ISSN 1019-9624 www.rda.gov.bd

Bangladesh Rural Development Studies

Volume 26 June, 2023 Number 1

Journal of the Rural Development Academy, Bogura

Rural Development Academy (RDA), Bogura

Bangladesh Rural Development Studies (BRDS)
ISSN 1019-9624; Web: www.rda.gov.bd

Comparative study on mechanical system of rice intensification (MSRI) and system of rice intensification (SRI) with different fertilizer rates in Aus season

Samsul Huda Soyeb[1*], Md. Tanjil Anwary[1], Abdullah Al Mamun[1]

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

ARTICLE INFO

Keywords:
MSRI
SRI
Tricho-compost
Yield
Aus rice

Received: 22 May, 2023
Revised: 10 June, 2023
Accepted: 14 June, 2023

***Corresponding Email:**
samsulhuda191@gmail.com

ABSTRACT

*A field experiment was conducted at the Rural Development Academy (RDA), Bogura, Bangladesh's research field during the Aus season. This experiment was set up to evaluate two planting methods, system of rice intensification (SRI) planting method and mechanical transplantation in system of rice intensification (MSRI) planting method, against three rice (**Oryza sativa**) varieties named BRRI dhan 48, BINA dhan 19, and BRRI dhan 98, with the application of two types of fertilizer, traditional fertilizer dose and recommended fertilizer, by the Soil Resource Development Institute (SRDI). The experiment was laid out in a randomized block design with three replications. MSRI had the highest yield parameters, including plant height, effective tiller, panicle length, grain per panicle, 1000 grain weight, and crop yield. Two additional treatments were experimented with for tricho-compost application along with recommended fertilizers against BRRI dhan 48 and BINA dhan 19. It was observed that the best results come from using tricho-compost along with the recommended fertilizer in the MSRI transplantation method for the production of rice.*

How to Cite: Soyeb, S. H., Anwary, M. T., & Mamun, A. A. (2023). Comparative study on mechanical system of rice intensification (MSRI) and system of rice intensification (SRI) with different fertilizer rates in Aus season. *Bangladesh Rural Development Studies, 26*(1), 01-12.

Introduction

Bangladesh is an agriculture dominated country, with 70% of the territory being agricultural land (World Bank, 2014). Rice is a major staple food crop in Bangladesh. Bangladesh is the world's fourth largest per capita rice consumer and producer (FAO, 2015). Rice is the dominant crop in the country, and it covers three-fourths of all cropland area and contributes 70% of calories consumed (Majumder et al., 2016). There are three major cropping seasons in Bangladesh, namely Aus, Aman, and Boro. Aus is typically planted in March–April and harvested in June–July, which corresponds with the hot summer season (March–May). Aus rice occupies only about 11.15% of the total cropped area, where modern varieties cover only 10.23% and local varieties cover 0.92% (BBS, 2021). Only 8.73% of total production comes in Aus season and currently the total area and production of Aus rice are 3.22 million acres and 3.33 million MT (BBS, 2021). The Aus rice area and production has been decreasing continuously compared to Boro, which is the dominant rice crop in

Bangladesh. Boro rice cultivation fully depends on irrigation, and the pressure of ground water is increasing day by day and ground water level is depleting. Aus rice requires only 5% supplement irrigation, thus pressure on ground water is minimum compared to Boro (Rahman, N. M. F. et al., 2016). It is critical to prioritize the cultivation of Aus rice over Boro rice in order to ensure the country's long-term food security. The population of Bangladesh is projected to reach 179.00 million by 2030, and it will increase further to 192.57 million in 2050. Bangladesh accounts for 2.1 percent of the world population (UN, 2019). Due to the drastic population growth, the country will demand more rice production in the future. But the arable land area of the country is even decreasing over time due to increasing demand for residential and industrial use (Hasan et al., 2013). While the population and food demand are both growing, rice production is becoming unstable due to climate change impacts rice cultivation. Organizations such as BRRI, BINA, IRRI, and others have recently brought to light rice varieties with high yield and climate change tolerance. The varieties of rice and their cultivation are affected by the climatic differences from region to region. It is estimated that rice cultivation and production will decrease by almost 51% during the next century due to global climate change. Agricultural performance, on the other hand, contributes to global warming, accounting for 10-14% of total global greenhouse gas emissions and 18% of total methane discharged from paddy rice fields (Hussain et al., 2020). Therefore, moderation and adaptation strategies such as alternate wetting and drying, intercropping with short-term vegetation, limiting chemical fertilizers by precise farming, the usage of rice cultivars with low methane emissions, improved tillage, farm mechanization and developing an integrated rice farming system are needed to hinder greenhouse gas emissions from rice fields. A new technique of plant management, bio-fertilizer application, and water management with resultant high yields in rice production was found in Madagascar in 1983 by Father Henri de Laulan'e, a French Jesuit priest, and later propagated worldwide by the Cornell International Institute for Food, Agriculture, and Development. This method, named "System of Rice Intensification" (SRI) today, is deliberated to save water yet achieves a high yield compared to the conventional method (Thakur et al., 2010; Chapagain and Yamaji, 2009). Stoop et al. (2002) reviewed the SRI method practiced around the world, explaining how high yields are achieved through SRI's key principles through a range of environmental factors and agronomic management practices, including variety selection.

Farm mechanization is required for the profitability of agriculture. It is apparent that mechanization has positive impression and execution to increase productivity and profitability of rice producers. Therefore, the contribution of mechanized farming on progressive farm level production and efficiency has yet to be analyzed in the country context. The purpose of the study is to assess the production of rice under different methods of rice plantation, fertilizer application among different varieties of rice in Aus season. In this article, first, we present the quantitative data results of rice yield and finally, the test results are discussed in comparison with the interactive effect of fertilizer, methods, and varieties which is followed by the conclusions. The main objective of this study is to compare the efficacy of SRI and MSRI based on different varieties and fertilizer rates.

Materials and methods

In this study, we used System of Rice Intensification (SRI) techniques in two ways: one is the plantation of seedlings in the field with the help of manual labor (SRI), and another was by using a mechanical rice transplanter (MSRI). These techniques were synchronized with two fertilizer application methods. The parent organization of the rice variety provides the general fertilizer rate in one method, and SRDI provides the recommended dose of fertilizer after testing a soil sample in the other. A comparative study of SRI and MSRI in Aus growing rice would aid in understanding the constraints and opportunities of Aus rice, thereby guiding policy development.

Study area

The experiment was carried out in the research plot of the Rural Development Academy (RDA), Bangladesh demonstration field, from April 12 to July 26, 2022. The site is located between latitude 24.70 N and longitude 89.39 E and is 20 m above the mean sea level. The study area has a subtropical monsoon climate characterized by huge fluctuations in rainfall, air temperature, and humidity. The following weathers are recorded in the study area: humid summer from March to June, rainy monsoon season from June to October, and winter from November to March. The daily average temperature is 24.8 ˚C, where the average maximum and minimum temperatures are 34.6 ˚C and 11.9 ˚C in summer and winter, respectively. The mean total annual rainfall in the study site is 1610 mm (Islam & Shamsad, 2009). Rainfall is distributed from April to October, and July is the highest rainfall month of the year. The predominant soil type is sandy loam, with a pH value ranging from 5.5 to 6.5.

Field preparation

Rice field was tilled twice, and after the first till, organic fertilizer was applied. Then the field was irrigated and puddled thoroughly.

Transplantation method

Two types of transplanting practices for SRI were done in the field. T_1 represents SRI implementation by manual labor force, while T_2 represents SRI implementation using mechanized rice transplanter machine. In both methods, seedlings were transplanted at 30x30 cm spacing. Here, T_1 is the System of Rice Intensification with manual transplantation by manual labor; T_2 was the Mechanized System of Rice Intensification method by mechanical rice transplanter; and T_3 represented MSRI transplantation where tricho-compost was applied. Seedlings were transplanted 12 days after growing on a seedling tray for MSRI, and 2/3 of the seedlings were planted per hill in both systems.

Variety of rice

Three different UFSHI (HYV) varieties of Aus rice were collected from BRRI and BINA to test the suitability of the respective varieties in the Aus growing season. They were marked as V_1, V_2, and V_3, where V_1 representing BRRI 48; V_2 representing BINA 19; and V_3 representing BRRI 98.

Fertilizer dose

General fertilizer rates were provided by the parent organization of the rice variety that farmers use traditionally. In another method, soil sample was collected from the field and tested in Soil Resource Development Institute lab Bogura and lab recommended fertilizer application dose was used as F_1 and F_2, where F_1 = traditional and F_2 = recommended by the Soil Resource Development Institute (SRDI).

Treatments/ experimental design

The experiments were placed in Randomized Block Design (RBD) with three replications for a total of 12 treatments. The treatments represented as $T_1V_1F_1$, $T_1V_1F_2$, $T_1V_2F_1$, $T_1V_2F_2$, $T_1V_3F_1$, $T_1V_3F_2$, $T_2V_1F_1$, $T_2V_1F_2$, $T_2V_2F_1$, $T_2V_2F_2$, $T_2V_3F_1$ and $T_2V_3F_2$. Two additional treatments were included with for tricho-compost application along with the recommended fertilizer. Those treatments were $T_3V_1F_2$ and $T_3V_2F_2$. T_1 = SRI with manual transplantation by manual labor; T_2 = MSRI method; T3 = MSRI + trico-compost along with recommended fertilizer; V_1 = BRRI 48; V_2 = BINA 19; and V_3 = BRRI 98; and F_1 = fertilizer traditional; and F_2 = recommended fertilizer by SRDI after the test. Plots using the T_1 transplant method cover 40 m^2 area, while plots using the T_2 treatment cover 396 m^2 area.

Weed/ pest management

Weed was controlled by mechanical weeder machine primarily. Manual laborers were used to clear weeds when plants got matured.

Agronomic measurement

The experimental plots were planted at a general spacing of 30 x 30 cm using a mechanical transplanter by running lengthwise of the field on the puddled and leveled surface. The seedlings were transplanted within 30 minutes after uprooting, and 3-7 seedlings were placed in each hill. The water level in the field was kept at 2 cm only to prevent seedlings from floating. Four to five seedlings per hill and young seedlings of 8-12 days old from quality seeds ensure vigorous seedling growth, absolute field establishment, a uniform plant population and accelerated growth rate, pest and disease resistance, and uniform maturity at harvest. Most importantly, a high-quality seed with a germination rate of more than 90% was chosen. Rice straw was used as a cover material over the trays for retention of soil moisture.

The collected data was tested by ANOVA (Analysis of Variance) using R statistical software. Later, LSD test was conducted to identify the differences in development among different treatments. Biometrical observation was carried out on plant height, effective tiller, length of panicle, grain/panicle and 1000 grain weight.

Plant height: The height of plants from five randomly selected plants was measured using the meter rule from the base of the plant to the growing tip.

Number of effective tillers: The number of tillers per square meter was taken by counting the number of tillers on five (5) randomly selected plants.

Number of grains per panicle: Numbers of filled and unfilled grains were counted to determine the number of grains per panicle of the sampled 20 panicles

1000-grain weight: Thousand grains were counted from the randomly separated grain yield of a plot and weighed with the help of a portable automatic electronic scale.

Crop yield: Crop yield was measured by weighing the rice grains from 10m^2 areas of a plot, and the data was converted to kg per hectare.

Harvesting

Combined Harvester machine was used to harvest the crops plot by plot. Agronomic measurements were done before harvesting.

Results and Discussions

Two rice production methods, MSRI and SRI, were tested in RDA, Bogura. It was observed that MSRI method had a significant advantage over SRI method. Considering yield and yield contributing characteristics for traditional fertilizer (F_1), the MSRI method had greater panicle length, effective tillers, length of panicle, grains per panicle and crop yield than the SRI method in the cases of BRRI dhan 48, BINA dhan 19, and BRRI dhan 98 (Table 1). We found that the MSRI method applied in BRRI dhan 98, BRRI dhan 48, and BINA dhan 19 showed the highest plant heights of 102.33 cm, 101.4 cm, and 98.67 cm, respectively. In consideration of effective tillers, length of panicle, and grains per panicle, we observed the best results for the MSRI method in BRRI dhan 98 and the lowest results for the SRI method in BRRI dhan 48. In terms of the parameter 1000 grains weight, the optimum results in the MSRI method were for BRRI dhan 98 and BRRI dhan 48, which were 24.63 g and 23.77 g, respectively. If we compared these two methods, MSRI method yielded 10.3 cm higher plant height for BRRI dhan 48, 6.97 cm higher plant height for BINA dhan 19, and 13.07 cm higher plant height for BRRI dhan 98.

Considering effective tiller, length of panicle, and grain per panicle for BRRI 48, the MSRI method yielded 12 more effective tillers per hill, 11.1 cm higher length of panicle, and 40 more grains per panicle than that of the SRI method. (Table:1)

In terms of effective tiller, panicle length, and grain per panicle for BINA dhan 19, the MSRI method produced 12.33 more effective tillers per hill, 5.3 cm longer panicle length, and 36 more grains per panicle than the SRI method.(Table:1)

In consideration of effective tiller, length of panicle, and grain per panicle for BRRI 98, the MSRI method yielded 13.67 more effective tillers per hill, 10.73 cm higher length of panicle, and 50 more grains per panicle than that of the SRI method (Table 1).

The undermentioned Fig. 1 demonstrates the mean yield of rice in kg per hectare of different varieties of rice under SRI and MSRI

Table 1: Comparative data of variety and transplantation method with respect to traditional fertilizer

	Variety	Method	Plant height (cm)	Effective tillers/ hill	Length of panicle (cm)	Grains per panicle (no.)	1000 grain weight (g)	Crop yield (kg/ ha)
Traditional Fertilizer (F_1)	BRRI dhan 48	SRI	91.1	11	20.4	89	23.77	2795
		MSRI	101.4	23	31.5	129	23.77	2984
	BINA dhan 19	SRI	91.7	11.67	20.5	96	24.5	2262
		MSRI	98.67	24	25.8	132	24	2536
	BRRI dhan 98	SRI	89.26	11	21	92.67	24	2190
		MSRI	102.33	24.67	31.73	142.67	24.63	2647

transplantation method in terms of traditional fertilizer dose (F_1). The chart indicate MSRI practice of BRRI 48 (V_1T_2) has shown better result than others having a value of 2984 kg/ha. It is closely followed by SRI practice of BRRI 48 (V_1T_1) and the lowest yield of rice is observed in SRI of BRRI 98 (V_3T_1).

Recently, The result of various rice establishment techniques was evaluated in Bangladesh and the utmost grain efficiency (54.8 q ha^{-1}) was observed under the adaptation of rice intensification method followed by mechanical transplantation (MSRI) (49.8 q·ha–1), planting a sprouted seed with SRI marker (45.2 q ha^{-1}), line transplanting (44.9 q ha^{-1}), manual transplanting (39.6 q ha^{-1}) and least productivity of grain (39.50 q ha^{-1}) (Rahaman, et al., 2022). The mechanical transplanting altogether elevated grain yield around 23%, 37%, and 63%, straw yield around 17%, 14% and 22%, and natural yield around 20%, 24%, and 39% over manual transplanting, dry direct seeding, and direct seeding of sprouted rice in puddled conditions, separately. Similar research finding were also reported by (Tejeswara Rao et al., 2020); MSRI method in paddy recorded 20.76% yield over normal transplanting method of paddy cultivation during both Kharif seasons at Visakhapatnam district of Andhra Pradesh.

Considering yield characteristics for recommended fertilizer (F_2), the MSRI method had greater panicle length, effective tillers, length of panicle, grains per panicle, and crop yield than the SRI method in the cases of BRRI dhan 48,

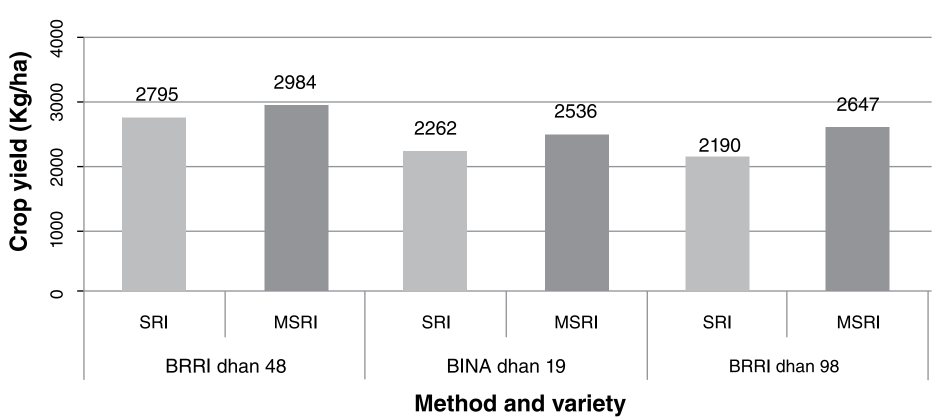

Figure 1: Comparison of crop yield for traditional fertilizer dose (F_1) in variety and methods (kg/ha)

Table 2: Comparative data of variety and transplantation method with respect to recommended fertilizer

	Variety	Method	Plant height (cm)	Effective tillers per hill	Length of panicle (cm)	Grains per panicle (no)	1000 grain weight (g)	Crop yield (approx.) (kg/ha)
Recommended Fertilizer (F_2)	BRRI dhan 48	SRI	95.6	10	20.53	90.67	24.49	2780.71
		MSRI	101.4	25	33.83	144	23.91	2910.80
	BINA dhan 19	SRI	95.27	11	20.6	96.67	24.76	2430.54
		MSRI	98.5	25	25	126	24.49	2846.28
	BRRI dhan 98	SRI	89.5	10.33	20.93	97	24.62	2655.40
		MSRI	101.93	23.67	29.97	134	24.33	2740.00

BINA dhan 19, and BRRI dhan 98 (Table 2). It was found that the MSRI method applied in BRRI dhan 98, BRRI dhan 48, and BINA dhan 19 showed the highest plant heights of 101.93 cm, 101.4 cm, and 98.5 cm, respectively. In consideration of effective tillers, length of panicle, and grains per panicle, we observed the best results for the MSRI method in BRRI dhan 48. In terms of the parameter 1000 grains weight, the optimum results in the SRI method were observed for BINA dhan 19 and BRRI dhan 98, which were 24.76 g and 24.62 g, respectively. If compared these two methods, MSRI method yielded 5.6 cm higher plant height for BRRI dhan 48, 3.23 cm higher plant height for BINA dhan 19, and 12.43 cm higher plant height for BRRI dhan 98.

Considering effective tiller, length of panicle, and grain per panicle for BRRI 48, the MSRI method yielded 15 more effective tillers per hill, 13.3 cm higher length of panicle, and 53.33 more grains per panicle than that of the SRI method.

Compared to effective tiller, length of panicle, and grain per panicle for BINA dhan 19, the MSRI method produced 14 higher effective tillers per hill, 4.4 cm higher length of panicle, and 29.33 more grains per panicle than that of the SRI method.

Considering tiller, length of panicle, and grain per panicle for BRRI 98, the MSRI method yielded 12.43 more effective tillers per hill, 13.34 cm higher length of panicle, and 37 more grains per panicle than that of the SRI method.

Fig. 2 shows the mean yield of rice in kg/ha of different varieties of rice under SRI and

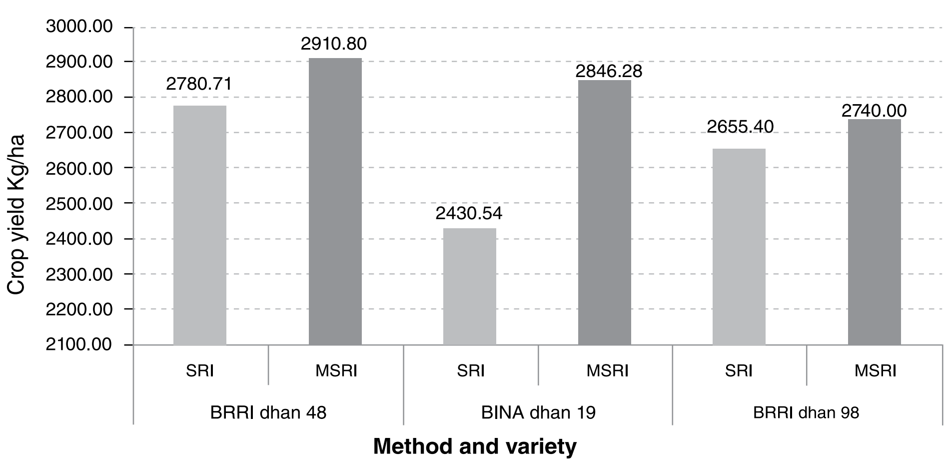

Figure 2: Comparison of crop yield for recommended fertilizer dose (F_2) in variety and methods (kg/ha)

Table 3: Comparative data of variety and transplantation method with respect to recommended fertilizer along with tricho-compost

	Variety	Method	Plant height	Effective tiller	Panicle/ hill	Grain/ panicle	1000 grain weight (gm)	Crop yield (approx.) (kg/ha)
Recommended Fertilizer (F_2)	BRRI 48	Tricho-compost + MSRI	117	20	23	168	28.48	4808.38
		MSRI	101.4	25	33.83	144	23.91	2910.8
		SRI	95.6	10	20.53	90.67	24.49	2780.71
	BINA 19	Tricho-compost+ MSRI	106	25	27	198	25.38	3924.61
		MSRI	98.5	25	25	126	24.49	2846.28
		SRI	95.27	11	20.6	96.67	24.76	2430.54

MSRI transplantation methods in terms of the recommended fertilizer dose (F_2). The figure indicates the MSRI method practice for BRRI 48 (V_1T_2) has better results than others, with a mean yield of 2984 kg/ha. It was closely followed by MSRI management practice for BINA 19 (V_2T_2), and the lowest yield of rice (2430.54 kg/ha) was observed for SRI management practice for BINA 19 (V_2T_1**)**.

In the cases of BRRI dhan 48 and BINA dhan 19, MSRI method along with tricho-compost had increased panicle length, effective tillers, length of panicle, grains per panicle, and crop yield than the MSRI and SRI methods for recommended fertilizer (F_2) as shown in Table 3. It was found that the MSRI method along with tricho-compost applied in BRRI dhan 48 and BINA dhan 19 showed the highest plant heights of 117 cm and 106 cm, respectively. In consideration of effective tillers, length of panicle, and grains per panicle, we observed the best results for the MSRI method in BINA dhan 19. In terms of the 1000 grain weight parameter, we found the best results in the MSRI method with tricho-compost for BINA dhan 19, which was 28.48 gm, which was higher than the rest of the group. If compared, all of these methods, MSRI method with tricho-compost produced 15.6 cm higher plant height for BRRI dhan 48 and 7.5 cm higher plant height for BINA dhan 19 than that of the SRI method.

Considering effective tiller, length of panicle, and grain per panicle for BRRI 48, the MSRI method with tricho compost produced 5 fewer effective tillers per hill, 2 cm longer length of panicle, and 24 more grains per panicle than that of the MSRI method as shown in Table 3.

The MSRI method along with tricho-compost yielded the same effective tillers per hill, 10.83 cm less length of panicle, and 72 more grains per panicle compared to effective tiller, length of panicle and grain per panicle for BINA dhan 19.

Fig. 3 shows the mean yield of rice in kg/ha of different varieties of rice under SRI and MSRI transplantation methods in terms of recommended fertilizer dose (F_2) and trichocompost application. It shows that the tricho-compost+MSRI practice of BRRI 48 (V_1T_3) produced more rice 4808.38 kg/ha than others, while the tricho-compost +MSRI practice of BINA 19 produced the least 3924.61 kg/ha. The SRI of BINA 19 (V_2T_1) had the lowest rice yield 2430.54 kg/ha.

The effects of *Trichoderma* seedling treatment with SRI management were compared to SRI without *Trichoderma* application in a tropical environment, Nepal (Khadka, R. B., & Uphoff, N. 2019). It was found that the yield increase with *Trichoderma* treatments across all trials was 31% higher than that of untreated plots (4.9 vs. 4.5 mt ha-1). With *Trichoderma* treatment,

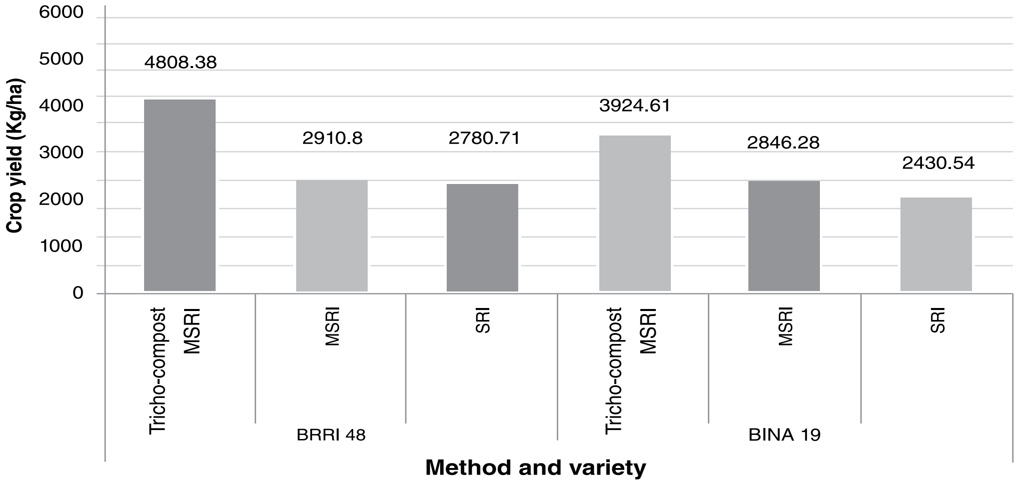

Figure 3: Comparison of crop yield for recomended fertilizer dose (F_2) in variety and methods with tricho-compost application (kg/ha)

yields compared with non-treated plots were 24% higher with organic SRI (6.38 vs. 5.13 mt ha-1) and 52% higher with non-organic SRI (6.38 vs. 3.53 mt ha-1). With regard to varietal differences, under SRI management, *Trichoderma* inoculation of the improved variety Sukhadhan-3 led to a 26% higher yield (6.35 vs. 5.04 mt ha-1), and with the heirloom variety Tilkidhan, the yield was 41% higher (6.29 vs. 4.45 mt ha-1) (Khadka, R. B., & Uphoff, N. 2019). Similar research finding were also reported by Nahar et al., (2010) and it was clarified that yield enhances in tricho-compost treated plots over un-amended control were 63.4%, 51.7% and 45% higher in some vegetables.

Table 4 describes the interactive effect of fertilizer and variety analysing some descriptive statistics. In analysis, it shows that there was no significant difference among the treatment means of V_1F_2, V_2F_2, and V_1F_1 in consideration to plant height. But these treatment methods are significantly different from V_3F_1, V_2F_1 and V_3F_2 when considering plant height. There is no significant difference among the treatment methods with respect to the parameter of grain or panicle. In consideration of a 1000 grain weight, the treatment mean V_1F_1 is significantly different from all other treatment means. In consideration of overall parameters such as plant height, effective tiller, panicle/hill, and grain/

Table 4: Interaction effect of fertilizer and variety on vegetative growth and yield of Aus rice

Treatment means	Plant height	Effective tiller	Panicle/hill	Grain/panicle	1000 grain weight
V_1F_2	98.500 a	17.500 a	27.183 a	117.33 a	24.200 ab
V_2F_2	96.883 ab	18.000 a	22.800 c	111.33 a	24.627 a
V_1F_1	96.267 ab	17.167 a	25.950 a	109.33 a	23.773 b
V_3F_1	95.800 b	17.833 a	26.233 a	117.67 a	24.627 a
V_3F_2	95.717 b	17.000 a	25.450 ab	115.50 a	24.480 a
V_2F_1	95.200 b	17.833 a	23.150 bc	114.00 a	24.280 ab
Standard Error	1.24	0.83	1.20	4.94	0.26
CV%	2.58	1.72	2.48	10.24	0.53
Critical T value 2.074					

Table 5: Interaction effect of fertilizer and methods on vegetative growth and yield of Aus rice

Treatment means	Plant height	Effective tiller	Panicle/hill	Grain/ panicle	1000 grain weight
T_2F_1	100.81 a	24.000 a	29.689 a	134.56 a	24.156 b
T_2F_2	100.61 a	24.556 a	29.600 a	134.67 a	24.244 ab
T_1F_2	93.46 b	10.444 b	20.689 b	94.78 b	24.627 a
T_1F_1	90.70 c	11.222 b	20.533 b	92.78 b	24.298 ab
Standard Error	1.01	0.68	0.98	4.03	0.21
CV%	2.10	1.40	2.03	8.36	0.43
Critical T value 2.074					

panicle, it is observed that the better result is in V_1F_2 (recommended fertilizer in BRRI dhan 48), followed by V_2F_2 (recommended fertilizer in BINA dhan 19), and V_3F_2 (recommended fertilizer in BRRI dhan 98).

CV= The coefficient of variation, Means followed by the same letter (s) within a column do not differ significantly whereas means with dissimilar letter differ significantly according to the least significant different (LSD) test.

Table 5 shows the interactive effect of fertilizer and transplantation method. There is no significant difference between T_2F_1 and T_2F_2 in consideration of the parameters of plant height, effective tiller, panicle/hill, and grain/panicle. As a result, the better results in the treatment mean of T_2F_2 (recommended fertilizer in MSRI transplantation method) were followed by the treatment mean of T_2F_1 (traditional fertilizer in MSRI transplantation method), followed by T_1F_2 (SRI transplantation with recommended fertilizer), and T_1F_1 (SRI transplantation with traditional fertilizer).

CV= The coefficient of variation, Means followed by the same letter (s) within a column do not differ significantly whereas means with dissimilar letter differ significantly according to the least significant different (LSD) test.

The interactive effect between variety and method are shown in Table 6 considering to the following parameters such as plant height, effective tiller, panicle/hill, grain/panicle, and 1000 grains weight, respectively:

Plant Height: From the table, it is observed that there is significant difference among treatment means. V_1T_3 treatment mean is showing better results than others. Plant height was highest with V_1T_3 as 117.00 whereas the lowest

Table 6: Interaction effect of variety and methods on vegetative growth and yield of Aus rice

Treatment means	Plant height	Effective tiller	Panicle/hill	Grain/ panicle	1000 grain weight
V_1T_1	93.35 c	10.500 d	20.467 d	90.17 d	24.133 b
V_2T_1	93.50 c	11.333 d	20.533 d	96.33 d	24.627 c
V_3T_1	89.38 d	10.667 d	20.833 d	94.83 d	24.627 c
V_1T_2	101.42 b	24.167 b	32.667 a	136.50 c	23.840 b
V_2T_2	98.58 c	24.500 b	25.417 bc	129.00 c	24.280 b
V_3T_2	102.13 b	24.167 b	30.850 a	138.33 c	24.480 b
V_1T_3	117.00 a	20.00 c	23.83 c	168.00 b	28.48 a
V_2T_3	106.00 b	25.00 a	27.00 b	198.00 a	25.38 ab
Standard Error	1.24	0.83	1.20	4.94	0.26
CV%	2.58	1.72	2.48	10.24	0.53
Critical T value 2.074					

number of plant height was observed as 89.38 with V_3T_1.

Effective Tiller: It is observed from the table that there is significant difference among treatment means in terms of number of effective tiller. Better result was shown by V_2T_3 treatment mean. Effective Tiller was highest with V_2T_3 as 25.00 whereas the lowest number of Effective tiller was observed as 10.500 with V_1T_1.

Panicle/hill: It is observed from the table that there is significant difference among treatment means in terms of number of panicle per hill. Better result was observed in V_1T_2 followed by V_3T_2 treatment mean. Panicle/hill was highest with V_1T_2 as 32.667 and the lowest number of Panicle/hill was observed as 20.467 with V_1T_1.

Grain/panicle: It is observed from the table that there is significant difference among treatment means in terms of number of grain/panicle. The treatment mean of V_2T_3 shows significantly higher value of 198.00 than others whereas the lowest number of grain/panicle was observed as 90.17 in V_2T_1.

1000 grain weight: There is significant difference between the treatment means of 1000 gm grain weight. It was highest with V_1T_3 (Tricho-compost along with recommended fertilizer in BRRI dhan 48) as 28.48 followed by V_2T_3 (Tricho-compost along with recommended fertilizer in BINA dhan 19) as 25.38 and lowest number of 1000 grain weight was observed as 24.627 with V_2T_1 and V_3T_1.

CV= The coefficient of variation, Means followed by the same letter (s) within a column do not differ significantly whereas means with dissimilar letter differ significantly according to the least significant different (LSD) test.

Doni et al., (2018) found the grain yield parameter of Trichoderma-inoculated rice plants was 30% increased than that from the uninoculated SRI control plots, which simply as a result of changes in management practices produced rice yields that were twice the current average in Malaysia. Similarly, Aravindan et al., (2016) carried out an experiment to evaluate the efficacy of seed treatment with different Trichoderma spp. isolate against leaf blast in four rice varieties; Swarna, IR-64, Samba Mahsuri, and Sahbhagi dhan under upland rice conditions at Almora and Hazaribag. Trichoderma spp. (isolate Th-3) treated seed of Samba Mahsuri (57%) showed highest plant height percentage followed by Tv-12 isolate with Samba Mahsuri (44%) as compared to control. It additionally increases root length (51–93%), general quantity of leaves (6-60%), tillers (3-41%), panicles (4–39%), flag leaf length (2-30%) and panicle length (5–32%) comparison to untreated control.

Tricho-compost has high nutrient values which can be used effectively as fertilizer or soil amended and this fertilizer also can minimize the application of organic fertilizer. Moreover, integrated application of fertilizer or combination of Tricho-compost and NPK showed comparatively better results and gave the highest yield. So, Tricho-compost can play a vital role in consumption of chemical fertilizer or increasing of soil fertility and this integrated approach can contribute to improve crop production. The mechanized system of rice intensification is one of the best practices for improving rice production with low input and maximum output (yield).

Conclusion

Mechanized system of rice intensification (MSRI) is comparatively easier, less time-consuming and more effective than manual planting in SRI due to laborer non-availability and higher wages for skilled laborers. On the basis of biometric analysis of the overall parameter (such as plant height, effective tiller, panicle/hill, grain/panicle, grain weight, and crop yield), the MSRI transplantation method is considerably better than the SRI transplantation method. But it was observed that the best results come from using tricho-compost along with the recommended fertilizer in the MSRI transplantation method. Cost-benefit analysis was not executed in this research. A similar further research can be conducted by other researchers with the intention to evaluate proper adoptable cultivation method. Results reported so far are not conclusive enough to understand these complex effects and can be contradictory to one another.

Hence, there appears the necessity to undertake further investigations.

References

Aravindan, S., Yadav, M. K., & Sharma, P. (2016). Biological control of rice blast disease with Trichoderma spp. under upland rice system. *ORYZA - An International Journal on Rice*, *53*(2), 167-173.

Bangladesh Bureau of Statistics (BBS). (2021). *Yearbook of Agricultural Statistics of Bangladesh*. Government of Bangladesh.

Chapagain, T., & Yamaji, E. (2009). The effects of irrigation method, age of seedling and spacing on crop performance, productivity and water-wise rice production in Japan. *Paddy Water Environment*, *8*, 81-90. https://doi.org/10.1007/s10333-009-0187-5

Doni, F., Zain, C. R. C. M., Isahak, A., Fathurrahman, F., Anhar, A., Mohamad, W. N. A. W., ... & Uphoff, N. (2018). A simple, efficient, and farmer-friendly Trichoderma-based biofertilizer evaluated with the SRI Rice Management System. *Organic Agriculture*, *8,* 207-223. https://doi.org/10.1007/s13165-017-0185-7

Food and Agriculture Organization (FAO). (2002). *FAO rice information*. Vol. 2.

FAO. (2015). *Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT)*. https://doi.org/10.4135/9781483346304.n170

Hussain, S., Huang, J., Huang, J., Ahmad, S., Nanda, S., Anwar, S., ... & Zhang, J. (2020). Rice production under climate change: adaptations and mitigating strategies. *Environment, climate, plant and vegetation growth,* 659-686. https://doi.org/10.1007/978-3-030-49732-3_26

Islam, M. S., & Shamsad, S. (2009). Assessment of irrigation water quality of Bogra district in Bangladesh. *Bangladesh Journal of Agricultural Research*, *34*(4), 507-608. https://doi.org/10.3329/bjar.v34i4.5836

Khadka, R. B., & Uphoff, N. (2019). Effects of Trichoderma seedling treatment with System of Rice Intensification management and with conventional management of transplanted rice. *PeerJ*, *7*, e5877. https://doi.org/10.7717/peerj.5877

Majumder, S., Bala, B. K., Arshad F. M., Haque, M. A., & Hossain, M. A. (2016). Food security through increasing technical efficiency and reducing postharvest losses of rice production systems in Bangladesh. *Food Security, 8*(2): 361-374. https://doi.org/10.1007/s12571-016-0558-x

Nahar, M. S., Rahman, M. A., Ilias, G. N. M., Rahaman, M. A., Yasmin, L., Afroz, M., ... & Miller, S. A. (2010). Effect of Tricho-compost on soil borne diseases and production of some vegetable crops. *Bangladesh Journal of Plant Pathology*, 26(1/2), 1-7.

N M F Rahman, M M Hasan, M I Hossain, M A Baten, S Hosen, M A Ali and M S Kabir. Forecasting Aus Rice Area and Production in Bangladesh using Box-Jenkins Approach, *Bangladesh Rice Journal*. 20 (1): 1-10, 2016. https://doi.org/10.3329/brj.v20i1.30623

Pun, I., & Yamaji, E. (2014). Comparative study of the structural development of rice, Plants by SRI and non-SRI methods in a lysimeter experiment (unpublished manuscript).

Rahaman, H., Rahman, M. M., Islam, A. K. M. S., Huda, M. D., & Kamruzzaman, M. (2022). Mechanical rice transplanting in Bangladesh: Current situation, technical challenges, and future approach. *J. Biosystems Engineering, 47*, 417–427. https://doi.org/10.1007/s42853-022-00161-x

Rao. K. T., Kumar, P. B. P., & Chandrayudu, E. (2020). Mechanized system rice intensification (MSRI) in rice cultivation at Visakhapatnam district of Andhra Pradesh. *Internat. Plant Science, 15*(2): 135-138. https://doi.org/10.15740/has/ijps/15.2/135-138

Stoop, W.A., Uphoff, N., & Kassam, A. (2002). A review of agricultural research issues raised by the system of rice intensification

(SRI) from Madagascar, Opportunities for improving farming system of resource-poor farmers. *Agricultural System*, *71*, 249-274. https://doi.org/10.1016/s0308-521x(01)00070-1

Thakur, A. K., Rath, S., Patil, D. U., & Kumar, A. (2010). Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implication for crop performance. *Paddy Water Environment*, *9*, 13-24. https://doi.org/10.1007/s10333-010-0236-0

World Bank. (2014). Agricultural insurance in Bangladesh: Promoting access to small and marginal farmers.

Bangladesh Rural Development Studies (BRDS)
ISSN 1019-9624; Web: www.rda.gov.bd

A GIS and remote sensing based multicriteria analysis for identifying potential agricultural land: A case study on Savar Upazila, Bangladesh

Raju Ahmed[1*], Shaikh Mehdee Mohammad[2], Ummul Momanin Coalee[1], Khandakar Hasan Mahmud[1]

[1] Department of Geography and Environment, Janagirnagar University, Savar, Dhaka- 1342

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

ARTICLE INFO

Keywords:
GIS and remote sensing
Land suitability
Multicriteria evaluation
Sustainable agriculture
Analytical hierarchy process

Received: 25 May, 2023
Revised: 12 June, 2023
Accepted: 14 June, 2023

***Corresponding Email:**
raju.45@geography-juniv.edu.bd

ABSTRACT

Despite of gradually decreasing its contribution to gross domestic product (GDP), agriculture, however, is the backbone of the Bangladeshi economy. Farming is the primary mean of rural livelihoods in Bangladesh but agricultural land is slowly declining day by day. Although, at present, Bangladesh is self-sufficient in terms of producing food, especially rice and some other major agricultural products, it is predicted that, in near future, the country is going to face immense challenges due to climate related threats. The research aims to identify the potential lands for suitable farming in Savar Upazila (sub-district) under Dhaka district applying a geographic information system (GIS) and remote sensing (RS) based multicriteria analysis. Relevant biophysical characteristics of soil, terrain, and landuse and land cover (LULC) were considered. Soil and evelvation data was collected from Soil Resource Development Institute (SRDI)and Shuttle Radar Topography Mission (SRTM), respectively, whereas satellite images were collected from Landsat-8. The maximum likelihood supervised classification technique was used for LULC classification, and the multicriteria evaluation (MCE) and analytical hierarchy process (AHP) approach was employed to identify suitable areas for farming. The research finds the LULC classes are agricultural land, built-up area, fallow land, vegetation cover, waterbodies, and wetland are 12.42%, 31.01%, 25.69%, 25.98%, 4.81%, and 0.09%, respectively. This research also finds that agricultural land suitability was classified as highly suitable, moderately suitable, marginally suitable, and not suitable are 24.28%, 29.53%, 24.66%, and 21.53%, respectively. In contrast, the current agricultural land usage accounts for just 12.42% of the total land area in this research area. The Kappa accuracy has been measured at a value of 0.88 and an overall accuracy value of 0.90 which indicates that the LULC classification is done almost perfectly. This study offered information at the local level that farmers may utilize to decide on cropping patterns and appropriateness.

How to Cite: Ahmed, R., Mohammad, S. M., Coalee, U. M., & Mahmud, K. H. (2023). A GIS and remote sensing based multicriteria analysis for identifying potential agricultural land: A case study on Savar Upazila, Bangladesh. ***Bangladesh Rural Development Studies, 26***(1), 13-26.

Introduction

Bangladesh is a land of agriculture due to its soil characteristics and agro-climatic conditions. Agriculture is regarded as one of the most significant sustainable and progressive natural resources. Thorough, dependable, and accurate information on agricultural resources is critical for countries like Bangladesh since agriculture is the backbone of our economy (World Bank, 2016). The main employment sector is agriculture, which employed around 45.33% of Bangladesh's workers but contributed 11.22% of the national GDP (BBS, 2022). Using land most rationally and feasibly possible is imperative because existing land usage in Bangladesh, as in many developing countries is unsuitable (Barkat et al., 2007; Hasan et al., 2017; Parvin et al., 2017). According to the Sustainable Development Networking Programme (SDNP), land use in Bangladesh is incompatible with the country's overall social and economic goals (Bangladesh Planning Commission, 2013). It also states that fertile agricultural land which could be used to produce food is being lost to non-agricultural uses such as private development, housing facilities, brickfields, and so on (Sarak et al., 2013; Titumir, 2021).

The rapidly rising population of Bangladesh significantly strains the limited natural resources. According to BBS (2022), the population was 169.83 million in Bangladesh, accounting for 2.07% of the global population. However, it is under pressure from rapid population increase and natural disasters like floods, droughts, tropical cyclones, and soil erosion. As a result, land productivity is diminishing, and the country is unable to produce sufficient food to feed its growing population (Josephson et al., 2014). The reduction of agricultural land significantly impacts national food production and food security. Especially, the rapid urbanization and industrialization of Savar Upazila as the rural-urban fringe notably losses arable land, making the situation critical due to high population density and scarcity of agricultural suitable land. However, Bangladesh urgently requires more efficient and sustainable agriculture production techniques.

In this regard, GIS and RS technologies provide a dynamic instrument for a multidimensional landuse system. RS offers synoptic, repeated, and objective landscape observations, which is a valuable source of spatial data, including LULC, hydrology, and topography. GIS is useful for geological and environmental study and natural resource evaluation (Dai et al., 2001; Pourghasemi & Gokceoglu, 2019). It enables the user to merge databases created from multiple sources, including RS, on a single platform and evaluate them efficiently in a spatio-temporal dimension (Breunig et al., 2003). Especially, GIS and RS tools can robustly assess the potential agricultural suitable land using spatial and multicriteria approaches. In these circumstances, the broad aim of this research is to identify the potential agricultural land using geospatial technologies in Savar Upazila, Bangladesh.

Materials and methods

This research was conducted based on secondary data. Secondary data include soil and landform database, topography database, satellite imagery, and weather data. Soil and landform data were collected from SRDI, topography database, satellite imagery, and weather data were collected from SRTM, Landsat, and Bangladesh Meteorological Department (BMD), respectively. ArcGIS tools were used to georeferenced and digitized the soil base map at the 1:50,000 scale the SRDI gave. Also, a digital elevation model (DEM), slope, aspect, 3D and TIN with 90-metre spatial resolution were generated. In addition, LULC was conducted using Landsat8 imagery with 30-metre spatial resolution, along with the assessment of Kappa and overall accuracy. Finally, the analytical hierarchy process (AHP) and multicriteria evaluation (MCE) techniques were used to identify and assess potential agricultural land in the study area. The core methodological framework is demonstrated in the Figure 1.

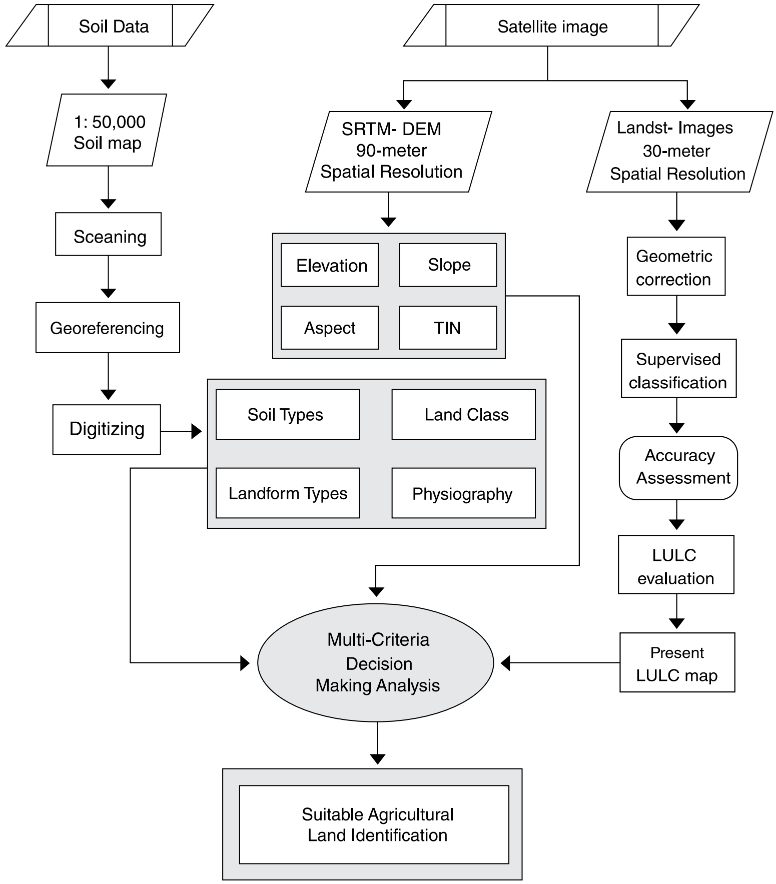

Figure 1: Methodological framework of this study.

Soil, landform, and physiography map preparation

Soil and landform classified images were collected from SRDI and employing ArcGIS tools to georeference the raster dataset. The georeferencing techniques are conducted step by step. To begin, raster image data has been integrated into the GIS programme. The Georeference tab is then used to generate control points that link the newly entered raster data to known positions on the map. Following that, the control points and errors were examined and eliminated. A control–point polynomial and the least–squares fitting (LSF) technique are used in the polynomial transformation. The polynomial transformation yields two formulas (ESRI, 2023): one for computing the output x–coordinate for an input (x,y) location and another for computing the output y–coordinate for an input (x,y) location (equations 1 and 2). Finally, the georeferenced image has been exported in .img (imagine image) file format. However, the georeferenced image has been digitized across the entire study area as polygon feature, and separate thematic maps were created based on soil category and landform types.

$$x^1 = Ax + By + C \quad (1)$$

$$y^1 = Dx + Ey + F \quad (2)$$

Where, x is the column count in image space, Y is the row count in image space, x^1 is the horizontal value in coordinate space, y^1 is the vertical value in coordinate space, A is the width of the cell in map units, B is a rotation term, C is the x^1 value of the center of the upper-left cell,

D is a rotation term, E is the negative height of the cell in map units, and F is the Y^1 value of the center of the upper–left cell.

Land use and land cover classification

LULC classification maps serve a significant and pivotal role in planning, managing, and monitoring programs at the local, regional, and national levels (Alshari & Gawali, 2021). Supervised image classification techniques were used for conducting LULC analysis in this study area using Landsat 8 images with 30-metre spatial analysis. Several training samples were taken for each LULC class. Following this approach, the output image is categorized according to each class, which is referred to as training. The maximum likelihood classifier calculates for each class the probability of the cell belonging to that class given its attribute values. The maximum likelihood classification techniques are used as (Richards, 1999)–

$$g_i(x) = 1np(w_i) - {}^1/_2\, 1n| \textstyle\sum_i | - {}^1/_2\, (x - m_i)^T \textstyle\sum_i^{-1}(x - m_i) \ldots\ldots\ldots\ldots (3)$$

Where, i is class, x is the n–dimensional data (where n is the number of bands), $p(c)$ is the probability that class w_i occurs in the image and is assumed the same for all classes, $| \sum_i |$ is determinant of the covariance matrix of the data in class $v_i, \sum_i$, is its inverse matrix, and m_i is a mean vector.

Confusion matrix

The efficiency of a classification system is described using a confusion matrix table. It exhibits and summarizes a classification algorithm's performance. Creating a confusion matrix is one of the most popular ways to represent classification accuracy. The first stage in generating an error matrix, which depends on the development of that matrix, is to locate ground reference test pixels or a sample collection. In this sense, there are several mathematical strategies. In general, it is advised that each LULC class should include at least 50 samples. This research has occupied 116 sample points for accuracy assessment. Data sampling was conducted using random procedures. An error matrix is used to compare the relevant classification result to known reference data (ground data).

Accuracy Assessment

Additionally, using accuracy evaluation point (AEP) tools, several points were constructed for the purpose of accuracy assessment. With a single band or integer data format, this tool primarily intends in order to determine the correctness of the characteristics found in the categorization pictures. Finally, according to the actual data, the accuracy evaluation divides the current class features into their original features. By calculating the confusion matrix from this procedure, an analysis of accuracy evaluation may be made. Confusion matrix tables allow analysts to see the precision of each feature used in SVM classification.

Overall accuracy

The entire classification accuracy is represented by overall accuracy (OA). The calculation is done by dividing the total number of correctly recognized pixels by the total number of reference pixels. This measure's limitation is not providing information on how accurately various groups are categorized. Producer and user accuracy are widely applied measures for class consistency depending on the omission and commission accuracy.

$$OA = \frac{Number\ \ of\ correctly\ \ classified\ \ samples}{Number\ \ of\ samples} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Producer's accuracy

The accuracy of the producer is the possibility that a certain feature of a location on the ground will be identified as such. It is computed by dividing the total correctly classified pixels by the total number of sample pixels for this class (column total).

$$PA = \frac{Number\ \ of\ correctly\ \ classified\ \ samples\ \ of\ spacific\ \ class}{Sum\ \ of\ classified\ \ samples\ \ of\ spacific\ \ class} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (5)$$

User's accuracy

The likelihood that a map pixel labeled as a particular class is actually this class is known as the user's accuracy. It is derived by dividing the number of pixels properly recognized in this category by the total number of pixels correctly identified in this category. Usually, the accuracy of the producer and the user differ. For instance, water has a producer accuracy of 100% and a consumer accuracy of 93%.

$$PA = \frac{Number\ \ of\ correctly\ \ classified\ \ samples\ \ of\ spacific\ \ class}{Sum\ \ of\ reference\ \ samples\ \ of\ spacific\ \ class} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (6)$$

Kappa coefficient

A distinct multivariate approach employed in accuracy evaluation is the Kappa coefficient. A proportion of correctly classified pixels will be generated through the classification process, in which classifications are randomly allocated to pixels. Although the assignment of pixels during image classification is not random, statistical techniques try to consider random chance when assessing categorization accuracy. The derived Kappa metric corrects for categorization chance agreement. It implies how much improved the categorization accuracy than the likelihood of allocating random pixels to the right categories. This is how the Kappa coefficient is written:

$$\widehat{K} = \frac{(P_o - P_e)}{(1 - P_e)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

Where, $\widehat{K}$ indicates Kappa coefficient, P_o are relative observed agreement P_e among raters, and is hypothetical probability of chance agreement.

These can be calculated as:

$$\widehat{K} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (8)$$

where, r is the number of rows in the error matrix, x_{ii} is the number of observations in the row i and column i, $x+i$, is total of observations in row i, $x+i$ is total of observations in column i and N is the total number of observations included in the matrix.

Topography, slope, aspect, and TIN generation

The DEM was derived from SRTM with a spatial resolution of 90-metre. Topography is crucial in agriculture because it directly affects food production. Water drainage, soil erosion, and crop suitability are all affected. It facilitates the planning of irrigation systems, the management of slopes, and the optimization of land use. The topographic map was generated using the SRTM database through ArcGIS. In this work, the geodesic approach was used to calculate the slope. It was carried out in a 3D Cartesian coordinate system with the earth's shape assumed to be an ellipse. The angle between the topographic surface and the referenced datum determines the slope value. It computes using a three-by-three cell neighbourhood (moving window). The geodesic computation employs an X, Y, and Z coordinate derived from its geodetic coordinates (latitude φ, longitude λ, height h).

The aspect tool was used to determine the direction of the downhill slope in Savar Upazila. The DN values of each cell in the resulting raster represent the compass direction that the surface faces at that point. It is measured in degrees clockwise from 0 (due north) to 360 (again due north), completing a full circle. Flat locations with no downslope direction are assigned the rating -1.

$$\tan A = -\left(\frac{\partial Z}{\partial Y} \div \frac{\partial Z}{\partial X}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (9)$$

Where, A indicate slope aspect, $\frac{\partial Z}{\partial Y}$ is a rate of elevation change in Y direction, and $\frac{\partial Z}{\partial X}$ is a rate of elevation change in x direction. Further order methods are–

$$\frac{\partial Z}{\partial X} = \frac{(Z_4 - Z_8)}{2\Delta x} \text{ ……………..…………….. } (10)$$

$$\frac{\partial Z}{\partial Y} = \frac{(Z_2 - Z_6)}{2\Delta y} \text{ ……………..…………….. } (11)$$

Where, Z represents the elevation of a pixel, Δx is the pixel size in the x–diraction, and Δy is the pixel size in the y–diraction.

The surface morphology of Savar Upazila has been represented using triangular irregular networks (TIN). TINs are vector-based computational geographic data created by triangulating a collection of vertices (points). A network of triangles is formed by connecting the vertices with a set of edges. The TIN model for the investigation was created using the Delaunay triangulation method.

Weather and climate variability of Savar Upazila

Climate variability is a crucial contributor to the fall in agricultural production and significantly impacts agricultural productivity (Fischer et al., 2002; Rahman & Rahman, 2019). Agriculture is the most sensitive industry to the consequences of rapid wearther parameter fluctuations, such as temperature changes, changing rainfall, and flood and drought occurance patterns, and so on (EPA, 2017). Hence, the most significant concern is that Savar upazila has microclimatic variability, but this microclimatic variability database is unavailable. Also, there is no significant rapid weather variability, so this research considers the average monthly weather data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov	Oct	Dec	Year
Record high °C (°F)	36.53 (97.75)	39.75 (103.55)	42.97 (109.35)	47.27 (117.09)	48.34 (119.01)	42.97 (109.35)	40.82 (105.48)	40.82 (105.48)	40.82 (105.48)	38.67 (101.61)	38.67 (101.61)	36.53 (97.75)	48.34 (119.01)
Average high °C (°F)	27.88 (82.18)	31.98 (89.56)	36.57 (97.83)	38.98 (102.16)	38.16 (100.69)	36.37 (97.47)	35.03 (95.05)	35.25 (95.45)	34.93 (94.87)	33.73 (92.71)	31.42 (88.56)	28.38 (83.08)	34.06 (93.31)
Daily mean °C (°F)	22.78 (73.0)	26.29 (79.32)	31.04 (87.87)	34.25 (93.65)	34.46 (94.03)	33.57 (92.43)	32.49 (90.48)	32.5 (90.5)	32.11 (89.8)	30.46 (86.83)	27.41 (81.34)	24.04 (75.27)	30.11 (86.2)
Average low °C (°F)	16.36 (61.45)	18.83 (65.89)	23.08 (73.54)	27.35 (81.23)	28.94 (84.09)	29.22 (84.6)	28.64 (83.55)	28.54 (83.37)	28.09 (82.56)	25.82 (78.48)	21.88 (71.38)	18.41 (65.14)	24.6 (76.28)
Record low °C (°F)	8.59 (47.46)	12.89 (55.2)	15.04 (59.07)	22.56 (72.61)	18.26 (64.87)	19.34 (66.81)	21.49 (70.68)	18.26 (64.87)	21.49 (70.68)	20.41 (68.74)	15.04 (59.07)	11.82 (53.28)	8.59 (47.46)
Average precipitation mm (inches)	1.4 (0.06)	12.14 (0.48)	24.58 (0.97)	111.9 (4.41)	140.82 (5.54)	139.24 (5.48)	135.29 (5.33)	102.64 (4.04)	120.11 (4.73)	77.53 (3.05)	18.14 (0.71)	5.5 (0.22)	74.11 (2.92)
Average precipitation days (≥ 1.0 mm)	0.48	1.46	5.47	14.85	17.88	18.17	17.29	16.8	16.21	8.98	1.56	0.98	10.01
Average relative humidity (%)	56.14	48.71	51.66	63.86	73.87	81.89	85.9	85.03	84.42	80.48	69.85	63.21	70.42
Mean monthly sunshine hours	9.26	9.44	12.46	13.38	13.63	12.98	12.4	12.56	11.77	10.78	9.13	9.15	11.41

Figure 2: Weather variability on a monthly basis in Savar Upazila.

Sources: Data collected from BMD and compiled by authors, 2023.

Assigning weight of factors and suitability analysis

The goal of weighting is to convey the relevance or preference of each component concerning the impacts on crop production and the growth rate of other factors. Suitability levels for each element were established, and these levels served as the foundation for creating the criterion maps (one for each factor). The appropriateness levels were as follows: according to the framework of the FAO land suitability classification, highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N) (Makungwe et al., 2021). The framework of the FAO land suitability categorization is shown in Table 1.

Table 1: Structure of the FAO land suitability classification

Symbol	Suitability level	Description
S1	Highly suitable	Land without significant limitations. This land is not perfect, but it is the best to be hoped for appropriate use.
S2	Moderately suitable	Land that is clearly suitable has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared with those needed on SI land.
S3	Marginally suitable	Land with limitations so severe that benefits are reduced and the inputs needed to sustain production are increased, so this cost is only marginally justified.
N	Not Suitable	Land that cannot support land use sustainably or land on which benefits do not justify necessary inputs.

Source: Guidelines for land-use planning. FAO, I 993.

MCE's overall method consisted of numerous stages. To begin, the pertinent were identified. A pair-wise comparisons matrix was created using the above-specified elements as the criterion. Although there are several ways for weight generation, one of the most promising is the pair-wise comparisons matrix (PWCM) created by Saaty (1980) in the framework of AHP (Saaty, 2008; Sepehrian et al., 2021). AHP adopts an inherent g scale with values ranging from 1 to 9 to score the comparative preferences for the two elements. Table 2 illustrates the numerical ratings proposed for the decision-spoken maker's preferences. This technique has been theoretically and experimentally evaluated for a wide range of decision-making circumstances, including spatial decision-making, and has been included in a GIS-based decision-making mechanism.

Table 2 : Numerical rating of the fundamental scale

Verbal Preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely	8
Very strongly	7
Strongly to very strongly	6
Strongly	5
Moderately to strongly	4
Moderately	3
Equally to moderately	2
Equally	1

Source: Karayalcin, 1982.

The MCE approach (weighted linear combination) demands that all components be normalized or changed into units compared afterwards. In this research, the factor mappings were standardized/ranked via a conversation with a crop production specialist using Saaty's fundamental scale with values ranging from 1 to 9.

After obtaining the composite layer and their weights, the MCE technique in ArcGIS was used to generate the map of acceptable regions. Finally, the rice crop suitability map was created using ArcGIS spatial analyst tools and a weighted overlay. The land suitability assessment was completed in two stages. The initial stage was to divide the entire arable land into distinct suitability groups using AHP and MCE. The LULC map obtained from satellite data was superimposed in the second stage, and the extent of every suitability level per LULC class was computed.

Overlay existing LULC and the suitability map

The current LULC map and the agriculture suitability map were overlaid to find contrasts and similarities between existing and future land uses. A cross table between the map of appropriate areas and the LULC map was generated for crops. As a result, this research gathered helpful information on the geographical distribution of different appropriateness levels based on Landsat 8 data. Because the resulting layer offered information on how the agro crop was spread throughout the various land suitability zones, we could fine-tune results at this step. Weighted overlay has been incorporated in the spatial analysis tools in this research. Climate variable data, topographic data, soil classification data, and slope aspect data have been overlayed, and LULC data multiplied with the weighted overlay data using raster calculator tools.

Study area

Savar Upazila is located in the northeastern outskirts of Dhaka city. It is crossed by national highway N5, a major route that links Dhaka with northern Bangladesh (Figure 3). This sub-district is located between coordinates 23°44' and 24°02'N and 90°11' and 90°22'E and has an area of 283 km^2, including 20 km^2 of river and 8 km^2 of forest (Mahmudet al., 2021). According to the Bangladesh Bureau of Statistics (2011), the population in 2011 was 587,041 people, where Males constituted 54.20% of the population and females 45.80%. Savar Upazila has undergone a substantial population increase and changes in conventional agrarian land usage over the last several decades as a result of rapidurbanization and industrialization (Hassan et al., 2019; Mahmud et al., 2021).

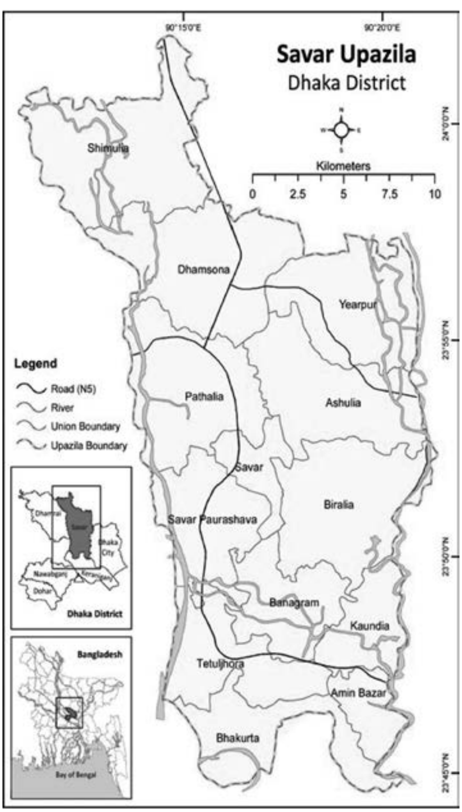

Figure 3: Location map of the study area (Savar Upazila, Bangladesh).

The main economic areas are agriculture and manufacturing in Savar Upazila.Rice, jute, peanut, onion, garlic, chilli, and other vegetables are the principal crops farmed here. Aus rice, sesame, linseed kaun, and Mas Kalai (black gram) are all extinct or virtually extinct crops in the region. Fruits grown here include jackfruit, mango, papaya, olive, guava, berry, kamranga, and banana. There are 181 total dairy, fisheries, and poultry operations, 209 poultry operations, five hatcheries, and 1319 fisheries. The garments industry, ceramic industry, beverage industry, foot ware, jute mills, textile mills, press and publication, printing and dyeing factory, automobile industry, transformer industry, pharmaceutical industry, biscuit and bread factory, soap factory, brickfield, cold storage, welding, plant nursery, and so on are examples of manufacturing facilities. The hydrological conditions are ideal for agricultural activity. Rivers, canals, and ponds are the supplemental groundwater sources for agricultural usage in Savar Upazila (Ahmedet al., 2017). However, there is a tremendous opportunity for enhanced cultivation from surface and groundwater resources. The depth of the inundation affects the type of crop and cropping strategy. The most incredible depth of flooding ranges between 30 and 180 cm (Mirza et al., 2003). Agriculture is performed in the study region using both rainfed and irrigated methods.

Result and discussion

LULC image processing of Savar Upazila

The LULC map derived from the Landsat 8 satellite image obtained from the supervised classification is shown in Figure 4(a). This LULC map shows six categories of LULC of Savar Upazila, which were produced from the combination of the multispectral bands corresponding to green (G), red (R), and near-infrared (NIR) that were found to be appropriate to identify the LULC types in the study area. The image processing and classification have been completed through the supervised classification

Table 3: Land use and land cover area of Savar Upazila

Type	Area (hectares)	Percentage
Agricultural land	3548.74	12.42
Built-up area	8861.39	31.01
Fallow land	7342.14	25.69
Vegetation cover	7424.13	25.98
Water bodies	1373.20	4.81
Wetland	26.60	0.09

approach and the maximum likelihood algorithm, ensuring that an acceptable percentage of the classified pixels were correctly classified. The LULC classification has been classified into six classes: agricultural land, built-up area, fallow land, vegetation cover, wetland and water bodies. The area-categorized classes have been extracted using ArcGIS tools shown in Table 3.

According to the current land use and land cover map, the agricultural land area was 3548.74 hectares, the built-up area was 8861.39 hectares, fallow land was 7342.14 hectares, vegetation cover was 7424.13 hectares, water bodies was 1373.20 hectares, and wetland was 26.60 hectares within the total area of 28576.20 hectares. The LULC classification is shown in Figure 4 (a), and the agricultural land of Savar Upazila was 12.42%, shown in Table 3 and Figure 4 (b). Most of the agricultural land was located rural fringe of Savar Upazila. The middle portion was industrialized, and the residential and middle-left portions were market.

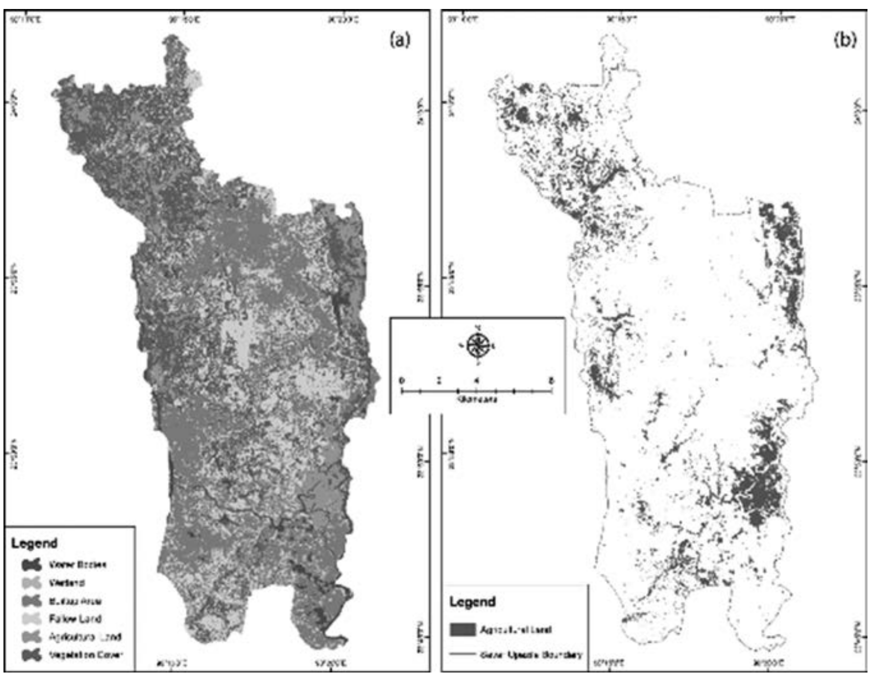

Figure 4: Land use and land cover of Savar Upazila (a) LULC map, (b) Spatial distribution of of existing agricultural land.

Agriculture (20.46%), non-agricultural laborer 3.09%, industry 2.82%, commerce 20.55%, transport and communication 5.75%, service 28.74%, construction 2.84%, religious service 0.18%, rent and remittance 2.67%, and other 12.90% are the major earning sources in Savar Upazila (Asian Development Bank, 2021). Important crops include rice, jute, groundnut, and vegetables. This extracted map (Figure 5) shows the agro-based land use of Savar Upazila, where positive value means highly agro-based land and negative value generated non-agro-based land use.

Accuracy assessment

Accuracy assessment is essential to the LULC categorization process connected with other assessments. The accuracy impacts the result of the entire suitability assessment directly. Accuracy

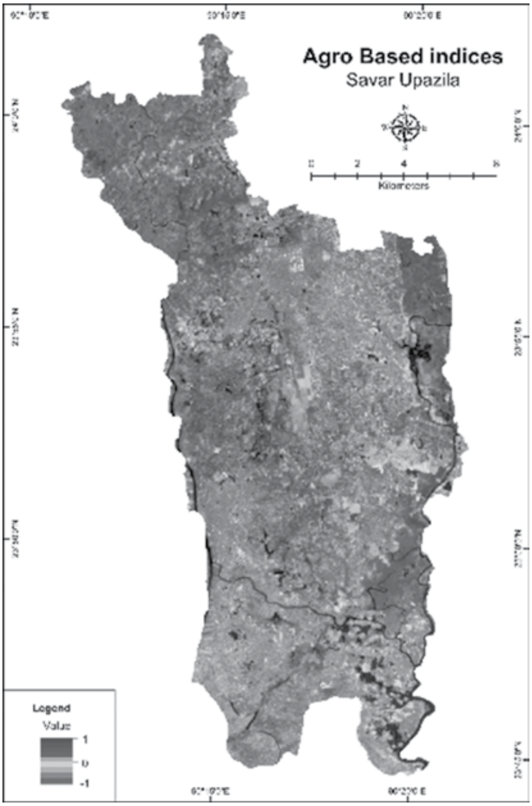

Figure 5: Agro-based indices for agricultural land use of Savar Upazila

evaluation aims to quantify how well pixels were sampled into the right land cover groups. In the study area, 116 points (locations) were formed and ground truthing was conducted by field verification. The Kappa accuracy has been measured at a value of 0.88 and an overall accuracy value of 0.90. Cohen suggested the Kappa result be interpreted as values 0.81–1.00, indicated as almost perfect agreement. This accuracy analysis demonstrates that the LULC classification is almost perfectly in agreement. The overall 116 points have been perfectly placed within 104 sample points. The overall producer accuracy of Agricultural Land, Built-up Area, Fallow Land, Vegetation, Waterbodies, and Wetland was 0.88, 0.94, 0.87, 0.89, 0.90, and 0.90, respectively; on the other hand, the overall used accuracy 0.91, 0.89, 0.87, 0.85, 0.95, and 0.90, respectively (Figure 6).

Topographic characteristics of Savar Upazila

The principal geomorphic units of Savar Upazila are the highland, also known as the Dhaka terrace, and the lowland, also known as floodplains, depressions, and abandoned waterways. Other significant topographic features in and around the Upazila are low-lying swamps and marshes. The topographic elevation, slope, and aspect map area are shown the Figures 7 (a-d).

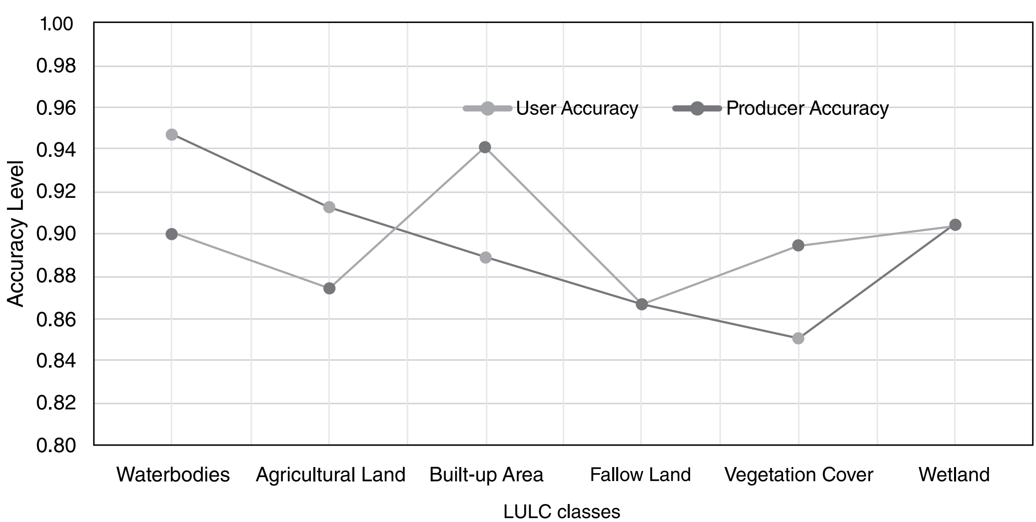

Figure 6: User and producer accuracy of LULC classification of Savar Upazila.

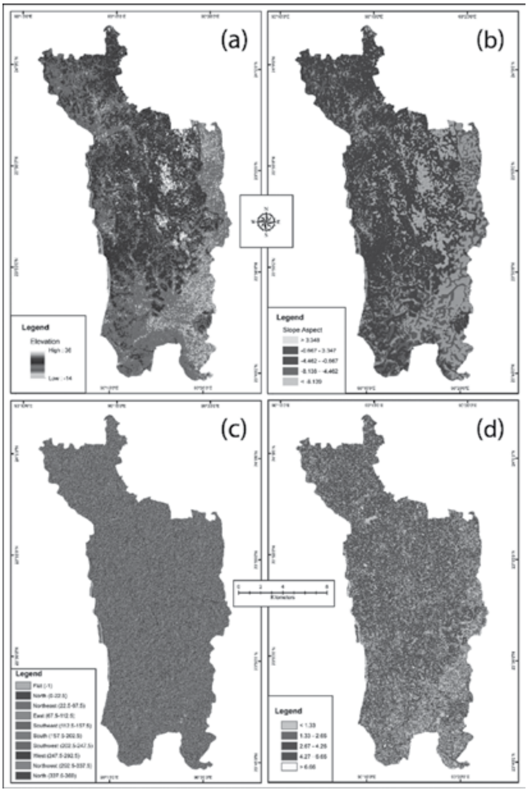

Figure 7: Topographic map of Savar Upazila (a) elevation map, (b) triangular irregular networks model, (c) aspect map, and (d) slope map.

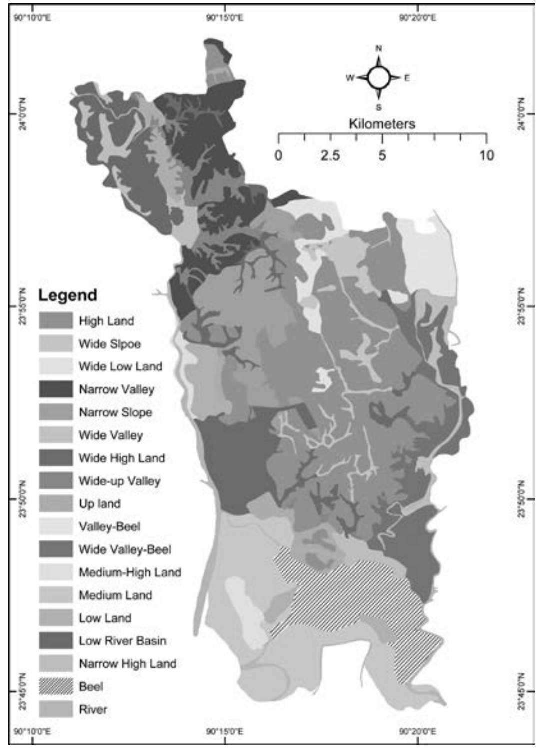

Figure 8: Figure 8: Soil map of Savar Upazila.

Soil of Savar Upazila

Agriculture disrupts the natural cycle of nutrients in the soil. Plant nutrients may be successfully mined from the soil by intensive crop production and harvesting for human or animal use. Soil additives are often necessary for conserving soil fertility for adequate agricultural yields. A fertile soil also offers crucial nutrients for plant development, producing healthful food containing all the substances required for human health. Furthermore, fertility influences economic activity and is thus linked to economic growth and poverty alleviation. However, SRDI of Bangladesh has designated 14 soil groups and 10 soil mapping units in Savar Upazila. Figure 8 shows the soil types, soil classes due to height, soil topography, soil physiography and landform types. A soil group comprises much identical soil series, generally 1-4, and is named by the dominating soil series (Islam, et al., 2017; SRDI, 2021). The soil mapping unit is a map-delineated region of land. This is a geographical entity whose land attributes are not always uniform. Soil mapping units (1–10) are identified based on landform, land type, and physical and chemical soil properties.

Multi-criteria evaluation and agricultural land suitability

Soil and topographic characteristics were investigated in this research to assess site suitability for Agricultural cultivation. After obtaining the factor maps and the weight of composite layers, the physical suitability mapping at four suitability classes (SI, S2, S3, N) for agricultural land was evaluated using a weighted overlay (Figure 9). Figure 9 (a) shows the number of hectares available for each suitability class: very suitable (S1) 6921.57 ha, moderately suitable (S2) 8419.38 ha, marginally suitable (S3) 7031.79 ha, and not suitable (N) 6139.98 ha (Table 4), and Figure

9 (b) shows the overlay of existing agricultural land in suitable land classes.

Table 4: Agricultural land suitability area calculation

Level of suitability	Area (ha.)	Percentage (%)
Highly suitable (S1)	6921.57	24.28
Moderately suitable (S2)	8419.38	29.53
Marginally suitable (S3)	7031.79	24.66
Not suitable (N)	6139.98	21.53

The findings revealed that highly suitable regions (S1) were predominantly identified in soil mapping units 3, 5, and 9. The soil mapping units 3, 5, and 9 (S1 areas) in Savar Upazila were characterized by: inundation land type high land, which is above regular flood level, soil drainage inadequately to imperfectly drained, soil moisture high, slope level (1%), and texture class clay; these values are consistent with those considered in the literature. In general, not suitable zones (N) were found along the industrial and built-up areas. Furthermore, significant components in unsuitable places included sandy soil, medium low land that is flooded to a depth of 90-180 cm for several months during the rainy season, and a slope of 5.00%. During the Rabi season, some of this land is planted with mustard and wheat, while most of it remains fallow or grassland the rest of the year. To enhance the LULC, the suitability mapping for agricultural cultivation was overlaid to highlight discrepancies and similarities between both current and future land uses for agricultural land. This was done because identifying and accurately describing present and future producing regions is critical for research and agricultural production.

Conclusion

This research used GIS and RS approaches to identify suitable areas for agricultural cultivation. The findings of this study suggest that integrating GIS-RS and utilizing MCE with AHP might

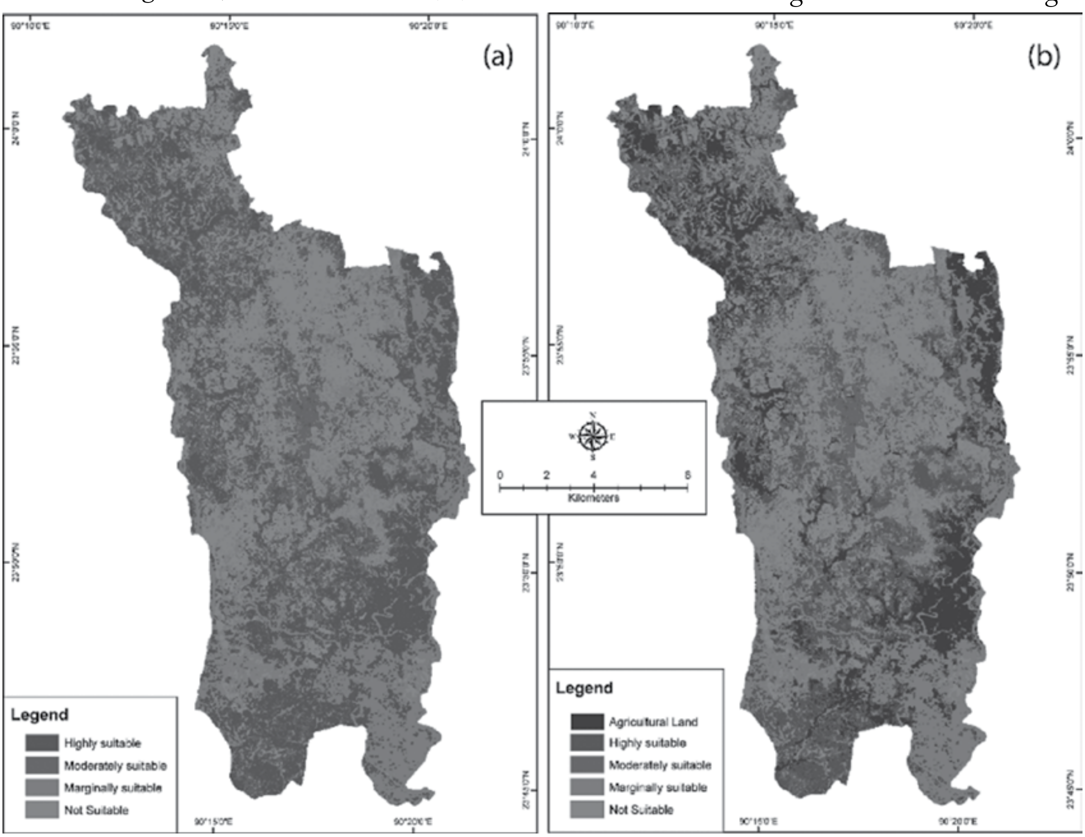

Figure 9:Land suitability of Savar Upazila (a) Suitable area of agricultural land, and (b) spatial distribution agricultural suitability and overaly of existing agricultural land.

give a superior database and guidance map for decision-makers contemplating agricultural harvesting substitution in order to improve agricultural productivity. The study demonstrated that the spatial distribution of agro-crops derived from RS data, in conjunction with the valuation of physical and biological variables of soil and topographic information in the GIS context, is beneficial in crop management options for intensification or diversification. Such an approach yielded excellent information about the relative relevance of the parameters under consideration and might serve as a beneficial model for future agricultural productivity research. This study also offers generic possibilities for local farmers in the context of agricultural land use planning for crop production. The findings of this study may be valuable to other researchers who may apply them in various investigations. This study considered present LULC, topography, and soil characteristics, all of which influenced the appropriateness categorization of land use categories. As a result, it produces main results. For further research, it has been advised to identify additional elements such as soil, climate, irrigation infrastructure, and socioeconomic aspects that impact land sustainability. In this circumstance, it needs to take the initiative to protect agricultural land, which is the recommendation based on this research assessment. The protection plans assist local governments in inventorying significant farmlands establishing goals for its conservation, and identifying implementation mechanisms.

References

Ahmed, A. U., Mondal, P., & Islam, M. (2017). Community-based Adaptation: An Analysis of Best Practices in the South-western Region of Bangladesh. *Dhaka, CARE Bangladesh*, 70.

Alshari, E. A., & Gawali, B. W. (2021). Development of classification system for LULC using remote sensing and GIS. *Global Transitions Proceedings*, *2*(1), 8-17.

Asian Development Bank. (2021).Bangladesh: Second City Region Development Project. Prepared by Local Government Engineering Department (LGED), Government of Bangladesh for the Asian Development Bank.

Bangladesh Planning Commission. (2013). National Sustainable Development Strategy 2010–21 (NSDS).

Barkat, A., Ara, R., Taheruddin, M., Hoque, S., & Islam, N. (2007). Towards a feasible land use policy of Bangladesh. *Human Development Research Centre, Dhaka*.

BBS. (2022).Gross Domestic Product (GDP) of Bangladesh 2021-22. Bureau of Bangladesh, Statistics and information division, MInistry of planning.

Breunig, M., Türker, C., Böhlen, M. H., Dieker, S., Güting, R. H., Jensen, C. S., ... & Scholl, M. (2003). Architectures and implementations of spatio-temporal database management systems. In *Spatio-Temporal Databases* (pp. 263-318). Springer, Berlin, Heidelberg.

Dai, F. C., Lee, C. F., & Zhang, X. H. (2001). GIS-based geo-environmental evaluation for urban land-use planning: a case study. *Engineering geology*, *61*(4), 257-271.

EPA, U. (2017). Climate impacts on agriculture and food supply. *United States Environmental Protection Agency, Washington, DC*.

FAO. (1993). Guidelines for land-use planning. Food and Agriculture Organization of the United Nations, Rome.

Fischer, G., Shah, M. M., & Van Velthuizen, H. T. (2002). Climate change and agricultural vulnerability.

Hasan, S. S., Deng, X., Li, Z., & Chen, D. (2017). Projections of future land use in Bangladesh under the background of baseline, ecological protection and economic development. *Sustainability*, *9*(4), 505.

Hassan, M. M., Juhász, L., & Southworth, J. (2019). Mapping time-space brickfield development dynamics in Peri-Urban Area of Dhaka, Bangladesh. *ISPRS International Journal of Geo-Information*, *8*(10), 447.

Islam, M. A., Hasan, M. A., & Farukh, M. A. (2017). Application of GIS in general soil mapping of Bangladesh. *Journal of Geographic Information System*, *9*(5), 604-621.

Josephson, A. L., Ricker-Gilbert, J., & Florax, R. J. (2014). How does population density influence agricultural intensification and productivity? Evidence from Ethiopia. *Food Policy*, *48*, 142-152.

Karayalcin, I. I. (1982). The analytic hierarchy process: Planning, priority setting, resource allocation: Thomas L. SAATY McGraw-Hill, New York, 1980, xiii+ 287 pages,£ 15.65.

Mahmud, K. H., Hafsa, B., & Ahmed, R. (2021). Role of transport network accessibility in the spread of COVID-19-a case study in Savar Upazila, Bangladesh. *Geospatial Health*, *16*(1).

Makungwe, M., Chabala, L. M., Van Dijk, M., Chishala, B. H., & Lark, R. M. (2021). Assessing land suitability for rainfed paddy rice production in Zambia. *Geoderma Regional*, *27*, e00438.

Mirza, M. M. Q., Warrick, R. A., & Ericksen, N. J. (2003). The implications of climate change on floods of the Ganges, Brahmaputra and Meghna rivers in Bangladesh. *Climatic change*, *57*(3), 287-318.

Overview of georeferencing. ESRI. Imagery and remote sensing. Retrieved on June, 2023. Available at– https://pro.arcgis.com/en/pro–app/latest/help/data/imagery/overview–of–georeferencing.htm

Parvin, G. A., Ali, M. H., Fujita, K., Abedin, M. A., Habiba, U., & Shaw, R. (2017). Land use change in southwestern coastal Bangladesh: Consequence to food and water supply. In *Land use management in disaster risk reduction* (pp. 381-401). Springer, Tokyo.

Pourghasemi, H. R., & Gokceoglu, C. (Eds.). (2019). *Spatial modeling in GIS and R for earth and environmental sciences*. Elsevier.

Rahman, M. S., & Rahman, M. A. (2019). Impacts of climate change on crop production in Bangladesh: a review. *Journal of Agriculture and Crops*, *5*(1), 6-14.

Richards, J. (1999). *Remote Sensing Digital Image Analysis*, Berlin: Springer-Verlag (1999), 240 pp.s

Sarak, K. K., Hossain, M. S., Islam, M. R., & Bari, M. A. (2013). of the Research Project: Trends in the availability of agricultural land in Bangladesh.

Sepehrian, Z., Khoshfetrat, S., & Ebadi, S. (2021). An Approach for Generating Weights Using the Pair-wise Comparison Matrix. *Journal of Mathematics*, *2021*.

SRDI. (2021). Annual Report 2020-21. Soil Resource Development Institute, Ministry of Agriculture, Mrittika Bhaban, Farmgate, Dhaka-1215

Titumir, R. A. M. (2021). Agriculture in Bangladesh. In *Numbers and Narratives in Bangladesh's Economic Development* (pp. 33-61). Palgrave Macmillan, Singapore.

Wind, Y., & Saaty, T. L. (1980). Marketing applications of the analytic hierarchy process. *Management science*, *26*(7), 641-658.

World Bank. (2016). Bangladesh: Growing the Economy Through Advances in Agriculture.

Bangladesh Rural Development Studies, 26(1), 2023 (27-38)

Bangladesh Rural Development Studies (BRDS)
ISSN 1019-9624; Web: www.rda.gov.bd

Assessment of flood vulnerability and adaptation: A study on smallholders in Gaibandha district, Bangladesh

Ram Proshad Barman[1*], Md. Mazharul Anowar[2]

[1] Department of Sociology, Begum Rokeya University, Rangpur, Bangladesh.

[2] Rural Development Academy, Bogura, Bangladesh.

ARTICLE INFO

Keywords:
Flood
Vulnerability
Sensitivity
Exposure
Smallholders
Adaptation

Received: 28 May, 2023
Revised: 12 June, 2023
Accepted: 14 June, 2023

***Corresponding Email:**
rpbarman@brur.ac.bd

ABSTRACT

Disaster, vulnerability and adaptation have been the highly recognized studies in the contemporary globalized environment. The primary purpose of the study is to assess the flood vulnerabilities and adaptation strategies of smallholders in Gaibandha, a northern district of Bangladesh. The primary data of the study were collected from 110 respondents of five villages in Saghata Upazila who had been randomly selected by using survey questionnaire. Employing descriptive statistical tools, such as frequency test to explore the research objectives, the research data were collected from January 11 to May 20 in 2022. The study has discovered several determinants of flood vulnerability, such as less education, more frequencies of flood events, heavy rainfall, acute dependency to nature for cultivation, insufficient relief, faulty cropping system, lack of advanced infrastructure and lack of resilience. The study also found out various challenges to adaptation; i.e. resource scarcity, lack of alternative livelihood options, poor employment status, lack of early preparation and experiences, inadequate flood resistant cropping and lack of fund to tackle recurrent flood events in the study area. At final stage, several recommendations are suggested including both the government and international policies of disaster management for successful flood adaptations in the study region.

How to Cite: Barman, R. P., & Anowar, M. M. (2023). Assessment of flood vulnerability and adaptation: A study on smallholders in Gaibandha district, Bangladesh. ***Bangladesh Rural Development Studies, 26***(1), 27-38.

Introduction

As a densely-populated and low-lying country, Bangladesh is located in South Asia, has a strong connection of rivers making largest sedimentary deposits around the globe (Akter et al., 2016; Alam, 1996). With a long coastline on the northern littoral of the Bay of Bengal, Bangladesh lies in the Ganges-Brahmaputra-Meghna (GBM) delta which increase the range of flood events (Brown et al., 2018; ESPA, 2018; Islam, 2016). For this, Bangladesh has identified climate change as rapidly emerging issue, though the developed world is primarily responsible for maximum carbon and greenhouse gas emissions, the Third World countries like Bangladesh are the core victims of the adverse effects of climate change and socio-economic and political spheres are also being influenced by it. In fact, during monsoon 30-35% of the total surface of Bangladesh is being flooded every year (Milliman et al., 1989). Hence, the country is highly vulnerable to severe floods and ranked 6th most climate vulnerable in terms of flood and these events upset people's lives damaging resources like crops, livestock and other properties at a great extent (BCAS, 2001; Brammer, 1990; Islam et al., 2016; UNDP, 2004). Many studies (Azad et al., 2013; Faruque, 2021; Leya et al., 2020) observed that northern Bangladesh is affected by floods and much more vulnerabilities are being experienced by the people over the years while in Gaibandha disastrous floods create shortage of drinking water, and loss of lives and resources. Even, a greater number of people are compelled to migrate, to transform profession and depend on natural resource because of geographic location.

Again, climate induced disasters including floods cause large economic losses, reduce economic growth, especially in Bangladesh, the direct annual costs are estimated at 0.5-1% of gross domestic product (MoF, 2019). About disaster risk financing issues, Bangladesh will have to cost approximately $3.2 billion per year because of cyclones and floods (Ozaki, 2017). Again, since 1960s, Bangladesh has already been investing $10 billion for enhancing disaster preparation, coping mechanism and measures for losses reduction (Kabir & Hossain, 2013).

In 2004, flood events inundated more than 38% of land area and as a result the country experiences a damages of over $2 billion in various sectors including infrastructure, agriculture, and industry (MoEF, 2005). Especially in Saghata Upazila of Gaibandha district, the 2017 flood events damaged approximately worth about $140 million transplanted Aman crops. While seedbeds were washed away by the surging water and poor and marginal farmers faced more difficulties for preparing fresh seedbeds (The Daily Star, 2017). Whereas, integration of policies and its implementation from local to national level to combat climate variability is prioritized by international organization, in Bangladesh phases of policy implementation remains limited and only few empirical studies investigated the sustainability of climate adaptation strategies in the 21st century (ActionAid, 2012; UNDSEA, 2008). Again, adaptation to flood events in Bangladesh is urgent because of greatly impact on agriculture and socio-economic characteristics (Shrestha et al., 2018). Therefore, the objectives of the study were to assess the ranges of vulnerabilities of smallholders and to assess the adaptation strategies against flood events. Chamberlin (2007) defined smallholders as resources poor farmers who have limited land availability, shortages of capital, partitioned holdings and poor ownership to other inputs. The holding size of smallholders is directly linked with small farm sizes only 0.5 hectares or 1.23553 acres.

Vulnerability and adaptation

Vulnerability and adaptation can be defined in multifarious aspects depending on the depth of research outline and relevancy of the concepts needed for analysis. For instance, Menoni and Pergalani (1996) identified that vulnerability can be understood as damage goods, people, buildings, infrastructures and activities in hazardous condition.

In this study, the conceptual framework of Turner et al. (2003) is utilized to understand the flood vulnerability of the smallholders, where vulnerability is illustrated as a function of exposure, sensitivity and adaptive capacity (figure 1). Exposure is the state and change in external stresses that a system is exposed to (Lawrence et al., 2011). Susceptibility is the probability of negative consequences of floods to the environment and society (Samuels et al., 2009) . Further, sensitivity can be understood as the degree to which a system is affected, adversely or beneficially, by a given exposure (IPCC, 2007a).

Resilience is the capacity of a community to adapt to changes in a hazardous area by modifying itself to achieve an acceptable structural and functional level (Galderisi et al., 2005).

In operational conception for this study, vulnerability is identified as inability of community people to cope an adverse flood event. Flood adaptation is defined as the capability of adjustment in facing flood events, which has destructive consequences to people's livelihood.

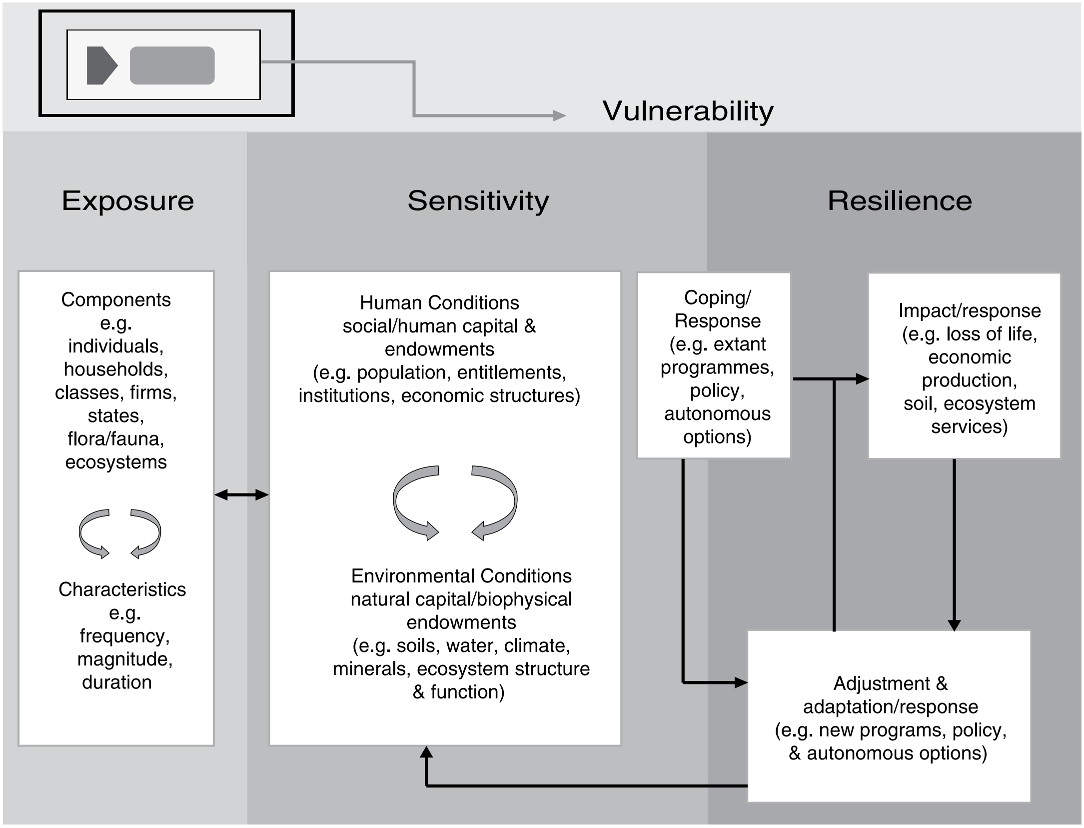

Figure 1: The conceptual framework of vulnerability

Source: Turner et al. (2003)

The researchers have concentration on the importance of using technology in the crop fields, crop storages, training services from agriculture extension. The research findings reveal how smallholders face vulnerability induced by flood events recurrently and their challenging adaptation strategies. Moreover, the research outcome will also be useful for practitioners and further researchers about the adaptation approach, strengths and weakness following the needs of future generations. Lastly, the study recommends functional and sustainable adaptation strategies for the flood affected areas.

Literature review

In the recent decades, many researchers examined people's vulnerabilities exploring their adaptive capacities in the event of natural hazards, such as, flood across the world.

Azad et al. (2013) studied about flood vulnerabilities and relevant encountered problems especially for women in Sirajganj district, Bangladesh. They found that poor and disadvantaged women were more vulnerable than men. They also identified some other problems to their study as well; food, fuel, safe drinking water and unavailability of shelter. Floods also created social vulnerabilities among children, old aged and poor and destitute group.

In a paper of Food and Agriculture Organization explored that due to change of climatic factors agriculture in developing countries experience vulnerability and marginalization (FAO, 2002). Despite the contribution to the overall development ranging from 30-60%, employing maximum portion of people, getting foreign currency by exporting production with standard livelihoods, agriculture sector is threatened compared to other sectors. With the advanced technology, productivity is taken into consideration experiencing multiple hazards for instance, natural and social hazards in the Asian countries including Bangladesh. In another study of FAO (2010), it is described that in developing countries climate change affected 11 % arable land, while 65 countries of the world lost 16 % agricultural GDP in cereal production.

In a study, among the other researchers, Peng et al. (2004) intimately investigated various data of rice production for six years regarding 227 farms categorizing six prime countries relating to rice production largely in Asian continent. They found that ranging from 10-20% of crops are seriously damaged by the increasing temperatures in that region.

In Asia-Pacific region, comparing with other sectors, agriculture is mostly vulnerable for various reasons. Because poor and rural farmers are severely affected by climatic disasters like extreme droughts, floods over the time, which directly influence their production level resulting the reluctance of sustainability of their strategy. Finally, the study is concluded by providing suggestions on disaster management from various level (Dev, 2011).

According to IPCC (2007a) for the duration of the next decades, billions of people, mostly in developing nations will face life-threatening freshwater. Basis on this, several studies predicated standing problem of complete water scarcity in over a third of the global population by 2025. Therefore, using sustainable water management, agricultural productivity and food security for global hungers can be improved (Rosengrant & Cai, 2002; Seckler et al., 1998).

In a report, World Bank stated that in 2008 destructive cyclone Nargis damaged more than US$4 billion while floods in 2015 caused a loss of US$1.51 billion in Myanmar. The floods of 2015 destroyed more than one fifth of cultivated crops (Myint et al., 2015). For this reason, Government of Myanmar Initiated Climate Change Strategy Plan (MCCSAP) which started in 2016 and to be continued till 2030 unlike the other countries like Bangladesh, focusing response, recovery and agricultural adaptation strategies (MoNREC, 2017) Adaptive strategies to climate change in Bangladesh were reviewed by Younus (2014) where he highlighted that the community-based adaptation measures were inadequate for experiencing and managing particular hazards and disasters including floods. The review noted that the poor farmers in the rural area faced miserable consequences to revive in the agricultural activities. The economic crises during the flooding periods left them helpless and vulnerable limit their further adaptive capacities to come back in the regular livelihood conditions.

Addressing the issues related to climate adaptations, Asian Development Bank and *International Food Policy Research Institute* have recognized vulnerable nations to climate change in Asia-Pacific and described into three categories according to the agenda of adaptive capacity, exposure and sensitivity (Asian Development Bank, 2009).

A research survey is conducted on 380 households in Sirajganj and Tangail districts by Alam et al. (2017). They found that recurrent droughts, destructive cyclones and uneven floods increased more from earlier decades representing 91%, 81% and 83% respectively. The findings of the research revealed that their livelihoods were being vulnerable with the climate change because they faced crises in infrastructure, adequate heath privileges. Introducing new crop varieties, mapping time framework of planting crops with generated new policy and acceleration of high value crops are considered as adaptation options in that study.

Methods and materials

The 'Northern Bangladesh' comprising 16 districts of Rangpur and Rajshahi divisions. Since, the northern part of Bangladesh experience severe floods, and three districts like; Gaibandha, Kurigram and Lalmonirhat lie to devastating flood prone region. The data of the study were collected from January 11 to May 20 in 2022. Applying a range of sampling procedures, the study area and respondents were selected. At the outset, employing purposive sampling, the researchers selected Saghata Upazila of Gaibandha district.

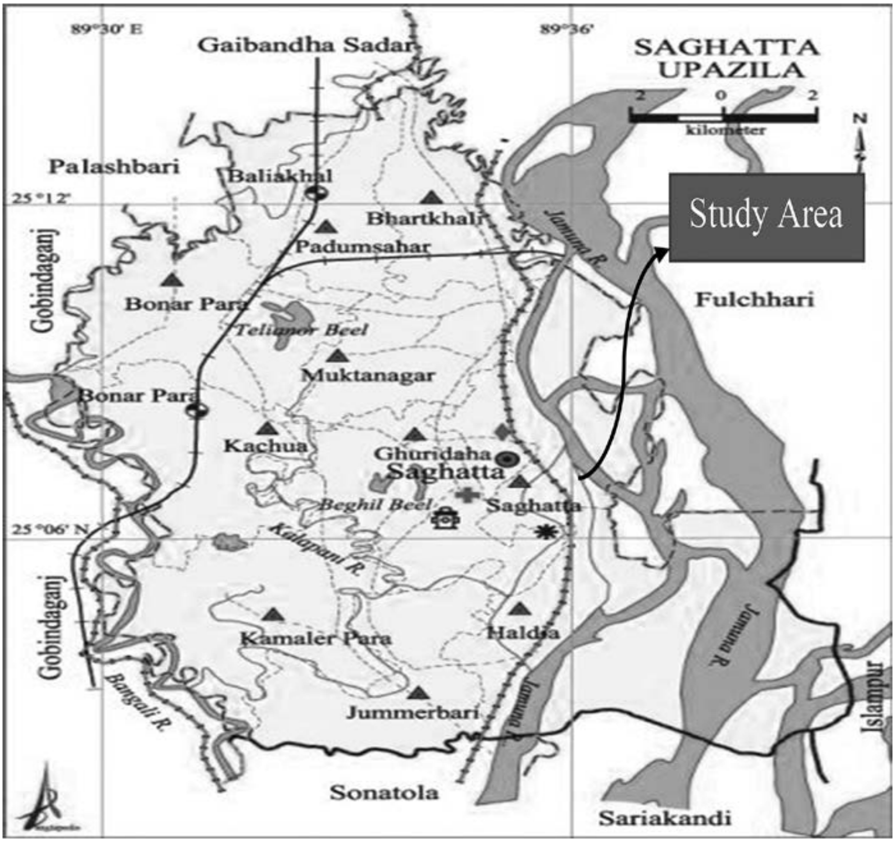

Figure 2*:* Location of the study area (Coordinates: 25°6.3´N 89°35.2´E)

Using simple random sampling, the study is covered on the five villages namely Chinirpatal, Haldia, Gobindi, Nalchity, Hasilkandi of Saghata Upazila under Gaibandha district which lies in 25°6.3° North and 89°35.2° East in northern Bangladesh. The Upazila has been chosen for couple of reasons, for instances, the area considered one of the most flood prone areas, and the Upazila is located to the adjacent of the corresponding researcher's living place. Thus, it was the convenient place for collecting data. Using survey, structured questionnaire, the researchers collected quantitative data.

Statistical package for social science (SPSS) was used to analyze and interpret quantitative data. Again, based on written transcripts, coding categories and subcategories are generated while open and semi-structured questions are coded, cleaned and refreshed. For data presentation, the researchers used figures, charts, and tables.

Results and discussions

Determinants of flood vulnerability

In this section, several factors that determine flood vulnerability were identified in the five study villages of Saghata. These factors comprise the education level, frequency of floods, infrastructure, cropping system, loss of cultivation, rainfall, trainings, flood relief, employment status, warning system and flood insurance. On the basis of the depth of the respondents, these factors likely to contribute to the creation of flood vulnerability in the region.

Ranges of flood vulnerability

In order to measure and assess the ranges of vulnerability, the major four components (social, economic, environmental and physical) and three groups of indicators (exposure, susceptibility and resilience) were utilized in the study area. Table 1 shows the necessary indicators, valuable components, identified factors of flood vulnerability, relationship with vulnerability connecting with components and factors and lastly description of the respondents. A total of 11 indicators were identified from household level for assessing vulnerabilities induced by flood events.

Compare to other factors, education level influenced more to their vulnerability because it has a great connection to sensitivity. While, a large portion of the respondents (45%) remained beyond literacy and only 37 % acquired primary education only, though few of them earned more than primary school degree. Besides, due to insufficient literacy, overall consciousness of farmers to their livelihoods, crops production, standardization of health, nutrition, and dealing with poverty also be vulnerable (Barman & Islam, 2020; MoF, 2019). Again, climate policy-oriented training can be useful to recover the devastating situation of any flood affected areas with a chance to the vulnerability reduction (WHO, 2002). Most of the respondents did not get any training (95%) regarding climate adaption which represents another limitation of education level. So, lack of trainings for the resilience and as social components flood vulnerability were determined.

Employment status is regarded another characteristic of social and economic components. The diversified status of employment has low risk of vulnerability because stronger socio-economic features reflect better resilience in a specific region (Cardona et al., 2012). Unfortunately, all of the participants in the study lead their livelihoods depending on agricultural production, farming as main source of survival. At the same time, smallholders are affected by various difficulties in order to cultivate crops and managing production system in the current ongoing climatic variation, which also added other dimensions of weakness to adaptability.

Studies conducted by IPCC (2007b), Islam et al. (2016) and Lawrence et al. (2011) demonstrated that vulnerabilities also being increased with the more recurrent flood occurrences in a specific region. Similarly in this study, the heavy rainfall and frequencies of flood events in the livelihoods of smallholders make vulnerable because of involvement to exposure and susceptibility factors respectively. It is also evident that 81.8% farmers face floods and most of the flooding events are riverine (72.2 %) meaning that either upstream water from other rivers join to the region or heavy rainfall and existing water of the rivers submerge the region. The findings revealed that the people of these five villages experience heavy rainfall and flood twice (56%) in a year. In some areas, even everyday (54%) people face heavy rainfall especially from June to September and in the monsoon periods. Nonetheless, on the basis of these findings, it is unwise to generalize flood vulnerability because each region is different from others (Munyai et al., 2019).

The cropping variations and more cultivation as economic components has positive roles to reduce vulnerability. But the fact is that as the exposure factors, almost half of the respondents (44%) claimed variations of crop production did not play role for the vulnerability because crops are being damaged, submerged by the flood events. In the matter of food production, majority (70%) of the respondents argued that their paddy fields are greatly submerged while farmers mostly depended on paddy fields as main crops production. In addition, damages of seedbeds, vegetables, diseases of crops, and pond fish migration also contribute to the level of vulnerability.

Infrastructure is more crucial for the development of any country and acts as sensitive factors of vulnerability determinants. The more advanced infrastructure, the less opportunity to be vulnerable, but when the roads and bridges are damaged, submerged shelter centers, houses are washed away the ultimate results belongs to chances of vulnerability that happened mostly in the region.

There is a high social vulnerability compare to economic and environmental vulnerability in the study region. The smallholders are possessed by several factors for their vulnerability for instance;

Table 1: Flood vulnerability indicators, components, factors, relationship with vulnerability and description of respondents (N=110)

Indicators	Components	Factors	Relationship with vulnerability	Description	Responses %
Education/ literacy level	Social	Sensitivity/ susceptibility	Less education, high chances of vulnerability and low rate of consciousness	Illiterate Primary Secondary Higher secondary Graduation	45 37 13 3 2
Frequency of flood events	Environmental/ physical	Sensitivity/ susceptibility	Higher flood occurrence in a year, higher vulnerability	4 times 3 times 2 times 1 time	30 56 9 5
Infrastructure	Economic	Sensitivity/ susceptibility	Good quality of housing and infrastructure, low rate of vulnerability	Damage of road and bridges Flooded houses Damage of shelter center Electricity problem Transport and mobile network	23 47 18 7 5
Cropping/ cultivation	Economic	Exposure	Variations of cropping and more production, lower vulnerability	Aman rice Boro rice Jute Vegetables Corn Fish	38 32 10 7 5 8
Loss of crops/ cultivation	Economic	Exposure	More losses of crops/ cultivation, higher vulnerability	Crops damage Spread diseases Seedbeds Storage Migration of pond fish	44 31 10 8 7
Rainfall	Environmental /physical	Exposure	More and heavy rainfall, high chances of vulnerability	24 hours 72 hours Weekly Fortnightly Monthly	54 26 12 6 2
Employment status	Social/ economic	Resilience	More employment, less chance of vulnerability	Farmer Business Teacher No job	94 2 2 2
Warming system	Social	Resilience	Having warning, less vulnerability	Monsoon Event oriented Daily Weekly Monthly	8 17 68 5 2
Relief	Social/ economic	Resilience	More relief, less vulnerability	Dry food Money Animals Seeds No relief	62 15 8 6 9
Training on climate policy	Social	Resilience	Having training, less vulnerability	Yes No	5 95
Flood insurance	Social	Resilience	More insurance policies, less vulnerability	Yes No	7 93

Table 2: Flood adaptation strategies and description of respondents (N=110)

Adaptation options	Description	Respondents (%)
Alternative Livelihood/ employment	Driving rickshaw/auto rickshaw	32
	Shopkeepers	7
	Moving to safer place/migration	18
	Fish seller	3
	Day labor	25
	Working in garments	8
Loan/debt	Yes	78
	No	22
Flood resistant cropping	Very high	1
	High	1
	Medium	4
	Low	7
	Very low	87
Water purification	No boiling	7
	Boling	11
	Purifying by medicine	4
	No purification	78
Safety of shelter/house	Making hyacinth barrier	9
	Rising homestead	11
	Leaving house during flood	25
	Using rooftop	14
	No measure	41
Raising fund	Available fund	8
	Available distribution	9
	No active fund	72
	No measure	11
Dam/storage of carrying waterbody	Yes	7
	No	93

flood insurance, relief and warning system. For the resilience, relief is ranked on the top but the affected communities reported something silly. Because dry food items (62%) are distributed as flood relief though few of them reported money and cattle's, their numbers are not so high. Another important social component flood insurance (not registered 95%) is badly needed to the region, it can be very handy for the reconstruction of cottages and houses after disasters like floods. About weather warning, it is discovered that people unconsciously ignore warning forecast, though it broadcast daily (68%). We found several reasons regarding respondents' ignorance about weather warning such as; less social awareness, lack of trainings, inadequacy of access to information and traditional mentality of negligence. So, vulnerability remains in their shoulders directly or indirectly.

Adaptation strategies of smallholders

Several strategies were adopted for livelihood, for instance; rickshaw pulling, migrating to other place, what Ngie (2012) called relocation as part of the adaptations.

Some of respondents engaged in selling labor power, starting small business and started working in the industry. Interestingly, smallholders chose auto-rickshaw driving (32%) and involvement to day labor (25%) as alternative options instead of farming.

Consequently, due to the dependency on nature for agriculture, farming as main profession, the poor employment ability and inadequate earning, the community goes to loan (78%) though the interest rate hesitates them. Again, lack of resources makes them helpless because establishment of dam and such infrastructures need a great involvement, the responsibilities belong to the state and forcefully smallholders have nothing to do in this regard.

To the recovery and resilience of flood affected region specially the farmers, flood resistant cropping cultivation is urgent (ReliefWeb, 2017). The ways need to be implemented the flood resistant crops for the community, hasn't developed yet from the government and Bangladesh Agricultural Development Corporation (BADC) in the flood affected region. As a result, very low numbers of smallholders cultivate and practice flood resistant cropping system.

Hence, water is called life and when this water is contaminated by germs can be caused of dangerous disease. In the study region, maximum people drink water without any purification (78%) especially during the flood events. Even, boiling is impossible for some respondents, resulting various diseases and cost a lot to cure the diseases after the events. Saving the shelter is another option of adaptation, though few number attempt to make water hyacinth barriers, some people use rooftop, a greater number leaves house for survival and 41% takes no measure for the safety of housing what actually the real example of their economic and social conditions of the locality. In the developed nations, raising climate fund reduces the minimum losses of resources during and after flood events as recovery and rehabilitation stage (UNEP, 2010). Whereas in Bangladesh need more climate fund for the community level and its equal distribution to the root level so that victims can be beneficiary. The majority raised voice about active climate fund (72%) for the reconstruction of the smallholders to reduce the vulnerability.

Again, to correlate the current findings with other studies, we found similarities and dissimilarities relevant to flood adaptation strategies. For instance; Anik and Khan (2012) found that with the changes of climatic hazards, local people adopted a changing pattern to their current livelihood strategy. A study conducted by Ngie regarding coping strategies of flood affected people in Diepsloot, it is revealed that people adopted relocation and evacuation as coping mechanism (Ngie, 2012). In addition, Munyai et al. (2019) suggested various social and economic components, which contribute for determining respondent's capability and response power during flood events.

Conclusion and recommendations

From above discussion, it is concluded that smallholders of northern part of Bangladesh especially Saghata Upazila of Gaibandha district are vulnerable in facing flood events and adaptation strategies. Using conceptual framework of vulnerability Turner et al. (2019), 11 indicators are identified for measuring flood vulnerability utilizing four components of vulnerability. From the determinants of vulnerability, it is discovered that several indicators mostly influence to the vulnerability level of smallholder's livelihoods; poor literacy level, infrastructural rigidity, more frequencies of flood events, traditional cropping system and loss of crop production, insufficient relief, scarce resources, dependency on nature for agricultural production, no training and funds for rehabilitation. Again, socio-economic characteristics also responsible for their vulnerability with lack of resilience and sensitivity. However, smallholders adopted various strategies of adaptation, though there exist more challenges which should be undertaken as serious concern by the ministry of disaster management and relief for further safety of such flood affected communities around Bangladesh.

The following measures can be undertaken to build resilience against floods. Developing public awareness is vital for community resilience. Besides, efficient early warning systems can be reduced flood vulnerability. For this, effective campaigns about vulnerability and adaption strategies should be conducted by both the government departments and NGOs. Thus, local resilient funds can be raised for. Further, advanced response and recovery mechanisms for affected communities may be developed. The government should take effective initiatives for river engineering and settlements along the mighty rivers. Nonetheless, considering agrarian societal ecosystem in rural Bangladesh, agricultural research institutes and universities should invent more flood tolerant crop varieties for addressing national food security.

References

ActionAid. (2012). *Climate resilient sustainable agriculture: A real alternative to false solutions*.

Akter, J., Sarker, M. H., Popescu, I., & Roelvink, D. (2016). Evolution of the Bengal delta and its prevailing processes. *Journal of Coastal Research*, *32*(5), 1212–1226. https://doi.org/10.2112/JCOASTRES-D-14-00232.1

Alam, G. M. M., Alam, K., & Mushtaq, S. (2017). Climate change perceptions and local adaptation strategies of hazard-prone rural households in Bangladesh. *Climate Risk Management*, *17*, 52–63. https://doi.org/10.1016/j.crm.2017.06.006

Alam, M. (1996). *Subsidence of the Ganges—Brahmaputra delta of Bangladesh and associated drainage, sedimentation and salinity problems*. In J. D. Milliman and Bilal U. Haq (Eds), Sea-Level Rise and Coastal Subsidence: Causes, Consequences, and Strategies. Kluwer academic publishers. 169–192. https://doi.org/10.1007/978-94-015-8719-8_9

Anik, S. I., & Khan, M. A. S. A. (2012). Climate change adaptation through local knowledge in the north eastern region of Bangladesh. *Mitigation and Adaptation Strategies for Global Change*, *17*(8), 879–896. https://doi.org/10.1007/s11027-011-9350-6

Asian Development Bank. (2009). *Building Climate Resilience in the Agriculture Sector of Asia and the Pacific*.

Azad, A. K., Hossain, K. M., & Nasreen, M. (2013). Flood-induced vulnerabilities and problems encountered by women in northern Bangladesh. *International Journal of Disaster Risk Science*, *4*(4), 190–199. https://doi.org/10.1007/s13753-013-0020-z

Bangladesh Center for Advanced Studies (BCAS). (2001). *2001 State of Environment Report – Bangladesh*. http://www.sacep.org/pdf/Reports-Technical/2001-State-of-Environment-Report-Bangladesh.pdf

Barman, R. P., & Islam, M. (2020). Root Causes and Consequences of Extreme Poverty in Northern Bangladesh. 8(3). 139-146 DOI: 10.18034/abcra.v8i3.497

Brammer, H. (1990). Floods in Bangladesh. II. Flood mitigation and environmental aspects. *Geographical Journal (United Kingdom), Vol 156 (2), 158-165*. https://doi.org/10.3/JQUERY-UI.JS

Brown, S., Nicholls, R. J., Lázár, A. N., Hornby, D. D., Hill, C., Hazra, S., Appeaning Addo, K., Haque, A., Caesar, J., & Tompkins, E. L. (2018). What are the implications of sea-level rise for a 1.5, 2 and 3 °C rise in global mean temperatures in the Ganges-Brahmaputra-Meghna and other vulnerable deltas? *Regional Environmental Change*, *18*(6), 1829–1842. https://doi.org/10.1007/s10113-018-1311-0

Cardona, O. D., Van Aalst, M. K., Birkmann, J., Fordham, M., Mc Gregor, G., Rosa, P., Pulwarty, R. S., Schipper, E. L. F., Sinh, B. T., Décamps, H., Keim, M., Davis, I., Ebi, K. L., Lavell, A., Mechler, R., Murray, V., Pelling, M., Pohl, J., Smith, A. O., & Thomalla, F. (2012). Determinants of risk: Exposure and vulnerability. *Managing the risks of extreme events and disasters to advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*, *9781107025*, 65–108. https://doi.org/10.1017/CBO9781139177245.005

Chamberlin, J. (2007). Defining smallholder agriculture in Ghana: Who are smallholders, what do they do and how are they linked with markets? *Ghana Strategy Support Program (GSSP)*, *Background*.

ESPA. (2018). *Well-being in Deltas Integrated Assessment*.

FAO. (2002). *The role of agriculture in the development of least-developed countries and their integration into the world economy*. http://www.fao.org/3/a-y3997e.pdf

FAO. (2010). *"Climate-Smart" agriculture: Policies, practices and financing for food security, adaptation and Mitigation.*

Faruque, O. (2021). Socio-economic conditions of flood affected people of northern districts in Bangladesh. *ABC Journal of Advanced Research*, *10*(2), 147–158. https://

doi.org/https://doi.org/10.18034/abcjar.v10i2.587

Galderisi, A., Ceudech, A., & Pistucci, M. (2005). Integrated vulnerability assessment: The relevance "to" and "of" urban planning, in Proceedings (CD format) of the 1st ARMONIA Project Conference 'Multi-hazards: Challenges for risk assessment, mapping and management', Barcelona, Spain, 05–06 December, 2005, pp. 5–6

IPCC. (2007a). *AR4 Climate Change 2007: Impacts, Adaptation, and Vulnerability — IPCC.*

IPCC. (2007b). *Climate change: Impacts, adaptation and vulnerability*. Cambridge University Press. https://doi.org/10.1016/B978-008044910-4.00250-9

Islam, M. S., Solaiman, M., Islam, M., Tusher, T., & Kabir, M. (2016). Impacts of flood on Char livelihoods and its adaptation techniques by the local people. *Bangladesh Journal of Scientific Research*, *28*(2), 123–135. https://doi.org/10.3329/bjsr.v28i2.26783

Islam, S. N. (2016). Deltaic floodplains development and wetland ecosystems management in the Ganges–Brahmaputra–Meghna rivers delta in Bangladesh. *Sustainable Water Resources Management*, *2*(3), 237–256. https://doi.org/10.1007/s40899-016-0047-6

Kabir, H., & Hossain, N. (2013). *Climate change and sustainable development: Bangladesh.*

International Conference on Climate Change Impact and Adaptation (I3CIA-2013)

Center for Climate Change and Sustainability Research (3CSR), Department of Civil Engineering DUET - Gazipur, Bangladesh

Lawrence, J., Tegg, S., Reisinger, A., & Quade, D. (2011). *Vulnerability and adaptation to increased flood risk with climate change - Hutt Valley*. The New Zealand Climate Change Research Institute. *NZCCRI 2011 Report 02*, *October*.

Leya, R. S., Saha, D., Bala, S. K., & Huq, H. (2020). Gender vulnerability assessment due to flood in northern part of Bangladesh (A Case Study on 2017 Flood). In A. Haque & A. I. A. Chowdhury (Eds.), *Water, flood management and water security under a changing climate: Proceedings from the 7th International Conference on Water and Flood Management* (pp. 235–249). Springer International Publishing. https://doi.org/10.1007/978-3-030-47786-8_17

Mahendra Dev, S. (2011). *Climate change, rural livelihoods and agriculture (focus on Food Security) in Asia-Pacific region*. Indira Gandhi Institute of Development Research (IGIDR) Goregaon (E), Mumbai- 400065, INDIA.

Menoni, S., & Pergalani, F. (1996). An attempt to link risk assessment with land use planning: a recent experience in Italy. *Disaster Prevention and Management: An International Journal*, *5*(1), 6–21. https://www.academia.edu/11714901/An_attempt_to_link_risk_assessment_with_land_use_planning_a_recent_experience_in_Italy

Milliman, J. D., Broadus, J. M., & Gable, F. (1989). *Environmental and economic implications*

of rising sea level and subsiding deltas: The Nile and Bengal examples. Vol.18 Environmental Science AMBIO: *A Journal of the Human Environment*

https://agris.fao.org/agris-search/search.do?recordID=SE8900227

MoEF. (2005). *Bangladesh: National adaptation programme of action - NAPA (2005) - Policy, plans & statements.*

MoF. (2019). Climate financing for sustainable development. *Mininstry of Finance, People's Republic Bangladesh Government*, *Budget report 2019-2020*.

MoNREC. (2017). *Myanmar Climate Change Strategy and Action Plan (MCCSAP) 2016–2030*.

MoP. (2008). *Report on the cost of production of Aman paddy*. Updating and Extension of Agriculture Cluster Plots and Survey of Cost of Production Project (UCPSCP). Bangladesh Bureau of Statistics.

Munyai, R. B., Musyoki, A., Nethengwe, N. S. (2019). An assessment of flood vulnerability and adaptation: A case study of Hamutsha-Muungamunwe village, Makhado municipality', Jàmbá: *Journal of Disaster Risk Studies* 11(2), a692. https://doi.org/10.4102/jamba.v11i2.692

Myint, N., Martin, C., Kumar, V., & Barbour, P. A. (2015). *Myanmar country partnership framework for the period 2015-2017*. http://documents.worldbank.org/curated/en/132341486543566177/pdf/112661-WP-P147364-PUBLIC-myanmarcountrypartnershipframework.pdf

Ngie, A. (2012). *A GIS approach for flood vulnerability and adaptation analysis in diepsloot*. Published by: University of Johannesburg. https://www.google.com.bd/books/edition/A_GIS_Approach_for_Flood_Vulnerability_a/f6IxmAEACAAJ?hl=en

Ozaki, M. (2016). Disaster Risk Financing in Bangladesh (September 2016). ADB South Asia

Working Paper Series No. 46, September 2016, Available at SSRN: https://ssrn.com/abstract=2941319 or http://dx.doi.org/10.2139/ssrn.2941319

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X., Centeno, G. S., Khush, G. S., & Cassman, K. G. (2004). *Rice yields decline with higher night temperature from global warming*.

ReliefWeb. (2017). *Better farming practices for resilient livelihoods in saline and flood-prone Bangladesh*. https://reliefweb.int/report/bangladesh/better-farming-practices-resilient-livelihoods-saline-and-flood-prone-bangladesh

Rosengrant, M., & Cai, X. (2002). World water and food to 2025. International Food Policy Research Institute (IFPRI).

Samuels, P., Gouldby, B., Klijn, F., Messner, F., van Os, A., & Sayers, P. et al. (2009).

Language of risk – Project definitions. Flood site project report T32-04-01, HR Wallingford publishers. Project website: www.floodsite.net. https://repository.tudelft.nl/islandora/object/uuid:268e1ef4-7b45-4b4d-8504-13d2f252e4d9?collection=research

Seckler, D., Amarasinghe, U., Molden, D., de Silva, R., & Barker, R. (1998). World water demand and supply, 1990 to 2025: scenarios and issues. In *Research Report (IIMI)*. The International Irrigation Management Institute, Srilanka.

Shrestha, R. P., Raut, N., Maung, L., Swe, M., & Tieng, T. (2018). *Climate Change Adaptation Strategies in Agriculture : Cases from Southeast Asia*. 7(3), 39–51. https://doi.org/10.5539/sar.v7n3p39

Singh, U.P. (2002). Boro Rice in Eastern India. Rice-Wheat Consortium Regional Technical Co-ordination Committee Meeting. 10-14 February 2002. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India.

The Daily Star. (2017). Flood takes toll on crops. *The Daily Star* (Sep 6, 2017). https://www.thedailystar.net/country/flood-takes-toll-crops-1458109

Turner II, B. L., Kasperson, R. E., Matson, P. A., Mccarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., & Schiller, A. (2003). *A framework for vulnerability analysis in sustainability science*. www.pnas.orgcgidoi10.1073pnas.1231335100

UNDP. (2004). *A global report: Reducing disaster risk: A challenge for development*.

UNDSEA. (2008). *UNDESA Commission on Sustainable Development Sixteenth Session Addressing climate change in national sustainable development strategies - common practices.*

UNEP. (2010). *Green Climate Fund*. https://www.unep.org/about-un-environment/funding-and-partnerships/green-climate-fund

WHO. (2002). *Floods: Climate change and adaptation strategies for human health. A report on a WHO meeting*. 52.

Younus, M. A. F. (2014). Flood vulnerability and adaptation to climate change in Bangladesh: A review. *Journal of Environmental Assessment Policy and Management*, *16*(3), 1450024 (1-28) https://doi.org/10.1142/S1464333214500240

Bangladesh Rural Development Studies, 26(1), 2023 (39-47)

Bangladesh Rural Development Studies (BRDS)
ISSN 1019-9624; Web: www.rda.gov.bd

Live and livelihoods in wetland waterlogging: Study from southwest Bangladesh

Md. Reaz Mahmud[1*], Shaikh Mehdee Mohammad[2], and Hasan Imam Munna[3]

[1] Bangladesh Academy for Rural Development, Kotbari, Cumilla-3503, Bangladesh

[2] Rural Development Academy, Bogura-5842, Bangladesh

[3] Department of Geography and Environment, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh

ARTICLE INFO

Keywords:
Natural hazards
Waterlogging
Wetland livelihoods
Geo-informatics

Received: 25 November, 2022
Revised: 22 May, 2023
Accepted: 14 June, 2023

***Corresponding Email:**
reaz@bard.gov.bd

ABSTRACT

Waterlogging is a major hazard that often underestimated even by scientists and policymakers because of its slow onset effects on environment and society. However, it habitually brings miserable sufferings for the communities living around low-lying wetlands, generally called 'Beel' in Bangladesh and primarily depending on the natural resources of those wetlands for their livelihoods. The study examines the causes of prolonged waterlogging in Bhutiar Beel situated in Khulna district of southwest Bangladesh and how this hazardous event impacts on the livelihoods of the communities living around the wetland. The study has followed a mixed approach through using both quantitative and qualitative methods for collecting empirical data with questionnaire survey, in-depth interviews, and focus group discussion. Besides, satellite images from Landsat MSS, Landsat TM and Landsat ETM of different years have also been analysed to identify how the territory and area of Bhutiar Beel has been shrunk over the last couple of decades. Apart from increasing fish production, the study explores that crop production has drastically been decreased and the cropping pattern has been changed due to the localized wetland based livelihoods. The present study, however, recommends community based action plans such as disaster risk management and wetland based natural resource management may assist policymakers to formulate appropriate policies for sustainable livelihoods in wetlands.

How to Cite: Mahmud, M. R., Mohammad, S. M., & Munna, H. I. (2023). Live and livelihoods in wetland waterlogging: Study from southwest Bangladesh. ***Bangladesh Rural Development Studies, 26***(1), 39-47.

Introduction

Bangladesh is well-known as one of the most vulnerable countries to natural hazards across the globe. Water sector of the country would likely be affected significantly due to anticipated changes (Ahmed, 1998; 2005). Most of the adverse effects of climate change are in the form of extreme weather events, while water related hazards such as floods and waterlogging are likely to be exacerbated (Asaduzzaman, 1997; Choudhury, 2005; Huq, 1996; Mohammad, 2016).

Waterlogging is the recent concern at the backdrop of climate change that becomes worsens in the southwest Bangladesh (Awal, 2014). The study argued that the prolonged waterlogging had caused significant displacement presenting humanitarian challenges in safe water supply, sanitation, shelter, food security, employment opportunity and so on. There are areas where people are compelled to live in waterlogged condition for nine months in a year; even many cultivated croplands are permanently inundated losing valuable agricultural production especially, the rice production. Socio-economic and agricultural activities have largely been hampered due to waterlogging (Adri, 2010; Islam, 2012). Lives and livelihoods of the people in the southwest Bangladesh are greatly influenced by water availability. Water resources offer enormous potentiality in this region by providing income and employment opportunity for most of the people. Conversely, water resources have particularly detrimental impacts on the peoples' lives and livelihoods as well as biodiversity and environment (Masud, 2014). The rivers of southwest Bangladesh are characterized by active deposition of sediment causing significant reduction in their drainage capacity.

The rural people are seriously facing devastation when peak monsoon intercepts the region. Loss of livelihoods due to submergence of land often forces male to go far away for weeks in search of alternative livelihoods. Rural women being the primary care giver of the family are compelled to live within the waterlogged premises, shouldering the entire burden for managing and cooking food, collecting drinking water, taking care of the family members and their livestock as well. Social demoralisation, diseases, unemployment and migration have increased in the locality where the places protracted by waterlogging (Ahmed, 2000; Awal, 2014; Neelormi, 2009; Salauddin, 2011; Sarker, 2012).

Besides, construction of coastal polders that de-linked the flood plains from the rivers, and diminished upstream flow during the dry season deteriorated the sedimentation problem in the region. Consequently, the area has been experiencing severe drainage congestion and water logging since the early 1980s. In Khulna and part of Jashore districts, 39 polders (about 410,392 hectares) were constructed (Unnayan Onneshan, 2006). Sedimentation in the tidal rivers in the moribund delta of Southwest Bangladesh is the main reason behind waterlogging problem. These troublesome sediments have blocked the rivers and caused upstream drainage congestion and flooding (Tutu, 2009).

Millions of people, especially the poor and landless farmers, sharecroppers, agricultural wage workers, petty traders and others lost their livelihoods because of waterlogging. Waterlogging induced salinity has already damaged almost all varieties of vegetation in the region. Agricultural production has drastically reduced and even homesteads vegetation and cattle rearing become quite impossible (Moni, 2014).

Waterlogging is a complex hydro-geomorphological challenge in Bangladesh. Waterlogging has created a dynamic change in Bhutiar Beel at Terokhada Upazila (sub-district) in Khulna district where this study was conducted. In the wetland, continuous waterlogging for the last couple of decades is mainly due to river bed siltation and intensive rainfall. About 13 square kilometres area is covered by this waterlogging at Bhutiar Beel. Massive amount of crops is damaged regularly because of waterlogging. It also destroys the fisheries sector, particularly local shrimp farms and natural vegetation.

Aim and objectives of the study

The aim of the study is to examine the causes and impacts of waterlogging in the study site and how the livelihoods of the communities living around the wetland affected. The specific objectives of the study are:

i. To explore the reasons behind creating waterlogging in Bhutiar Beel;
ii. To understand vulnerability conditions occurred in the wetland due to waterlogging; and
iii. To investigate how the lives and livelihoods of the communities living around the wetland affected by waterlogging.

Research methods

Study area

The study area is Bhutiar Beel situated at Terokhada Upazila in Khulna district. The drainage system of the wetland is directly linked with the Atharobaki-Chitra River basin. The wetland that constituted from Shachiadah, Chagladah and Terokhada unions of Terokhada Upazila drains to adjacent Chitra River (Figure 1). The river finally drains to Atharobaki River and Kaliabordia River. Presently Atharobaki River is partially dead due to siltation; however, Kaliabordia River is still alive. Nevertheless, 5,329 hectares croplands of Bhutiar Beel become waterlogged due to recent siltation of Chitra River. Bhutair Beel is situated the northeastern part of Khulna district. Field works were undertaken in each of the nine villages over which the wetland spread such as Balardhana, Adampur, Saciadha, Pathla, Kushlo, Noliarchar, Kamarol, Indurhati and Adalatpur in three Unions (e.g. Terokhada, Saciadha and Pathla).

Data collection

To fulfill the objectives of the study both primary and secondary data were used. Data were collected from both formal and informal interviews, and focus group discussion (FGD) with community people living surrounding the wetland. A semi-structured questionnaire was developed, pretested and adopted prior to the actual survey properly. The key issues incorporated into the questionnaire are: (i) present status of the various habitats under Bhutiar Beel; (ii) fish biodiversity; and (iii) causes of habitat and biodiversity degradation and their possible mitigation measures. A total of 80 stakeholders including fishers, fish farmers, Upazila fisheries officers, local leaders, school teachers and housewives participated in this study. Nine FGD sessions were conducted in nine villages of Bhutiar Beel. The characteristics of the stakeholders were including the nature of any primary dependency on the wetland. Stratified scatter sampling was used for questionnaire survey. All the respondents have more than 20 years' experience on agriculture.

Data analysis

The spatial data has been analysed by using some GIS software namely ArcGIS 10.3 and statistical analysis by MS Excel. Finally, the both types of analysed data have been integrated and presented as maps, tables and graphs in the Study.

Results and discussion

Changes in the size and shape of the wetland basin

Earlier waterlogging in the wetland was a normal situation. During the dry seasons the wetland was used to dry out. Around 3.63 square kilometres that is the core point of Bhutiar Beel was deepest part of the wetland that was full of water year round (Figure 2).

That was the lower part of the basin. But after waterlogged the shape of the basin were changed. The area of deepest part also changed. Nowadays an area about six square kilometers of the wetland is inundated round the year. It seems to be a radical change of the shape and size of Bhutiar Beel basin. Waterlogging has made a dynamic change in the basin. This also affected the crops land around the wetland. These are the main causes for reducing crops production in this area.

Changes of soil quality

In the past, most of the area of the wetland was dried every year during the summer season. Then the farmers ploughed the land and harvested several rice varieties such as Aus, Aman and Boro. After some months, in rainy season the wetland again turned into a basin with full of water. It helps to maintain a balanced wetland ecosystem. Then water submerged the soil of the wetland only few months. Rainwater drained with sediments and other soil nutrients into the wetland which helped the local farmers to produce a variety of crops and vegetables round the year. But now the scenario is totally changed. A substantial part of the wetland is submerged round the year. It has a great impact on soil quality of the wetland. As the water cannot dry any time of the year, soil cannot be close to the atmosphere. So, soil cannot contain sufficient oxygen, nitrogen and other essential micro-elements which come directly from the atmosphere. Besides, sunlight cannot reach on the surface of the wetland. Waterlogging, however, creates favourable environment for growing of some water loving plants like water lily, lotus, water hyacinth and different types of darnels. The dead parts of these plants mix with the surface soil of the wetland. Thus, the soil quality of submerged surface of the Bhutiar Beel has been changed.

Fishes

Fisheries is one of the main means of the people living surrounding the wetland. However, a fish catch monitoring programme was introduced in the wetland area in 1997 through Community Based Fisheries Management (CBFM) Project. The project focused on developing community based approaches which would encourage participation of community people, particularly the fishers in sustainable fisheries management. The study explored the amount and varieties of fishes have increased from the past. According to the local authority, "due to waterlogging, water is available year round in the wetland. It helps for the production of fishes. Present varieties of fishes increased as well as the total amount. In the past, the wetland was dried out during the summer. Then most of the fishes were caught by the fisherman, farmer and even by other common people. So, the growth of most fish varieties is hampered. Some of them were relieved for the next generation. Some small fishes were grown enormously because they hatched on the dried field. Some of the varieties are Koi (Badis), Taki (spotted snakehead), Shing (torrent catfish), Puti (Pool Barb), roina (mottled Nandus), Khalisha (banded gourami), Shoil (striped snakehead), Gojal (butter catfish), Tangra (Tista Batasio), etc. Now many fishermen live their livelihood by catching fish through Bhutiar Beel. The inland fishery of Bangladesh is considered the most important aquatic resource of the country. How much of fish are being caught every year by the fishermen and how much money they get from this profession?

Croplands and cropping pattern

Unlike fish production, the croplands of Bhutiar Beel have decreased with apprehension rate. Before waterlogging the whole area was under cultivation. But now about 25-30% land are used as cultivable land. Most of the farmers have changed their occupation. They diverted their occupation and some of them lead hand to mouth life. Waterlogging of Bhutiar Beel also shrunk the crop land.

Cropping pattern does not exist in the wetland which was continued in the past. Waterlogging has brought a radical change in cropping pattern. In the past, the whole area of the wetland was used to produce Aus and Aman rice varieties. The production of Aman rice was very good. The farmers were very happy because they more production of crops made them well off. But they became poorer because of lack of agricultural land. Waterlogging has brought about a huge change in crops production and pattern. Most of the upper land is not suitable for Aman production. So they have to change their cropping pattern and the local farmers have to switch from one crop to others. The study also found that the production of other crops is not well than the before.

Flora and fauna

There have been a comprehensive changed in flora and fauna at Bhutiar Beel. As the wetland maintained alternately a wetting and drying cycle is suitable for growing and living a diverse nexus of flora and fauna. Nowadays the wetland does not get dry up even in winter due to waterlogging. About 60-70% of the total area of the wetland is submerged round the year. Thus, some new types of flora and fauna grow. The plants which can grow in water and can live on or under water are available in Bhutiar Beel such as water lily, lotus, water hyacinth, and different types of darnels.

Availability of birds

The numbers of birds have increased due to waterlogging in Bhutiar Beel. The number of local birds has increased as well as a substantial number of migratory birds are available. The wetland is full of many types of small fish and insects which are being used as feed of birds. On the other hand, different type of water plants and darnels helps birds to make their nest.

Level of water

The average water level has been increased due to waterlogging. Every year in rainy season, floods occur in the wetland. Floods regularly damage shrimp farms surrounded by the wetland. On the other hand, some crops are cultivated around the side of the Bhutiar Beel. But sudden flood hampers these crops. In the past the water level was very low which was suitable for crop production and shrimp culture. But, nowadays, high floods hamper the local livelihoods and put the communities at risk.

Impact of waterlogging on livestock

There were around 3,000-4,000 cows rearing surrounded villages of Bhutiar Beel and primarily depended on the wetland for their fodder. Nowadays grass cannot grow properly in submerged areas. Although some water grasses grow, the production is low and cattle do not like to eat them. Meanwhile, the price of industry based fodder is gradually increasing. As a result, traditional dairy farmers are reducing their cows and searching alternate way of living.

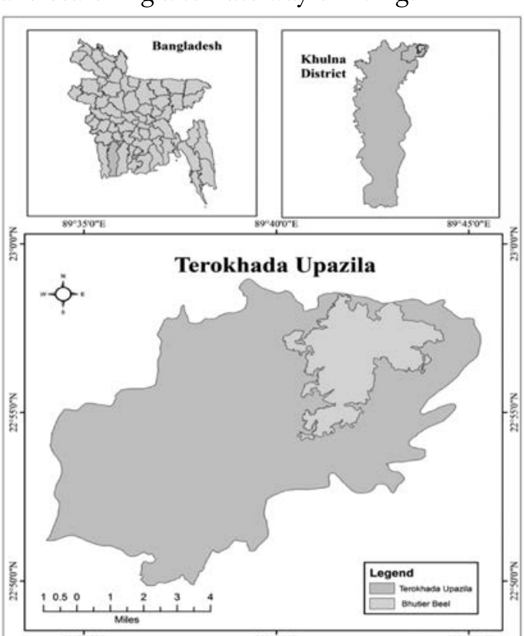

Figure 1: Map of the study area

Waterlogging and community vulnerability

The associated communities are directly affected by waterlogging of Bhutiar Beel in many ways. This study has a special emphasis on to find out the relation between waterlogging and surroundings community. This study found that waterlogging has many type of impact on associated community. Waterlogging has created many social disruptions like children school dropout, housing, healthcare, drinking water, sanitation and hygiene, market facilities, women's mobility and so on. The opportunities of paid work e.g. reduced crop production, transport disrupted, stifled non-farm activities are gradually declining. In agriculture sector, depressed Aman season production; possible reduced yield and returns from Boro. Conversion of crop land to shrimp farm has great impact on localized livelihoods. Earlier sharecroppers could produce rice by leasing or rented lands from others but after introducing shrimp farming this group of landless sharecroppers have no choice to either work as wage labourers in shrimp farms or migrate outside their localities. Such observation has already been addressed in a number of previous studies, for example, Mohammad (2016). The findings of FGD sessions indicate that there are some other direct impacts of waterlogging in terms of increasing community vulnerability such as shrunk crop land, reduction of crop production, particularly rice, jute, wheat, sugarcane, etc., unexpected floods, loss of plants, shrimp culture and other fisheries, and increase of poverty and malnutrition.

Causes of waterlogging

There are many causes of waterlogging in Bhutiar Beel. However, the main cause is inadequate drainage system. Velocity of river water is very low. It increases the pattern of siltation on wetland bed and decreases the drainage capacity. Over the period, the natural drainage system has been collapsed and created waterlogging in the wetland.

Intensive rainfall is another main cause of waterlogging of this wetland. From FGD session,

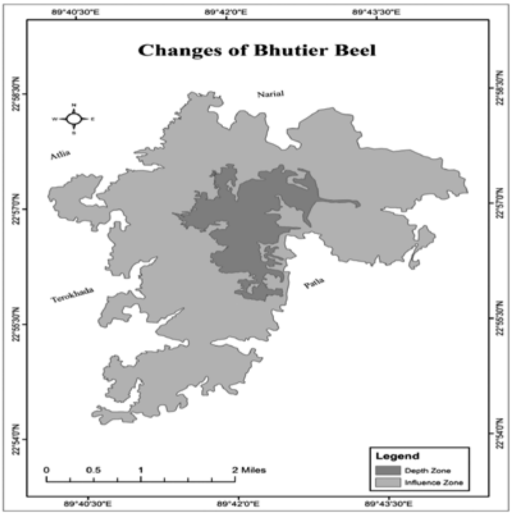

Figure 2: Changes between before and after waterlogging of Bhutiar Beel

heavy rainfall of July 2015 turned it into flooding and became a permanent waterlogging scenario. About 81% of the respondents considered intensive rainfall as one of the main causes of waterlogging of Bhutiar Beel. Sometimes water from linked wetlands accelerates the situation of waterlogging. Besides, river tides play a vital role increasing the water level of Bhutiar Beel.

Impact of waterlogging

Almost all respondents (95%) opined that waterlogging has negative impact in every aspect. Most of the farmers lose their valuable land. At present it is very challenging to maintain their livelihoods. However, a little number of the respondents (5.0%) gave positive answer because they are fishermen.

Waterlogging of Bhutiar Beel declined crop production around 1,300 ha land (Table 1). Like the rest of the country, rice is the main crop of this wetland mainly Boro. Earlier Aman was famous variety of rice of this Beel. Jute, wheat and sugarcane etc. also produced in this area. Nowadays the economic condition of most of the local farmer is miserable.

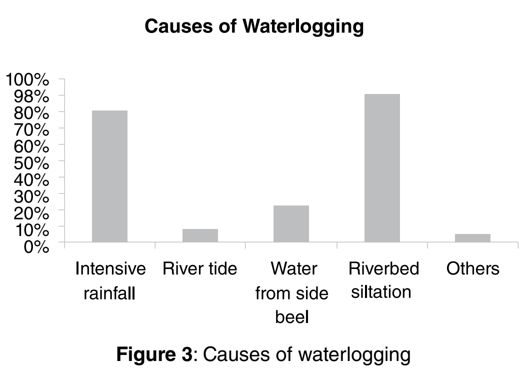

Figure 3: Causes of waterlogging

Table 1: Impact of waterlogging

Types of impact	Parentage (%)
Declined crop production	100
Damaged shrimp culture and pisciculture	76
Shrunk cultivable land	85
Create unusual flooding	64
Affected livelihoods	93
Impact on natural vegetation	57
Others	12

Many shrimp farms were prepared in Bhutiar Beel during mid-80s and early 90s of the last century. After waterlogging the wetland inundated every year. So farmer cannot continue the loss; they stopped it. This waterlogging also destroyed all types of pisciculture. It has a negative impact on our national economy. The land which was the main resource of their economy is now inundated. The impact of water logging is immeasurable.

Waterlogging and changes of land use pattern

Waterlogging has direct impact on local land use pattern. To explore the actual condition of this study area, satellite image analysis has been done and for that reason three satellite images have collected and interpreted with interval of 20 years (1973, 1995 and 2015). Waterlogging shrunk the cultivate land. At present the amount of cultivate land is 820 acre which was 3,417 acre in 1995. Water body contains 4,541 ha at present and it was 752 in 1995.

In 1973, estimated agricultural land in Bhutiar Beel was 28% (Table 2). In that time a substantial area of the wetland was useable for agriculture (Figure 4). It is observed from the map that there were few deepest parts of the wetland. The amount of core water body of the

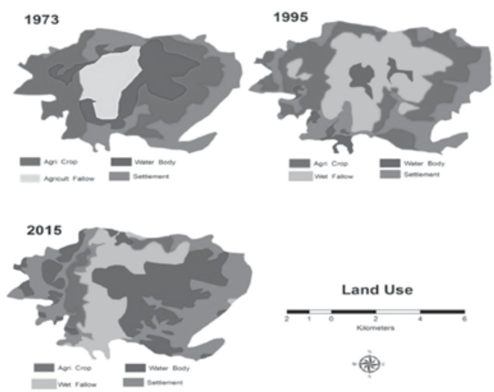

Figure 4: Satellite image analysis of 1973, 1995 and 2015 (**Sources**: Landsat MSS, Landsat TM, and Landsat ETM)

wetland was 21.83%. Aman rice was cultivated about total area of the study area. In the side of the wetland rest of highland are shown in that map. That represent the residential areas and

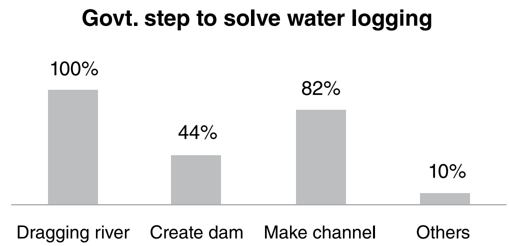

Figure 5: Causes of waterlogging

some are cultivated over the year.

In 1995, the agricultural land (28.39%) was slightly increased whereas amount of water body (6.25%) was dramatically declined compared to 1973. However, the deepest part of the wetland also increased. The amount of Wet fallow land (34.08%) increased very rapidly whereas cultivable croplands decreased at the same time.

In 2015, waterlogging situation has changed the land use pattern of Bhutiar Beel. Around 37% of the

Table 2: Land use data of Bhutiar Beel in 1973, 1995 and 2015

Name of the villages	Year	Water body	Agriculture fallow land	Agriculture cropland	Settlement	Grand total
Atlia	1973	218	584	698	608	2108
	1995	56	916	345	787	2104
	2015	628	821	143	529	2121
Chamta	1973	177	0	308	407	892
	1995	1	273	295	270	839
	2015	381	0	0	515	896
Joy Sena	1973	150	0	0	490	640
	1995	0	87	207	358	652
	2015	219	0	59	374	652
Kamarol	1973	1134	39	1118	1256	3547
	1995	76	1170	1066	1179	3491
	2015	1459	522	128	1475	3584
Patla, Nachunia & Gobindapur	1973	868	1023	1270	844	4005
	1995	572	1504	1310	618	4004
	2015	1672	1360	204	839	4075
Terokhada	1973	99	111	0	717	927
	1995	47	152	194	553	946
	2015	182	72	286	406	946
Grand total	**1973**	**2646**	**1757**	**3394**	**4322**	**12119**
	1995	**752**	**4102**	**3417**	**3765**	**12036**
	2015	**4541**	**2775**	**820**	**4138**	**12274**

total area of the wetland became water body. Not only low land it also submerged the major portion of the high cultivate land. 60% of the wetland is covered by water over the year. The rest of 40% is also covered by water for about 10 months of the year. Aman production is totally destroyed. Water also shrunk the Boro cultivated land. About 80% of Boro cultivation reduced for waterlogging.

Government initiatives to address waterlogging

The government has taken some steps to solve this problem. Dredging the Atharobaki and Chitra Rivers is the big government project in this area (Figure 5). Most of the respondents are concerned about the project activities. Although the local government institutions have taken some steps like building earthen dams and cutting channels, they created many dams around the wetland that may stop water flows from the surrounding wetlands. They made five channels which may discharge water from the wetland.

Figure 5: Government steps to solve waterlogging problem

Are the government initiatives sustainable?

When this question was asked to the local farmers, 76% of them gave negative voice. But most of them said that "these activities will solve the problem for a short time. After 1-2 years we will face this problem again". They argued dredging rivers and wetlands was an expensive option and drained public money into inappropriate solutions. Besides, dredged soil is often piled off along the riversides and within few months the soil slop down on river bed. Such activities hamper riverine and wetland ecosystems. On the other hand, rest of 24% of the respondents agreed to dredge works and canal cut in immediate actions but they also claimed that we looked for a sustainable solution. When it was asked about what the sustainable solution is, they simply replied that we should accumulate both scientific and local knowhow but we should sincerely consider phenomena such as river morphology, wetland and riverine ecosystems, local lives and livelihoods.

Conclusion and recommendations

Exploring the best adaptation practices are time demanded with the prevention and mitigation of waterlogging in the region (Awal, 2014). Local government institutions (LGIs) like Union Parishad and even Upazila Parishad have few options to solve the issue. However, both LGIs take some immediate actions to help affected people. Nonetheless, the concerned Upazila Parishad pursued to the central government taking permanent solutions through the relevant departments. An appropriate coastal zone water management policy can guide the local level practitioners taking sustainable solutions.

Farakka Barrage reduced the water flow of Padma River and her tributaries (Kawser & Samad, 2016) and that has a direct impact on wetlands of southwestern Bangladesh like Bhutiar Beel. Water velocity of the Chitra and the Atharobaki Rivers is very low which increases the riverbed siltation. Finally, interrupts on water discharge from Bhutiar Beel creates waterlogging. The study has already highlighted that a substantial number of farmers ware losses their cultivable lands in Bhutiar Beel. Local initiatives especially by the LGIs failed to solve the problem. Thus, continuous and sustainable channelization of river flows is a main solution with the special attention to societal issues like local lives and livelihoods. Appropriate policies such as coastal zone water management and wetland management will guide local practitioners to implement sustainable community based projects and programmes. Then we can hope the communities, particularly 6,000 marginal farmers in Bhutiar Beel protect their cultivable lands from waterlogging.

References

Adri, N., & Islam, I. (2010). Water logging in Keshabpur: a focus to the coping strategies of the people. *Proceeding of International Conference on Environmental Aspects of Bangladesh (ICEAB10)*, September 2010, Japan. http://benjapan.org/iceab10/6.pdf

Adri, N., & Islam, I. (2012). Vulnerability and coping strategies in waterlogged area: A case study from Keshabpur, Bangladesh. *Int. J. Environ*, *2*(1). 48–56.

Ahmed, A. U., Alam, M., & Rahman, A. A. (1999). Adaptation to climate change in Bangladesh: Future outlook. In Huq, S., Karim, Z., Asaduzzaman, M., & Mahtab, F. (Eds.), *Vulnerability and adaptation to climate change for Bangladesh.* Dordrecht: Springer Netherlands, 125–143.

Ahmed, A. U. (2005). Adaptation options for managing water related extreme events under climate change regime: Bangladesh perspectives. In Mirza, M. M. Q., & Ahmad, Q. K., *Climate change and water resources in South Asia*. Balkema Press, 255-278.

Asaduzzaman, M., Reazuddin, M., & Ahmed, A. U. (1997). *Global climate change: Bangladesh episode*. Department of Environment, Government of the People's Republic of Bangladesh.

Awal, M. A. (2014). Water logging in southwestern coastal region of Bangladesh: Local adaptation and policy options. *Science Postprint***.** doi:10.14340/spp.2014.12A0001

Choudhury, A. M., Neelormi, S., Quadir, D. A., Mallick, S., & Ahmed, A. U. (2005). Socio-economic and physical perspectives of water related vulnerability to climate change: Results of field study in Bangladesh, Science and Culture (Special Issue), 71(7-8): 225-238.

Huq, S., Ahmed, A.U. and Koudstaal, R., (1996) Vulnerability of Bangladesh to climate change and sea level rise. In Downing, T. E. (ed.), *Climate change and world food security*, NATO ASI Series, 137, Springer-Verlag, Berlin, Hiedelberg, 347-379.

Kawser, M. A., & Samad, M. A. (2016). Political history of Farakka Barrage and its effects on environment in Bangladesh. *Bandung: Journal of the Global South, 3*, 16. https://doi.org/10.1186/s40728-015-0027-5

Masud, M. M. A., Moni, N. N., & Azad, A. K. (2014). Impacts of water logging on biodiversity – Study on south-western region of Bangladesh. *Journal of Environmental Science, Toxicology and Food Technology*, 8(9), 20-27.

Mohammad, S. M. (2016). *Adaptation to climate change through disaster risk reduction in Bangladesh: Community engagement in local level intervention*, PhD Thesis. Northumbria University.

Neelormi, S., Adri, N., & Ahmed, A.U. (2009) Gender dimensions of differential health effects of climate change induced water-logging: A case study from coastal Bangladesh. *IOP Conf. Ser.: Earth Environ. Sci.* 6(14): p. 142026. doi:10.1088/1755-1307/6/4/14202

Salauddin, M., Ashikuzzaman, M., (2011) Nature and extent of population displacement due to climate change-triggered disasters in the south-western coastal region of Bangladesh. *Manage. Environ. Quality: An Int. J.*22 (5). 620–631.

Sarker, S. S. B. B. (2012). *Why water logging in southwestern region of Bangladesh?* Physical geography – a web based academic blog. http://www.pg-du.com/why-water-logging-in-southwestern-region-of-bangladesh

Tutu, A. U. A., Masum S. J. H., Tipu, M. A. R., & Hasan, M. M. M. (2009). Tidal river management in Bangladesh: People's initiative on coastal river basin management to solve water logging in the southwest coastal region of Bangladesh. In Water for the People Network (ed.) *Water for the People. People's Water Resource Management Strategies,* pp. 1–30. http://www.w4pn.org/index.php/w4pn-resources-download/doc_download/2-water-for-the-people-peoples-water-management-strategies.pdf

Unnayan Onneshan. (2006). The development disaster: Waterlogging in the southwest region of Bangladesh. *IFI Watch Bangladesh, 3*(2), 1–9. http://www.unnayan.org/documents/International_Economic_Relations/IFIv3n2.pdf

Bangladesh Rural Development Studies (BRDS)
ISSN 1019-9624; Web: www.rda.gov.bd

Adoption of rice production technologies: Experience from farmer field schools in Bangladesh

M. Nazrul Islam[1*], M. Hammadur Rahman[2], M. Zulfikar Rahman[2]

[1] Department of Agricultural Extension, Ministry of Agriculture, Bangladesh.

[2] Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh, Bangladesh.

ARTICLE INFO

Keywords:
Adoption
Farmer field school
Integrated farm management
Department of Agricultural Extension
Rice production technologies

Received: 11 December, 2022
Revised: 26 May, 2023
Accepted: 14 June, 2023

***Corresponding Email:**
nazrul67588@gmail.com

ABSTRACT

Adoption of improved agricultural technologies is important drivers of agricultural development. On the other hand, farmer field school (FFS) approach is an important extension approach to disseminate the technologies provided an empirical framework for the study. The main focus of this study is to determine the extent of adoption and factors affecting adoption of selected rice production technologies in Bangladesh using the FFS approach. A sample of 338 farmers (including 182 FFS farmers and 156 non-FFS farmers) was chosen for the study using random sampling. Data were collected from Kaliganj Upazila under Lalmonirhat district in Bangladesh where the Department of Agricultural Extension (DAE) implemented FFSs under integrated farm management component (IFMC) Programme from the first phase (2013-2018). Data were collected by using a pre-test interview schedule. The Statistical Package for Social Sciences (SPSS) version 20 software was employed in analyzing primary data. As per results, the adoption rate was found to be higher among the FFS farmers compared to non-FFS farmers. Factors (farmers' characteristics) like innovativeness, risk orientation, knowledge on Integrated Farm Management (IFM), extension media contact, and access to market facilities affected adoption of rice production technologies. Therefore, it is recommended that the Department of Agricultural Extension (DAE) conduct more FFS in the country, and five factors, namely risk orientation, extension media contact, innovativeness, market access and knowledge on integrated farm management that significantly affect adoption, should be taken into account when disseminating new technologies for rice cultivation. The findings of the study may be a support for DAE and other extension organizations in planning to further design programmes filling the research gap in rice production of the country.

How to Cite: Islam, M. N., Rahman, M. H., & Rahman, M. Z. (2023). Adoption of rice production technologies: Experience from farmer field schools in Bangladesh. *Bangladesh Rural Development Studies, 26*(1), 49-60.

Introduction

The world population is increasing day by day. It is no longer possible to meet the needs of increasing numbers of world population and to achieve food security by expanding areas under cultivation since the fertile land is not increasing over time. But this problem can only be solved by increasing agricultural productivity of farm households. However, achieving agricultural productivity growth will not be possible without developing and disseminating yield-increasing technologies and adoption of these technologies by farm households (Challa and Tilahun, 2014).

In Bangladesh, almost 72% of the cropped land is used to grow rice, which accounts for more than 90% of the grain production in the country (BBS, 2018). Rice productivity and total rice output in Bangladesh have chance to expand if appropriate management technologies are applied. However, farmers usually do not use improved agricultural technologies, which cause a yield gap between the farmer's field and the possible output of a specific variety of rice in the country (Shelly et al., 2016). It is true that in order to make a beneficial impact on agriculture, it is essential to convey modern technologies to rice farmers and encourage their adoption of those technologies. The farmer field school (FFS) is a popular way to teach farmers how to make farming decisions that fit different and changing field conditions (Van den Berg et al., 2020). It is obvious from the existing literature that the adoption of technologies is influenced by a number of factors (Farid et al., 2015). Understanding the factors that influence or hinder adoption of agricultural technology is essential in planning and executing technology related programmes for meeting the challenges of food production in developing countries (Mwangi & Kariuki, 2015). Some studies (Hossain, 2017; Jacob, 2012; Kabir, 2015; Moniruzzaman, 2009; Roy et al., 2013) have been undertaken in Bangladesh addressing different farming components and constraints related to FFS approach. But no direct study was conducted on adoption of modern technologies through FFS. On the other hand, it is a great challenge to recognize the major adoption barriers in order to successfully encourage farmers' adoption of advanced agricultural technologies (Zheng et al., 2022). To find the way to overcome this challenge, a number of adoption related studies were undertaken by Miah et al. (2015), Nazu et al. (2021), Rahman et al. (2020), and Sarker et al. (2021). However, not enough literature related to adoption of agricultural technologies at the household level is available in the country (Tama et al., 2021). Considering the facts, the researcher has undertaken the study to get answers of the following research questions:

i. What is the status of FFS and non-FFS farmers in adopting rice production technologies?
ii. What are the factors affecting the adoption of rice production technologies transferred through FFS by the farmers?

Materials and methods

Locale, population and sample

The study was conducted at Kaliganj Upazila in Lalmonirhat district, the northern part of Bangladesh where 52 integrated farm management FFS (IFM-FFS) were implemented during 2013–2018. An experimental design was used in association with a cross sectional survey. Using Cochran's (1977) sample size formula 182 farmers were randomly selected from the list of 2600 FFS farmers. As there is no list of non-FFS farmers and potential participants were hard to find, 156 non-FFS farmers were randomly selected from the same communities of FFSs in eight unions (at least 18 per union). Thus, a total of 338 farmers (both FFS and non-FFS) were selected as a sample for the study.

Variables and their measurement

Farmers' adoption of rice production technologies was the main focus variable of the study. Ten technologies out of 21 transferred through IFM-FFS were chosen for the study based on judge ratings. The technologies were ideal seedbed, proper aged seedlings, roguing, line transplanting, farm yard manure (FYM), vermicompost, guti urea and light trap. Adoption of these technologies was measured by asking the respondents whether they adopted the technologies or not where the responses for a particular technology were coded as 1 and 0, respectively. Sixteen characteristics of the farmers

Table 1: Selected characteristics of the farmers and their measurement

Farmers' characteristics	Methods of measurement
Age	Measured based on actual years
Level of education	Unit scores (1, 2, 3 etc.) was given for each completed schooling year
Household size	Total number of household members
Farm size	Total land owned by the respondents measured in hectare (ha)
Annual household income	Measured by calculating annual household income of a respondent from different sources (calculated in Thousand Taka)
Farming experience	Year of farming experience of the respondents
Aspiration	A 4-point rated scale (score 0, 1, 2 and 3 for four options) was used for nine items of aspiration. Possible score range was 0 to 27.
Training exposure	Measured by counting duration of different training received in days
Risk orientation	A 5-point Likert scale (1, 2, 3, 4 and 5 for 'strongly disagree', 'disagree', 'undecided', 'agree' and 'strongly agree' respectively) was used for nine items of risk orientation. Possible score range was 9 to 45.
Extension media contact	A 4-point rating scale (0, 1, 2 and 3 for contact with media as 'frequently', 'occasionally', 'rarely' and 'not at all' respectively) was used for twelve items of extension. media contact. Possible score range was 0 to 36
Credit exposure	Measured based on credit received by a respondent in the previous year expressed as thousands of taka.
Innovativeness	Measured based on the extent of adoption of specific technology using by a respondent. A 4 point rated scale (0, 1, 2, and 3 for 'do not use', 'adopted after 1 year', 'adopted after 2-3 year' and 'adopted after 4-5 year') was used for ten innovations (modern technologies. Possible score range was 0 to 30.
Organizational participation	Measured based on the degree of a respondent's involvement in all organizations. A 4 point rated scale (0, 1, 2, and 3 for extend of participation as 'no involvement', 'ordinary member', 'executive committee member' and 'president/secretary/treasurer. Secretary/ Treasurer) was used for nine items. Possible score range was 0 to 27.
Attitude towards FFS	A 5-point Likert scale (1, 2, 3, 4 and 5 for 'strongly disagree', 'disagree', 'undecided', 'agree' and 'strongly agree' respectively) was used for ten items. Possible score range was 10 to 50
Market access	A 5-point rated scale (1, 2, 3, 4 and 5 for degree of facilities as 'very poor', 'poor', 'average', 'good' and 'very good') was used for three items regarding nature of market access for the respondent. Possible score range was 10 to 50.
Knowledge on IFM	Measured assigning score for twenty items as per Bloom's revised taxonomy of cognitive learning domain (Anderson and Krathwohl, 2001). Twenty one items were assigned for different knowledge components (Scoring for remembering-04, understandning-04, understanding-04, applying-04, analyzing-04, evaluation-03 and creating-02).Possible score range was 0 to 43.

were considered as factors (independent variables) affecting the adoption. The variables were measured as stated in the Table 1. Test-retest (Table 2) was done in this study as it is one of the most straightforward methods for estimating reliability. In this case, a correlation (the r' value) was found to be greater than 0.90, which is considered good for perceptual field tests (Hajjar, 2018). The values of the Chronbach's alpha (between 0.6 and 0.8) used to measure the internal consistency for the items of the scale variables (Table 3).

Table 2: Results of the test-retest method for scale variables

Sl. No.	Variables	Test-retest 'r' value (N=20)
1	Aspiration	0.962**
2	Risk orientation	0.984**
3	Extension contact	0.996**
4	Innovativeness	0.948**
5	Attitude towards FFS	0.924**
6	Market access	0.989**
7	Knowledge on IFM	0.995**
8	Attitude towards intension	0.917**
9	Subjective norms	0.988**
10	Perceived behavioural control	0.993**
11	Intensions to adopt technologies	0.914**
12	Adoption of rice production technologies	0.996**

Data collection and analysis

A structured interview schedule was developed in accordance with the objectives of the study and through a series of activities, which include literature review, discussion with the farmers of the study area and consultation with the academicians, extension experts and researchers from various research institutes and universities. The interview schedule was piloted among 20 farmers of the study area and necessary modifications and improvements were done based on the experiences of the pilot study. Data were collected by the researcher through face-to-face interviews using the pre-tested structured interview schedule from August to November, 2021. Data were coded, compiled and analyzed with the use of SPSS version 20. Descriptive statistics like frequency distribution, percentages, mean and standard deviations were used to describe the characteristics of the respondents and the main variables. The t-test for the difference in mean values was done to compare the specific characteristics of FFS and non-FFS farmers. The Pearson correlation coefficient was used to examine the probability relationship between adoption and specific farmer characteristics.

Table 3: Results of the internal consistency for the items of scale variables

Sl. No.	Variables	Chronbach's Alpha (n = 338)
1	Aspiration	0.777
2	Risk orientation	0.709
3	Extension contact	0.736
4	Innovativeness	0.606
5	Attitude towards FFS	0.724
6	Market access	0.721
7	Knowledge on IFM	0.812
8	Attitude towards intension	0.654
9	Subjective norms	0.580
10	Perceived behavioural control	0.846
11	Intensions to adopt technologies	0.606
12	Adoption of rice production technologies	0.704

Linear and stepwise multiple regression analyses were conducted in order to determine the overall influence of the characteristics on the adoption of selected agricultural technologies for rice production. Only factors with a significant association to rice production technology adoption were included in the regression analysis model.

Results and discussions

Socio-economic characteristics of farmers

In total 16 socio-economic characteristics of respondent farmers were taken into account for the study. The characteristics were age, education, household size farm size, annual household income, farming experience, aspiration, training exposure, risk orientation, extension contact,

Table 4: Salient features of the selected characteristics of respondents

Characteristics (Measuring unit)	Possible range	Observed range		Mean and Standard deviation		't' value for difference of means
		FFS farmer	Non-FFS Farmer	FFS farmer	Non-FFS farmer	
Age (Year)	Unknown	23-76	25-76	46.66 (11.53)	47.30 (13.40)	-0.473
Level of education (Level of pass year)	Unknown	0-14	0-14	6.97 (4.47)	5.36 (4.54)	3.274**
Household size (Number of person)	Unknown	1-15	1-12	5.32 (2.11)	5.01 (1.97)	1.372
Farm size (Hectare)	Unknown	0.06-4.87	0.11-3.93	1.11 (0.78)	0.75 (0.56)	4.768**
Annual household income (Thousands Taka)	Unknown	55-1530	87-1127	387.86 (197.23)	278.90 (158.6)	2.487*
Farming experience (Year)	Unknown	5-60	3-60	31.26 (14.07)	30.49 (12.24)	-0.536
Aspiration (Scale score)	0-27	3-23	7-24	15.20 (4.1)	13.46 (3.73)	4.028**
Training exposure (Days)	Unknown	0-90	0-10	2.30 (7.80)	0.30 (1.25)	3.167**
Risk orientation (Scale score)	9-45	21-40	19-35	31.84 (3.96)	26.56 (3.217)	13.303**
Extension media contact (Scale score)	0-36	4-22	2-20	14.13 (3.67)	9.16 (3.23)	13.105**
Credit exposure (Thousands Taka)	Unknown	0-600	0-200	26.19 (60.22)	10.49 (26.70)	3.012**
Innovativeness (Scale score)	0-30	5-24	2-16	11.66 (3.22)	7.38 (2.35)	13.746** (0.000)
Organizational Participation (Scale score)	Unknown	0-114	0-120	12.18 (19.76)	4.46 (13.92)	4.089**
Attitude towards FFS (Scale score)	10-50	24-45	21-37	35.30 (4.15)	30.53 (3.30)	11.563**
Market access (Scale score)	3-15	5-12	6-12	8.96 (1.32)	8.57 (1.28)	2.689**
Knowledge on IFM (score)	0-43	14-43	3-35	27.59 (5.42)	18.46 (4.26)	16.999**

SD[1]= Standard deviation

***** P<0.01, **P<0.05 and *P<0.10 are the level of significance**

Table 5: Categories of the respondent farmers based on their overall adoption status of rice production technologies

Possible score range: 0-10, observed range:1-9

Categories based on adoption of technologies (score)	FFS farmer (n=182)		Non-FFS farmer (n=156)		FFS farmer		Non-FFS farmer		't' value (for compare means)
	Freq.	Percent	Freq.	Percent	Mean	Std.	Mean	Std.	
Non adoption (0)	0	0	2	1.3	6.70	1.14	4.21	1.36	18.38***
Low adoption (Less than 4)	3	1.6	41	26.3					
Medium adoption (4 to 7)	138	75.9	112	71.8					
High adoption (above 7)	41	22.5	1	0.6					

Freq. = Frequency; Std. = Standard deviation, ***= P<0.01

credit exposure, innovativeness, organizational participation, attitude towards FFS, market access and knowledge on IFM. Based on the analysis, it was found that most of the farmers were between middle-aged and old. The highest proportion of the farmers had secondary level education, while a considerable portion had no formal education or was illiterate. Because of the FFS selection procedure, a few FFS farmers had a graduate or higher level of education. The average household size of both FFS and non-FFS farmers (5.32 and 5.01 persons, respectively) was higher than the national average of 4.06 (BBS, 2018a). The majority of FFS (56.6%) and non-FFS (69.9%) farmers were classified as small to medium. The majority of FFS farmers (43.4%) had a high annual income, while the majority of non-FFS farmers (46.8%) had a low annual income. The majority of FFS (88.5%) and non-FFS farmers (85.3%) had high levels of farming experience. The majority of farmers, both FFS and non-FFS, had a moderate level (above 60%) of aspiration. FFS farmers received more training than non-FFS farmers. It could be observed that the majority of FFS farmers (60.5%) had a medium to high level of risk orientation. On the contrary, most of the non-FFS farmers (93%) were medium-risk oriented, and only a negligible portion (1.9%) had a high-risk orientation. The majority of the FFS farmers (78.1%) had medium level extension media contact. However, the majority of non-FFS farmers (73.1%) had little or no extension contact. The majority of FFS (56%) and non-FFS (74.4%) farmers had no credit exposure. It was found that FFS farmers had more access than non-FFS farmers. The majority of FFS farmers (61.6%) had moderate innovativeness, whereas most non-FFS farmers (91.7%) had low innovativeness. The highest number of FFS farmers (37.9%) and non FFS farmers (75%) had no organizational participation, indicated that FFS farmers participated in more organizations than non-FFS farmers. FFS farmers were more likely to participate in social organizations also. The majority of the respondent farmers (>60%) had a favourable attitude towards FFS. The majority of the farmers (>70%) had medium access to market facilities. FFS farmers had significantly higher IFM knowledge scores than non-FFS farmers. The t-value for the difference in means and other additional information are presented in Table 4.

Adoption of improved agricultural technologies transferred through FFS

Respondent farmers were classified based on their adoption of 10 different technologies. The descriptive statistics are presented in Table 5. It was found that there were no FFS farmers who did not adopt any of the 10 technologies, whereas a few (1.3%) non-FFS farmers belonged to this category. The majority of FFS farmers were medium (75.9%) to high adopters (22.5%) and only a few (1.6%) were low adopters. Similarly, the majority of non-FFS farmers (71.8%) were medium adopters, but a considerable percentage of them (26.3%) were low adopters. High adoption rates were found in only a negligible percentage (0.6%) of non-FFS farmers. Shah et al. (2014) and Ekram et al. (2018) found almost similar result in their study.

Table 6: Adoption of improved technologies for rice production by the farmers

Technologies	FFS farmer (182)		Non-FFS farmer (156)	
	Frequency	Percent	Frequency	Percent
Ideal seedbed	177	97.3	120	76.9
Air sealed container	179	98.4	151	96.8
Proper aged seedling	182	100	139	89.1
Rogueing	180	98.9	71	45.5
Line transplanting	173	95.1	119	76.3
Crop rotation	159	87.4	32	20.5
FYM	108	59.3	8	5.1
Vermicompost	32	17.6	2	1.3
Guti urea	27	14.8	9	5.8
Light trap	3	1.6	0	0

There was a difference between FFS and non-FFS farmers in the adoption of various technologies transferred through IFM-FFS ('t'-value 18.38). The descriptive statistics on the adoption of specific IFM technologies for the production of rice by FFS and non-FFS farmers are presented in Table 6.

Ideal seedbed

From Table 6, it can be revealed that 97.3% of FFS farmers adopted ideal seed bed technology, whereas 76.9% of non-FFS farmers adopted this. FFS farmers had a high percentage because they practiced ideal seedbed in an experimental plot during FFS sessions and observed the results.

Air sealed container

Using an airtight container is a very effective and popular technology for seed preservation. Table 6 demonstrates that 98.4% of FFS farmers used this technology, while 96.8% of non-FFS farmers used it for seed preservation. FFS farmers had a slightly higher adoption rate because they were taught about this in FFS sessions and practiced in experimental plots. Non-FFS farmers in the community, however, had access to the technology from DAE personnel and FFS farmers. As a result, the adoption rate of them has also been found to be high.

Proper aged seedling

The age of the seedling is important because it has a significant impact on tiller production, grain formation, and other yield-related characteristics (Faruk et al., 2009). From the table, it has been found that, all of the FFS farmers (100%) utilized this technology in their crop cultivation. But in case of non-FFS farmers, 89.1% of farmers adopted this technology.

Rouging

Two times roguing, combined with an optimal fertilizer dose, results in the best seed production in rice (Sultana et al., 2019). As per Table 6, almost all FFS farmers (98.9%) adopted roguing for quality seed production, whereas only 45.5% of non-FFS farmers did. FFS farmers had the opportunity to learn and practice quality seed production in experimental plots during FFS sessions. Therefore, their percentage was comparatively high in this case.

Line transplanting

Line transplanting method produce the highest total tillers, effective tillers hill^{-1}, grain yield and harvest index of rice (Sarker et al., 2014). Almost all FFS farmers (95.1%) transplanted rice in line; on the contrary, 76.3% of non-FFS farmers did exactly the same thing (Table 6).

Crop rotation

The social, economic, and environmental benefits of rice cultivation are considerably increased when agricultural diversification is achieved through rotations (Dun-Chun et al., 2021). That is why crop rotation is considered important technology for modern rice production. Table 6 shows that 87.4% of FFS farmers and only 20.5% of non-FFS farmers adopted this technology in their crop cultivation. FFS farmers had a higher adoption rate because they had more opportunities to realize the benefits of crop rotation through FFS sessions.

Farm yard manure (FYM)

Table 6 demonstrates that farm yard manure (FYM) was used by 59.3% of FFS farmers and only 5.1% of non-FFS farmers. This was due to the fact that FFS farmers had greater opportunities to learn about soil and crop management technology than non-FFS farmers (Bunyatta et al., 2006). The non-FFS farmers adopted this less likely than FFS farmers because they were unaware of its benefits.

Vermicompost

Vermicompost enhances productivity significantly when combined with other traditional inputs, and its users are more technically proficient (Rahman & Barmon, 2019). However, the technology did not make a significant impact on the farming community. Table 6 shows that 17.6% of FFS farmers and only 1.3% of non-FFS farmers adopted it. This might be the reason that FFS farmers learned the use and application of vermicompost in FFS sessions but did not broadly apply it in their fields because of technical complexity and other limitations. On the other hand, the non-FFS farmers practically had no or very few opportunities to observe the benefits of the application of vermicompost.

Guti urea

Farmers' involvement in the use of guti urea technology has a large beneficial effect on farm productivity and a 1.00% increase in adoption of guti urea technology results in a considerable boost in agricultural productivity when other factors remain the same (Sarma, 2021). But this technology was not properly adopted by the farmers due to many constraints, like sandy soil type, unavailability in the market during the season, high price, and application complexity (Sikder & Xiaoying, 2014). As per Table 6, 14.8% of FFS farmers and only 5.8% of non-FFS farmers adopted this technology in rice fields. This was because FFS farmers were actively involved in the application of guti urea during training sessions and could see the direct benefits from it.

Light trap

The light trap is an effective instrument for forecasting and controlling insect pest attacks in crop fields. However, this is not widely used by the farmers in Bangladesh. DAE officials and other extension agents make an attempt to spread this information to farmers. According to Table 6, only 1.6% of FFS farmers used this in their field. However, the adoption rate was found to be 0% among non-FFS farmers.

Contribution of the farmers' characteristics and adoption of rice production technologies transferred through FFS

The correlation coefficient (r) reported in Table 7 indicates that twelve of the sixteen selected characteristics were significantly associated with

Table 7: Relationship between adoption and selected characteristics of all farmers (both FFS and non-FFS farmers)

Farmers' Characteristics	Correlation Coefficient (r) with 336 df
Age	-0.057
Level of education	0.159**
Household size	0.044
Farm size	0.214**
Annual household income	0.191**
Farming experience	-0.063
Aspiration	0.200**
Training exposure	0.103
Risk orientation	-0.148**
Extension media contact	0.567**
Credit exposure	0.158**
Innovativeness	0.652**
Organizational participation	0.121**
Attitude towards FFS	0.438**
Market access	0.187**
Knowledge on IFM	0.540**

** Correlation is significant at the 0.01 level; df = degrees of freedom

Table 8: Regression coefficient of adoption with the selected characteristics of the farmers

Farmers' characteristics	Unstandardized coefficients	Unstandardized coefficients	t- value
	B	Beta	
Constant	-1.206		-1.585
Level of education	-0.012	-0.031	-0.689
Farm size	-0.008	-0.003	-0.070
Annual household income	-0.834	-0.009	-0.182
Aspiration	-0.006	-0.015	-0.316
Risk orientation	0.090	0.230***	4.604
Extension media contact	0.061	0.149***	2.745
Credit exposure	-0.001	-0.024	-0.566
Innovativeness	0.188	0.379***	7.128
Organizational participation	-0.003	-0.028	-0.669
Attitude towards FFS	-0.005	-0.013	-0.261
Market access	0.103	0.079**	2.025
Knowledge on IFM	0.046	0.173***	3.207

R^2 = 0.545, Adjusted R^2 =0.528 F value = 32.432, P<.001

the adoption of rice production technologies through FFS. However, the results of the linear regression analysis (Table 8) showed that the regression coefficients of five factors, namely risk orientation, extension media contact, innovativeness, market access, and knowledge on IFM were statistically significantly associated to rice production technology adoption. The other variables had no meaningful impact on adoption.

The R^2 value was 0.545 and the corresponding F-value was 32.432 which were significant at .001 level. The R^2 value indicated that 54.5% of the total variation in the adoption of rice production technologies was explained by the 5 variables included the regression analysis. The adjusted R^2 =0.528, indicating that the model accounted for 52.8% of total variance in criterion variables indicating very little multicollinearity. However, to find out actual contribution of the factors affecting the adoption of technologies, the stepwise multiple regressions was carried out (Table 9).

Table 9 reveals that adoption of rice production technologies was positively and significantly influenced by farmers' innovativeness. This could be because innovative farmers realized the benefits of the technologies and gathered practical experiences with the technologies transferred through FFS. They are continuously looking for

Table 9: Stepwise multiple regression coefficient of adoption with the selected characteristics of the farmers

Farmers' Characteristics	Unstandardized coefficients	Unstandardized coefficients	t- value
	B	Beta	
Constant	-1.421		-2.343
Innovativeness	0.181	0.367***	7.330
Risk Orientation	0.092	0.235***	5.084
Knowledge on IFM	0.037	0.150***	3.093
Extension media contact	0.055	0.132***	2.580
Market access	0.107	0.082***	2.145

R^2 =0.541, Adjusted R^2 =0.534, F value =78.283, P<.001

new ways to improve their practises; hence, they adopt technologies faster than other farmers. Congnogo et al. (2021) and Mishra et al. (2018) also observed similar finding.

Usually, farmers differ greatly in their willingness to take or avoid risks while making decisions. That is why more risk-oriented farmers are usually more likely to adopt technologies. In this study, the farmers who realized the benefits of the improved technologies took the risk of adopting the technologies. The result is supported by Congnogo et al. (2021).

IFM knowledge had a significant impact on the adoption of rice production technologies. Farmers with greater knowledge of IFM were more inclined to use the technologies because they were more aware of their benefits. This finding is consistent with the study of Chuang et al. (2020).

Access to extension services is often regarded as a critical aspect of technology adoption. Many authors have found a significant relationship between extension services and technology adoption. Agricultural extension agents usually play a significant role in the dissemination of agricultural technologies to farmers through various training programmes, group approaches, individual contact, demonstrations, and field days. Participating farmers might learn technology through the FFS approach, which was led by extension agents or trained farmer facilitators, and non-FFS farmers could learn from them. On the other hand, farmers had a great opportunity to learn and were motivated to adopt technologies through various print and electronic media. That is why extension media contact was found to have a significant relationship with the adoption of improved rice production technologies (Table 5). Almost similar findings were found by Shah et al. (2014) and Walisinghe et al. (2017).

From Table 8, the findings suggest that there was a significant and positive relationship between the adoption of improved rice production technologies and market access. Access to the market primarily consists of the ability to sell agricultural products, as well as storage and transportation facilities for agricultural products from farm to market. Considering these points, a farmer usually decides to adopt improved technologies regarding rice production. This finding is similar to the findings of Ali et al. (2021) and Sarker et al. (2021).

Conclusions

FFS farmers had a much greater adoption rate of improved rice farming technologies than non-FFS farmers. It was discovered that farmers' innovativeness, risk aversion, knowledge of IFM, extension media contact, and access to the market facilities play a significant role in determining the adoption of improved technologies for rice cultivation. Therefore, the implementation authorities (DAE and others) should organize more FFS in other parts of the country to ensure that improved technologies for rice farming are successfully implemented. The factors influencing the adoption of rice production technologies should be taken into account when promoting the adoption of technologies in the rice farming system.

Acknowledgements

The researchers would like to acknowledge the Bangabandhu Science and Technology Fellowship Trust, Ministry of Science and Technology, Government of Bangladesh for funding this research. The authors would also like to express their appreciation to the farmer facilitators and, of course, the responding farmers for their assistance in the research.

References

Ali, E. (2021). Farm households' adoption of climate-smart technologies in subsistence agriculture: Evidence from northern Togo. *Environmental Management, 67*, 949–962.

Anderson, L. W. & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of educational Objectives. New York: Longman.

BBS. (2018a). Yearbook of Agricultural Statistics 2017. Bureau of Statistics, Statistics and Informatics Division, Ministry of

Planning, Government of the People's Republic of Bangladesh.
BBS (2018b). Preliminary Report on Household Income and Expenditure Survey. Yearbook of Agricultural Statistics, 2018: Bangladesh Bureau of Statistics, Ministry of Planning.
Bunyatta D, Joseph G, Christopher A, Nyango O. & Ngesa F. (2006). Farmer field school effectiveness for soil and crop management technologies in Kenya. *Journal on International Agriculture and Extension Education, 13*(3), 47-63.
Challa, M. & Tilahun, U. (2014). Determinants and impacts of modern agricultural technology adoption in West Wollega: The Case of Gulliso District. *Journal of Biology, Agriculture and Healthcare, 4*(20), 63–77.
Chuang, J. H., Wang J. H. & Liou, Y. C. (2020). Farmers' knowledge, attitude, and adoption of smart agriculture technology in Taiwan. *International Journal of Environmental Research and Public Health, 17*(19), 1-8.
Cochran, W. G. (1977). *Sampling Techniques*, 3rd Ed. John Wiley and Sons, Inc.
Congnogo, D., Dentoni D. & Bijman J. (2021). Adoption of climate smart agriculture among smallholder farmers: Does farmer entrepreneurship matter? Land Use Policy, 109, 105666.
Dun-Chun, H., Yan-Li, M., Zhuan-Zhuan, L., Chang-Sui, Z., Zhao-Bang, C., & Jiasui, Z. (2021). Crop rotation enhances agricultural sustainability: From an empirical evaluation of economic benefits in rice production. *Agriculture, 11*(2), 1-14.
Ekram, M. Z, Hossain, K. Z., Islam, M. R., & Rahman, M. S. (2018). Adoption of commonly used Integrated Pest Management (IPM) Practices by the Boro Rice Growers. *Journal of Agriculture and Rural research, 2*(1-2), 9-14.
Farid, K. S, Tanny, N. Z., & Sarma, P. K. (2015). Factors affecting adoption of improved farm practices by the farmers of northern Bangladesh. *Journal of Bangladesh Agricultural University, 13*(2), 291–298.
Faruk, M. O., Rahman, M. A., & Hasan, M. A. (2009). Effect of seedling age and number of seedling per hill on the yield and yield contributing characters of BRRI dhan 33. *International Journal of Sustainable Crop Production, 4*(1) 58-61.
Hajjar, S. T. (2018). Statistical analysis: Internal-consistency reliability and construct validity. *International Journal of Quantitative and Qualitative Research Methods, 6*(1), 27-38.
Hossain, Q. A. (2017). Effectiveness of farmer to farmer training in dissemination of farm information. PhD Thesis, Department of Extension and Information System, Sher-e-Bangla Agricultural University, Bangladesh.
Jacob, R. G., George, W., Norton, J., Alwang, M. M., & Gershon, F. (2012). Cost effectiveness of integrated pest management extension method: An example for Bangladesh. *Applied Economic Perspectives and Policy, 30*(2), 20-29.
Kabir, M. H. (2015). *Factors influencing adoption of IPM by vegetable farmers*. PhD Thesis, Universiti Sains, Malaysia.
Mia, M. A. T. (2005). *Adoption of integrated pest management (IPM) practices by the vegetable growers of Magura district*, MS Thesis, Department of Agricultural Extension & Information System, Sher-E-Bangla Agricultural University, Dhaka.
Miah, M. M., Afroz, S., Rashid, M. A. & Shiblee, S. A. M. (2015). Factors affecting adoption of improved sesame technologies in some selected areas in Bangladesh: An empirical study. *The Agriculturists, 13*(1), 140-151.
Mishra, P. K., Upadhyay, R. G. & Upadhyay, A. D. (2018). Diagnostic analysis of technology adoption and factors influencing adoption level of tribal farmers of Madhya Pradesh. *Economic Affairs, 63*(1), 1-7.
Moniruzzaman, K. M. (2009). *Comparative analysis between FFS and Non-FFS farmers on knowledge, skill and attitude towards integrated pest management in Boro rice*,

PhD Thesis, Bangladesh Agricultural University, Department of Agricultural extension Education, Mymensingh.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development, 6*(5), 208-216.

Nazu, S. B., Khan, M. A., Saha, S. M., Hossain, M. E., & Rashid, M. H. (2021). Adoption of improved wheat management practices: An empirical investigation on conservation and traditional technology in Bangladesh. *Journal of Agriculture and Food Research, 4*, 1-11.

Rahaman, M. S., Kabir, M. J., Sarkar, M. A. R., Islam, M. A., Rahman, M. C., & Siddique, M. A. B. (2020). Factors affecting adoption of BRRI released Aus rice varieties in Mymensingh district. *Agricultural Economics, 5*(5), 210-217.

Rahman, S., & Barmaon, B. S. (2019). Greening modern rice farming using vermicompost and its impact on productivity and efficiency: An empirical analysis from Bangladesh. *Agriculture, 9*(11), 1-13.

Roy, D., Farouque, M. G., & Rahman, M. Z. (2013). Problem confrontation of the FFS farmers in participating farmer field school training session. *Progressive Agriculture, 24*(1&2), 273-280.

Sarker, M. R., Galdos, M. V., Challinor A. J., & Hossain, A. (2021). A farming system typology for the adoption of new technology in Bangladesh. *Food and Energy Security, 10*(3), 1-18.

Sarker, T., Hossain, M., Salam, M., & Rabbani, M. (2014). Effect of seedling age and method of transplanting on the yield of Aman rice. *Progressive Agriculture, 24*(1-2), 9–16.

Sarma, P. K. (2021). Adoption and impact of super granulated urea (guti urea) technology on farm productivity in Bangladesh: A Heckman two-stage model approach. *Environmental Challenges, 5*, 1-8.

Shah, M. M. I., Grant, W. J., & Stocklmayer, S. (2014). Adoption of Hybrid Rice in Bangladesh: Farm Level Experience. *Journal of Agricultural Science, 6*(7), 157-171.

Shelly, I. J., Nosaka, M. T., Nakata, M. K., Haque, M. S., & Inukai, Y. (2016). Rice cultivation in Bangladesh: Present scenario, problems, and prospects. *Journal of International Cooperation for Agricultural Development, 14*, 20–29.

Sikder, R. & Xiaoying, J. (2014). Urea super granule (USG) as key conductor in agricultural productivity development in Bangladesh. *Developing Country Studies, 4*, 132-139.

Sultana, A., Salim, M., Kader, M. A., Akter, M. B., Kamruzzaman, M., & Hoque, M. I. (2019). Effect of different levels of nitrogen & phosphorus fertilizer and roguing on seed production of rice in Bangladesh. *International Journal of Plant & Soil Science, 27*(4), 1-8.

Tama, R. Z., Ying, L., Yu, M., Hoque, M. A., Adnan, K. M. M., & Sarker, S. A. (2021). Assessing farmers' intention towards conservation agriculture by using the extended theory of planned behaviour. *Journal of Environmental Management*, 280, 1-10.

Van den Berg, H., Phillips, S., Dicke, M., & Fredrix, M. (2020). Impacts of farmer field schools in the human, social, natural and financial domain: a qualitative review. *Food Security, 12*, 1443–1459.

Walisinghe, B. R., Ratnasiri, S., Rohde, N., & Gue, R. (2017). Does agricultural extension promote technology adoption in Sri Lanka. *International Journal of Social Economics, 44*(12), 2173–2186.

Zheng, Y. Y., Tie-hui, Z. H. U., & Wei, J. I. A. (2022). Does internet use promote the adoption of agricultural technology? Evidence from 1449 farm households in 14 Chinese provinces. *Journal of Integrative Agriculture, 21*(1), 282-292.

Bangladesh Rural Development Studies (BRDS)
ISSN 1019-9624; Web: www.rda.gov.bd

Menstrual concepts, hygiene practices and health seeking behaviour of adolescent girls in Bangladesh: A study on slum areas in Rajshahi

Most. Ummay Hani Kulsum[1]

[1] Dept. of Social Work, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Jamalpur

ARTICLE INFO

Keywords:
Menstruation
Hygiene practices
Health seeking behaviour
Slum
Adolescent

Received: 25 January, 2023
Revised: 13 May, 2023
Accepted: 14 June, 2023

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

ABSTRACT

The aim of this research is to explore the conceptions towards the menstruation cycle, hygiene practices during menstruation and the health seeking behaviour during menstrual problems of the adolescent girls from some selected slums in Rajshahi city who are primarily migrated from rural areas. In total, 30 in-depth interviews and two focus group discussions (FGDs) were conducted. The study findings reveal that adolescent girls have no idea about menarche before their menstruation that is why the majority of the adolescent girls get frightened during their menarche and become nervous about their situation. There are various misconceptions towards menstruation. Majority of the slum dwelling adolescent girls think that menstruation is a shameful issue. The study findings show that majority of the adolescent girls from slums face different types of health issues related to menstruation. Among those difficulties are lower abdominal pain, stress, anxiety, white discharge with bad smell, excessive white discharge, itching in the private part, iron deficiency, abdominal cramps, irregularity of menstruation, muscle spasms of leg, vomiting, nausea, headache, excessive bleeding, less bleeding during menstruation, lumbago etc. Due to insufficient awareness and poor financial condition of family they cannot take proper treatment which is very alarming for their reproductive health.

How to Cite: Kulsum, M. U. H. (2023). Menstrual concepts, hygiene practices and health seeking behaviour of adolescent girls in Bangladesh: A study on slum areas in Rajshahi. *Bangladesh Rural Development Studies, 26*(1), 61-69.

Introduction

In Bangladesh, adolescent girl population is approximately 36 million, who face many challenges as they are physically, mentally and socially vulnerable (Ministry of Health and Family Welfare, 2016). Adolescence is a very crucial time in every girl's life, because in this time there are different types of changes occurred in a human body, both in physical and mental in nature. Especially every adolescent girl faces an important situation in their teenage life known as menstruation which is called menarche at the first experience of menstruation cycle. Menstruation is a very important issue of reproductive health in a girl's life. It is a natural process in a female's body. According to World Health Organization (1999), 10-19 years of age is considered as the adolescent period. Menstruation is one of the major natural causes of adolescent changing in a girl's life. Adolescent girls experience this menstruation cycle suddenly in their lives and for the changes in body created by it also creates impacts on their mental health. In such a situation, they need more care and mental as well as nutritional support. But in reality, there is much ignorance towards the issue of menstruation in slum areas in Bangladesh. It also remains a forbidden topic for discussion, especially in front of male members of the family; in Bangladesh, menstruation is a hidden thing, a taboo. If anyone talks with a male about this issue, it creates a shameful situation for a girl. In many countries in the world, it is considered a female issue and a matter of infrequent talking (Mohite & Mohite, 2016). Menstrual hygiene practices and proper knowledge about this issue is very important for adolescent girls. In many cases it is noticed that majority of adolescent girls do not have any idea about menstruation before their first experience of menstruation (Hussain, 2020). In the slum areas in Bangladesh, menstrual issue is also a topic of secret discussion and there are many superstitions towards this. Slum denotes a high densely populated area within a narrow space in the city area and the population is very poor in this area, they are deprived from different types of facilities (Kamruzzaman & Hakim, 2016). This study has tried to explore the conceptions, hygiene practices and health seeking behaviour towards the menstruation cycle of adolescent girls in the slum area.

Objectives

i. To explore the conceptions towards the menstruation cycle;
ii. To assess the hygiene practices during the menstrual cycle;
iii. To know the health seeking behaviour during menstrual problems of adolescent girls in the study area.

Methodology

The present study was based on primary data; in addition to this primary data, secondary data e.g., books, journals, public documents, website etc. were used. It adopted qualitative research approach. In-depth interviews and FGDs were undertaken to collect data in this research work. Thirty in-depth interviews and two FGDs consisting 6 persons were undertaken for collecting data in this study.

Study area, population and sampling

Among the 12 city corporations in Bangladesh, Rajshahi City Corporation (RCC) was selected purposively as the study and from this city corporation two wards were selected. According to the Community Development Centers (CDCs) under RCC, there are 195 slums or poverty prone areas in the city and most of the slum dwellers migrated from the remote parts of the country. Among these areas, Bulonpur Sweeper Colony, Nahupara Bulonpur, Keshabpur Nadir Dhar areas under Ward No. 4 and Charsat Baia Purba, Charsat Baria Paschim under Ward No. 29 are selected as the study areas. The respondents were adolescent girls (married or unmarried) between the ages of 12 to 19.

Data collection and analysis

To collect necessary data semi-structure interview guidelines were prepared to achieve the research objectives. In the context of in-depth interviews and FGDs, interviews were audio recorded with the permission of the respondents and after that recordings were transcribed and translated into English. After translating the interviews, the data were coded, tabulated and thematically analyzed to explore the situation.

Findings of the study

Conception about menstruation and pre-menarche

The study findings show that adolescent girls in the slum areas did not have any idea about menstruation before their menarche. Their family members did not give any idea regarding this issue. The following excerpts clarify the situation: one of the interviewees of the study area said that, "I didn't know or I have no idea about menstruation cycle before my menarche." But it is important for every adolescent girl's guardian to inform of this issue, so that they can take necessary steps and be mentally prepared for it. Another respondent in this research opined that "If I knew about menstruation before starting my menstruation, then I could easily handle it.

Because when I first experienced it, I became afraid and couldn't understand with whom I can share this issue." Coherent to this study there is a previous study which demonstrate that majority of that study population, teenage girls, did not know about menarche before their own experiences, among them 57.8% were afraid and 49.1% were tensed to see their first menstrual blood and it affected their mental health (Onia et al., 2022).

In the study one interviewee mentioned that, "When I first saw blood in my dress, I felt scared and started weeping but I could not share this with anybody." Another one clarified that, "At first day of my menstruation I thought that from somewhere blood splattered my dress. After few moments I could understand that it was coming from my own body and became afraid but could not share it with my family members." Kaur et al. (2018: 1) revealed "In many parts of the country especially in rural areas girls are not prepared and aware about menstruation so they face many difficulties and challenges".

The study findings demonstrate that adolescent girls in the study area have various misconceptions towards menstruation. The following excerpts clarify the issue, one interviewee said that "Menstrual material is very sensitive because if anyone cuts it, she can do black magic by using this and it may result in infertility in a girl's life." Like this interviewee another one thought that, "If any snake or any beetle touch the menstrual materials, it causes various health risks which results in infertility in future, so I am very sincere about my rags to preserve it for further uses". A related study revealed that majority of respondents gave opinion if their menstrual materials come to the touch of any snake or eaten by snake, it may be the causes of their infertility (Coast et al., 2019). On the other hand, another one thought menstruation to be a shameful mater; she said that, "I think menstruation is a very shameful issue, my mother said that I can't share about menstruation because menstruation is only the subject of a female and it is a female issue." That means it should be hidden from the male members in a family. Another interviewee demonstrated, "I don't take bath during this period, my mother prohibited me for taking bath because it hampers the menstruation cycle." But in reality, during menstrual period hygienic practices are vital for reproductive health. From the in-depth interviews one interviewee demonstrated following issue:

"During my menstruation time my grandmother does not allow me to cook and take some certain foods; e.g. pickle, cold water. Besides, I don't wash my hair with shampoo, because she told that if I do these it impedes the blood flow which is very harmful for my body."

One interviewee even thinks that *"menstruation is a monthly disease of every female and it is a shameful issue for a female."*

Menstrual hygiene practices

The study findings reveal that a significant number of adolescent girls in the study area are using Nekra (cotton cloth often used old one) during their menstruation. This is made by cutting old saree, orna or dress. The following excerpts clarify the issue: one of the interviewees in the study area said that "I use Nekra during menstruation. My family is very poor for this reason they can't afford sanitary napkin on a monthly basis. That's why I use this Nekra". Another study coherent to this study demonstrates that, in the slum area women use old cloths and they reuse it, which causes reproductive health hazard to the women (Afiaz & Biswas, 2021). Majority of the slum families in the study area are poor and they live from hand to mouth. So, using sanitary napkin is a luxury for the adolescent girls of these families. Another interviewee stated that, "I have heard that sanitary napkin is very hygienic during menstrual time, but it is very expensive. If its price were low my family could give me pads. In addition, menstruation occurs in every month, so that I think using pads is burden for my family." Majority of the respondents in the study area use old cloths as their menstrual materials. One of them clarify, "In the first menstrual cycle my mother gave me her old sarees' pieces to use, from that time on, I use that Nekra as my menstruation material

This study reveals that majority of the adolescent girls in the study area clean their rags using only water rather than soap or detergent. One interviewee said that "maximum time I clean my menstruation rags by using only water, sometime I use soap or any detergent powder." When they take soap into the toilet for washing rags male member in this slum make comments, which is embarrassing for them. Regarding this matter one informed, "I feel easy to wash my rags by using water rather than any detergent powder, because the washroom is common for other family members."

The study also finds out that during menstrual cycle the adolescent girls face many difficulties to wash their rags. In the study area, i.e. the slum areas there are two common washrooms for eight families. The girls also face problem in changing rags due to lack of privacy; as they consider menstruation shameful situation for a girl's life and try to hide it from the male members. The following narratives clarify the issue: "I feel very shy to take rags to the wash room, when I go to wash these rags, I think other persons in the slum stare at my hand which is hidden in my dress." Another interviewee clarifies that, "In the day time it is difficult to wash my rag; that's why I wash my rags very secretly and dry it in a hidden corner in our room, so that nobody can see this cloth." Yet another interviewee said that, *"I change my rags when it gets fully wet at home; but at school, I can't change rags. In our school there is no private space to change rags or wash it. In addition to that I also feel discomfort to change rags in my home when others slum members are using the common toilets."*

The study findings also show that the menstruation materials are buried or throw away (when it became torn to use long time) outside home after use. Majority of the respondents reuse the materials of menstruation. The following excerpts clarify the issue: "During the menstruation period I use old cloths and after using these cloths I keep it for reusing in the next time. I don't throw away these materials." Adolescent girls in this slum reuse their rags until they tear, then replace it with another piece of old cloth. One interviewee said that, "When the menstrual rags are torn apart, I throw them away outside my house, then I take another old cloth from my mother." Here one's statement denotes menstrual disposal system is taken very seriously by the adolescent girls in the study area because there is a popular myth about the menstrual materials in the slum area. One interviewee in the study area denotes that, "I don't throw away the used rags, because it is very dangerous for health. Anyone can easily misuse these rags. That's why I bury these rags."

The study findings also demonstrate that during menstruation school going adolescent girls confront some difficulties to change rags, and hesitate about blood stains on clothes being seen by others. A previous study conducted related to these findings revealed that, during the menstruation period missing school is a common practice among the adolescent girls and 41% girls in that study missed school during menstrual period (Alam, et al., 2017). In many schools there are no separate toilets or washroom for the girls to wash or change rags. The following section elucidates the situation: "During my menstruation times I hesitate to go to school because there is no private space to change and wash rags in our school." Another one clarifies that, "In our school I can't change a rag that's why I do not go to school at the time of my menstruation." Hesitation is a common issue in the adolescent girls during menstrual time. "During my menstruation time I feel hesitation in my classroom as well as school in fear of blood stains on my dress being seen by others."

Health seeking behaviour during the menstruation related health problems

The findings of the study signify that majority of the slum dweller adolescent girls face different types of health problems related to menstruation; e.g., lower abdominal pain, abdominal cramps, irregularity of menstruation, muscle spasms in leg, vomiting, nausea, headache, excessive bleeding, les bleeding during menstruation, lumbago etc. The following narratives described the situation: one interviewee described, "I have faced severe lower abdominal pain prior to start of the menstruation." Another one said, "Every month I have mild headache during my menstruation time and excessive bleeding is a common problem at that time." During menstrual period adolescent girls in the study area face more or less health difficulties. Another one clarified that, "My menstruation is irregular, after six or seven months it starts and there is very less bleeding which stay only two days." Related to this study there are some research works that was reveals that, most of the respondents faced different types of menstrual health related difficulties as well as premenstrual syndrome. Among those respondents in that study 76% suffered from headache, 80% from lower abdominal pain and 62.5% suffered from fatigue (Sultana et al., 2021).

The study findings show that in the slum area majority of the adolescent girls who face menstrual health difficulties do not consult doctors due to their family's poor financial condition. Some adolescent girls go to drugstores or homeopathic doctor for their menstrual problem. The following excerpts clarify the situation: "my menstruation is irregular but I do not go to any specialist doctor due to my father's poor financial condition. I think it will be solved automatically by the grace of Allah." In many cases adolescent girls ignore their menstrual problem. One respondent clarified, "in my menstruation problem I go to a homeopathy doctor near to our house and take medicine then I feel better and recover quickly." One of the study respondents said that,

"My husband is very poor. That's why I can't receive any treatment of my menstruation problem. At the time of menstruation excessive bleeding and severe lower abdominal pain is a common picture. Because of my menstruation problem I can't conceive, I'm very scared about this issue."

One interviewee in the study area manages her menstrual health problem by using medicine. She claimed "when I face any menstrual health problem my father buys medicine from pharmacy and it gives me relief from problem."

It is also demonstrated in the study that some adolescent girls who face various health problems related to menstruation have apathy towards taking treatment. They do not take it seriously. Following narrative indicates the situations: "I have faced some difficulties; e.g. excessive bleeding, bleeding stay near about 10 to 15 days monthly during the menstruation time, but I do not care about it, I think that it will automatically heal." Some of the respondents in the study area don't panic about problems related to menstruation. "In the menstruation time it is normal to have abdominal pain, headache, leg cramps; and so, what? Female should have patience."

Discussion

Menstruation and pre-menarche: conception and misconception

The study findings reveal that adolescent girls have no idea about menarche before their menstruation, that's why majority of the adolescent girls get frightened during their menarche and became nervous about their situation. In another research related to this demonstrate that without any previous conception towards menarche around half of Bangladeshi girls face their menarche stage with fear and hesitation (Mehjabeen et al., 2022). It is very important to inform adolescent girls about menarche before their practical experience about it, so that they can easily accept the menstruation situation and handle it very carefully without any hesitation or nervousness. If they are made aware about menarche, the adolescent girls will feel comfortable which will support their mental condition. In another study it is revealed that more than one third (44.8%) of the respondents in that study had no concept or preparation towards menarche (Aniebue & Patricia Nonyelum Aniebue, 2009).

The findings of this study also demonstrate that during the first day of menstruation, i.e., menarche, the adolescent girls in the slum area became scared and couldn't share this issue with other members of their family. At the time of menarche, the adolescent girls hide it from their mother and didn't understand whatever they should do at that time.

There are various misconceptions towards menstruation. Majority of the slum dwelling adolescent girls think that menstruation is a shameful issue and it should be kept hidden from the male members of family. The mothers or grandmothers of the adolescent girls of the slum area advise not to disclose this issue to their father or brother. Another study related to this revealed that many respondents of that study opined that clothes used to manage menstruation should be kept out of sight of men and in the evening, girls are not allowed to go out during their menstruation time (Mondal et al., 2017). In the study area some adolescent girls are very conscious regarding their used rags, because they believe that by using these materials anybody can easily perform black magic and consequently be the cause of a girl's infertility. The study findings are also coherent with other study which revealed that, majority of that study area's women had misconception and superstition towards menstrual fluids that anyone can misuse this fluid by doing black magic, so they cleaned their rags at night when others were asleep (Sommer et al., 2013).

The findings of the study indicate that majority of the adolescent girls in the study area are prohibited by their mother to take bath during the menstruation cycle. Some adolescent girls of the slum area are not allowed to cook, shampoo their hair, eating some food; e.g. pickle, sour types of food- as their family believe that those things impede the flow of bleeding during menstruation. Related to this finding is another previous study and, in that study, it was showed that, during menstrual period girls have some food restriction, where they are prohibited from eating spicy and non-vegetarian foods; because it was considered that these foods may hamper the flow of bleeding (Tiwari et al., 2006). The findings of this study also demonstrate that majority of the adolescent girls in the slum area, think that menstruation is a monthly disease of every female and it is only the concern of a female rather than the male.

Hygiene practices during menstruation

The study findings show that the adolescent girls use old cotton clothes cut from cotton sarees or dress. After using these clothes, they preserve it to reuse in the next menstruation period. When these menstruation materials are torn apart, they throw these away; otherwise, they continue to use and reuse these old clothes. In the slum area majority of the slum dwelling adolescent girls' family are very poor, that's why they can't afford the sanitary napkin. Sanitary napkin is very costly for these families to afford. Many of them are of opinion that if the price of the sanitary napkin is affordable for the family, they can use it. Another relevant study demonstrates that 89.5% girls were using old cloths as a menstrual material and they also reused it the next time (Prajapati et al., 2015).

In the findings of the study, it is demonstrated that the majority of the adolescent girls wash their rags using only water rather than soap or any detergent powder. Some girls use soap to clean their menstruation materials. In another study coherent to this it is shown that majority of the slum dwelling adolescent girls face difficulties to clean their menstrual materials due to lack of private place (Hussain, 2020).

The study findings indicate that the rags are dried in the room or in the private corner in their house so that none can see the rags. As they think it a shameful issue. They can't give these under the sunlight due to the male members of family. This is very unhygienic for reproductive health. So, education about menstruation is important. Another research works coherent to this demonstrate that adolescent girls should be educated towards the issue of menstruation and its hygiene management after that they can change their menstrual practices (Devi & Ramaiah, 1994).

The findings are also coherent with another study which was qualitative research which conducted 46 in-depth interviews, 11 FGDs and KII. In this research, it was revealed that some respondents were not allowed to cook or go to school during the menstrual period (Kambala et al., 2020). Some respondents said that as sanitary napkins were very expensive, they use sanitary pads for the first two days when the blood secretion is high and after two days of menstruation, they use old cloths as menstrual material.

The study findings show that majority of the adolescent girls change their rags after those get fully wet when they are at home but outside of the home in cases of working or during school time, they can't change their rags timely, due to lack of private places of changing. Outside home, they feel discomfort with wetness of rags but they have nothing to do about it. Sometimes they face difficulties in their homes too due to privacy issues in the slum area. In the study area there are limited toilets and washrooms for a huge number of slum members.

Health seeking behaviour in context of menstruation related health problems

The study findings show that majority of the slum dwelling adolescent girls face different types of health difficulties related to menstruation. Among those difficulties there are- lower abdominal pain, stress, anxiety, white discharge with bad smell, excessive white discharge, itching in the private part, iron deficiency, abdominal cramps, irregularity of menstruation, muscle spasms of leg, vomiting, nausea, headache, excessive bleeding, les bleeding during menstruation, lumbago etc. Due to financial condition of family, they cannot take proper treatment which is very alarming for their reproductive health. Lower abdominal pain and muscle spasms are the common problems of the adolescent girls living in slums during their menstruation. Majority of the respondents feel that they should take proper treatment but their family can't afford economic support.

The findings also indicate that problems of menstruation can affect the mental side. In the slum area the girls who have experiences about irregular menstruation and other health problems related to menstruation, face many mental problems. The study findings also show that the guardians of the adolescent girls living in slums are very apathetic towards their daughters' as well as wives' treatment. They take these health problems as a natural part of menstruation.

Maximum slum's families cannot afford treatment due to poor financial condition. Like this study another related study revealed that when the adolescent girls became very sick during their menstrual health related problems, they took them to the medical center but at the early stage they were not allowed to go to seek for treatment because the ignorance of their family members (Bhattarai et al., 2020).

Conclusion and policy recommendations

Respondents in this study have no clear idea about menstruation as well as majority of them have various misconception about menstruation cycle which is very alarming for their reproductive health. In this study, adolescent girls in the study area use and reuse the old cloths as menstrual material. The findings of this study demonstrate that the slums' adolescent girls' families are unable to afford sanitary napkin which is very important for their menstrual hygiene management. In addition to that the adolescent girls face different types of challenges during their menstrual period; e.g. washing the materials, opportunity of menstrual materials changing time both at home and in school in the context of school going girls, lack of private places. Many of them face different types of physical health problems related to menstruation; e.g. lower abdominal pain, stress, anxiety, white discharge with bad smell, excessive white discharge, itching in the private part, iron deficiency, abdominal cramps, irregularity of menstruation, muscle spasms of leg, vomiting, nausea, headache, excessive bleeding, les bleeding during menstruation, lumbago etc. Due to poor economic condition and unwillingness, they cannot take proper treatment. So, it is important for the government and policy makers, social workers, NGOs workers to take necessary initiatives for the slum adolescent girls. If sanitary napkin's price becomes affordable, they can easily use these hygienic products and this will be useful for their reproductive health. Thus, it should be taken in the priority list for the betterment of the slum girls' reproductive health.

References

Afiaz, A., & Biswas, R. K. (2021). Awareness on menstrual hygiene management in Bangladesh and the possibilities of media interventions: Using a nationwide cross-sectional survey. *BMJ Open, 11*(4), 1-10. doi:10.1136/bmjopen-2020-042134

Alam, M. U., Luby, S. P., Halder, A. K., Islam, K., Opel, A., Shoab, A. K., Ghosh, P. K., Rahman, M., Mahon, T., & Unicomb, L. (2017). Menstrual hygiene management among Bangladeshi adolescent schoolgirls and risk factors affecting school absence: results from a cross-sectional survey. *BMJ open*, *7*(7), 1-10. doi.org/10.1136/bmjopen-2016-015508

Aniebue, U. U., & Patricia Nonyelum Aniebue, T. O. (2009). The impact of pre-menarcheal training on menstrual practices and hygiene of Nigerian. *Pan African Medical Journal, 9*(2), n.d. Retrieved 11 03, 2022, from http://www.panafrican-med-journal.com/content/article/2/9/full

Bhattarai, K., Karkee, R., Ghimire, A., Pvakurel, P., & Prasad, P. (2020). A qualitative study to explore adolescent girls belief on menstruation and health seeking behaviour. *Biomedical Sciences, 6*(2), 31-37. doi:10.11648/j.bs.20200602.13

Coast, E., Lattof, S. R., & Strong, J. (2019). Puberty and menstruation knowledge among young adolescents in low- and middle-income countries: A scoping review. *International Journal of Public Health, 64*, 293-304. doi:10.1007/s00038-019-01209-0

Devi, K. D., & Ramaiah, P. V. (1994). A study on menstrual hygiene among rural adolescent girls. *Indian J Med Science, 48*(6), 139-143. https:pubmed.ncbi.nlm.nih.gov/7927585/

Hussain, M. M. (2020). Health problems, misconceptions and challenges: Experiences of slum dweller adolescent girls in Bangladesh. *Asian Social Work Journal, 5*(2), 6-16. doi:10.47405/aswj.v5i2.134

Kambala, C., Chinabgwa, A., Chipeta, E., Torondel, B., & Morse, T. (2020). Acceptability of menstrual products interventions for menstrual hygiene management among women and girls in Malawi. *Reproductive Health, 185*(17), 1-12. doi:10.1186/s 12978-020-01045-z

Kamruzzaman, M., & Hakim, M. A. (2016). Socio-economic status of slum dwellers: An empirical study on the capital city of Bangladesh. *American Journal of Business and Society, 1*(2), 13-18. http:www.aiscience.org/journal/ajbs

Kaur, R., Kaur, K., & Kaur, R. (2018). Menstrual hygiene, management, and waste disposal: Practices and challenges faced by girls/women of developing countries. *Journal of Environmental and Public Health, 2018*, 1-9. doi:10.1155/2018/1730964

Mehjabeen, D., Hunter, E. C., Mahfuz, M. T., Mobashara, M., Rahman, M., & Sultana, F. (2022). A qualitative content analysis of rural and urban school students' menstruation-related questions in Bangladesh. *International Journal of Environmental Research and Public Health, 19*(16), 1-15. doi:10.3390/ijerph191610140

Ministry of Health and Family Welfare. (2016). *National Strategy for Adolescent Health 2017-2030.* Government of the People's Republic of Bangladesh, MCH Services Unit, Directorate General of Family Planning.

Mohite, R. V., & Mohite, V. R. (2016). Menstrual hygiene practices among adolescent girls. *International Journal of Community Medicine and Public Health, 3*(7), 1729-1734. doi:10.18203/2394-6040.ijcmph20162033

Mondal, B. K., Ali, M. K., Dewan, T., & Tasnim, T. (2017). Practices and effects of menstruation hygiene management in rural Bangladesh. *40th WEDC International Conference* (pp. 24-28), Loughborough University. https://hdl.handle.net/2134/31512

Onia, M. A., Zakaria, M., Jahan, N., Akter, D., Zhou, Y., Cheng, F., & Xu, J. (2022). Teenage girls' interpersonal communication with mothers after experiencing menarche in Bangladesh. *Research Square, 1*, 1-20. doi:10.21203/rs.3.rs-1607111/v1

Prajapati, D. J., Shah, J. P., & Kedia, G. (2015). Menstrual hygiene knowledge and practice among adolescent girls of rural Kheda district. *National Journal of Community Medicine, 6*(3), 349-353. https://njcmindia.com/index.php/file/article/view/1206/956

Sommer, M., Kjellen, M., & Pensulo, C. (2013). Girls and women's unmet needs for menstrual hygiene management (MHM): The interactions between MHM and sanitation systems in low income countries. *Journal of Water Snitation and Hygiene for Development, 3*(3), 287-297. doi:10.2166/washdev.2013.101

Sultana, M. S., Razon, A. H., Sarwar, M. T., & Ahmad, T. (2021, August 24). Assessment of the prevalence of menstrual complications with knowledge, attitude and practice regarding menstruation of rural girls in Jashore, Bangladesh. *Science Journal of Public Health, 9*(5), 162-168. doi:10.11648/j.sjph.20210905.14

Tiwari, H., Oza, U., & Tiwari, R. (2006). Knowledge, attitudes and beliefs about menarche of adolescent girls in Anand district, Gujarat. *Eastern Mediterranean Health Journal, 12*(3-4), 428-433. https://apps.who.int/iris/handle/10665/117103

World Health Organization. (1999). *Programming for adolescent health and development*. https://apps.who.int/iris/handle/10665/42149