorophyll (0.46%), protein (0.44%), total sugar (0.22%), reducing sugar (0.11%) and mineral (0.30%) were greater in mulberry + wheat crop combination over the sole mulberry plant. However, the leaf qualities for intercropped wheat and rice were more or less similar, except protein and total sugar percentages have statistically differed.

The total chlorophyll, protein and mineral content were statistically greater for intercropped rice and wheat than for the sole mulberry garden. These types of findings were limited to mulberry crops. However, similarly, the previous findings of Islam et al. (2023) found that the leaf quality of mulberry plant was significantly better in intercropping of mulberry + cauliflower crop combination. It may be due to improvement of soil properties viz: Cu, Zn, Mg, K and P both for intercropped of wheat and rice respectively might be enhanced the balanced establishment of the mulberry plant as well as improved the leaf qualities compared to the sole mulberry garden.

Effect of cereals intercropping on silkworm rearing performance

The silkworm feed on wheat intercropped mulberry leaves significantly impacted silkworm rearing performance. Among the intercropped of wheat and rice with mulberry silkworm rearing performances viz: weight of larvae, single cocoon weight, weight of shell, cocoon shell ratio, length of filament, renditta and cocoon productivity were comparatively better for the crop combination of mulberry + wheat followed by the crop combination of mulberry + rice and sole. The silk cocoon productivity per 100 dfls was statistically similar for T_1 and T_2 treatments. However, the highest cocoon productivity (70.6 kg/100dfls) was 4.83% greater and renditta was 8.93% lower in the T_1 treatment on top of the T_0 treatment. Besides, the cocoon productivity was also greater for the T_2 treatment, followed by the sole mulberry cultivation. These findings were more or less similar to the previous findings of Rajegowda et al. (2020). They found that the silkworm larval wt. (4.56 g), single cocoon wt. (1.76 g), shell (0.44 g), pupal weights (1.33 g), shell ratio (25.01%), and cocoon yield (70 Kg/100 DFLs) were comparatively greater for the silkworm feed on cowpea + mulberry growing mulberry leaves as compared to the sole mulberry (4.54g, 1.71g, 0.43g, 1.32g. 24.94% and 68.41 kg/100 DFLs) respectively.

In this study, the silkworm-rearing performance might be due to the comparatively improved mulberry leaf quality of the mulberry + wheat crop combination, which may enhance the silkworm-rearing performance. Because the leaf quality of mulberry influences successful silkworm rearing by 38.20% (Miyashitha, 1986). This speculation was aligned with the findings of Vanitha et al. (2019). They found that the silkworm hybrids reared on leaves of tree mulberry

revealed higher larval and cocoon parameters than silkworms reared on bush mulberry leaves due to the superior quality of tree mulberry leaves.

Cereals intercropping effect on post-harvest soil properties

Cereal intercropping with mulberry magnifies the fertility status of soil compared to the cultivation of sole mulberry. Post-harvest soil character consequently differed by the cereals intercropped in the mulberry field. The study of the experiment noticed the diverse soil attributes for different spices cultivation in mulberry fields as intercrop. The post-harvest soil of the wheat intercropped mulberry field displays the maximum organic matter, nitrogen, phosphorus and magnesium content. Similarly, rice-intercropped soil denoted the better potassium, zinc, iron, and copper in post-harvest soil. The organic matter contained was comparatively greater for the intercropped wheat and rice, respectively, followed by the sole mulberry.

Such findings in mulberry are limited. However, it may be due to the nutrients uptake by the respective cereal crop was varied because it is widespread that the growth nature, nutrient requirement and root position in the soil differed from crop to crop, resulting in the nutrient status in respective cereal intercropped post-harvest soil could fluctuate. Another speculation was that intercropped wheat and rice with mulberry may have enhanced the microbial as well as microorganism activities in the soil, resulting in improved soil nutrient levels, microbiota composition, and enzymatic activity favourably and that microorganisms had played a crucial role in the nutrient cycling both for the crop combination of mulberry + wheat and mulberry + rice.

The above speculation was lined with the previous findings of (Bedoussac & Justes, 2009; Cuartero et al., 2022; Gao & Xie, 2023; Li & Wu, 2018; Liu et al., 2014). They reported that intercropping systems improved the carbon and nitrogen concentrations, physicochemical traits, bulk density, and pH of the soil, as well as that intercropping impacts the soil nutrient levels, microbiota composition, and enzymatic activity favourably and that microorganisms have crucial roles in play in nutrient cycling. Because the intercropping in mulberry increased biomass production compared with monoculture mulberry, the beneficial effect may be attributed to the soil nutrient improvement, similar to the previous findings of Zheng et al. (2011). They reported that the biomass of intercropped mulberry increased by 65.7% compared with monoculture mulberry, and the beneficial effect may be attributed to the soil nutrient enrichment.

Effect of cereal intercropping in the mulberry field on the economy

Intercropping of cereals with mulberry had a substantial effect on the mulberry economy. Intercropping of wheat with mulberry showed a significantly greater total gross return (380,511 Tk/ha), net return (251,311 Tk/ha) and B: C ratio (1.95), followed by the intercropping of rice and sole mulberry, respectively. However, the 2nd obtained total gross return (366,309 Tk/ha), net return (236,409 Tk/ha), and B: C ratio (1.82) for the crop combination of mulberry + rice which was comparatively greater than the recorded total gross return (259,200 Tk/ha), net return (162,700 Tk/ha), and B: C (1.69) ratio of sole mulberry. It may be due to better leaf qualities, higher cocoon productivity, and extra income from intercropping wheat and rice with mulberry. Rajegowda et al. (2020) reported a more or less similar finding. They noted the optimum total gross return (67,779 Rs/ha), net return (42,079 Rs/ha) and B: C ratio (2.63) in mulberry + cowpea intercropping which was par on intercropping of mulberry + ragi (24,500; 38,325; 2.56), mulberry + groundnut (57,844; 34,344; 2.46) due to higher cocoon productivity and extra income of cereal intercropped with mulberry respectively and least recorded in sole (38,895; 23,595; 2.54), mulberry.

Similarly, in the case of legume intercropping with mulberry, Ramamurthy and Jagdish (2006) found that mug bean and chickpea intercropping with mulberry the greater net returns were the same as 28,500 Rs./ha/year and B: C ratio 1.9 respectively whereas the crop net profit for sole

mulberry was 15,000 Rs./ha/year. Furthermore, in the same way, Mir et al. (2018) found that legume intercropping in mulberry gardens in Shiwaliks and Pir Panjal, India, could increase an income from Rs. 2,373/- to Rs 4,920/- respectively, the selling of cocoon crops aside from annual mean income was increased with the attractive on mulberry based intercropping system discriminating 206.16% (Pir Panjal) to 27.62% (Shiwalik) which was also confirmed this results.

Conclusions

Intercropping wheat with mulberry could increase leaf quality, improve soil nutrient status and cocoon productivity, and earn extra income, thereby facilitating crop diversification and generating income for sole mulberry-growing sericulture farmers. The results showed that intercropping in mulberry takes steps to use the land between the plants properly. Traditionally, the sericulture-related farmers in the study area seemed to modify from one cropping to the intercropping of mulberry, whose crops are to be grown quickly with the optimum application of land that could help the community amplify their earnings. Cereal intercropping became greater than the earnings of sericulture farmers accompanied by the sericulture pursuit. Thus, intercropping cereal with mulberry would help increase the sericulture farmer's income and attain sustainable development goals on a large scale. Eventually, growing wheat as an intercrop with mulberry was designated to create more supplementary income and fertility status in the soil.

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Marketing and value chain analysis of Gangetic Koi fish in Mymensingh district of Bangladesh

Israt Jahan Jany[1*]

[1] Department of Agricultural Marketing, District Agricultural Marketing Office, Netrakona 2400, Bangladesh.

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***Corresponding Email:**
janyisratjahan@gmail.com

ABSTRACT

This study evaluates the value chain of Gangetic Koi (Anabas testudineus) fish in the Mymensingh district of Bangladesh to identify the key actors with their roles and analyzed the marketing costs, margins, and value addition at different stages of the value chain. A total of 60 actors were vigorously selected and data collected during September to October 2016 from four (Fulbaria, Muktagacha, Trishal, and Sadar) sub-districts of Mymensingh including 20 fish farmers, 15 Aratdars (wholesalers), 15 Paikers (intermediaries), and 10 retailers. Analysis revealed that Koi fish farmers incurred the highest costs (Tk. 78.65 per kg), followed by retailers (Tk. 21.19 per kg), Paikers (Tk. 6.89 per kg), while Aratdars had the lowest cost (Tk. 0.96 per kg). Retailers contributed the highest value addition (Tk. 27.10 per kg), followed by farmers (Tk. 14.85 per kg) and Paikers (Tk. 13.80 per kg), with Aratdars contributing the least (Tk. 0.04 per kg). The primary challenges reported by farmers included non-remunerative prices, high feed costs with poor quality, price instability, low-quality fingerlings, and limited capital. Other actors identified challenges including price volatility, limited market information, high transportation costs, and poor infrastructure.

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Introduction

Bangladesh is regarded as one of the best countries in the world for freshwater aquaculture due to its abundant resources and agroclimatic circumstances (Ahmed, 2010; Tabassum et al., 2023). Freshwater fisheries are now the second most valuable agricultural activity in Bangladesh, playing a substantial role in nutrition, food security, employment and income generation, trade, a source of foreign exchange earnings, and, above all, poverty reduction in the economy (DoFB, 2013). Aquaculture production has been continuously increasing each year, in contrast to marine and capture fisheries. Pond fisheries are largely responsible for the growth, accounting for nearly 53% of the country's total production (Ali et al., 2010; DoFB, 2013). Pond aquaculture in Bangladesh has flourished commercially on a small scale all over the country and created a great potential for farmers to earn higher income as well as self-employment generation. However, the annual fish production per hectare is still low in Bangladesh, which is the lowest in the world, even far lower than many Asian countries (Karim et al., 2006). Moreover, the demand for fish is constantly increasing in Bangladesh, with about

three million people being added every year to the population (Chowdhury, 2009). Therefore, it is widely believed that in order to guarantee the food and nutritional security of the expanding population, several measures must be taken to boost domestic production. Gangetic koi fish can play a crucial role in meeting the growing demand for fish, thereby significantly improving human nutrition and food security for the following reasons: the growth and productivity of koi are much higher than those of other fish species cultured in Bangladesh (Chandi, 1970). Although the overall growth performance is impressive, growth fluctuates widely from one year to another, indicating that there might be some problems in Koi culture in the study area causing fluctuations in production.

The value chain emphasizes specific activities through which firms can generate value and consequently is a helpful tool to simplify analysis (Long, 2013). The fish marketing system in Bangladesh has historically been organized by the private sector. The government provides support in the form of roads and infrastructure but does not play an active role in properly regulating market behavior and market performance. Price is determined by direct bargaining between the sellers and buyers (Sarker et al., 2014). Marketing of fresh fish in Bangladesh is characterized by the involvement of many actors. Though demand for fish is high in Bangladesh, markets are localized in some areas, and fish producers (farmers and fishers) have limited ability to reach better alternative markets. The involvement of some actors seems redundant; their presence just adds a cost to the consumer and a loss to the fisherman. Moreover, the superfluous involvement of actors keeps fishers and markets separated, not allowing them to be market responsive (ibid.).

Value chain analysis is one of the most important topics in the field of marketing. Almost every agricultural product goes to the ultimate users or consumers through some successive value addition by different value-addition actors. The agricultural marketing value chain for products constitutes an important scope for value chain analysts (Hasan & Jahan, 2022). The fish value chain is exclusively controlled by the private sector, which links fishermen and retailers within the country, as well as with other countries in the subcontinent. Middlemen (such as broker, store man and commission agent) often exploit fishermen due to their isolation, challenges posed by poor roads, lack of transportation, and limited communication. Middlemen can also exploit fishers by controlling their access to the market chain and consumers. However, the most serious market differentials seem to occur in remote communities that lack transport, ice and road facilities, where fishermen are in a particularly weak position in relation to actors such as fish transporter and labors (Acharjee et al., 2023).

However, existing value chain studies of fish and fish products in Bangladesh and abroad are reviewed to see the gap and purpose the policy for further studies (Hasan et al., 2022). There is clearly no significant study on the value chain of Gangetic koi fish marketing in the Mymensingh district of Bangladesh. This circumstance prompts the researcher to investigate the value chain of Koi fish marketing in the Mymensingh districts of Bangladesh, which could serve as a pilot study to further investigate the problem.

The chain of actors through which the transaction of goods and services takes place between the producer and consumer is known as a marketing channel. The product passes from farmers to consumers through various actors, including Aratder, inter-district Paiker, local Paiker, and retailers. The study revealed that there is a movement of Koi fish from the production point to the consumption point through some marketing actors involved in the value chain of Koi fish. Therefore, fish marketing in Bangladesh is neither efficient nor modern and is mainly carried out by private traders with a large number of actors between producer and consumer, thereby reducing the fisherman's share in consumer profit. A sharp increasing trend is observed in Koi culture in some selected areas of Bangladesh; particularly, it is predominant in several upazilas in the Mymensingh district. Therefore, this study aims to analyze the marketing of Koi fish through value chain analysis. The

specific objectives are to assess the marketing costs, margins, and profits of the various actors in the domestic market. In addition, the study will examine the Koi fish value chain to identify the value added at different stages of the marketing process.

Method and materials

Study area

This study was done in four Upazilas (Fulbaria, Muktagacha, Trishal and Mymensingh Sadar) which are the leading zone in respect of culture fish production and marketing of Mymensingh district in Bangladesh (Figure 1). On the basis of concentration of cultivation of Koi fish, Mymensingh district was selected purposively as the study area. The field survey data for the study were collected during the period of September to October in 2016. Several visits were made during the period of data collection.

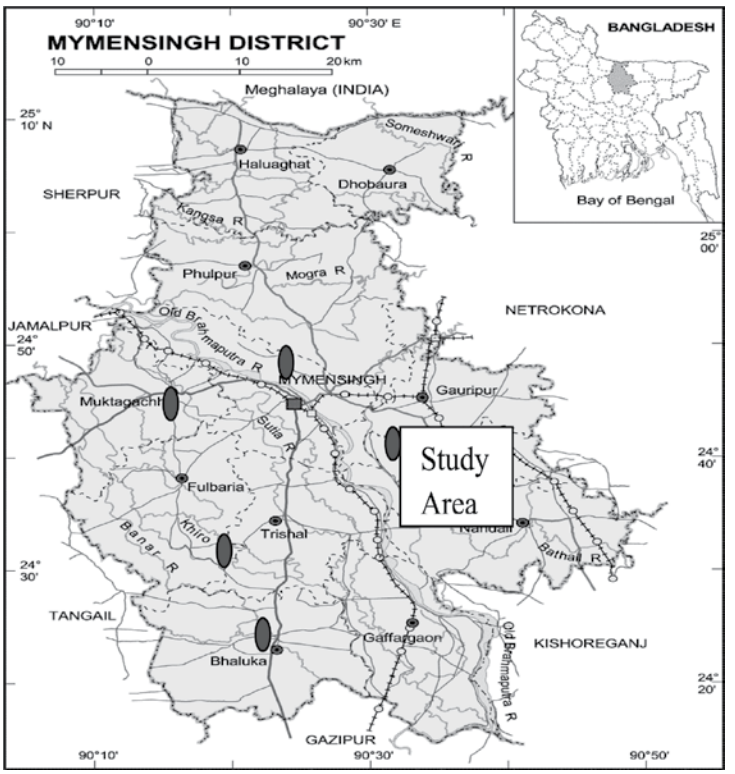

Figure 1. Data collection area of Mymensingh district (Mymensingh Sadar, Muktagacha, Fulbaria and Trishal Upazilas).

Sampling technique and data collection

A total of 60 respondents were selected from the study area, comprising 20 fish farmers/ producers and 40 market actors involved in fish trading. The actors involved in Koi fish marketing were divided into three categories such as, (i) Aratdar (commission agents), (ii) Paiker (wholesalers) and (iii) Retailers. Fish farmers from Muktagacha, Churkhai and Shambuganj union of Mymensingh sadar, Aratder and Paiker from Trishal and Fulbaria upazila, retailers from KR market (BAU), Mintu college kacha bazaar, Machua bazaar of Mymensingh town were selected purposively for this study. The required data for the study were collected from primary and secondary sources. The primary data were collected by the researcher from selected respondents by direct interview with a pretested interview schedule.

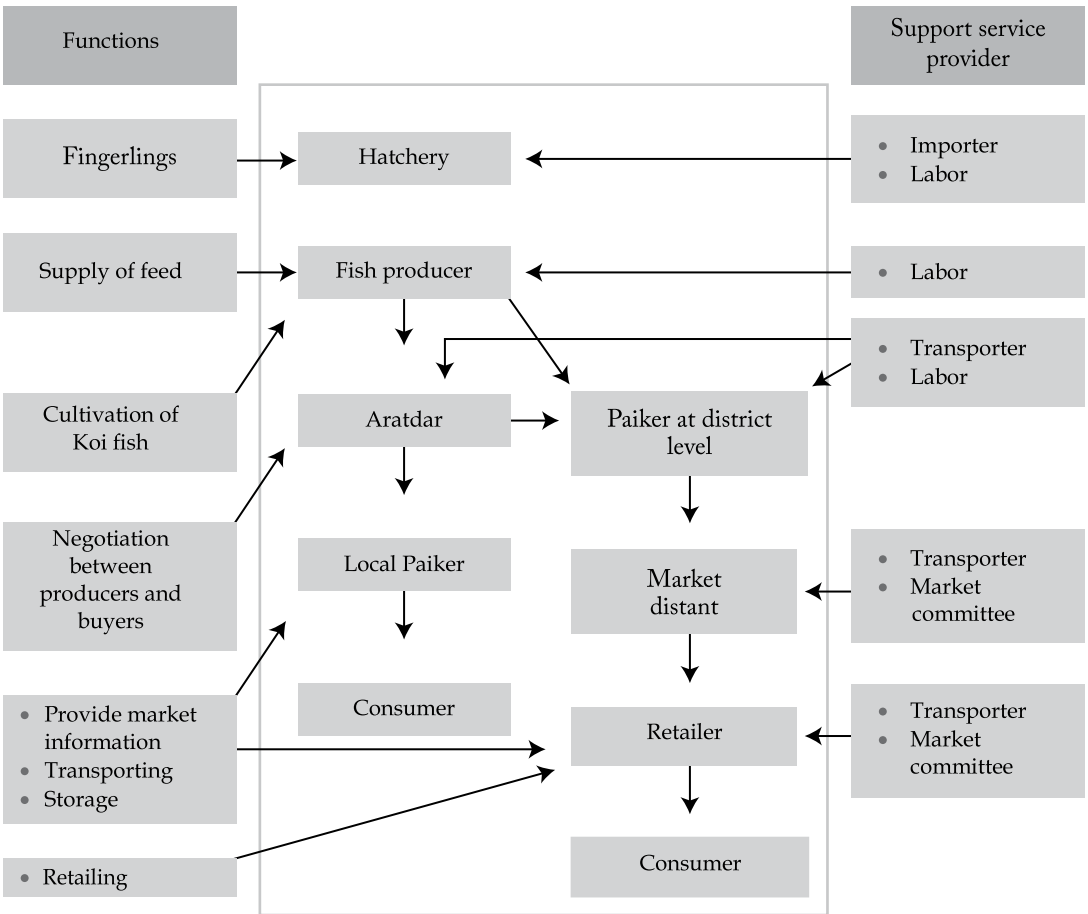

Figure 2. Detail value chain channel of Koi fish marketing in Mymensingh district.

Value chain analysis

Following profit equation was used to estimate the gross margin/value addition of the Koi fish at producer's level:

$\Pi = PF \times QF - (TVC+TFC)$

Where, Π = the Producer profit, PF = Price of production, QF = Quantity of production, TVC= Total variable cost, TFC= Total fixed cost.

Gross return was calculated by multiplying the total volume of output by per unit of its price in harvesting period. To estimate gross return (GR) following equation was used:

$GR = \Sigma Pb \times Qb$

Where, GR = Gross return from fish, Pb = Price of fish, Qb = Quantity of fish

Gross margin is calculated using the following equation:

$GM = TR - VC$

Where, GM = Gross margin, TR = Total return, VC = Variable cost.

Net margin was calculated by deducting all cost (marketing cost and total production cost) from gross margin. The following equation was used for calculating net margin:

$\Pi = GM\text{-}MC$

Where, Π Net margin, GM = Gross margin, MC = Marketing cost

Marketing of value chain actors

Marketing margin is the difference between the producers and consumers prices. Marketing

margin and Net margin of different value chain actors were calculated by the following formula:

Marketing margin = Sales price – Purchase price

Net marketing margin = Marketing margin – Marketing cost

Value Addition (%) = (Marketing margin/ Purchase Price) × 100

Results

Mapping the value chain of Koi fish marketing

Mapping the value at different levels of the value chain by calculating cost and margin provided an overview of the earnings at the different stages. The value chain map identifies the problems faced by different actors in the Koi fish value chain while they are performing their functions. The most straightforward distinction is to categorize actors according to their main occupation. For example, producers are those who involved in production while collectors are those who perform the task of collection. Other classification criteria could be ownership (households, private-owned, cooperative, government-owned etc.), scale (small, medium or large-scale, national or international etc.), location, poverty ranking etc. For the present research actors are uncovered according to their main occupation like producers (Koi fish farmer), collectors (wholesalers and retailers). However, other problems are also identified during the value chain analysis. The research analysis depicts that marketing of Koi fish in Mymensingh district is moved from the hands of farmers to the hands of consumers through some separate chain actors. Value chain of Koi fish started from fish fingerling production. First value adding stage was identified as fish farmer/ producer then Aratdar, Paiker and finally retailer. These types of actors added value in the marketing channel.

Koi fish marketing in Mymensingh district is moved through the following chains (Figure 2):

Chain I: Farmer→Aratdar→ Paiker at district level (Mymensingh, Jamalpur, Haluaghat)→ Market distant (Comilla, Dhaka, Rangpur) →Retailer→Consumer

Chain II: Farmer→Aratdar→Paiker at district level→Retailer →Consumer

Chain III: Farmer→Aratdar→Local Paiker→Retailer →Consumer

Chain IV: Farmer→Aratdar →Retailer→Consumer

Chain V: Farmer→ Paiker at district level →Retailer →Consumer

Characteristics of value chain actors

Marketing channels are the alternative ways of product flows from producers to consumers. Value chain may be short or long for a particular commodity depending on the nature of producers and consumers, qualities of products, size and the prevailing social and physical environment. It is clear that with the farmers, a number of actors are involved in the marketing of Koi fish from the production point to the consumption point. The activities involve in the transfer of goods are completed through the functions of buying and selling. Koi fish farmer sell 80% of their fish to Paiker through Aratdar and remaining 20% fish sell to the Paiker directly. Aratdar perform the function of negotiation between buyer and seller of Koi fish and take commission. Paiker sell their fish to retailer through Aratdar. Sometimes Paiker sell their fish directly to the retailer. And finally, retailer sells their fish to the ultimate consumers.

Financing

For effective operation, financing is a crucial importance in the whole marketing system of fish. The sources of finance for the value chain actors in the study areas are shown in Table 1. Most of the fish farmer, Aratdar, Paiker and retailers of Koi fish marketing are self-financed. Other sources of finance for farmers are banks, friends and relatives and NGOs. Paiker takes loan from banks, NGOs and friends and relatives. A minor portion of Aratdar sources of finance are banks and friends. Most of the retailers use their own funds and some are borrowed from friends, relative and NGOs.

Table 1. Sources of finance of Koi fish actors

Sources of finance	Market actors (%)			
	Farmer	Aratdar	Paiker	Retailer
Personal fund	78	90	75	70
Bank	12	0	10	0
NGOs	8	7	12	25
Friends and relatives	2	3	3	5
Total	100	100	100	100

Packaging

Basket is very important part of proper transportation of fish which is made of bamboo, rope and polythene are used for packaging by farmer, Aratdar, Paiker and retailer of Koi fish. Plastic drums are used for Koi fish while transported in live from production area to various places like Dhaka, Comilla, Tangail districts of Bangladesh.

Pricing

In the study areas, all actors are involved in buying and selling of fish. The actor of Koi fish practices open bargaining, auction and prevailing marketing prices and prefixed price for selling Koi fish. Most of the retailers follow open bargaining for selling their fish to consumer. Price depends on size, weight, quality, market structure, supply and demand and taste (Table 2).

Table 2. Pricing practices of Koi fish value chain actors

Pricing method	Value chain actors (%)			
	Farmer	Aratdar	Paiker	Retailer
Open bargaining	0	-	70	90
Auction	-	100	-	-
Market price	80	-	20	10
Prefixed prices	20	-	10	-

Value chain governance of Koi fish farmer

There are four types of actors (fish farmer, Aratdar, Paiker, retailer) of Koi fish value chain are depending upon one another from the production level to the consumption level. Some of their rules and regulations are discussed below- Koi fish grows very quickly. For better cultivation and better quality of Koi, it is rising in the pond with proper system of cultivating and every Koi fish farmer should know about it. They must know how they efficiently cultivate Koi fish in their pond for better quality. For this every fish farmer should use proper method of cultivation to maintain their fish quality high. But, now-a-days some fish farmer does not have much interest in maintain good quality of Koi fish, they just drive the way of earning more profit. That is how Koi fish is lost their position in the consumer market because of their low quality. So that it is very important to take care of this point by the fish farmer of Koi. It is one type of Koi fish governance of Koi fish farmer. For the marketing of every Koi fish actor such as Aratdar, Paiker and Retailer should maintain some rules for transferring the fish from the production level to the consumption level. Paiker should use plastic drum with the facility of supply oxygen system when they transfer Koi from the production place to another district marketplace. If supply oxygen system is not properly use it causes damage to the Koi fish. On the other hand, retailer also maintains these rules while they are transferring Koi. Aratdar should create the facility of auction between

paiker and farmer for buying and selling Koi smoothly. Other marketing function such as grading, pricing, collection of market information etc also strictly maintain by every actor of Koi fish value chain. These all type of rules what is called as value chain governance of Koi fish marketing.

Value addition of Koi fish

Variable cost

In this study variable costs includes labor, fingerlings, feed, manure, fertilizer, lime and medicine harvesting and water pumping. Here average total variable cost is estimated at Tk. 76.32 per kg (Table 3).

Table 3. Average variable production cost of Koi fish value chain

Cost items	Cost for Koi fish (Tk./kg)	% of total cost
Fingerlings	13.57	17.79
Feed	55.39	72.58
Pumping water	0.71	0.93
Human labor	5.19	6.80
Fertilizer	0.47	0.62
Manure/cow dung	0.11	0.14
Lime and medicine	0.22	0.29
Harvesting	0.64	0.84
Total	76.32	100.00

Fixed cost

Fixed cost of Koi fish cultivation includes cost of land use and pond preparation. Here average fixed cost is Tk. 2.33 per kg. Summation of the costs of variable and fixed input made total production costs, which are Tk. 78.65 per kg (Table 4).

Table 4. Average fixed and total production cost of Koi fish value chain.

Cost items	Cost of Koi (Tk/kg)
Land use cost	1.52
Pond preparation	0.81
Total fixed cost	2.33
Total production cost (TVC+TFC)	78.65

Note: TVC= Total variable cost, TFC= Total fixed cost

Marketing cost

The marketing cost of Koi fish producers includes loading and unloading, transportation cost and commission of Arartdar etc. If fish producers sell their fish from their pond then there is no marketing cost for them. In this study there is no marketing cost of farmer. All Koi fish producers sell their fish in their pond, in where Paiker/ Bepari collect fish from them. Paiker take their responsibility on their own while purchase fish from producer of Koi fish.

Cost of Aratdar

Figure 3 shows the marketing cost which is incurred by Aratdar. Aratdar is mainly commission agent, and they arrange auction of fishes for selling them to Paiker or retailer. They are the middlemen of farmer and Paiker, Faria and Paiker, Bepari and Paiker, Paiker and retailer. They take commission from both parties but do not have any uniform rate of commissions. In this study Aratdar perform the auction of Koi fishes. For performing this auction Aratdar have to incur some marketing cost, like shop rent, electricity cost, personal expenses, security cost and telephone bill etc. The total marketing cost of Aratdar is estimated at Tk. 0.96 per kg. Shop rent is the highest cost item comprising 57.29 percent of the total marketing cost. The next highest cost item is electricity, which accounted for 10.42 percent of total marketing cost (Figure 3).

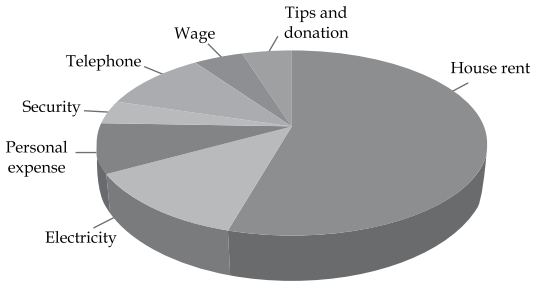

Figure 3. Marketing cost of Aratdar

Cost of Paiker

The marketing cost of Paiker is reported in Figure 4. Paiker perform exchange function of bying and selling. They purchase fish from local Arat center and sell them to the Paiker through Aratdar at different terminal markets and other markets. The total marketing cost of Paiker is calculated at Tk. 6.89 per kg. Transportation cost is the highest cost item which is 30.33 percent of total marketing cost. The second highest cost item is Aratdar commission which is 24.96 percent of total marketing cost (Figure 4).

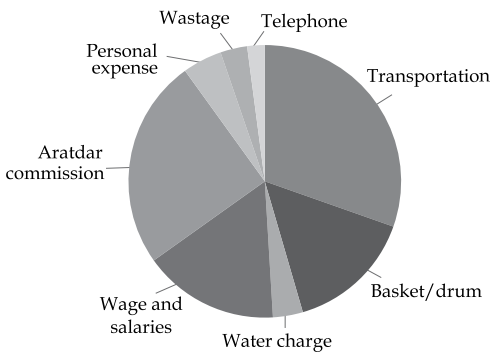

Figure 4. Marketing cost of Paiker.

Cost of retailer

The marketing cost of retailer is illustrated in Figure 5. Retailer is the last link in the marketing channel. They purchase fish from Paiker through Aratdar and sold to the consumer. The total marketing cost of retailer is calculated at Tk. 21.19 kg. Shop rent is the highest cost item including 33.85 percent of total marketing cost. The second highest cost component is the basket/drum which accounted for 23.59 percent of total marketing cost (Figure 5).

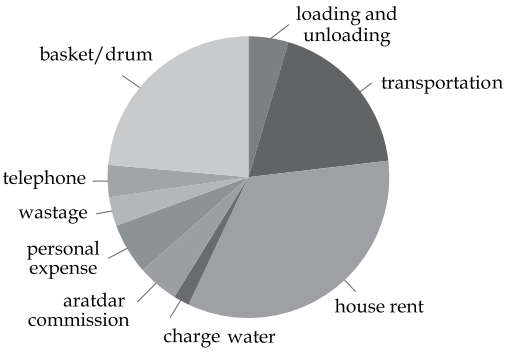

Figure 5. Marketing Cost of retailer.

Returns of fish farmers

To estimate the net return of Koi fish farmers it is important to calculate farmers gross return. Gross return is estimated by multiplying the total amounts of fish produce by average sales price. Net return of fish farmer = Gross return- Gross cost (production cost+ marketing cost). Average gross return of Koi fish farmer is Tk. 93.60 per kg, gross margin is Tk. 17.28 per kg and net return is Tk. 14.95 per kg (Table 5).

Table 5. Gross return and Net return of Koi fish farmer

Items	Amounts (Tk/kg)
Gross return	93.60
Variable cost	76.32
Fixed cost	2.33
Gross margin (I-II)	17.28
Net return (IV-III)	14.95

Marketing margin

Marketing margin is the price of all utilities adding activities and functions that are followed by the actors (Aratdar, Paiker, and retailer). Total marketing margin is difference between price received by the fish farmers and price paid by the consumers. Marketing margin of fish is estimated separately for different actors. Gross marketing margin of each type of actors is estimated by deducting the purchase price of fish from their sales price. And net marketing margin or profit is calculated by deducting marketing cost from gross marketing margin.

Aratdar charges 3-5% commission from farmer and this is the gross margin of Aratdar.

In this Koi fish marketing except channel (V) Aratdar is the actor who creates the facilitation of the Koi fish marketing. They are the actors who help Koi fish farmer and Paiker to operate their business smoothly. They also create the facility for fish buying and selling. The gross margin of Aratdar is Tk. 4.26 per kg and net margin is Tk. 3.30 per kg (Table 6).

Paiker of fish marketing play controlling role in price mechanism. As a result Paiker receive the net marketing margin which are Tk6.92 per kg. The gross margin of Koi fish Paiker is Tk. 13.81 per kg (Table 6). Gross marketing margin of retailer of Koi fish is Tk. 26.84 per kg. The net margin of Koi fish is Tk. 13.25 per kg.

Table 6. Average marketing margin of retailer of Koi fish.

Particulars	Tk./kg
Purchase price	117.99
Sales price	144.84
Gross margin	26.84
Marketing cost	13.60
Net margin	13.24

Value addition of Koi fish

Figure 6 highlighted the value addition by all actors of Koi fish value chain. Value addition activities are mainly concerned with the change of utilities. In these study it is found out the value addition by farmer is Tk. 14.85 per kg, Aratdar Tk. 0.04 per kg, Paiker Tk. 13.80 per kg and retailer Tk. 27.10 per kg.

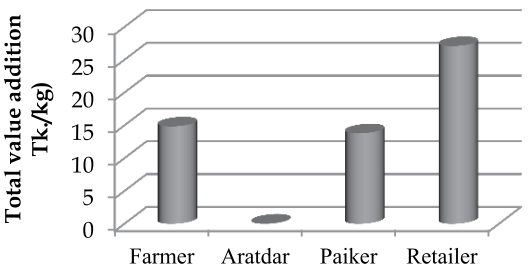

Figure 6. Total value additions of Koi fish.

Discussions

In Koi fish production two types of costs are included. They are fixed cost and variable cost. In this study variable costs include labor cost, fingerlings cost, feed cost, manure/cow dung cost, fertilizer cost, lime and medicine cost, harvesting cost and water cost. The average total variable cost is estimated at Tk. 76.32 per kg. And fixed cost of Koi fish cultivation includes cost of land use and pond preparation. Here average fixed cost is Tk. 2.33 per kg. Summation of the costs of fixed and variable inputs made total costs, which are Tk. 78.65 per kg. Average gross return of Koi fish farmer is Tk. 93.60 per kg, gross margin is Tk. 17.28 per kg and net return is Tk. 14.95 per kg. The other actors relate in Koi fish value chain is Aratdar, Paiker and retailer. The total marketing cost of Aratdar is estimated at Tk. 1.02 per kg. Shop rent is the highest cost item comprising 53.9% of the total marketing cost. The next highest cost item is electricity, which accounted for 12.75 percent of total marketing cost. Aratdar charges 3-5% commission from farmer and this is the gross margin of Aratdar.

In this Koi fish marketing except Channel (V) Aratdar is the actor who creates the facilitation of the Koi fish marketing. They are the actors who help Koi fish farmer and Paiker to operate their business smoothly. They also create the facility for fish buying and selling. The gross margin of Aratdar is Tk. 4.26 per kg and net margin is Tk. 3.31 per kg. The total marketing cost of Paiker is calculated at Tk. 6.89 per kg. Transportation cost is the highest cost item which is 30.38 percent of total marketing cost. The second highest cost item is Aratdars commission which is 24.90 percent of total marketing cost. Paiker receive the net marketing margin which are Tk 6.92 per kg. The gross margin of Koi fish Paiker is Tk. 13.81 per kg. Retailer is the last link in the marketing channel of Koi fish value chain. They purchase fish from Paiker through Aratdar and sold to the consumer. The total marketing cost of retailer is calculated at Tk. 21.19 Tk/kg. Shop rent is the highest cost item including 33.85 percent of total marketing cost. The second highest cost component is the basket/ drum which accounted for 23.59 percent of total marketing cost. Gross margin of retailer of Koi fish is Tk. 26.84 per kg. The net margin

of Koi fish is Tk. 13.25 per kg. Value addition activities are mainly concerned with the change of utilities. In this study, it is found out the value addition by farmer is Tk. 14.85 per kg, Aratdar Tk. 0.04 per kg, Paiker Tk. 13.80 per kg and Retailer Tk. 27.10 per kg. However, we identified few crucial recommendations for improving the Koi fish value chain.

1. Production of own fish feed, ensuring reasonable price of Koi, measures to maintain high quality of fish fingerlings and ensuring adequate scientific techniques and methods.
2. Other actors of Koi fish value chain (Aratdar, Paiker, retailer) suggested arrangement of adequate market information, well developed transportation system, removal of tips and donation and improvement of physical facilities.

Conclusion

This study identified that the marketing and value chain of Gangetic Koi fish in the Mymensingh district is a profitable enterprise, supported by robust communication infrastructure, particularly advancements in mobile technology, and well-developed market facilities. The value chain analysis revealed that retailers secured the highest profit margins among value chain actors, surpassing farmers, wholesalers, and intermediaries. To enhance profitability and efficiency in the Koi fish value chain, targeted measures are necessary. These include developing a more efficient marketing system that minimizes marketing costs and enhances service delivery. Additionally, strategic efforts to improve market information flow and support for adopting advanced production techniques are recommended. Implementing these improvements can strengthen the overall value chain, thereby increasing productivity and profitability within the Koi fish sector in Mymensingh region of Bangladesh.

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Conflicts of interest

The authors declare no conflicts of interest.

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People's perception on changes in agricultural technology and rural women empowerment in Bangladesh

Md. Harunur Rashid[1*], Maruf Hasan Rumi[2] Shukti Bala[3]

[1] Department of Public Administration and Governance Studies, Jatiya Kabi Kazi Nazrul Islam University, Trishal, Mymensingh, Bangladesh.

[2] Department of Public Administration, University of Dhaka, Bangladesh.

[3] Department of Public Administration, Gopalganj Science and Technology University, Gopalganj, Bangladesh.

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***Corresponding Email:**
harun_du.rashid92@yahoo.com

ABSTRACT

The employment of modern technologies in agriculture in Bangladesh is gradually expanding and change of agricultural technologies exhorts to increase the women empowerment. This study aimed to explore the relationship between changes in agricultural technology and the empowerment of rural women in Bangladesh. In this study, a cross-sectional quantitative research design was adopted. A survey comprised with structured questionnaire was conducted to collect required data and information. Respondents for this study were selected following simple random sampling method; the size of sample was 456. The findings showed that most of the respondents perceived that there exists a statistically significant relationship between changes in agricultural technology and the status of rural women empowerment. Positive changes also occurred in women's education, level of awareness, training and engagement in the utilization of modern agricultural technology. Workload on women has been diminished and increased women leadership decreased inequality and discrimination against women; the study explored. The findings of the study will be useful for concerned stakeholders to find ways for adoption of new agricultural technologies to increase the status rural women empowerment in Bangladesh.

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Introduction

Agriculture contemplates as the engine of economic growth in a nation which is accounted for 4.0% of global GDP, 25% of less-developing countries GDP and requires the combined efforts of both men and women (World Bank, 2022). A study of Food and Agricultural Organization [FAO], (2011) showed that 43% of the world's agricultural labour force is made up of women. On the other hand, in developing countries, women are regarded as the backbone of the rural economy, where women make up about 50% of the agricultural workforce which ranges from 20% in Latin America to 50% in Eastern Asia and Sub-Saharan Africa (FAO, 2011; World Bank, 2017, 2018). Despite of this contribution, women are neglected and have less access to agricultural resources, inputs, and

skills than men (FAO, 2011). To enhance the agriculture's economic contribution, several renewed technologies have been introduced in the agricultural sector where agricultural mechanization has a significant relationship with women empowerment (Ashby, 1985; Sraboni et al., 2014). The 5th goal of the Sustainable Development Goals (SDGs) emphasizes on gender equality which intends to obtain women empowerment (Jones et al., 2019). FAO (2011) emphasized on the equal access of women in agricultural technology to ensure the economic empowerment of rural women.

In Bangladesh, most inevitable and primary source of the economy is agricultural sector which contributes 14.74% of the nation's GDP and employs 41% of the workforce (Ministry of Finance [MoF], 2017). Here, women play crucial role in farming by constituting 60% of agricultural labour force and contributing 48% of their families' financial needs but still their contribution haven't gained official recognition (The Daily Star, 2021; FAO, 2016). The nation's agricultural sector has witnessed momentous changes with new agricultural technologies. These technologies are divided into five broad sectors including Information Technology (e-Farmers' Hub, 7676, Query System for Farmer arranged by MPOWER, Krishi Batayan, e-Krishok), Market Linkages (Khaas Food, Parmeeda, Fish Bangla), Mechanization (Newer Irrigation Methods, Tractors, Seedling Guns), Accessibility to finance (iFarmer, MFS), Advanced Agro-Techs (Hydroponic Agriculture, lower cost Greenhouse facilities) etc. (LightCastle Analytics Wing, 2020). In Bangladesh, National Agricultural Policy (2018) and National Agricultural Mechanization Policy 2020 have been taken focusing on inclusive mechanization with gender equality (Ministry of Agriculture [MoA], 2020). Here, 90% of the land preparation, 95% of irrigation, 75% of rice-wheat cropping system have already been mechanized (Bangladesh Agricultural Research Council [BARC], 2025). The development of agricultural technology is aiming to increase the efficiency of production, ensuring security of foods and nutrition, poverty reduction, as 50% of the rural workers and 87% of the rural dwellers are directly or indirectly depended on agriculture (World Bank, 2016). Despite the effort some women benefit from the agricultural mechanization while others are being marginalized instead of being empowered for several dimensions (Theis et. al., 2019). Understanding this context, the study aimed to explore the peoples' perception on the relationship between changes in agricultural technology and the state of empowerment of rural women in Bangladesh.

Rationale of the study

To foster inclusive development in rural Bangladesh and enhance productivity, agricultural mechanization has been accepted widely. It is presumed that the women will be the ultimate beneficiary of the technological advancements with strengthened economy and participation in agricultural decision-making. The conventional unpaid responsibilities of women are steadily transforming into more managerial and entrepreneurial roles, a transition often referred to as "Feminization of Agriculture" (Jaim & Hossain, 2022). However, despite the active involvement of rural women in agriculture, they remain victims of wage disparities, poor training facilities and, limited access to man, money and material (FAO, 2011; World Bank, 2012). As a result, the empowerment of rural women remains incomplete and unrealized.

The fundamental problem resides not only in the gaps of technology use but also in the perceptions of community people regarding the linkage between rural women's empowerment and agricultural technology. To shape the behavior, usage trends and effectiveness of policies relies on the perceptions. If local stakeholders consider agricultural mechanization as male's domain, women's inclusion to technology and decisions will be limited despite of formal governmental efforts. Conversely, if they view mechanization as inclusive, government's mechanization policies will better promote the women empowerment. For effective policy-making, awareness of these perceptions in crucial. And so, learning about

the view of farmers, women and local leaders regarding technological changes can assist to formulate specialized strategies like financial access, training and public awareness initiatives that tackle both perceptional and structural hindrances.

Considering this, sampling frame of the study will concentrate on multiple categories of groups directly affected by agricultural mechanization comprising student, farmer, entrepreneur, businessmen, job holder, and housewife. By gathering perceptions across occupation, gender, profession, habitat, age, income, marital status, the study aims to generate a holistic understanding regarding the peoples' perceptions on how technological changes determines women empowerment in rural Bangladesh.

Literature review

Agricultural technology refers to the utilization of modern tools, techniques, machineries and innovations for improving the productivity, efficiency and sustainability in all steps of farming including crop cultivation to after-harvesting activities. Technological changes include agricultural mechanization, innovation and use of biotechnology and, information and communication technology (ICT), developed irrigation system, precision agriculture etc. (Ullah et al., 2021). Adoption of appropriate agricultural mechanization may reduce the drudgery and contain the potential to improve people's, especially women's participation in agriculture which in further ensures women's empowerment (Kabir et al., 2022). Generally, empowerment of women in agriculture refers their ability to access and control over resources, decision-making, control over income, community involvement etc. (Anik & Rahman, 2021; Kabir, 2022). The empowerment of women is multidimensional which can be enhanced through agricultural technology changes (Kabeer, 1999). According to Habtewold (2021), Kabir et al. (2022) and Kweka (2024), the dimensions for empowerment include time burden reduction, decision-making power, control over resources, self-efficacy and improved social status and, access to information and markets. They argued that adoption of technology reduces the labor burden of women which in further make free time for them to be involved in other productive activities. On the other hand, ICT platforms on agriculture enhance the accessibility of women towards information regarding agriculture and markets, and so their decision-making power improves. This also increases the self-confidence and control over resources among the rural women.

Several studies have focused on the importance of technology-based agriculture and women's empowerment along with their economic growth. Sanders et al. (1996) stated that technical advancement is regarded as the primary driver of worldwide agricultural expansion while traditional agricultural systems break down due to population pressure, soil infertility. Additionally, Jones et al. (2019) argued that agricultural technologies can boost economic output, also cut down time consumed on agricultural production, manufacturing, and transportation. Men and women have similar proclivities for using technology, resulting in a 4% rise in worldwide agriculture productivity.

In developing nations, like Asian and other countries such as India, China, Nepal, Myanmar, Bhutan, Pakistan, Vietnam, Cambodia and others, employ a large number of women in agriculture (Sraboni et al., 2014). Moreover, Davis et al. (2012) found that the productivity of female workers is higher than the male in agriculture. However, Wakhungu (2010) found that women involved in agriculture in Sub-Saharan Africa, are discriminated against and lagging behind rather than their male counterparts in terms of access to education, technology, land ownership, credit, food security, representation and improvement. On the other hand, Diiro et al. (2018) conducted a study on western Kenya's women and found that productivity using advanced agricultural technologies in agriculture and women's empowerment are related. Similarly, Agarwal (2018) and Gurung et al. (2013) said that factors like technological training, access to credit and decision-making is positively correlated with productivity of women.

Several studies have been conducted on the agricultural technology adoption in Bangladesh such as Zabeen et al. (2024) conducted a study on the issue and showed that agricultural tasks in Bangladesh including preparation of land, irrigation, threshing are highly mechanized. However, crop plantation, harvest management are less mechanized. Zabeen et al. (2024) also stated that in Nakla Upazila of Sherpur district, 61.8% women opined to medium use of technologies in agriculture such as water pumpers, power tillers and threshers. They also found that poor credit and training facilities were the key barriers for women towards agricultural mechanization. More surprisingly, Hossen et al. (2023) showed that patriarchal control over land ownership, mechanization, commercial use of land is reducing the participation and empowerment of the rural women. However, Thompson et al. (2021) have found a positive relationship between productivity change due to technological changing and women's empowerment. On the other hand, Anik and Rahman (2021) showed that agricultural mechanization enhances the crop production and reduce the labor burden on women which further improves their income through the fulfillment of other activities. However, there remains a confusion regarding the accessibility, benefits and control over those incomes. Masset et al. (2023) also supported the findings and stated that technology can reduce physical burden and manage time for childcare, community involvement, paid work etc. However, using free time in agriculture instead of paid work may produce negative implications for women. Aligning with the findings, Rahman et al. (2023) also stated that mechanization can enhance women's access to information, markets and networks but still there arises some cultural, financial and structural barriers. They identified gender-based restrictions as the key factor to hamper the women's mobility, their participation in social services and their ability to take part in market mechanisms. Interestingly, Zabeen et al. (2024) found that in rural Bangladesh women can't access or invest in agricultural technology adoption due to lack of credit, poor land tenure and limited collateral. They also argued that technology adoption in agriculture often ignores women's development, instead this targets male heads of the families. Rural women get less access to technologies and technology-adoption related training. The hiring of machines for agricultural activities is highly male-dominated while women have limited access to operate or own the mechanism (Masset et al., 2023).

Existing literature have explored the technology adoption situation in agriculture, their productivity, the empowerment effects, while very limited studies have focused on the people's perceptions regarding the agricultural technological changes in Bangladesh and empowerment of rural women. General people's perceptions on the agricultural technology adoption and their impacts on increased agricultural production and women's involvement, reduced workload with free time, women's political and human rights awareness, women's adaptability capacity, gender equality and self-efficacy etc. In the given context, a perception-based study will contribute to fulfill the gap by pertaining to the empowerment dimensions focusing on the concern of why only technology adoption can't promote women's empowerment without supportive perceptions of community people.

Objective of the study

The purpose of the study was to explore peoples' perception on changes in agricultural technologies and its influence on rural women empowerment in Bangladesh. The study also aimed to investigate quantitatively the nature of relationship between changes in agricultural technology and status of rural women empowerment.

Methodology

The study has been conducted among the adult men and women who are well informed about rural women's attachment with agricultural activities in Bangladesh during COVID-19 pandemic. This study used a cross-sectional quantitative research approach. A descriptive survey design was used in the study, which comprises determining the characteristics of a phenomenon that has been observed (Myers et al., 2013). This study employed a quantitative approach to

explore the perceptions of Bangladeshi people regarding the impacts of agricultural technology on rural women empowerment in Bangladesh. Quantitative research provides a quantitative or numeric explanation of patterns, behaviors, or attitudes in a group by analyzing a sample of that community (Babones, 2016). To collect required data, researchers employed multi-method data collection tools and techniques. In this study, data were collected from both primary and secondary sources. Primary data provided a field situation for the study, whereas secondary data assisted the researchers in precisely describing the outcome. For primary data collection, survey was conducted which was structured in close-ended questions and used Five-Point Likert Scale; the structured questionnaire was transformed into Google Form as data collection procedure was progressed amidst pandemic. The study followed simple random sampling technique, a total 456 participants participated in the survey via online using different social media tools and e-mail.

For the development of survey questionnaire, this study has taken several indicators of women empowerment which include human right, political awareness, suppressive mentality, patriarchal structure, sexual discrimination, women adaptability, and these are logically connected towards technology change. Agricultural technology change is supposed to enhance the women's accessibility and control over resources which further ensure their human rights and increase political awareness and participation towards decision-making. Due to resource owning, the self-confidence increases and suppressive mentality reduces which will further challenge the patriarchy and gender discrimination. Also, the access to information and networks develops for women which actually ensure women's empowerment in rural Bangladesh.

On the other hand, secondary data was gathered from relevant papers, fieldwork, essays, published materials from various organizations, government publications and journals, prior studies, Bangladesh Bureau of Statistics (BBS), various agriculture-related articles, and Acts and laws. The primary data were analyzed using Statistical Package for Social Sciences (SPSS 25) and presented in tables, graphs, pie charts, and figures. The researcher used the content analysis to analyze the gathered secondary data which have been used to support and validate the primary findings. The study also followed the ethical guidelines provided by WHO (2007) while collecting data.

Results

Demographic information of the respondents

Table 1. Demographic information of the respondents

Variables		Percentages
Gender	Male	68%
	Female	32%
Religion	Islam	90%
	Hinduism	8%
	Other religion	2%
Age	18-30	93%
	31-45	6%
	46-60	0%
	>60	1%
Habitat	Rural	52%
	Urban	48%
Educational status	Primary	0.20%
	SSC	10.50%
	HSC	1.30%
	Graduate	63.20%
	Post-graduate and above	24.80%

Variables		Percentages
Occupation of the respondents	Student	69.70%
	Farmer	0.20%
	Student and entrepreneur	11.60%
	Businessmen	1.50%
	Job holder	16.40%
	Housewife	0.40%
Respondents' fathers involvement in farming	Full farmer	21.90%
	Part-time farmer	8.80%
	Farming with other job	40.10%
	No involvement	29.20%
Marital status	Married	18%
	Unmarried	81%
	Others	1%
Family monthly income	0-10,000	28.30%
	10,000-20,000	13.40%
	20,000-30,000	5.50%
	>30,000	6.40%
	Others	46.50%

Among the respondents, more than two third (68%) are male and 32% of them are female and, 81% of the respondents are unmarried and 18% of them are married. Additionally, most of respondents were Muslim (90%) and 10% respondents were from other religion among whom (52%) were from rural area and rest of them (48%) were from urban area. As per the findings, most of the respondents are aged between 18 and 30 (93%) and only 6.00% of the respondents are aged 31 to 40. On the other hand, only 1.00% of the respondents are the age of more than 40. According to the responses, 21.90% respondents' fathers are full farmer, 8.80% are part time farmer, 40.10% are involved in farming with other job and 29.20% have no involvement with farming. Here, most of the respondents have strong attachment to farming either directly or through their families.

Technological changes and women empowerment

Table 2. Relationship status between technological changes and women empowerment

Variables	Attribute	Frequency	Percent	P-value increased women empowerment
Increase use of modern technology in agriculture	Strongly disagree	16	3.5	<.001
	Disagree	13	2.9	
	Neutral	240	52.6	
	Agree	187	41.0	
	Strongly agree	16	3.5	
Women involvement in using modern equipment in farming increased rapidly	Strongly disagree	13	2.9	<.001
	Disagree	117	25.7	
	Neutral	83	18.2	
	Agree	215	47.1	
	Strongly agree	28	6.1	

Variables	Attribute	Frequency	Percent	P-value increased women empowerment
Modern technology reduced women workload	Strongly disagree	13	2.9	<.001
	Disagree	113	24.8	
	Neutral	82	18.0	
	Agree	216	47.4	
	Strongly agree	32	7.0	
Crop yield machinery, social media-Facebook, apps, mobile phones etc. helps to increase agricultural production	Strongly disagree	1	.2	<.001
	Disagree	17	3.7	
	Neutral	24	5.3	
	Agree	264	57.9	
	Strongly agree	150	32.9	
Change in agriculture technology ensure women human rights and increase political awareness	Strongly disagree	3	.7	<.001
	Disagree	45	9.9	
	Neutral	56	12.3	
	Agree	255	55.9	
	Strongly agree	97	21.3	
Change in agriculture technology increases women adaptability in different situation	Strongly disagree	2	.4	<.001
	Disagree	40	8.8	
	Neutral	46	10.1	
	Agree	286	62.7	
	Strongly agree	82	18.0	
Change in agriculture technology reduces gender inequality and sexual discrimination	Strongly disagree	6	1.3	<.001
	Disagree	69	15.1	
	Neutral	74	16.2	
	Agree	262	57.5	
	Strongly agree	45	9.9	
Change in agriculture technology had positive influence in reducing suppressive mentality and patriarchal structure in society-	Strongly disagree	5	1.1	<.001
	Disagree	62	13.6	
	Neutral	85	18.6	
	Agree	261	57.2	
	Strongly agree	43	9.4	

The Chi-square analysis was conducted on eight statements regarding the perceptions of the respondents that indicates the changes of technology in agriculture and increasing women empowerment. Findings show that the perceptions of people denoting that the relationship between changes in agricultural technologies and status of rural women empowerment is statistically significant (P-value < 0.001). According to the table, the use of modern technology in agriculture increased greatly in the past two decades and that also increased the education and training of the women and this is agreed by 44.5% of the respondents. Besides, women's participation in the use of modern technology in agriculture is also increasing day by day. It is apparent that roughly 53.20% of respondents are agreed about the statement while 28.6% said that women's participation is not increasing.

At the same time, with the increase of

education and training among women, the work pressure on women related to rural or agricultural sector has also been decreased by using modern technology. Approximately 54.4% of respondents assumed this, while 18% remained impartial. On the other hand, roughly 92% of respondents agreed that the use of modern agricultural technologies like machineries, social media (e.g. Facebook), Apps, mobile phones, etc. induce crop production. Among the respondents 77% agreed that due to the influence of change of agricultural technology, women participation has been increased in social and political constituencies, and women leadership is being created.

Most of the respondents (80%) assumed that the direct or indirect result of the changes of agricultural technology increased the ability to accept the life of women both inside and outside the house. While only a few numbers of respondents showed their opposition to this statement. It has also been accepted by the respondents that agricultural technology changes are significantly associated with increased women empowerment. On the other hand, evident shows that most of the respondents perceive that inequality and sexual discrimination of women and men are being reduced in the society due to the direct or indirect influence of agricultural technology. Result also indicates the acceptance of the statement that increasing use of modern technology, positive change of the patriarchal mentality has significant relation with women empowerment. Moreover, approximately 67% percent of the respondents assumed that technological change will directly or indirectly will bring positive change in the patriarchal social mentality, while only 14.7% per cent disagree that this will not bring changes in mentality.

Discussion

Technological change affects the economic growth and agricultural development of a nation. In Bangladesh, agriculture is the primary source of income in which a huge number of women contribute significantly. At present, expansion of modern agricultural technology in Bangladesh is affecting the women meaningfully. The results of the present study confirm that most of the respondents perceive that the changes in agricultural technology have significant relation with the status of rural women empowerment. Agricultural diversification and usage of modern agricultural equipment also have high potential to promote women's empowerment in Bangladesh. Empowerment is widely acknowledged as a key measure of progress toward gender parity goals (Malapit & Quisumbing, 2015). According to Loevinsohn et al. (2013), new technological advancements motivate women to make independent decisions in their personal, economic, and social lives. Findings show that all the items of relationship between changes in agricultural technology and the increased women empowerment, have been highly supported by the respondents. Firstly, people perceived that the use of modern technology in agriculture and women's participation in these modern technology use increased greatly in the past two decades. Technological advancement creates awareness and increases women's financial ability and personal capability though proper training and education. 'She Power Project' of Bangladesh Government is such an initiative to train and provide jobs to thousands of women in Bangladesh (Gomes, 2020). Besides, this study explored that most of the respondents consider a significant association between the work pressure on women and the rural or agricultural sector. The work pressure has been decreased conspicuously compared to the previous years for using modern technology. This finding is similar to other recent study of Alauddin and Tisdell (1995), who claimed that Green Revolution technologies in Bangladesh decline the wok burden of women as well as give more facilities to women. The use of modern technology in crop yield are empowering women significantly in the agricultural sector. These instruments ease the life of rural women and they can easily share their demand and success by these modern tools. The sort of information available through the use of ICT is a significant aspect in the empowerment of women. According to Hafkin and Huyer (2007), ICT project for social

development in the direction of gender equality must take into account the content that speaks about the concerns of discriminated women like knowledge on their daily lives, business enterprises, and family responsibilities (Hasan, 2012). On the other hand, the agricultural technology influence to empower women in social and political constituencies, and create women's leadership. Women self-dependency and working capacity both inside and outside the house have increased. Moreover, the inequality and sexual discrimination of women in society are largely reducing that gives a huge opportunity to women to become self-reliant in rural and urban societies. The change of technology in the agriculture sector has brought a positive change in the mentality of rural people and the patriarchal structure of society which facilities to enhance women's sustainable economic and social independency.

Conclusion

The purpose of this study is to explore the people's perceptions on the linkage of rural women empowerment in Bangladesh with technological changes in agriculture. The findings of this study show that most of the participants opined that changes in agricultural technology have a direct influence on the status women empowerment in Bangladesh. With the advent of advanced technology in agriculture, women's participation in the usage of modern tools and technologies in agriculture is expanding day by day. Through adequate training and education, technological growth makes women conscious and provides them with financial and personal capabilities. Furthermore, this study discovered that work pressure on women participating in agricultural sector has lessened noticeably in recent years as a result of the use of modern technologies. Women can now work in a variety of fields and expand their personal involvement to the national economy. Women's empowerment has accelerated in social and political domains due to agricultural technology transformation, and women's leadership is emerging. Furthermore, inequity and sexual unequal treatment against women in society are substantially decreasing in a culture that provides a significant possibility for women to become self-sufficient in both rural and urban settings. Technological advancements in agriculture have a favourable impact on women's decision-making power, equal opportunity, financial independence, and political engagement, all of which contribute to women's empowerment. Several recommendations on the proper utilization of agricultural technology towards women's empowerment have arisen which include:

- The government should arrange gender-inclusive agricultural training especially for women on maintaining and operating the agricultural technologies smoothly.
- Additionally, gender-sensitive credit opportunities through banks and microcredit institutions need to be promoted along with enhanced accessibility of women in credit facilities.
- ICT tools focusing on agriculture need to be developed to provide rural women up-to-date agricultural information and to make these initiatives more beneficial digital literacy programs for women should be arranged.
- In local level agricultural committees and farmer's associations, women's participation and inclusion should be ensured for better women's representation.
- Organizing awareness campaigns for all categories of people to improve their perceptions regarding gender equality in agricultural production. Government should ensure the gender equality in agriculture through gender sensitive policies both at national and local level

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Ethical issues in developing and implementing laws and policies regarding aquatic biodiversity conservation

Md. Mostafa Kamal[1*]

[1] Institute of Bangladesh Studies (IBS), University of Rajshahi, Rajshahi, Bangladesh

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***Corresponding Email:**
kamalm@ru.ac.bd

ABSTRACT

Aim of this research paper is to analysis the ethical issues in developing and implementing laws and policies regarding aquatic biodiversity in Bangladesh. Present Bangladesh is facing different types of environmental problems, among these decreasing of aquatic biodiversity and resources is alarming. Some scholars assumed that defective as well as insufficient laws and policies as lacking implementation procedure is the major cause of aquatic biodiversity degration. Moreover, it is found that substandard and malfunctioning laws and policies as well as lengthy process of judiciary and injustice made this scenario more acute in recent decades which shows that it needs to address ethical issues during developing laws and policies regarding aquatic biodiversity conservation in Bangladesh.

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Prelude

Nature was created by one single creator. In this universe every single organism had its own identity, none other organism was in the situation to take place of another organism. Man has been interested in nature since time immemorial, but today he thinks himself to be the master of nature. On the other hand, nature tries to comprise with man and absorbs human onslaught in the form of waste material discharge, deforestation, intensive agriculture, desertification, urbanization etc. In the name of progress, forests are demanded that resulted deforestation, wetlands and waterbodies poisoned and polluted with pesticides, chemical fertilizers, industrial effluents and air fouled with noxious gases. Our earliest ancestors lived in a rich and competitive world closely tied to environment. They knew the sources of water and use of plants and animals for food and indicial purposes. But the hunters and gatherers exploited the environment to fulfill their requirements, by cutting down trees resulting into great changes in grass and shrubs with the use of fire. However, they could not cause excessive damage to environment due to their low population, nomadic way of life and primitive technology. The domestication of plants and animals gave impetus to agricultural technology. Human population started increasing beyond the limits previously fixed by natural food supply.

The development in machinery, technology, bio and genetic technology, fertilizers, pesticides, and high yielding varieties of different crops and vegetables caused unprecedented increase in agricultural productivity. Overgrazing, widespread destruction of forests and intensive agricultural practices demanded the land and

converted productive regions to barren areas. It is thus, quite amazing to recall the change from hunter gathered economy to that of agriculture and industry that marked by the changed natural habitat. The shifting role of man in the environment placed heavy demand on air, water and natural resources. As man was trying to gain control over environment, the link between him and nature got weakened. It therefore became necessary to regulate human behavior and social transactions with new and appropriate laws, designed to suit the changing conditions and values. In order to manage and face the myriad challenges of ever changing environment, the environmental laws emerged. But these laws are of no if it is not implemented or accepted by the society properly. Though government of Bangladesh introduced over abundance of legislations in the field of environmental law to develop and conserve environment and which directly or indirectly deals with environmental issues. Besides, there is bulk of legislations but this didn't have any impact on the condition of environment rather it is deteriorating day by day. Therefore one would always think there is plethora of legislations but why there is no improvement in the condition of environment. However, objective of the research paper are to findout the inherent defects in laws and policies and lacked of proper implementation guidelines and methods as well as to find out the absent of code of conduct in implementing process.

Environmental ethics and old traditions

Our age old traditions teach us to live in peace and harmony with nature and to develop and conserve it, as we all are creatures of one creator and we don't have any right to harm any of the living being in any manner as they are also one of the creations made by the almighty. This is taught to us since the very beginning of our civilization but as the civilization progressed we forgot everything and started thinking that we are the master of nature and everything in this world is made for us and we can utilize it, at any cost, as and when require, this is against our ethics and moral values.

Since ancient period the main motto of social life was "to live in harmony with nature". Sages, saints, and great teachers of different areas in the world were lived in forests, mediated, and expressed themselves in the form of nature. Thus we can imply that all the divine thoughts and literature which served as ideal for living life and taught guidelines how to live life came up when these saints and great thinkers were in touch with the nature. This literature of olden times preached in one form or the other a worshipful attitude towards plants, trees, earth, Akash (sky), vayu (air), water and animals and to keep benevolent attitude towards them. It was regarded a sacred of every person to protect them. Different religion enshrines a respect for nature, environmental harmony, and conservation. It instructed man to show reverence of divinity in nature. Therefore trees, animals, hills, mountains, rivers etc. are deeply loved and respected by men as symbol of reverence to these representative samples of nature. Religious scriptures reveal the principles of using resources, developing and conserving the environmental resources in such a ways so that future generation can also use these resources as they used at present such as

1. To respect nature and protect it,
2. One should be non-violent towards environment, biodiversity and ecosystems,
3. Use resources as really needs and conserve it for future generation as you are consuming at present,
4. One should think that he is also an inseparable and continual part of environment, so degradation or destruction of environment will also be the destruction of oneself.

Purity of thought and expression and cleanliness of the environment around us should be observed. All lives, human and non-human including trees are of equal value and all have same right to existence. It shows that the principle of sanctity of life is clearly ingrained in different religion scriptures. As different religions teach us from where we can derive inference that it would have developed slowly

and slowly in due course of time as man progressed. Man since the time immemorial knew the importance of nature, the things which helped him in progressing and he knew if we want to progress further we would require these things. People used to harvest and collected resources as they required living in.

In Current scenario people have forgotten their age old traditions of living in harmony with nature and conserving natural environment and natural resources. In the mad rush for industrialization and industrial development we are forgetting the importance of environment. Earlier man coexisted with nature like other creatures but slowly he started thinking that whole universe is meant for man and he is the master of whole universe. Previously he cared for the environment in which he lives in because he had place in his heart for everything and he was sensitive towards other organism because they thought they are inseparable part of environment but as civilization progressed the sensitive attitude of man towards nature started deteriorating and he had totally forgotten the importance of nature and he thought he is well aware of the fact that Industrialization brings with it problems of environmental pollution but doesn't at all wants to understand this simple fact.

Bangladesh has also age old tradition of tolerance, non-violence, equity, and compassion for animate objects. In olden times people were part of daily life and synthesized with religion. Religious teachings, social and political norms and economic policies treated as a part of nature not as molder or superior. All the living beings are creatures of one superior power God. The philosophical orientation of peaceful coexistence with nature is mentioned in the constitution of Bangladesh. State shall endeavor to protect and improve environment and to safeguard forest and wildlife of the country but without peoples' awareness and participation it is impossible for state to conserve the environment. It is the duty of every citizen of Bangladesh to protect and improve natural environment including forest, lake, rivers, different wetlands and water bodies, and wildlife and to have compassion for living creatures.

In Bangladesh there are a number of legislations for conservation of environment, biodiversity, and maintaining ecological balance. But these laws have some lacking and limitations as well as insufficient guidelines for appropriate implementation in respective areas. Also there is hardly seen the appropriate implementation of these laws. There are many laws and policies directly or indirectly regulating the environment in Bangladesh. The present research is conducting legal and ethical issues regading aquatic biodiversity conservation and there several laws relating directly or indirectly to aquatic biodiversity conservation. However, laws regarding aquatic biodiversity conservation are The Canals Act 1864, The Irrigation Act 1876, The Private Fisheries Protection Act 1889, The Agricultural and Sanitary Improvement Act 1920, The Tanks Improvement Act 1939, The Protection and Conservation of Fish Act 1950,The Embankment and Drainage Act 1952, The Government Fisheries (Protection) Ordinance 1959, The Agricultural Development Corporation Ordinance 1961, The Agricultural Pesticides Ordinance 1971, The Bangladesh Fisheries Development Corporation Act 1973, Bangladesh Irrigation Water Rate Ordinance 1983, The Fisheries Research Institute Ordinance 1984, The Protection and Conservation of Fish Rules 1985, Fisheries in Environmental Policy 1992, Environmental Conservation Act 1995, Jalmahal Management Policy 2009, Bangladesh Water Act 2013.

At present Bangladesh employs a range of regulatory instruments to develop and protect its natural resources. As a system of doing so, laws should be implemented properly. The legislature was quick enough to enact laws regulating most aspects of environment and it resources, but government is very cautious to sanction enforcement budgets or require effective implementation across the country. Government agencies wield vast power to discipline violators of environmental degradation. But environmental degradation and pollution are happening in everywhere and in some case it is observed that these laws and policies are seems useless. These are happening

due lack of planning of appropriate development projects and implementation. In addition, there is no code of conduct or mentioning ethical issues concerning to make laws and to develop and implement development projects.

As we know the dismal state of world fisheries including today's Bangladesh reflects humanity's moral failure to maintain the natural environment and its productivity while benefiting from nature's goods and services. Accelerating depletion of fishery resources jeopardizes not only ecological integrity, but also ecological ethics, risking human food security, resilience of fishing communities, and livelihood options for current and future generations. To analyze the approach, implementation, and evaluation of the ethical dimensions of fisheries, we review the law making process, implementing process of these laws and policies concerning aquatic resources especially fresh water fishery. We conclude that ethical issues in fishery development and conservation in Bangladesh originated from the law making and implementation processes.

From 1980s, government of Bangladesh realized the environmental problems and to protect and develop the deteriorating environmental situation government passed some new laws and policies and brought into enforcement these new laws with some earlier enacted legislation. In addition, government formed new enforcement agencies and strengthened the old ones. Some special bodies were made to perform specialized task like Environment Impact Assessment (EIA) Regulation in 1995. In 2000 government has established Environmental Court after enacted the Environmental Court Act 2000.

Despite these initiatives, threat to environment especially aquatic environment and biodiversity is increasing and the quality of environment continues to decline. Accordingly the threats to freshwater biodiversity and ecology in Bangladesh can be grouped under five interacting categories such as overexploitation; water pollution; water flow alteration/modification; destruction or degradation of habitat; and invasion by exotic fish species (Allan & Flecker, 1993). Environmental changes occurring in Bangladesh with the change of global scale, such as nitrogen deposition, warming, and shifts in precipitation and runoff patterns are superimposed upon all of these threat categories (Poff et al., 2003). Overexploitation primarily affects vertebrates, mainly fishes, reptiles and some amphibians; whereas the other four threat categories have consequences for all freshwater aquatic biodiversity from microbes to mega fauna. Pollution problems are pandemic, and although some industrialized countries have made considerable progress in reducing water pollution from domestic and industrial point sources but in case of Bangladesh it is getting more severe, threats from excessive nutrient enrichment and other chemicals such as endocrine-disrupters are growing (Smith, 2003). Habitat degradation is brought about by an array of interacting factors. It may involve direct effects on the aquatic environment such as excavation of river sand or indirect impacts that result from changes within the drainage basin. For example, forest clearance is usually associated with changes in surface runoff and increased river sediment loads that can lead to fish habitat alterations such as shoreline erosion, smothering of littoral habitats, clogging of river bottoms or floodplain alleviation.

Flow modifications are ever-present in running waters. They vary in severity and type, but tend to be most aggressive in regions with highly variable flow regimes. This is because humans in these places have the greatest need for flood protection or water storage. That existing dams retain approximately 10 000 km3 of water, the equivalent of five times the volume of all the world's rivers, illustrates the global extent of human alteration of river flow (Nilsson & Berggren, 2000).

Widespread invasion and deliberate introduction of exotic species adds to the physical and chemical impacts of humans on fresh waters and aquatic resources, in part because exotics are most likely to successfully invade fresh waters already modified or degraded by humans (Bunn & Arthington, 2002). There are many examples of large-scale and dramatic effects of exotics

on indigenous species in different wetlands of Bangladesh and in wetlands of other countries as well even in Southern Hemisphere lakes and streams and impacts are projected to increase further (Sala et al., 2000).

The particular vulnerability of freshwater biodiversity also reflects the fact that fresh water is a resource for humans that may be extracted, diverted, contained, or contaminated in ways that compromise its value as a habitat for organisms. In some instances, impacts have been sustained over centuries and, in the case of many of the major rivers of Bangladesh they have persisted for more than 4000 years (FAO, 2000). Indeed, some authors now believe it unlikely that there remain a substantial number of water bodies that have not been irreversibly altered from their original state by human activities (Lévêque et al, 2003). The extent of most freshwater systems is not confined to the wetted perimeter, but includes the catchment from which water and material are drawn. Their position in the landscape makes wetlands, waterbodies and rivers 'receivers' of wastes, sediments and pollutants in runoff. This is also true of seas and oceans, but inland water bodies typically lack the volume of open marine waters, limiting their capacity to dilute contaminants or mitigate other impacts.

Ethical issues in law making process

Law making process in Bangladesh

Legislation is the basic function of Bangladesh Jatiyo Shangshad. The Constitution of the People's Republic of Bangladesh has vested exclusively all the legislative powers of the Republic to Parliament. As per constitutional provision, article 80 and 82 of the constitution encompasses the basic provision of law making process. Besides article 26 of the constitution added that all existing law inconsistent with the provision of the fundamental rights guaranteed by the constitution, to the extent of such inconsistency, become void on the commencement of this constitution. Moreover the state will not make any law inconsistent with any provision of the constitution concerning fundamental rights. If any law is made which is inconsistent with the constitution shall be void. Article 7 of the constitution pronounces the supremacy of the constitution clearly stating that the constitution is, as the solemn expression of the will of the people, the supreme law of the republic, and if any other law inconstant with the constitution, that law shall, to the extent of the inconsistency, be void. The law making process of Bangladesh parliament is initiated primarily by the Member of Parliaments (MPs) submitting a notice to parliament secretary for seeking permission to raise a bill. Subsequently, crossing various stages, it passes by the parliament as a law and ends with the ascent of the President. After following various stages and long procedure, the bill turn into law and publishes officially as a Gazette. This article is intended to explain the procedural aspect of law making in Bangladesh.

How derives the idea of a new law

Law is a system of rules and guidelines which are enforced through social institutions to govern the behavior of its citizen (Hampstead, 1972). The law shapes politics, economics and society in countless ways and serves as a social mediator of relations between people. It is prepared by government and passed by its parliament following the constitution (written or unwritten) and the rights encoded therein. The need for making a new law is realized in respect of various existing social and political realities. There are a number of guiding values and benchmarks for the best practices of parliamentary law making. In many legislative systems, the body of a bill is preceded by a statement that explains the purpose and scope of the proposed legislation, which is generally called a "Statement of Purpose/ Explanatory Note" or a "White Paper" (Jahan & Amundsen, 2012). The purpose of the note is to inform the public on the reasons for the new law, the problems addressed by the bill and its connection to existing laws. When the government is presenting a white paper on an important issue, various concerned groups, individuals and interest groups can publicly debate the issue, and contribute further on the conditions of the bill. Then, taking the various opinions and their

own political concerns into consideration, the government can revise the white paper, and based upon this, formulate and present a new bill to the parliament. In case of Bangladesh, however, there is no precedence of white paper. In the law making process of Bangladesh, the idea of a new law can derives from a variety of sources: an election manifesto promise, from a government department after an election has been won, the influence of experts within their field, the direction of judiciary and public demand on a certain situation, mass media, civil society etc.

Types of bill

The constitution of Bangladesh has clearly mentioned about the procedure of how legislation can be enacted in parliament. As per the article 80 of the constitution, every proposal introducing in the house for making legislation shall be in a form of Bill, and when a Bill is passed by the parliament it shall be presented to the president for his/her assent. When the president has assented, or is deemed to have assented to a Bill passed by the parliament it shall become law and shall be called an act of parliament. The procedure for passing a Bill depends on its classification. In British Parliament, there are several types of bills such as: Public Bills, Private Bills, Private Members Bills, Hybrid Bills, Money Bills (Barnett, 2011). A Public Bill is one which has general application to all members of society. Public Bills embody government policy and a Minister introduces them. The bulk of Parliament's time is taken up with these types of bills. A Private Bill confers powers or benefits on particular persons or bodies in excess of or in conflict with the general law. It is promoted by outside bodies such as local authorities, charities, companies or occasionally individuals (Griffith & Ryle, 1990). A private Member's Bill is one promoted by an Individual Member of Parliament (MP) from any political party, as opposed to the government or, alternatively a matter which the government has been unable to fit into its legislative program but will subsequently adopt and provide time and support for the passage of the Bill. These rarely have any chance of becoming law as too much of Parliament's time is taken up with Government Bills and the time available for their consideration is restricted what Paul Silk mentioned "Government's chief weapon is time" (Paul, 1993). As a result of this, Parliament gets little chance to discuss Private Members Bills, let alone vote on them. Private Member's Bills follow the same legislative process as government Bills. Hybrid Bills in House of Common are very rare. The government or backbenchers introduce them. It is a mixture of private and public Bills and come about if someone or some people are going to be treated differently to others. A money Bill is one which is certified by the speaker as such, and contains other than financial measures.

In Bangladesh, there are three main classification of legislation: Ordinary Bills, Money Bills and Finance Bills (Murphy, 2006). Ordinary Bill is one which has no relation with the financial matters and may pass with general majority vote of the MP's in parliament. It can be further subdivided into Public Bills and Private Bills. If notice for introduction of the Bill has been given by a minister, it is known as government Bill, and if a non-minister MP introduces it, it is known as Private Member's Bill (Jahan & Amundsen, 2012). It does not require the prior recommendation of the president for introduction into Parliament. But both the "Money Bills" and "Financial Bills" require the prior recommendation of President before placing in the house. To take prior recommendation from the titular head of the state is a common style of the Westminster Model to place Money Bill in the House (Taylor, 1951). Similar recommendation is also mandatory in Canada before introducing spending bills, and likewise, motion is required before the introduction of bills to raise revenues through taxation. Law Making Process various functions of legislature, law making is a lengthy and to some extend complex process. Ceremoniously it is initiated as a form of Bill by the executive or individual member (for Private Bill) in the house as it mentioned earlier. Before submitting a Bill in the parliament, it follows some pre legislative procedure like; drafting,

policy development and cabinet approval. These all pre legislative activities are involved in Pre Legislative Phase. In the house, a Bill passes through three distinct stages which are known as Legislative Phase. In parliamentary parlance these three stages usually known as first reading (the title of the bill is announced), second reading (discussion on the principles of the bills takes place) and third reading (motion is moved to pass the bill) respectively. A new stage in the legislative phase, called the committee stage, is also now frequently referred to in many parliaments. This stage came into existence in Bangladesh when the seventh parliament set up a special committee, composed of members belonging to both ruling and opposition parties, to review all bills referred to the JS (Ahmed, 2002). There is a another phase named Post Legislative Phase which involve the ascent of President and the publication of gazette notification. Considering the above mentioned procedures it is seen that the law making process of Bangladesh devised into three broad phases: pre-legislative phase, legislative phase, and post-legislative phase.

Pre-legislative phase

In the pre-legislative phase, concerned ministry or line agency on behalf of executive submitted a proposal to cabinet for its approval to make a new law on a casual basis. Through cabinet approval, the law making process is initiated primarily from the sponsoring ministry. Usually, the Cabinet approves this primary proposal for making law on an individual basis as there is no central planning for legislative proposal in Bangladesh. As a result, the overall primacies of law remained indeterminate. But in Canada and the United Kingdom, where the planning of the government's legislative agenda begins well in advance of the opening session of Parliament in which legislative proposals are to be tabled and it makes easy to determine overall priorities. After cabinet approval, the concern ministry (for public Bill) begins to make a draft copy of Bill by its internal mechanism following the Rules of Business and Secretariat Instructions. As per article 55(6) of the Constitution, the President shall make rules for the allocation and transaction of the business of the government. According to the constitutional provision, currently these include the Rules of Business, 1996 (revised up to January 2009), and the Allocation of Business among the Different Ministries and Divisions (Schedule I to the Rules of Business, 1996). Besides, the Secretariat Instructions of 1976 is also confirm the consistency and efficiency in the observance of administrative practices and procedures. It is considered as a supplemental of booth the Rules of Business and the Allocation of Business among the different Ministries and Divisions. It is mandatory that all business of the government have to be directed in accordance with both the Rules of Business and the Secretariat Instructions. According to the Secretariat Instructions, every ministry or division is in charge for the formulation of policies of the government within its jurisdiction and also for the execution and review of those policies. Moreover, the Rules of Business and Secretariat Instructions also involve that any legislative proposal shall be started from the administrative ministry to which the law or a subject matter is assigned. Following the above mentioned Rules of Business and Secretariat Instructions, administrative ministry initiated drafting and policy making process for a possible law. Among senior officials in the rank of joint secretary of the concerned ministry, those who have expertise on the relevant issue, or in some cases, outside lawyers usually draft a preliminary Bill. After completion of making an initial draft Bill, the inter-ministerial consultation meetings are called for scrutiny where the professional legislative drafters from the Ministry of Law, Justice, and Parliamentary Affairs are also attended to provide comments and suggestions on the various aspects of the draft Bill. Thus, the policy for making a new law is formulated from an early stage by the concern ministry (TIB, 2000). Subsequently, following the Rules of Business, the administrative ministry initiates the legislative process by submitting a summary of draft Bill before cabinet for its approval. As it denoted in Rule 4(ii) of the Rules of Business, 1996, "No

important policy decision shall be taken except with the approval of the Cabinet" and the Rule16 (1) also mentioned, "Cases involving legislation, including the promulgation of Ordinance are to be brought before Cabinet". Besides, Rule 19 of the Rules of Business, 1996, prescribes the format of the summary. According to the format, the secretary of the ministry concerned conveys a brief and clear memorandum along with the draft Bill to the Cabinet Secretary which provides the contextual and pertinent facts, the points for discussion and the recommendations of the Minister-in-charge. The summary shall be self-contained as far as possible, and shall include as appendices such relevant papers as may be necessary for proper appreciation of the case. The number of copies of the summary to be supplied for Cabinet consideration will be specified by the Cabinet Division. In cases of proposals involving expenditure or abatement of revenue, the views of the Finance Division must also be obtained and recorded in the summary. Where a matter concerns more than one Ministry or Division, the summary shall, contain the recommendations of the Ministries if agreement is reached amongst them, or shall state the points of differences and the recommendations of each Ministry or Division concerned if no agreement is reached (Rules of Business, Rule:10). It is usually needed at least four clear days in advance of the Cabinet meeting for placing a summary on the agenda. After Cabinet meeting, the Cabinet secretary or Joint secretary prepares a brief record of the discussions and decision taken. This file is then placed to the prime minister for his approval, and once the approval is given, it is then disseminated to Cabinet Ministers. Relevant extracts of the decisions are also provided to the sponsoring minister and ministerial secretary for necessary action (Rules of Business, Rule: 21). As soon as the Cabinet agrees on an initial legislative proposal, the sponsoring ministry will send the file to the Ministry of Law, Justice and Parliamentary Affairs for preparation of a draft bill or for vetting of the preliminary draft bill already prepared and approved in principle by Cabinet (Rules of Business, Rule: 14).It is worth mentioning here that the Ministry of Law, Justice and Parliamentary Affairs has a Legislative Drafting Wing (the Drafting Wing) for that purpose. Then the Drafting Wing will scrutinize the draft Bill to certify that it encloses no measures that are ultra vires of the constitution or inconsistent with the fundamental principles of state policy. If no inconsistencies are identified, the Drafting Wing will recommend the sponsoring ministry accordingly. If there is found any anomaly, the Drafting Wing will return it to the ministry or division concerned and provide advice and recommendations for necessary modifications. Once amendments are made on the proposal, the matter is then returned to the Drafting Wing for redrafting (Secretariat instruction: 241). The drafting officials of the Ministry of Law, Justice and Parliamentary Affairs convert the legislative proposal into a standard draft bill through the application of legislative language. In regards of their action, the drafters may often hold consultations with officials from the sponsoring ministry or with outside experts and professionals who are well known in the subject matter of the Bill. They also may ask to Attorney General's office to provide legal advice on certain issues if it deemed any doubt on constitutional or legal ground. Even they may call upon the Law Commission of Bangladesh to assist in drafting on specific Bills, such as those relating to manifold and noteworthy issues. After confirmed the draft Bill from the Drafting Wing, it is promoted to the Secretary, Ministry of Law, Justice and Parliamentary Affair's for his approval. Once approval is obtained, the draft Bill is referred to both the Law Minister and State Minister of law for initial political support. Subsequently, the draft Bill is sent back to the sponsoring ministry, the ministry-in-charge of the Bill. The ministry again scans the Bill to satisfy itself that the bill properly reveals both the intentions of the ministry and the guidelines from Cabinet, and then the minister of concern ministry approves the bill as it is drafted. When an acceptable form of the bill is achieved, it is again forwarded to Cabinet for final approval as an official bill of the

government. As soon as Cabinet approves the bill for its endorsement, the sponsoring ministry carries it to the Parliament Secretariat to initiate the legislative phase.

Legislative phase

Legislative phase begins through submitting a notice to the parliament Secretary for seeking permission to introduce a bill in the house (ibid.). It has three distinct stages which are usually known in parliamentary parlance as first reading, second reading and third reading respectively (Jahan & Amundsen, 2012). Subject to the provision of the Rules of Procedure (ROP), the member-in-charge (Minister/MP) who shall desiring to move for leave to introduce a bill, must submit a written notice before seven days (for Government Bill) and fifteen days (for Private Member Bill) to parliament secretary. But in respect of Government Bill, Speaker for sufficient reasons may suspend this rule and allows the motion at a shorter notice (RoP:75). The notice is accompanied by two and three copies of bill for Government Bill and Private Member Bill respectively along with an explanatory statement of objectives and reasons. If the Bill is one that under the Constitution requires the previous recommendation of the President for its introduction, the notice has to contain a certificate by the minister that the Bill has been recommended by the President for introduction. Like the British House of Commons, the motion to introduce Government Bills and Private Member Bills in Bangladesh Parliament is also made following the order of days in a week which are known in parliamentary jargon as Government Business Day and Private Members Business Day (RoP:74,75). Thursday is reserved only for Private Members Business and Government Business can be done every day except Private Business day. When a Bill is introduced in the House, any member can oppose it. As soon as a motion for leave to introduce a Bill is opposed, the Speaker may allow a brief explanatory statement by the Member opposing the leave for introduction and the Member-in-charge moving for leave. Then after, the Speaker may without further debate put the question to the vote of the House to settle the matter. If permission is granted by the Speaker, the member in-charge, when called, formally moves a motion introducing the bill, and on the motion being made, the bill stands introduced. This process constitutes the first reading stage of a Bill. When the bill is introduced in the house, it is published in the Official Gazette. The secretary of the Parliament normally arranges for the bill's publication as early as possible, together with the statement of objects and reasons and, if applicable, a financial memorandum. The second reading stage of a Bill begins after a Bill has been introduced. The member-in-charge of the Bill may propose that it may be taken up for consideration, or referred to a standing committee or a select committee, or be circulated for eliciting public opinion. However, any member may make a counter-motion calling against the given proposal of member-in-charge, for example; if the member-in-charge moves that his Bill be taken into consideration, any member may move as an amendment that the Bill be referred to a Select Committee, or to a Standing Committee, or be circulated for the purpose of eliciting public opinion. Following any of the above mentioned motions, the lengthy, and to some extent complex, stage of the second reading commences. In the first phase of this stage, no amendment to the Bill may be moved. Only the principles or the general provisions of the bill are permitted to be discussed. Details of the Bill are not discussed beyond what is necessary to explain its principles. Considering the motion and counter motion calling, the Speaker then provides the issue on vote to decide where the Bill would forward for its next course of action. If the Bill is decided for consideration, then the speaker fixed a day for its clause by clause discussion and amendment. In this part, every decision regarding its amendment is taken through vote. When the bill is not accepted for consideration and decided to send it on Select Committee or to a Standing Committee for closer assessment, the committee returns the bill to the House with a report, which may or may not contain proposed amendments. The member-in-charge may then

move that the bill as reported upon be taken up for consideration. At this stage, debate on the motion is limited to consideration of the committee report or any alternatives consistent with the principles of the bill. Furthermore, any member may propose additional amendments to the bill. Copies of the committee report are made available to the members of the House. When a motion that the bill be taken into consideration has been carried, the speaker submits the bill, either clause-by-clause or as a whole, to the House for a vote. These all procedures are incorporated in the second reading stage of the Bill. The third reading stage is generally short. The member-in-charge makes a motion that the bill be passed as presented, and the speaker usually puts the motion to a vote without allowing any further debate. A bill is passed by a majority of the member's present and voting, subject to a quorum of the session.

Post-legislative phase

Post-legislative involved the assent of President and the publication of Bill as an Official Gazette. The assent of President to an Ordinary Bill or a Finance Bill is governed by Article 80 of the Constitution. The president must assent to a bill passed by Parliament within 15 days of presentation, or the bill is deemed to be automatically assented to after expiration of that period. Once a Bill receives assent, or is deemed to be assented to, it becomes law and is called an Act of Parliament. Alternatively, the president may return the bill to Parliament (provided it is not a money bill) with a message requesting reconsideration of amendments as may be specified in the message. Parliament will then reconsider the Bill and may pass it again with or without amendments. The reconsidered Bill will then be presented once again to the president. This time, however, assent shall be given within seven days, otherwise the Bill is deemed to have received assent (TIB, 2000). A Money Bill passed by Parliament and presented to the President for assent requires a certificate under the hand of the Speaker confirming that it is a Money Bill. This procedure probably acts as a reminder to the President that a Money Bill cannot be returned to Parliament for reconsideration, unlike an ordinary Bill. After assent by the President, the Secretary of the Parliament publishes the Bill as an Act of Parliament in the Official Gazette. One original signed copy of the Bill is preserved for verification and record purposes and shall not be allowed to pass out of the custody of the House without the permission of the Speaker.

Executive-legislature relations

Though the parliament can make the statuary law exclusively, but there is a functional integration among the branches like Legislature and Executive in Bangladesh. According to the above law making process, it is seen, the demand to make a law is first realized and raised by the executive branch which is articulated from the political system and, it took primary initiative by its concern department or line agency to prepare and process the laws then it put forward to the legislature as a Bill. Subsequently the legislature started its formal procedure independently to pass the draft Bill by means of its various mechanisms on the basis of cabinet's proposal. Among the three branches of the government, legislature and executive may have a very close relation with each other for achieving their common ends. In a parliamentary form of government like Bangladesh, Cabinet is exercised the real executive power and it is also considered as an integral part of legislature. Because cabinet is formed with the member of parliaments except in very few instances and they all are collectively responsible to the parliament. The inseparable relationship of both legislature and cabinet thus makes a fusion of power in the parliament of Bangladesh. This fusion of power is not working in a balance way but it tilted towards executive. As a result it has been observed an increasing trend to decrease the power of legislature and it resultant the ascendancy of the executive. Considering the executive-legislature relations in Bangladesh, one noted scholar mentioned that the executive is dominant and the legislature is dormant (Khan, 2006). In context of the increasing power of British cabinet H.J. Laski said, "The

house of commons is only formally a legislative assembly; its real business is to act as the cabinets organ of registration" and Ramsay Muir termed it "Dictatorship of Cabinet". There are so many reasons for the dominant position of the executive in Bangladesh context like: "executive control of the legislative agenda, the extremely powerful position of the Prime minister, use of ordinance making power by the president, inadequate debate on policy and legislation in the legislature, regular quorum crisis and ineffectiveness of legislative committees" (ibid.). Besides article 70 of the constitution restrict the rights of the MP's to such an extent that they do not have any option other than approving whatever measures their parties propose (Hasanuzzaman, 2007). As a result there are very few instances that an executive initiative for making a law has been in veined in the parliament.

Ethical issues in law making process

It is found from the above discussion about law making process that in law making process there is no code of conduct or ethical review committee in Bangladesh. Even there is no review committee for reviewing conflicting issues might arises among the relevant laws and for suggesting to avoid these conflicting issues in implementing these laws. Generally in many developed countries, there is ethical review committee in law making process. This ethical committee reviews the potential conflicting issues with other relevant laws if any and suggest for mitigation measures. In addition, review committee also reviews the potential threat of the new law to other sectors adjoining with new law as well as create threat in own sector where new law may implement for. For example, the protection and conservation of fish rules 1985 and National Fisheries Policy, 1998 were passed as suplimentary regulations for achieving the objectives of the Protection and Conservation of Fish Act, 1950 so that the development and conservation of fishery resources can be done in a sustainable manner, however in reality it is found that there are conflicting issues among the laws and policies, such as the Protection and Conservation of Fish Act, 1950 does not permit to cultivate any alien fish species in open waterbodies but the protection and conservation of fish rules 1985 and National Fisheries Policy, 1998 permits it. It is found from review of different fishery development projects as discussed earlier. On the other hand, the Protection and Conservation of Fish Act, 1950 was enacted only for fresh water fish development and conservation. But there many other flora and fauna in our river systems, flood plain wetland and water bodies those are very important of our aquatic biodiversity and ecosystems. It might be happening due to inappropriate law making process where a code of conduct is needed in law making process to mitigate these conflicting issues as well as to avoid the destructive provisions of laws.

Conclusion: Ethical issues in implementing process

Planning of any development project of a specific department or agency needs to comply with laws regulating the activities of that department or ministry. In this regards it is found that there are many conflicting issues in fishery development projects as implemented across the country. For example, there were some activities for acheiving the objectivs of these fishery development projects which are self contradictory and in some case inter department and intra departmental contradictory. It is assumed that in developing any fishery develop project which is environment sensetive issue needs a guideline and code of conduct which must be followed during planning and implementing to ensure the sustainable environmental development. Because code of conduct usually provides supplimentary guidelines to avoid the inter and intra departmental conflicting issues as well as destructive issues in implementation tenure.

In conclusion it is said that environmental ethics is one of the most important modern environmental conservation and sustainable development tools and involves in the early history of human civilizations. It has already been a global issue due to its implications in the development discoursed. But most of the

people in the underdeveloped and developed countries people are not aware about its importance. Considering the environmental ethics, it is very easy for all to carry out their duties and responsibilities properly that may lead to the sustainable development which we could not hope for; a peaceful and happy environment for our generations on this earth. It is in fact a human virtue supported by the religions on this earth. It is interlinked with the sustainable environment and development. It teaches us to be healthy and friendly to the global environment and development. This virtue is basically based on the international humanitarian law, international human rights, and of course the international environmental law under the public international law. The modern societies including the United Nations Organization (UNO) and its specialized agencies, International Union for Conservation of Nature (IUCN) and other national and regional organizations, etc; have been playing critical role in the process of implementing on the need for the environmental ethics for our society in order to attain the sustainable development. The compliance with the existing laws and policies along with the environmental ethics are also crucial for our existence on this earth, our home. It deals with the environmental rights, moral education, traditional knowledge and the environmental conservation issues, etc; which are very important for our sustainable development on this earth.

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Bangladesh Rural Development Studies (BRDS)

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- Agro processing and rural market extension
- Rural livelihoods and poverty reduction
- Education and skill development
- Entrepreneurship and financial inclusion
- Climate change and disaster management
- Social sciences and local governance
- Food and nutrition, health and hygiene
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2. The manuscript submission file is in Microsoft Word, or Word Perfect document file format and should be typed in a single column with 1.5 line spacing and numbering in the whole paper.
3. Manuscript is written in Microsoft Word, A4 pages, letter «Times New Roman» size 12, with 1.5 line spacing, 25 mm margins on each side, with page and line numbers. It is no longer than 25 pages (or 7000 words), figures and tables placed within the text, rather than at the end.

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Selective examples

Books

Dwee, D., Dion, H. B., & Brown, I. S. (2012). *Information behaviour concept: A basic introduction.* University of Life Press.

Book chapters

Yura, P. (2020). 'Good or bad': How people think of me is not important. In B. Rudy & H. Dion (Eds.), *Mental health policy* (pp. 368-389). University of Life Press.

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Rowling, L. (1993, September). Schools and grief: How does Australia compare to the United States [Paper presentation]. In Wandarna coowar: Hidden grief. 8th *National Conference of the National Association for Loss and Grief* (Australia), Yeppoon, Queensland (pp. 196-201). National Association for Loss and Grief.

Internet Documents

Australia. Department of Health and Aged Care. (2000). *National youth suicide prevention strategy.* http://www.health.gov.au/hsdd/mentalhe/sp/nysps/about.htm

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Kyratsis, A. (2014). Talk and interaction among children and the co-construction of peer groups and peer culture. *Annual Review of Anthropology*, 33(4), 231-247.

Vogels, A. G. C., Crone, M. R., Hoekstra, F., & Reijneveld, S. A. (2009). Comparing three short questionnaires to detect psychosocial dysfunction among primary school children: a randomized method. *BMC Public Health*, 9, 489. https://doi.org/10.1186/1471-2458-9-489

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Kissane, K. (1998, September 5). Kiss or kill: Who is the victim when a battered woman kills? *The Age: Extra*, p. 6.

Theses

Neo, M. C. (2000). *The role of education as a process of human release from various problems of life* [Unpublished M.Appl.Psy. thesis]. University of Life.

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Dr. Shaikh Mehdee Mohammad
Executive Editor
Bangladesh Rural Development Studies
Rural Development Academy (RDA)
Bogura-5842, Bangladesh
Cell: +88 01712 292666
Email: mehdeerda@gmail.com

Dr. Sultana Fizun Nahar
Member
Bangladesh Rural Development Studies
Rural Development Academy (RDA)
Bogura-5842, Bangladesh
Cell: +88 01742 687623
Email: sathybd71@gmail.com

Submission and Contact

Executive Editor
Bangladesh Rural Development Studies (BRDS)
Rural Development Academy, Bogura, Bangladesh
Email: mehdeerda@gmail.com