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Contents

Response of yield and yield contribution traits of hybrid chili (*Capsicum annuum* L.) to biological soil treatment and plant growth regulators

Fakhar Uddin Talukder[1]*, Md. Khalid Aurangozeb[1]

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

ARTICLE INFO

ABSTRACT

This study was intended to find out a way of increasing production using Trichoderma enhanced composts and PGRs. The experiment was carried out in completely randomized design (CRD) method having two factors with 12 treatment combinations replicated thrice. Here, Factor A= Biological soil treating element (e.g. S_0= Control/zero application of soil treating element, S_1= Tricho-compost @ 200 g/kg soil, S_2= Conventional compost @ 200g/kg soil); Factor B = Plant growth regulators (e.g. P_0= Control/zero application of plant growth regulator, P_1= Gibbrelic acid (100 mg/L), P_2= kinetin (100 mg/L), P_3= NAA -Naphthelene acetic acid 50 ppm). Height plant height was observed at 90 days under the combined treatment of Tricho-compost @ 200 g/kg soil and Gibbrelic acid (100 mg/L). Combination of Tricho-compost @ 200 g/kg soil and NAA Naphthelene acetic acid 50 ppm performed the height in respect of number of flowers per plant, number of fruits per plant, fruit length, chili yield. No limitations were found for conducting this study. Based on the results of present study, the use of Tricho-compost as soil treating agent and foliar spray of plant growth regulators improved the growth and physiological attributes of chili e.g. vegetative growth & yield simultaneously.

Introduction

A berry-fruit of plants (Genus-Capsicum), which belong to the nightshade family Solanaceae, chili peppers (also known as chili pepper, chili, chile or chile pepper,) are grown for their pungency. Chili peppers are universally used as a spice ingredient to give food some "heat" in a variety of cuisines. Green chilies slow down the aging process and are a rich source of vitamins A and C. Through microbial activities, composts have the ability to afford biological control of a variety of disease pathogens, especially those that are soil-borne (Hoitink and Fay, 1986; Inbar et al., 1993). While the use of composts made from different green wastes in agriculture is slowly making a come-back, the application of inorganic chemicals to agriculture is now a common practice. Compost is an excellent source of plant nutrients and has varying concentrations of N, P, and K. Due to the high cost and occasionally unavailability in the market, farmers are unable to apply inorganic fertilizers to crop fields at the best possible time (Reddy et al., 2017). Bangladesh's harvest of chilies falls well short of its potential.

Finding environmentally friendly solutions, like expanding the use of biocontrol agents, is urgently needed. Fungal genus is one of the many species, including bacteria and fungi, which are employed as biocontrol agents. According to Rajesh et al. (2016), Trichoderma produces a variety of enzymes that are important for bio control activities such as cell wall degradation, tolerance to biotic or abiotic stresses, hyphal growth, etc. According to Błaszczyk et al. (2014), Trichoderma spp. has a positive impact on plants by promoting plant growth and shielding them from bacterial and fungal diseases. An organic substance, either synthetic or natural, that alters or regulates one or more particular physiological processes in a plant is known as a plant growth regulator. One of the main issues with producing Chilies is flower and fruit drop, which is brought on by hormonal and physiological imbalances in the plants, especially in unfavorable environment like extreme temperature (Erickson & Markhart, 2001; Rylski, 1973, 1975). In addition, plants may grow more quickly thanks to the action of growth regulators. Small-scale PGR application alters plant growth primarily by activating or inactivating a portion of the plant's own growth regulatory system. PGRs have been shown to improve fruit set by strengthening the source-sink association and promoting photoassimilate translocation. Many of the sixty plant growth regulators that are currently marketed for use in agriculture have grown significantly in significance (Tamilselvi and Vijayaraghavan, 2014). Among these, cytokinin and gibberellin are crucial for promoting a plant's reproductive and vegetative growth. The most prevalent gibberellin, GA3, controls a number of developmental processes, such as fruit development, dormancy, elongation of the stem, and germination. Plant roots and shoots contain cytokinins, which stimulate cell division. They influence axillary bud growth, apical dominance, and leaf senescence in addition to their primary roles in cell growth and differentiation. One class of cytokinin that stimulates cell division is kietin. The growth and reproduction of chili peppers are enhanced by the application of the ideal concentration of plant growth regulators, GA3 and Kn.

Chili growth and yield are greatly enhanced by kinetin in particular (Anolisa et al., 2020). One of the main crops in our nation is chili. One of the best commercial spice crops is chili. It is the most popular all-purpose spice. Bangladesh's average yield of chilies is very low when compared to other top chili growing nations in the world because of poor farming management techniques. Gibberellins, kinetin, chlorophenoxyacetic acid, and nitrobenzene are examples of plant growth regulators that can aid in cell growth, elongation, division, first flowering, fruiting, etc. A greater PGR supply could enhance the morpho-physiological characteristics and yield of chili. It is imperative that the production of existing spice crops, such as chili, be improved by appropriately combining PGR with biological pesticides. With an annual production of 0.114 million metric tonnes, Chili occupies almost 1.04 thousand ha (Anonymous, 2014). According to Anonymous (2014), the average yield of Chilies is 0.08 t ha^{-1}, which is relatively low when compared to other nations. This low yield has a variety of causes. The primary causes are disease transmission, native soil depletion, and farmers' uneven and insufficient application of fertilizers. But in the modern era, agriculture is driven not only by output but also by the need to preserve all natural resources, including soil, for future generations.

Objectives of the study

1. To evaluate the performance of plant growth regulators and trichocompost on vegetative growth and yield contributing characters of chili
2. To find out the most effective combination of plant growth regulator and trichocompost for chili production
3. To compare between conventional compost and trichocompost in response to chili production.

Methodology

The 30 days old seedling winter chilies (Hybrid variety namely Bijli) were collected from Nursery Unit of Rural Development Academy (RDA), Bogura which are produced in controlled greenhouse lab. The research will be carried out in

Figure 1: Experimental Period

earthen pots at RDA, Bogura, Bangladesh in 2022 at 20 meter altitude.

The soil from an upland orchard was collected, and different sources of organic manure were mixed in according to treatment needs to create the pot media. The recommended dosages of urea, muriate of potash (MP), triple super phosphate (TSP) and gypsum fertilizer for chili cultivation in Bangladesh will be thoroughly mixed into the soil of the experimental pot. The soil will be supplemented with dry cow dung (8% moisture) in a 1:10 ratio. For this experiment, nearby grown chili plantlets served as the plant material. When necessary, intercultural practices such as mulching, weeding, irrigation, and pest control were carried out to ensure the regular growth and development of chili plants. GA3 and kinetin were applied foliarly 15 days afterward transplantation and the application were repeated twice a week until the harvest stage (Anolisa et al., 2020). The spraying was done in the morning with the hand sprayer. The selection of the NAA concentration is based on Tapdiya et al. (2018).

Statistical analysis: Microsoft Excel and Statistics 10 software were used for the statistical analysis of the collected data (Gomez & Gomez, 1984).

Results and Discussions

Plant Height: One substantial morphological parameter is plant height. At 15 days, the plants with the combination treatment of control (zero application of soil-treating element) and gibbrelic acid (100 mg/L) showed the lowest plant height. After 90 days of combined treatment with 200

Table 1: Combined effect of Tricho-compost as soil treating agent and foliar spray of plant growth regulators on the plant height

Treatments	Day 15	Day 30	Day 45	Day 60	Day 75	Day 90
S_0P_0	12.40	22.50	42.67	47.67	53.67	58.67
S_0P_1	11.83	16.33	33.67	44.33	52.33	57.00
S_0P_2	13.03	20.67	39.00	43.67	48.67	52.00
S_0P_3	14.73	23.17	41.67	47.33	50.67	55.33
S_1P_0	17.47	25.70	51.67	57.00	60.33	61.67
S_1P_1	18.00	28.67	52.33	69.67	71.33	80.67
S_1P_2	17.43	27.17	38.33	48.00	56.50	59.33
S_1P_3	16.83	23.83	37.00	36.33	34.50	40.33
S_2P_0	17.50	27.53	51.33	56.53	56.80	61.67
S_2P_1	15.03	24.77	40.00	46.50	47.83	51.33
S_2P_2	15.57	25.23	45.00	53.33	51.67	54.33
S_2P_3	15.57	26.33	59.00	65.00	66.00	70.33
STDV	2.12	3.39	7.65	9.45	9.36	10.02

g/kg soil Tricho-compost and 100 mg/L of gibbrelic acid, the plant's height was measured.

The effects of auxins' apical dominance may be the cause of the plant height increase. In addition to increasing nutrient uptake, growth regulators are involved in improving efficient assimilation of photosynthetic products, photosynthetic activity and quick cell division and prolonging in the growing portion of plants (Pandita et al., 1980). Growth regulators were found to have a similar positive effect on plant height in chilies by Daddlmani and Panchal (1989) and Revnappa (1998).

Number of branches per plant

The number of branches in the chili crop increased as the crop growth period progressed. 15 days was the lowest branching observed for nearly all treatments. Plant height was measured at 75 and 90 days when gibbrelic acid (100 mg/L) and Tricho-compost (200 g/kg soil) were applied together. The outcomes of this experiment are consistent with the conclusions of studies conducted in chili by Chaudhary et al. (2006) and Vandana Prajapati et al. (2014).

Number of leaves per plant

The quantity of leaves on a plant is a crucial morphological factor. As time went on, there was a change in the number of leaves per plant. After 45 days of treatment with gibbrelic acid

(100 mg/L) and Tricho-compost (200 g/kg soil), the highest number of leaves was seen. According to Shankhwar et al. (2017), the use of plant growth regulators had a momentous impact on the number of leaves, branches and height of the plants.

Number of flowers per plant

According to Tamilselvi and Vijayaraghavan's study (2014), spraying different growth regulators during flowering and 15 days later had an impact on the growth of the chili cv. K 1. The impact of growth regulators on improved plant growth, increased fruit set, and decreased flower and fruit drop may be the cause of the increase in the yield of chili and its constituent parts. Growth regulator-sprayed plants continued to be physiologically more active in order to accumulate enough food reserves (source) for the development of flowers and fruits (Raj et al., 2016). After 45 days of treatment with a combination of gibbrelic acid (100 mg/L) and Tricho-compost (200 g/kg soil), the highest number of flowers were seen.

Fruit Length (cm)

According to Natesh et al. (2005), GA3@100 ppm had the highest recorded length of fruit (16.3 cm), diameter of fruit (3.7 cm), and maximum number of fruits per plant (24.0). According to Kumari et al. (2016), applying
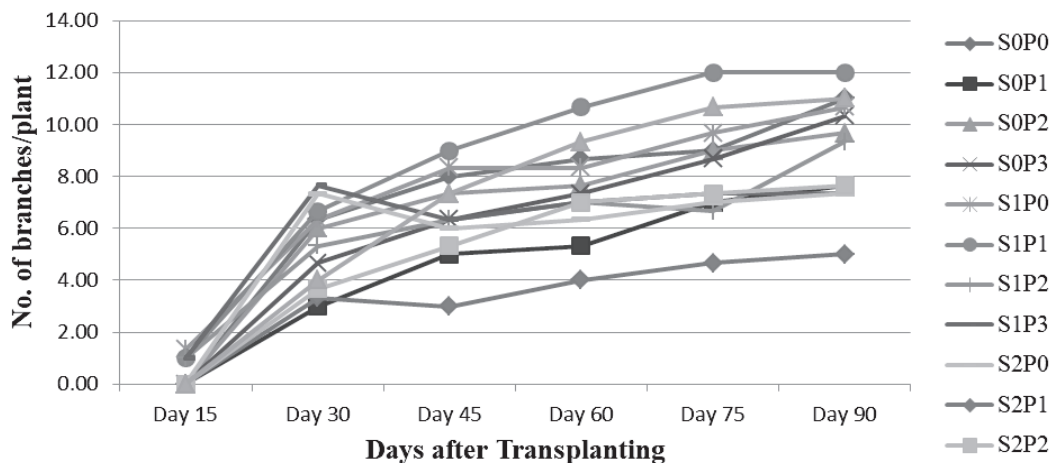
Figure 2: Combined effect of Tricho-compost as soil treating agent and foliar spraying of plant growth regulator(s) on number of branches per plant

Table 2: Combined effect of Tricho-compost as soil treating agent and foliar spray of plant growth regulators on the number of leaves per plant

Treatments	Day 15	Day 30	Day 45	Day 60	Day 75	Day 90
S_0P_0	10.33	58.33	93.67	83.67	91.67	91.67
S_0P_1	10.00	33.67	65.00	60.67	84.67	72.67
S_0P_2	10.00	40.67	79.00	82.00	92.67	88.67
S_0P_3	11.33	43.67	84.00	89.00	104.33	91.00
S_1P_0	12.00	49.33	115.33	92.67	108.67	90.00
S_1P_1	11.67	42.33	120.33	92.33	98.33	85.33
S_1P_2	12.00	38.00	78.00	81.00	98.67	91.00
S_1P_3	11.00	45.33	89.00	73.33	64.67	54.00
S_2P_0	12.33	41.33	86.00	69.67	69.00	73.33
S_2P_1	11.00	29.67	50.00	50.67	54.67	46.67
S_2P_2	10.33	25.67	63.00	70.00	66.67	67.00
S_2P_3	11.00	36.00	99.67	101.67	112.67	82.67
STDV	0.81	8.76	20.60	14.62	19.15	15.33

50 ppm of NAA produced the greatest fruits number (71.33) and length of fruit (8.55 cm). After 60 days of treatment with Tricho-compost at 200 g/kg soil and 50 ppm NAA (Naphthelene acetic acid), the highest amount of flowers was seen.

Number of fruits per plant

The treatment combination of 50 ppm of NAA (Naphthelene Acetic Acid) and zero application of Soil Treating Elements resulted in the greatest number of flowers being observed after 60 days. In 2012, Singh and colleagues found that in two different cultivars of California Wonder, capsicum and Solan Bharpur, the application of NAA @ 50 ppm, twice, at the onset of flowering and again 20 days after the initial spray on the flower cluster of the plant, resulted in the highest number of fruits per plant (35.44 & 32.77, correspondingly).

Chili yield

The combination of zero applications of a plant growth regulator and zero applications of a soil-treating element produced the maximum yield of chilies. The combination of 50 ppm of NAA (naphthelene acetic acid) and 200 g/kg of tricho-compost was found to yield the highest amount of chilies. NAA @ 60 ppm increased weight of fruit (169.66 g), fruit yield per plant (1.67 kg), and number of fruits per plant (9.87) according to Singh et al. (2015). The plant's increased photosynthetic activity, which may have led to a greater synthesis of carbohydrates and an increase in the growth, may be attributed to NAA. The factors that ultimately contribute to a higher yield of chilies are fruit size and weight (Mahindre et al., 2018).

Table 3: Combined effect of Tricho-compost as soil treating agent and foliar spray of plant growth regulators on the number of flowers/plant

Treatments	Day 15	Day 30	Day 45	Day 60
S_0P_0	11.67	1.00	0.00	0.67
S_0P_1	7.67	2.33	0.00	0.00
S_0P_2	10.00	2.33	0.67	1.67
S_0P_3	10.33	5.00	1.67	0.33
S_1P_0	8.33	7.00	0.67	1.00
S_1P_1	12.00	13.67	0.00	0.00
S_1P_2	4.33	2.33	4.33	8.00
S_1P_3	8.67	3.00	0.33	0.33
S_2P_0	7.00	4.00	0.00	1.00
S_2P_1	3.33	4.33	0.00	0.00
S_2P_2	6.00	6.33	2.67	1.33
S_2P_3	10.67	7.33	1.33	1.00
STDEV	2.79	3.42	1.35	2.19
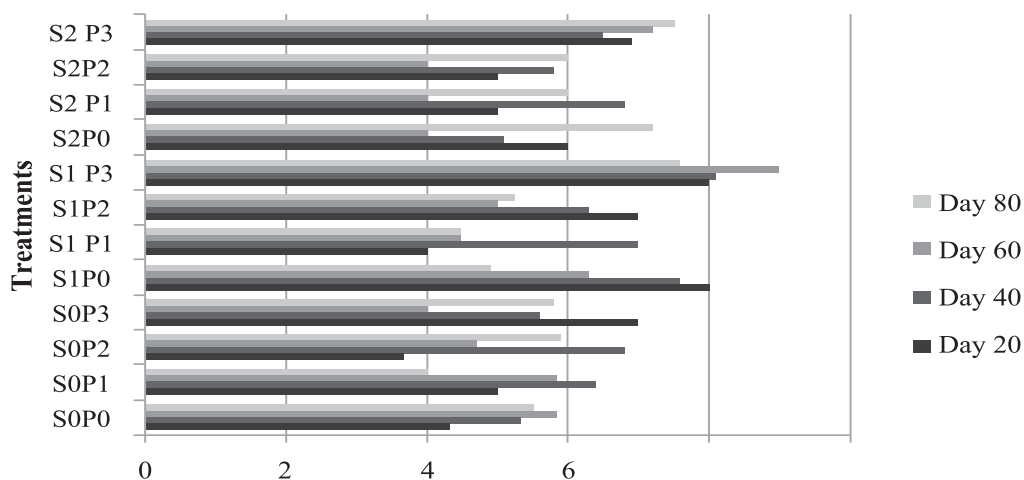
Figure 3: Combined effect of Tricho-compost as soil treating agent and foliar spray of plant growth regulators on fruit length (cm)

A specific concentration of a Trichoderma harzianum strain's spore suspension was combined with exact amounts of treated raw materials, e.g. sawdust, maize bran, vegetable wastes, water hyacinth, cow dung, and molasses to create Tricho-compost, a Trichoderma enhanced compost fertilizer (Nahar et al., 2012). According to Nahar et al., the use of Tricho-compost and Tricho leachate reduced the mortality of seedlings caused by *Sclerotium rolfsii* by approximately 98%. Plant diseases are the main crop production issues that cause significant global losses in productivity and production; as a result, diseases must be promptly controlled to ensure a steady supply of food to meet the enormous claim of expanding people/population (Yedidia et al., 2001). Excessive chemical use during disease management is negatively impacting environmental quality and has led to the emergence of organisms that are tolerant (Chao & Zhuang,

Table 4: Combined effect of Tricho-compost as soil treating agent and foliar spray of plant growth regulators on number of fruits per plant

| Treatments	Day 15	Day 30	Day 45	Day 60	Day 75	Day 90	Day 105
S_0P_0	6.33	9.00	6.33	6.33	7.67	8.00	5.00
S_0P_1	5.00	5.33	3.00	0.67	0.00	0.00	0.00
S_0P_2	4.33	6.33	9.67	14.33	12.33	9.33	7.33
S_0P_3	6.67	10.00	7.67	26.67	5.00	4.33	3.00
S_1P_0	5.33	11.33	13.33	18.33	5.33	5.33	6.67
S_1P_1	5.00	14.33	19.33	7.33	3.33	2.00	0.33
S_1P_2	2.00	4.33	10.00	9.00	7.67	3.67	2.00
S_1P_3	3.67	6.33	12.67	7.00	7.00	4.67	2.67
S_2P_0	3.33	7.33	9.00	8.33	4.33	6.33	7.33
S_2P_1	1.00	3.00	4.33	1.67	0.00	0.00	0.00
S_2P_2	2.00	6.00	13.33	11.67	6.33	4.67	1.67
S_2P_3	2.00	11.00	23.00	19.00	10.00	8.00	5.67
STDEV	1.86	3.31	5.84	7.57	3.64	3.00	2.82
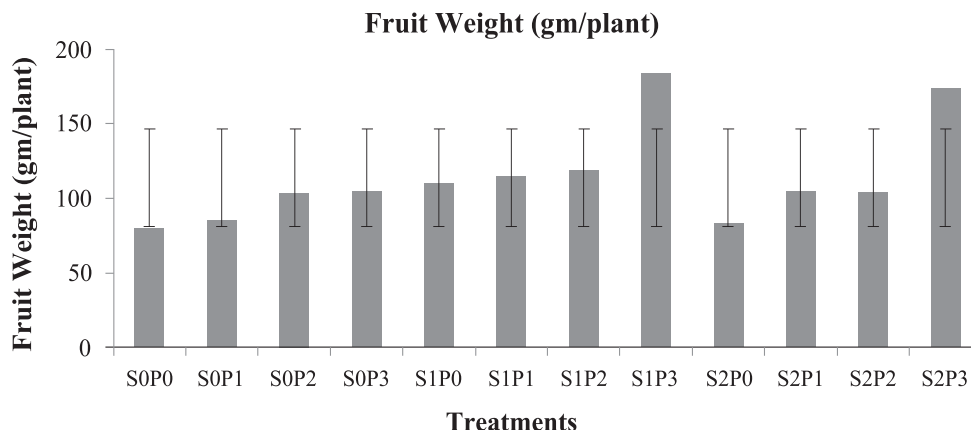
Figure 4: Combined effect of Tricho-compost as soil treating agent and foliar spraying of plant growth regulators on chili yield (gm/plant)

2019). Because of its mycoparasitic qualities, Trichoderma harzianum is a biocontrol agent that is extensively used in the dealing of fungal diseases (Shen et al., 2015). It is well known that plant growth regulators improve the source-sink relationship and promote photoassimilate translocation, which aids in improved fruit and flower retention. Immature flower and fruit drop is the main issue with chili production. This is brought on by hormonal and physiological imbalances in the plants, especially in critical environment like extremely high or low temperatures (Joshi and Singh, 2003; Erickson and Makhart, 2001). Regulators of plant growth that lessen flower drop (Tamilselvi and Vijayraghvan, 2014). Joshi et al. (1999) found that applying 40 ppm of NAA at the onset of the flower bud and 20 days later resulted in the highest plant height (74.80 cm) in Chili. According to Natesh et al. (2005), GA3 @ 100 ppm significantly increased plant height (85.7 cm) and the number of branches/plant (30.3) among the plant growth regulators that sprayed during the flowering period. GA3 @ 50 ppm and NAA @ 20 ppm were the next two plant growth regulators (PGRs) in chili that decreased flower drop (Tamilselvi and Vijayaraghavan, 2014). One class of cytokinin that encourages cell division is kienetin (Anolisa et al., 2020). Natesh et al. (2005), Singh et al. (2015) as well as Balraj et al. (2002) have reported higher concentrations of NAA with an influence on chilies.

Conclusion

To clarify the functions of Trichoderma's numerous gene products, a thorough metabolomic-genomic investigation is advised (Mukherjee et al., 2012). According to reports, growth regulators can quickly alter a plant's phenotypic and affect the growth of the plant from seed germination to senescence by either stimulating or inhibiting growth retardants and growth promoters, respectively. Growth promoters facilitate the ripening of fruit, which in turn may increase productivity and yield (Tamilselvi & Vijayraghvan, 2014). It might be enlightened to conduct more research on soil treating agents.

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A GIS-based bi-variate statistical approach for multispectral satellite indices in landslide susceptibility mapping, Rangamati district, Bangladesh

Khandakar Hasan Mahmud[1], Bibi Hafsa[1], Md. Sharafat Chowdhury[1*,] Md. Naimur Rahman[1], Md. Sujon Sheikh[1]and Sumaiya Ahmed[1]

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

ARTICLE INFO

ABSTRACT

Landslide susceptibility maps are generally prepared based on topographic, geologic, geomorphic, climatologic, and hydrologic parameters. However, the recent trend of using geographic information system (GIS) and remote sensing-based multispectral indices is also getting popular for landslide susceptibility mapping. Multispectral satellite image-based spectral indices have the potential to contribute to landslide susceptibility mapping as these spectral indices provide different aspects of land use/land cover characteristics. In this research, landslide susceptibility map of Rangamati Metropolitan Area has been prepared by using three spectral indices – normalized difference vegetation index (NDVI), bare soil index (BSI), and normalized difference clay index (NDCI) along with elevation, slope (degree), aspect, surface geology, distance to fault lines and distance to road. A landslide inventory of 198 events between 1999 and 2018 were considered here to prepare the landslide susceptibility map. The bi-variate statistical model of frequency ratio was employed to measure the relationship between landslides and associated conditional factors. The most significant relationship for landslide was found between geology (2.44), distance to a road (2.31) and NDVI (FR = 3.19). The NDCI (FR = 2.14) and BSI (FR = 1.86) also showed a significant positive impact on landslides. The Area under the Curve (AUC) of Receivers Operating Characteristic (ROC) was measured to validate the final map where the success rate of the map was 0.835 indicating a good accuracy level. This type of susceptibility map can be used for disaster mitigation planning.

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Introduction

Landslide is a geologic hazard that has become a common incident in the Tertiary hills of Bangladesh (e.g., the hilly districts of Khagrachhari, Rangamati, Bandarban and the hilly areas of Chattogram and Cox's Bazar districts). The frequency and magnitudes of these landslides are particularly significant in
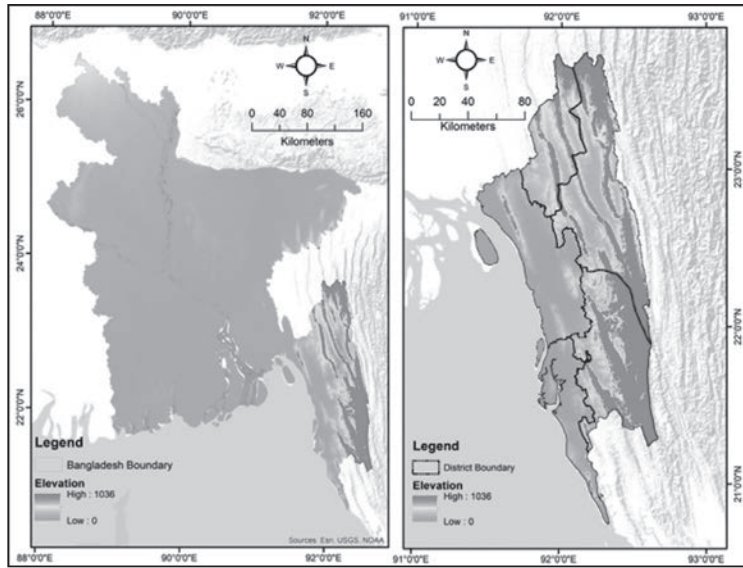
Figure 1: The geographical location of the landslide susceptible area of Bangladesh
Source: Compiled after USGS 2015 & BBS, 2011

the Chattogram Hill Tracts (CHT e.g., districts of Khagrachhari, Rangamati and Bandarban), which is located in the south-east portion of Bangladesh (Figure 1). It is also noted that most of these devastating landslides occur during the monsoon period (June – September annually) featured by heavy rainfall in this part of the country (Rabby et al., 2019; Alam, 2020; Ahmed, 2021; Hafsa et al. 2022). Heavy rainfall has the potential to wash away steep hillsides and shift unstable clay soil. This scenario could become more worsen in near future due to climate change because climate change is increasing the unpredictability and intensity of extreme weather (Anas, 2022). Although high rainfall is the primary cause of these landslides, there are a few other contributing factors, such as deforestation, hill cutting, and unauthorized
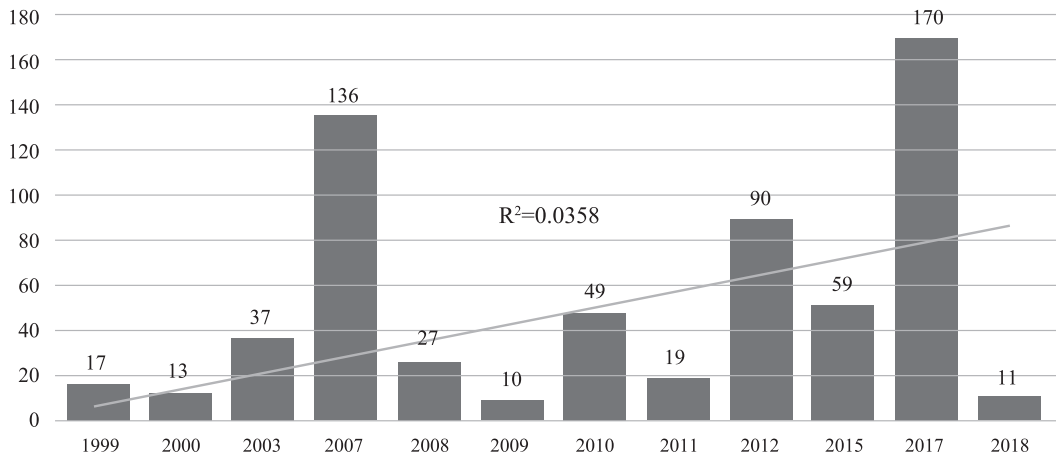
Figure 2: Increasing death tolls during last two decades in the south-eastern hilly region of Bangladesh due to landslides.
Source: Compiled after Anas, 2019

development operations – especially by the landless poor in-migrant population from other parts of the country. Although, local indigenous communities have knowledge for centuries how to live in the hilly areas by constructing homes on terraces using lightweight materials like bamboo and building in stages against softer slopes as opposed to digging into the hill. However, some of these traditions are also being lost by indigenous people as a result of urbanization. All these elements not only contribute to the occurrence of landslides but also to the aggravation of their effects (Ahmed, 2021; Chisty, 2014; Gariano & Guzzetti, 2016; Hafsa et al. 2022; Mia, 2016, 2017; Sifa, 2019).

As the most vulnerable locations become more populated, landslides have grown more dangerous. Severe landslides struck the CHT in the years of 1968, 1970, and the 1990s, but no death records were recorded. However, with changes in land use and land cover, landslides have become more severe over time in the mountainous regions of Bangladesh (Ahmed & Kelman, 2018; Anas, 2022). Figure 2 below shows an increasing trend of death tolls with time. The trend line reliability (R^2 = 0.5377) value also shows a positive inclination with time.

The landslide susceptibility map demarcates the areas into several zones according to degree of probability of landslide occurrences. The location of the landslides and the different types of factors relevant to the local environmental setting which are responsible for landslide occurrences such as elevation, slope, soil type, lithology, and water flow direction in an area are considered in landslide susceptibility mapping. The landslide susceptibility map is an effective tool for policy planning in landslide disaster management (Chapagai, 2011; Chen, 2017; Chowdhury & Hafsa, 2022; Dahal, 2007; Hafsa et al., 2022; Pourghasemi, 2012; Sifa et al., 2019; US Geological Survey [USGS], 2020). As the safety of current habitations and infrastructure components is evaluated using the landslide susceptibility of previous experience. This in turn aids in the planning of future development projects in mountainous areas (Sarker & Kanungo, 2017).

Recent advancements in GIS and remote sensing support utilizing diverse causative factors for landslide susceptibility mapping. The preparation of the thematic layers of landslide causative factors has become feasible by the accessibility and availability of many types of remote sensing data as well as sophisticated GIS processing techniques (Shahabi & Hashim, 2015). The availability of multispectral satellite images supports to produce various types of indices that can provide important information on the characteristics of the land surface. From the multispectral indices, both natural characteristics and anthropogenic activity can be identified. The analysis of Landsat images provides information about the topography and lithologic conditions of the earth's surface. Multispectral satellite indices have also been used to determine the roughness of the land surface composition and the chemical composition of rocks and minerals (Clark et al., 2003).

The aim of the current research is to prepare a landslide susceptibility map for the Rangamati Metropolitan Area which is highly vulnerable to landslides. To prepare the map, multispectral satellite image indices have been employed along with geological data and traditional Digital elevation model (DEM) processed data. The frequency ratio model, an extensively used and widely accepted bi-variate model, has been used to measure the degree of mathematical relationship between the inventory (comprise of past landslide events) and the selected landslide conditioning factors.

Materials and methods

Secondary data were the key to fulfilling the objectives of this research work. Primary field visits were conducted for ground truthing and field verification of the secondary information. Coordinate values of the location of the historical landslide events were collected using a standard global positioning system (GPS) (Figure 3). A total of 198 events were identified and GPS coordinates were verified in the field with a maximum of 131 landslide events were recorded in Rangamati Sadar Upazila (sub-district) only

between 1999 and 2018. At the same time Kaptai, Kawkhali and Naniarchar Upazilas recorded 45, 18, and 4 landslide events respectively indicating more events in the urbanized areas. DEM data were produced from a 30-meter resolution Shuttle Radar Topography Mission (SRTM) image. These SRTM images are freely available from National Aeronautics and Space Administration (NASA) (USGS, 2015). Slope, elevation, aspect, topography, etc. data were further measured from this SRTM-based DEM. The Geologic Map of Bangladesh from the Geological Survey of Bangladesh (GSB) was used for the geological classification of the study area (GSB, 2020). 30-meter resolution Multispectral Landsat 8 OLI imageries of 2019 were freely collected from the USGS website (USGS, 2020) for the calculation of the spectral indices.

Selection of the study area

Rangamati district lies between 22°27' and 23°44' north latitudes and 91°56' and 92°33' east longitudes (Figure 3). The district of Rangamati is bounded by the Indian estate of Tripura and Mizoram to the north and east respectively, the Chin State of Myanmar is in the south-east; Bandarban, Chattogram, and Khagrachhari districts of Bangladesh are to the south, east,

and north-east respectively (Bangladesh Bureau of Statistics [BBS], 2011). Rangamati consists of 10 Upazilas. In this research, the study area covers the Rangamati Sadar, Kawkhali, Nanirchar, and Kaptai Upazilas (Figure 3). Rangamati Sadar is the main urban sub-division in the district. Kaptai, Kawkhali, and Naniarchar are adjacent sub-divisions at the south-west, north-west, and north respectively. The landform of Rangamati consists of tertiary and quaternary sediments. The underlying sediments have been folded and faulted. The sedimentary landforms of the study area have been uplifted and dissected by rivers and streams. There is a significant alteration of sandstone and shale found in the soils of Rangamati. The sandstone, siltstone, and shale and the alteration of the soil composition make topography more vulnerable to landslides. Due to altered sandstone and shale, as well as a greater siltstone composition, the Bhuban, Bokabil, and Tipam sandstone formations in Rangamati district are relatively more subject to landslides (Abedin et al., 2020; GSB, 2020; Haque et al., 2018).

Landslide inventory

In landslide study, preparing the landslide inventory is considered the fastest and the most
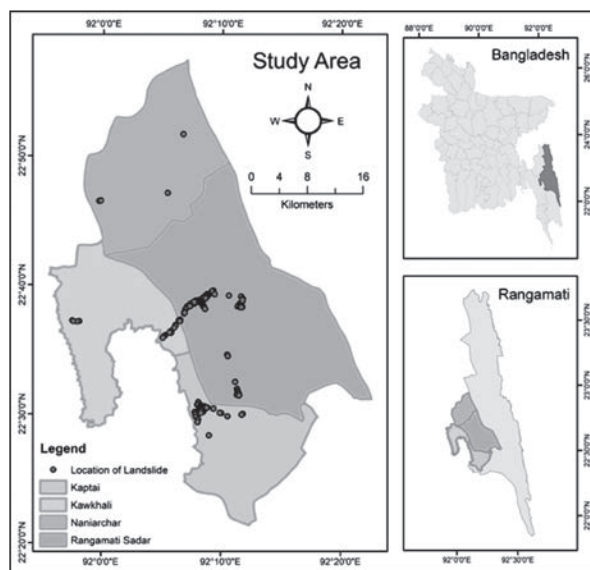
Figure 3: Location of the study area
Source: Compiled by authors after BBS, 2011
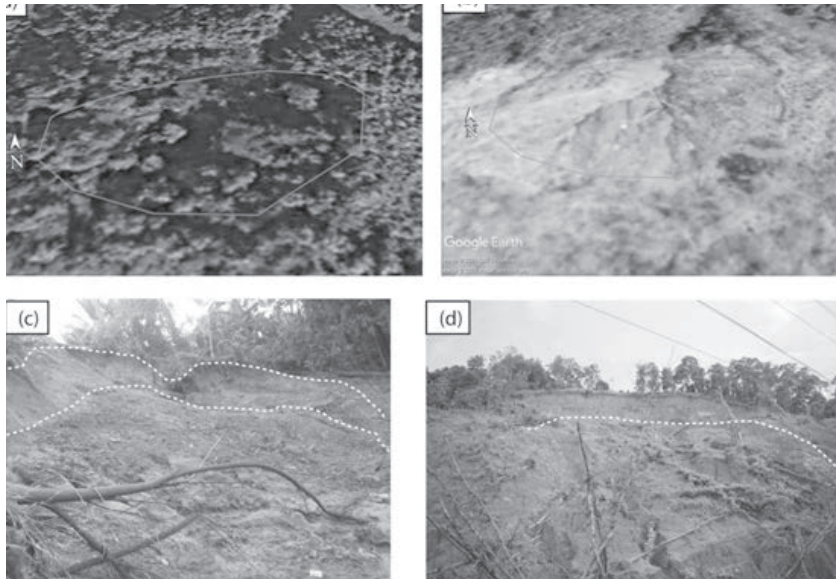
Figure 4: Site condition (a) before and (b) after landslide occurrence in Juraichhari detected from the time series image of Google Earth. Landslide in (c) Vedvedi (d) Rangamati-Chattogram Road captured during field survey

Source: Google Earth and Field Survey

fundamental step. A landslide inventory consists different characteristics of the past landslide events in a study area, especially the geographical location. The hypothesis behind inventory mapping is that in the same site condition of the past landslide events will feed the future landslides in a given study area (Devkota et al., 2012; Xu, 2013). The best way to prepare inventory data base is conducting field survey. In the current research, both field survey and Google Earth pro time interpretation were carried out to prepare the inventory database. Google Earth pro provides finer resolution time series data suitable for detecting landslides. In the Figures 4(a) and 4(b), landslide identification from Google Earth pro time series image interpretation has been shown. This landslide inventory database had been employed to calculate the mathematical relationships between landslides and the conditioning factor-induced corresponding site conditions. Figures 4(a) and 4(b) show the site condition before and after landslide occurrence, respectively, in the Juraichhari area. Figures 4(c) and 4(d) show images of landslides captured during the field survey that occurred at Vedvedi and Rangamati-Chattogram Road, respectively.

In most of the landslide sites in the study area debris material and mud content was dominant. It was also found during the field survey that clayey soil consisting of unconsolidated materials had been flowing following the slope direction (upslope to downslope).

Landslide conditioning factor selection

Landslides have been occurring in the south-eastern hilly areas of Bangladesh is a geological phenomenon where slope failure and shallow debris flow are common because of the surface geology of this region (Brammer, 2000; Islam, 2018). The previous study considered conditioning factors of slope angle, slope aspect, vegetation, land use, geology, and some other hydrologic and geomorphic factors to produce landslides susceptibility map of the Rangamati Metropolitan Area (Haque et al., 2018; Kafy et al., 2019; Sifa et al., 2019). There is no strict criterion that has been followed to select landslide conditioning factors. As a result different landslide causative factors were selected in different regions across the world for landslide susceptibility mapping. Though the number of conditioning factors varies from 6 or 7 to many, more conditioning factors do not always produce a better result (Guo et al., 2015; Wu et al., 2020).

Generally, landslide susceptibility assessment in Bangladesh focused on geological, hydrological, climatic, and some anthropogenic factors (BBS, 2011; Ahmed et al., 2015; Khatun et al., 2018; Sifa et al., 2019). However, in the current research, emphasis has been given to the geological factors and some spectral indices processed from remote sensing images to prepare landslide susceptibility map for the study area. The Landsat 8 satellite image processed indices of NDVI, BSI, and NDCI has been used in the research. BSI can calculate the degree of bareness, and NDCI can produce a clay content ratio index over the earth surface. Clay content ratio obtained from the NDCI reduces the requirement of detailed soil survey. The bands of Landsat images used to prepare NDVI, BSI and NDCI are shown in Table 2. Geological units and distance to fault lines were used as geological factors. Slope angle and slope aspect are processed from DEM images used as common topographic factors. Many areas of this region are inaccessible and are far away from the city. Using these types of landslide conditioning factors could improve the quality and acceptability of landslide susceptibility map even in the inaccessible in the regions. The degree of mathematical relationship between the selected landslide conditioning factors and the prepared inventory database of landslides was measured by bi-variate statistical models of frequency ratio considering that this same site condition will produce landslides in the future.

Data processing

The landslide conditioning factors was processed using ArcMap 10.5 software to prepare each of the thematic layers. NDVI, NDCI and BSI were calculated using the predetermined formula using the different bands of Landsat satellite images (Equation 1, 2 and 3). Slope degree and slope aspect are measured using the ArcMap toolbox. Distance to fault was calculated by buffer analysis tool of ArcMap 10.5 software. The geological map is divided into geological groups of the study area.

The elevation is considered an important landslide conditioning factor. Generally, high elevation is highly susceptible to landslides. Rainfall amount, vegetation characteristics and most importantly the potential energy vary with the variation of elevation (Vasu & Lee, 2016). The elevation was divided into five groups using the natural breaks classification techniques for the study area. The classes are 11-63, 63-114, 115-189, 190-296, >297 (Figure 5a).

Slope aspects were measured by processing DEM imageries for the study area by using the built-in tool of ArcMap 10.5 software. Nine types of slope aspects were identified in the study area namely (Fig. 3b): -1°(flat), 0°-22.5°; 337.5°-360° (north), 22.5°-67.5° (northeast), 67.5°- 112.5° (east), 112.5°-157.5° (southeast), 157.5°- 202.5° (south), 202.5°-247.5° (southwest), 247.5°- 292.5° (west), and 292.5°-337.5° (northwest).

Geology is considered one of the significant conditioning factors of landslides frequently used in landslide susceptibility mapping. Because the geological group formation substantially regulates the geo-mechanical properties of the slope significantly affecting the slope stability (Duo et al., 2015). Table 1 describes the geological group units of the study area and figure 5.c illustrates their distribution in the study area.

Another geological factor considered in this study is the distance to the fault line. Because the areas over and along the fault lines are considered tectonically active. As a result, the likelihood of landslide occurrences significantly increases with proximity to fault lines (Duo et al., 2015). The distance to the fault line is measured using a buffer analysis tool. In this study, distance to

Table 1: Geological groups of the study area

Code	Group name
Ava	Valley alluvium and colluvium
QTdd	Dihing and Dupi Tila formation undivided
QTdt	Dupi Tila formation
QTg	Girujan Clay
Tt	Tipam Sandstone
Tbb	Boka Bil formation
Tb	Bhuban formation
Kaptai Lake	Water body
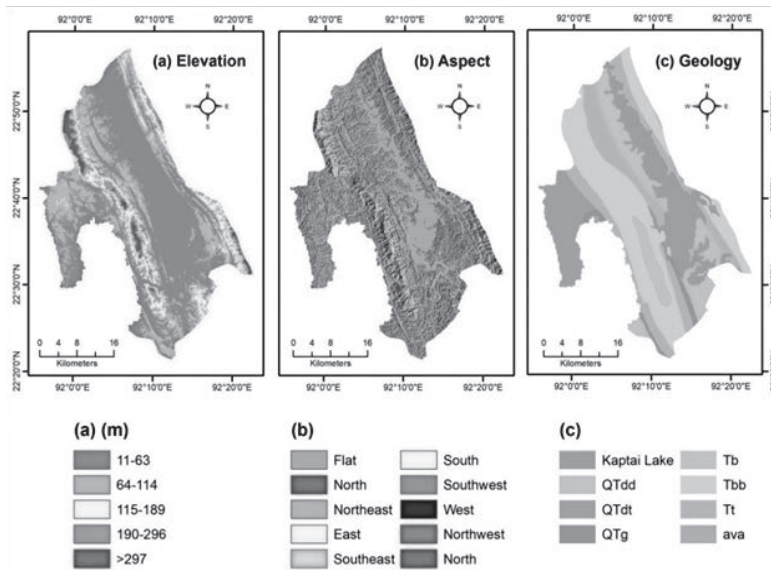
Figure 5: a) elevation, b) aspect, and c) geological units of the study area
Source: Compiled by authors after USGS, 2015 & GSB, 2020
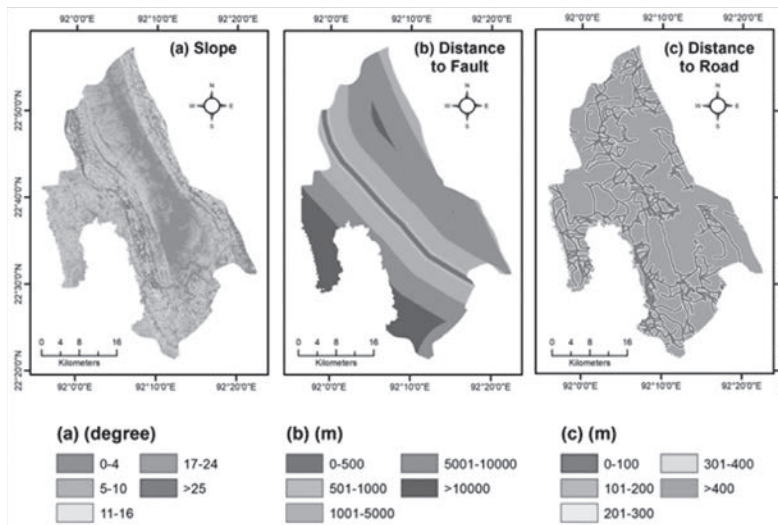
Figure 6: a) Slope, b) distance to fault, c) distance to road of the study area
Source: Compiled by authors after BBS, 2011; USGS, 2015 & GSB, 2020

fault line is manually divided into five classes: 0-500, 501-1000, 1001-5000, 5001-10000, >10000 (Figure 4b). The distance to the fault line varies linearly with increasing distance; as a result, the likelihood of a landslide is decreased with decreasing proximity to the fault line (Ilia & Tsangaratos, 2015).

Slope degree is also an important landslide conditioning factor. With increasing slope the shear strength decreases and the slope becomes unstable. As a result, there is a greater chance of landslide occurrence in the areas with steep slopes. The slope degree was calculated using ArcMap 10.5 software from DEM images.

It was classified into five classes of 0-4, 5-10, 11-16, 17-24 and >25 degree (Figure 5a) using the natural breaks classification method (Environmental Systems Research Institute, Inc. [ESRI], 2022; Khatun et al., 2018).

The road is an important anthropogenic landslide conditioning factor. Road construction modifies the regular natural pattern of the slope. Slope modification by road construction reduces slope stability and triggers landslides. In this research, distance to road was measured in five intervals of distance using the buffer analysis tool. They are: 0-100, 101-200, 200-300, 301-400, >401 (Figure 6c).

In landslide susceptibility analysis, NDVI is considered a common conditioning factor (Alam, 2020; Haque et al., 2018; Wang et al., 2019). NDVI is categorized into five classes using natural breaks (Figure 6a). The universal formula (equation 1) was used to measure NDVI from Landsat 8 OLI image:

$$N\ D\ V\ I\ \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})} \dots\dots\dots\dots\dots\dots (1)$$

Where, RED = Band 4 and NIR = Band 6 of Landsat 8 OLI

The presence of vegetation retains soil and prevents slope failure because of plant roots. As a result, barren areas are highly vulnerable to landslides (Dahal et al., 2007; Kumar & Anbalagan, 2019; Mathew et al., 2008). BSI exhibits the difference between markedly distinct vegetation types such as complete bare soils, light vegetation cover, and dense vegetation cover etc. in a given area. As a result, spatial distribution of bare soils and the pattern of vegetation cover with distinct background responses can be assessed using the value of this index. According to the increasing degree of surface bareness, the BSI index value positively increases (Erener et al., 2016; Jamal & Mandal, 2016). BSI is classified into five classes (Figure 6b). Equation 2 was used to measure the BSI index from Landsat 8 OLI image.

$$\text{BSI} = \frac{\{(\text{SWI} - 1 + \text{RED}) - (\text{NIR} + \text{BLUE})\}}{\{(\text{SWI} - 1 + \text{RED}) + (\text{NIR} + \text{BLUE})\}} \dots\dots\dots\dots\dots (2)$$

Where, SWI–1 = Short wavelength infrared-1, RED = Band 4, NIR = Near Infrared

and BLUE = Band 2 of Landsat 8 OLI image

Previous studies indicate the influence of clay minerals in reducing slope stability (Yalcin, 2007; Summa et al., 2010; El Jazouli et al., 2020). Many studies were conducted on detecting clay minerals from NIR and SWI bands of satellite images (Landsat 5, 7, 8 OLI and also ASTER) where researchers found acceptable results using ground truth data (Banerjee et al., 2019; El Jazouli et al., 2020; Gomez et al., 2018; Masoumi et al., 2016; Ouerghemmi et al., 2015). In the current research, NDCI was measured from Landsat 8 OLI images by using the equation proposed by Drury (1987) to obtain clay minerals from multi-spectral satellite images. The obtained NDCI was divided into five classes using natural break classification techniques (Figure 6c). Equation 3 was used to measure the NDCI index from Landsat 8 OLI image.

$$N\ D\ C\ I\ \frac{\text{SWI} - 1}{\text{SWI} - 2} \dots\dots\dots\dots\dots\dots (3)$$

Where, SWI–1 = Short wavelength infrared-1 and SWI–2 = Short wavelength infrared-2 of Landsat 8 OLI image

The natural break classification approach was used to classify NDVI, NDCI, and NDBI data in the study area. Because the natural break classifies the values according to natural groupings and inherent patterns of the data (Salamba et al., 2019). There is a large artificial reservoir in the study area free of landslides. The natural breaks method has automatically removed the influence of the values produced in the reservoir from the factor layers.

Frequency ratio (FR) model

Among the bivariate statistical models, FR is used most extensively because of its easy calculation procedure and accurate result (Allen et al., 2015; ESRI, 2022). The FR is a reliable tool that measures the degree of relationship between the natural phenomenon and its associated factors to predict the probability of that phenomenon (ESRI, 2022). The frequency ratio method with simple mathematical calculation can provide accurate probabilistic results quickly (Allen et al., 2015). This model can accurately predict
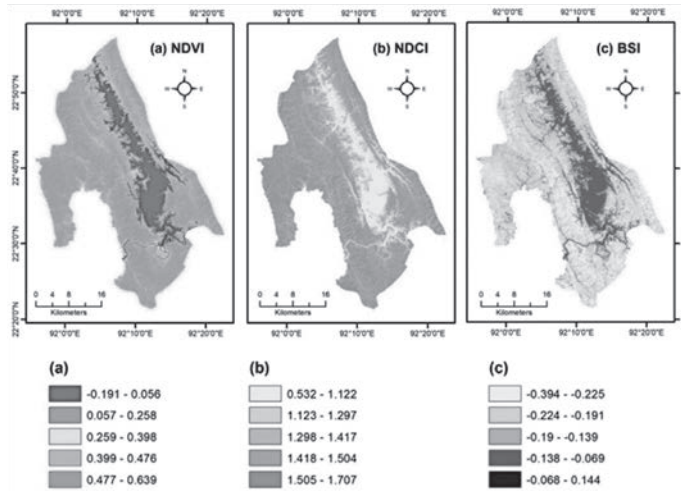
Figure 7: a) NDVI, b) NDCI, and c) BSI of the study area
Source: Compiled by authors after Landsat 8 OLI, USGS, 2020

landslide probability for each class within a thematic layer (Allen et al., 2015; Hong et al., 2015; Silalahi et al., 2019). Citing several sources of research, Zhang et al. (2020) concluded that the relatively higher accuracy of the frequency ratio method than other methods. Researchers prefer this model among other bi-variate models even in recent times (Aditian et al., 2018; Chen et al., 2017; Drury, 1987; Fayez et al., 2018; Hong et al., 2015; Khan et al., 2019; Pirasteh & Li, 2017; Regmi et al., 2013; Wu et al., 2020; Zhang et al., 2021), because the model is easy to execute through the GIS environment and it can produce relatively higher accuracy (Allen et al., 2015; Thanh et al., 2020). The threshold value of FR is 1. FR value above 1 indicates the likelihood of the events and a greater value indicates a higher probability. On the other hand, if the FR value is below 1, there is no chance of the occurrence of an event. The influence of each thematic layer is also derived from the FR model. It is indicated by probability ratio (PR), shown in Table 3. In the current research, the value of the FR was accounted using the Equation 4:

$$W_{ij} = \frac{FL_{ij}}{FN_{ij}} \dots \dots \dots \dots \dots \dots \dots \dots \dots (4)$$

In equation 4, W_{ij} = FR of class i of parameter j; FL_{ij} = frequency of landslides for class i

of conditioning factor j; and FN_{ij} = frequency of non-occurrence of landslides for class i of conditioning factor j.

In this research, equation 4 was used to account the frequency of each class of a causative factor. After that the values of all the conditioning factors were normalized to determine the PR of every conditioning factor. The results are shown in Table 1. The conditioning factors were combined by using equation 5 to prepare the final landslide susceptibility map (LSM).

$$LSM = \sum_{j=1}^{n} W_{ij} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (5)$$

In equation 5, Wij = measured weight of class i of the conditioning factor j, and n = sum of the conditioning factors used.

Results

Table 2 tabulates the results measured by the FR model. With a frequency ratio of 3.19, the NDVI has the highest positive influence on the likelihood of landslides among the selected conditioning factors. In the research area, geology exhibited the second-highest impact on landslides, with a frequency ratio of 2.44. Distance to road exhibited the third-highest impact with a frequency ratio value of 2.31, and NDCI (FR = 2.14) exhibited the fourth-highest impact.

Table 2: Statistical relationship between landslides and landslide conditioning factors using frequency ratio model (CP = class pixel, LS = landslides, FR = frequency ratio, RF = relative frequency, PR = probability ratio)

Factors	Class	CP	% CP	LS	% LS	FR	RF	RF %	PR
Elevation	11-63	812365	54.31	106	53.54	0.99	0.26	26.28	1.85
	64-114	454379	30.38	72	36.36	1.20	0.32	31.91	
	115-189	129025	8.63	18	9.09	1.05	0.28	28.10	
	190-296	70649	4.72	0	0.00	0.00	0.00	0.00	
	>297	29375	1.96	2	1.01	0.51	0.14	13.71	
Aspect	Flat (-1)	169640	11.30	0	0.00	0.00	0.00	0.00	1.00
	North (0-22.5)	79941	5.33	6	3.03	0.57	0.06	5.95	
	Northeast (22.5-67.5)	162395	10.82	21	10.61	0.98	0.10	10.25	
	East (67.5-112.5)	159755	10.64	31	15.66	1.47	0.15	15.38	
	Southeast (112.5-157.5)	166013	11.06	19	9.60	0.87	0.09	9.07	
	South (157.5-202.5)	176079	11.73	21	10.61	0.90	0.09	9.46	
	Southwest (202.5-247.5)	197560	13.16	43	21.72	1.65	0.17	17.26	
	West (247.5-292.5)	168317	11.21	28	14.14	1.26	0.13	13.19	
	Northwest (292.5-337.5)	150443	10.02	22	11.11	1.11	0.12	11.59	
	North (337.5-360)	70741	4.71	7	3.54	0.75	0.08	7.85	
Geology	Tt	255909	16.88	61	30.81	1.83	0.36	36.09	2.44
	Tbb	446541	29.45	57	28.79	0.98	0.19	19.32	
	QTdt	163362	10.77	4	2.02	0.19	0.04	3.71	
	Tb	154278	10.18	31	15.66	1.54	0.30	30.42	
	QTdd	129663	8.55	36	18.18	2.13	0.42	42.03	
	lake	314462	20.74	0	0.00	0.00	0.00	0.00	
	QTg	49454	3.26	9	4.55	1.39	0.28	27.55	
	ava	2453	0.16	0	0.00	0.00	0.00	0.00	
Slope	0-4	468871	31.24	16	8.08	0.26	0.05	4.62	1.44
	5-10	441433	29.41	66	33.33	1.13	0.20	20.24	
	11-16	346479	23.08	67	33.84	1.47	0.26	26.18	
	17-24	188712	12.57	41	20.71	1.65	0.29	29.41	
	>25	55389	3.69	8	4.04	1.09	0.20	19.55	

Factors	Class	CP	% CP	LS	% LS	FR	RF	RF %	PR
Distance to fault	0-500	56793	3.75	12	6.06	1.61	0.27	27.48	1.39
	501-1000	55180	3.65	12	6.06	1.66	0.28	28.28	
	1001-5000	466253	30.83	100	50.51	1.64	0.28	27.89	
	5001-10000	721849	47.72	67	33.84	0.71	0.12	12.07	
	>10000	212481	14.05	7	3.54	0.25	0.04	4.28	
Distance to road	0-100	224279	14.80	55	27.78	1.88	0.23	22.61	2.31
	101-200	172141	11.36	76	38.38	3.38	0.41	40.70	
	201-300	165187	10.90	48	24.24	2.22	0.27	26.79	
	301-400	121207	8.00	12	6.06	0.76	0.09	9.13	
	>400	832771	54.95	7	3.54	0.06	0.01	0.77	
NDVI	-0.191 - 0.056	215450	14.50	0	0.00	0.00	0.00	0.00	3.19
	0.057 - 0.258	57598	3.88	4	2.02	0.52	0.10	9.70	
	0.259 - 0.398	162563	10.94	64	32.32	2.95	0.55	54.98	
	0.399 - 0.476	503824	33.92	97	48.99	1.44	0.27	26.89	
	0.477 - 0.639	546111	36.76	33	16.67	0.45	0.08	8.44	
NDCI	0.532 - 1.122	230491	15.52	0	0.00	0.00	0.00	0.00	2.14
	1.123 - 1.297	78014	5.25	22	11.11	2.12	0.37	36.96	
	1.298 - 1.417	272304	18.33	69	34.85	1.90	0.33	33.21	
	1.418 - 1.504	489665	32.96	82	41.41	1.26	0.22	21.95	
	1.505 - 1.707	415072	27.94	25	12.63	0.45	0.08	7.89	
BSI	-0.394 - -0.225	360239	24.25	20	10.10	0.42	0.06	5.86	1.86
	-0.224 - -0.191	600057	40.39	71	35.86	0.89	0.12	12.49	
	-0.19 - -0.139	249200	16.77	83	41.92	2.50	0.35	35.15	
	-0.138 - -0.069	270485	18.21	22	11.11	0.61	0.09	8.58	
	-0.068 - 0.144	5565	0.37	2	1.01	2.70	0.38	37.92	

FR of sub groups of elevation showed that elevation ranges of 64-114 meters, 115-189 meters, 11-63 meters and >297 meters have the highest frequency ratio values of 1.20, 1.05, 0.99 and 0.51, respectively. Although higher elevation has a high probability of landslides; however a lower FR (FR=0) was found for the elevation ranges of 190-296 meter in the Rangamati Metropolitan Area. The highest probability of landslide is found in the elevation ranges of 11-63 and 64-114 where 53.54% and 36.36% of landslide points are concentrated, respectively. The low FR of these classes is produced because of the presence of a higher number of pixels in that class (Table 3). In Rangamati, landslide frequency is higher in the low-elevated areas. It is clear that with increasing elevation the likelihood of landslides is decreased.

The slope aspect indicates that the south-west-facing slopes had the highest FR value of 1.65. The other slope directions that have a relatively higher impact on landslides are east, west and northwest-facing slopes which have shown FR values of 1.47, 1.26 and 1.11, respectively. The slope aspect of southwest, east, west and northwest had a landslide percentage of 21.42%, 15.66%, 14.14% and 11.11%, respectively. The rest of the slope aspect showed an FR value <1. But the slope aspect of the south and southeast has 10.61% and 9.6% landslides respectively. It is clear
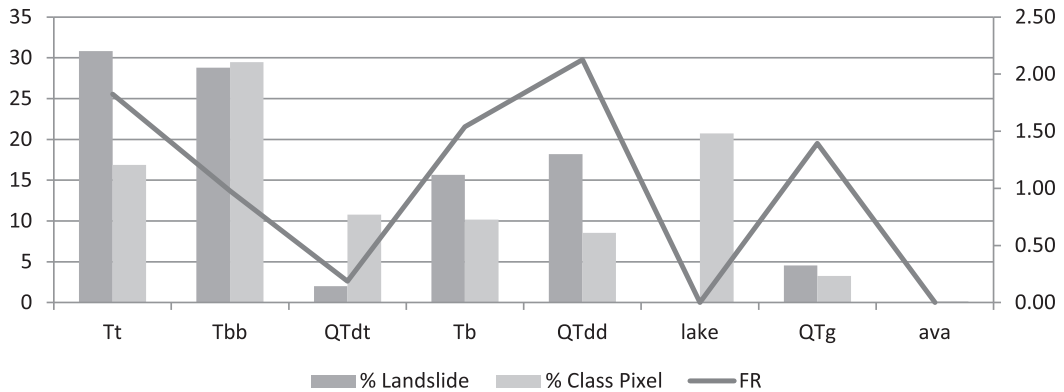
Figure 8: Frequency ratio, percentage of landslides and percentage of pixels in each geological group
Source: Compiled by authors, 2022

from the result that west oriented slope aspect has significantly affects landslides in Rangamati.

Among the geological groups, QTdd showed the highest FR value of 2.13. Tt, Tb and QTg showed FR values of 1.83, 1.54 and 1.39, respectively. The FR value was found <1 for the rest of the classes. In the case of geology, it is evident from the result that the number of pixels in each factor class and the associated landslide points significantly affected the FR value (Table 3 and Figure 8). In Tb and Tbb, 30.81% and 28.79% of landslides occurred, respectively. However, Tbb showed an FR value of 0.98 indicating no influence on landslide occurrence in the Rangamati Metropolitan Area (Table 3), because, the percentage of landslide and the percentage of

pixels of the factor class are the same (Figure 8). QTdd showed the highest FR value of 2.13 where 18.18% of the landslides occurred. Tb showed the third-highest FR values where 15.66% of landslides occurred. In the Rangamati, Tt and Tbb are responsible for landslide occurrence. These two geological groups had a higher concentration of sandstone. They also have two or more layers where shale or siltstone dominates the middle part. This type of structure becomes more unstable during continuous rainfall. Sandstone and siltstone have a higher capability to contain water. The higher concentration of water makes the soil flow according to the slope. This flow can occur even in the low elevated areas which were evident in the elevation classes.

Figure 9: Frequency ratio, percentage of landslides and percentage of pixels in each class of distance to fault line
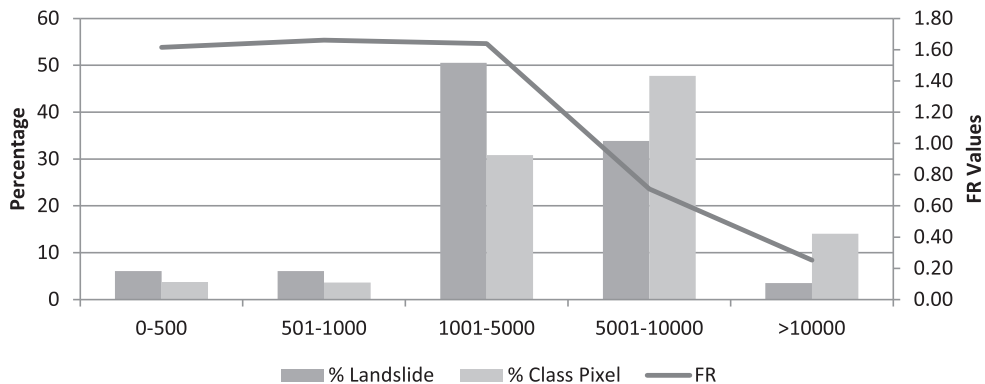**Source**: Compiled by authors, 2022

Figure 10: Frequency ratio, percentage of landslides and percentage of pixels in each class of NDCI
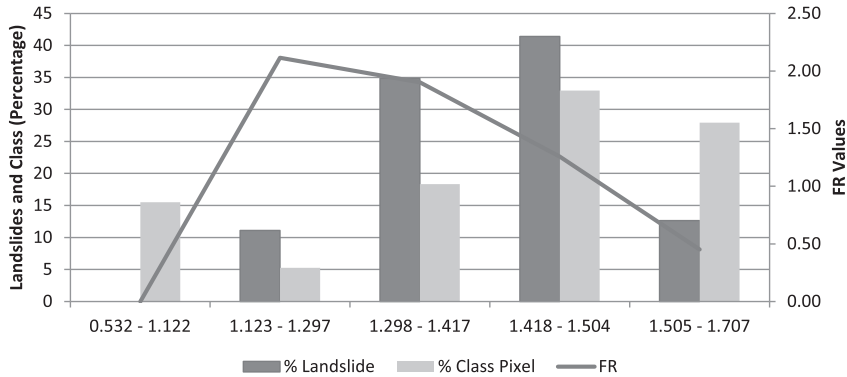**Source**: Compiled by authors, 2022

When it comes to slope angle, the likelihood of the landslide had been increased when the slope angle increased. However, after a certain extent, the likelihood of a landslide has declined. The slope angles of 11–16° and 17–24° have the largest percentage of landslides, with 33.33% and 33.84% of landslides, respectively. There exists a discrepancy between the FR value and the proportion of landslides for each factor class. The slope angles of 17 to 24° had the greatest FR value (FR = 1.65), followed by 11 to 16° (FR = 1.47) and 5 to 10° (FR = 1.13), in that order. However, it is evident that almost all of the landslides in the Rangamati Metropolitan Area occurred at a relatively lower slope angle. The percentage of landslides that happened below a slope angle of 17° and 24° was 75.25% and 94.96%, respectively (Table 3). On the other hand, it is evident from the results that a higher slope angle has a low likelihood of landslide occurrence. This is because; the low slopes in the study area are able to contain more water making the slope unstable to produce landslides. The anthropogenic activity in the low slope is also responsible for this kind of result.

The likelihood of a landslide occurring was significantly higher when the distance to the fault line was minimal. Like geology, the higher percentage of the area in a distance class and the corresponding landslide density in that class significantly affected the measured FR values. The highest landslides were found in the distance

to fault line class of 1001-5000 and 5001-10000 showing 50.51% and 33.84% landslides (Table 3 and Figure 9). The highest FR value was found in the distance to fault line class of 501-1000 (FR = 1.66) followed by 1001-5000 (FR = 1.64) and 0-500 (FR = 1.61).

Distance to road, an anthropogenic factor, is the most responsible cause of landslides in the Rangamati district. Table 3 indicates that as the distance to the road increases, the likelihood of landslide incidents reduces. However, the highest percentage of landslides, 38.38%, were found in the second class, which is between 101 and 200 meters. In the Rangamati Metropolitan Area, 90.4% of the landslides occurred within 300 meters distance from the road, 66.16% within 200 meters, and 27.78% within 100 meters. It is apparent that in the study area, slope failure is more controlled by a closer distance to the road. However, in the distance buffer classes higher FR values increase by increasing distance to road. The highest FR value of 3.38 was recorded for the distance to road in the second class, which is 101-200, while the third class, 201-300, had an FR value of 2.22. The first-class 0-100 (FR = 1.88) has the third-highest FR value. In the research area, the road has minimal impact on landslides over 300 meters distance.

In Rangamati, landslide occurrence was significantly impacted by high NDVI. Two NDVI classes in the research area, 0.259 - 0.398 and 0.399 - 0.476, respectively, had the most

significant effects on the landslide with FR values of 2.95 and 1.44. The FR value was found <1 for the other classes indicating no impact on landslide occurrences. The fifth NDVI class of 0.477 - 0.639 has 16.67% landslides but showed no impact on landslides. Due to the increased amount of class pixels in that class, the low FR value was generated for that class.

Although, medium to higher NDCI classes have higher percentage of landslides, however, the FR value decreased with increasing NDCI classes. Because lower NDCI classes have greater FR values, the chance of landslides occurring increases as NDCI classes increase. With 41.41% of landslides, the fourth NDCI class of 1.418 - 1.504 demonstrated a greater chance of landslide occurrence. The FR value of NDCI is also influenced by the class pixels. In the second and fifth classes, 11.11% and 12.63% of landslide events exist but the FR value of these classes are 2.12 and 0.45 respectively (Table 3 & Figure 10). The same result is also evident for the third and fourth classes. In the third and fourth classes of NDCI, 34.85% and 41.41% of landslide events exist however the FR values of these classes were 1.90 and 1.26, respectively (Table 2 & Figure 10).

With FR values of 2.50 and 2.70, respectively, the third (-0.19 - -0.139) and fifth (-0.068 - 0.144) classes of BSI had the greatest impact on landslides. The other classes of BSI showed a negative relationship to landslide occurrence in the Rangamati Metropolitan Area. But the highest percentages of landslide events exist in the third and fourth BSI classes. In the third class, 35.86% of landslides exist and in the fourth class, 41.92% of landslides exist. In the fifth class, only 2 landslide events existed but the presence of the lowest number of class pixels influenced to produce a higher FR value in this class.

Validation of LSM

The final and most crucial step in landslide susceptibility mapping is validating the LSM. The landslide community widely accepted the use of the ROC for validating LSMs that are sensitive to landslides. The ROC curve was used for estimating the success rate of the produced landslide susceptibility map of the Rangamati Metropolitan Area. The true positive rate and false positive have been plotted on the vertical axis (y-axis) and the horizontal axis (x-axis) of a diagonal plotting area which is the representation of the ROC curve. In the diagonal plotting area, the ROC curve depicts the 1-sensitivity on the y-axis and the 1-specificity on the x-axis. 1-sensitivity and specificity were accounted by engaging the true positive and negative and the false positive and negative values by Equations 6 and 7 (Das & Lepcha, 2019; Rasyid et al., 2016; Wen et al., 2017; Yalcin et al., 2011).

$$X = 1 - specificity = 1 - (\frac{TN}{TN + FP}) \dots\dots\dots\dots\dots\dots (6)$$

$$Y = sensitivity = 1 - (\frac{TP}{TP + FN}) \dots\dots\dots\dots\dots\dots (7)$$

The AUC of ROC curve for the current research was measure by using the training data. The ROC curve of the LSM indicates how properly the frequency ratio model classified the landslide zones using the existing landslides.

Table 2 The AUC of ROC is shown in Table 2 and Figure 11. The AUC of the ROC value was found 0.835 for the prepared LSM indicating a good agreement of the LSM to landslides and higher accuracy of the FR model (Yalcin et
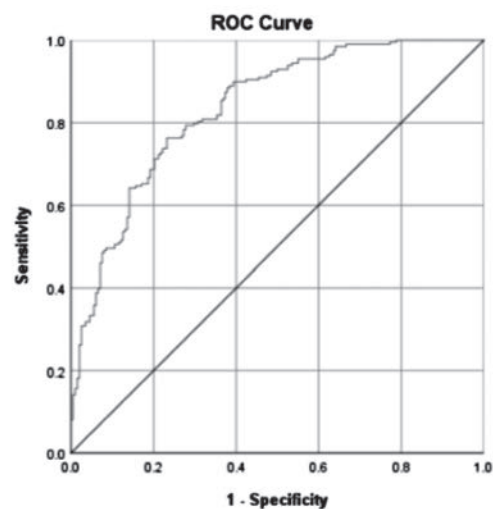
Figure 11: AUC of the ROC curve of landslide susceptibility map
Source: Compiled by authors, 2022

al., 2016). The accuracy suggests the considerable acceptance of the landslide susceptibility map and its further application in other research and disaster management.

All of the conditioning factors were combined by using Equation 5 to create the final landslide susceptibility map. The natural break classification technique was then applied to classify the landslide susceptibility map into five groups. The low to high values of the map were classified as very low, low, medium, high, and very high susceptible classes.
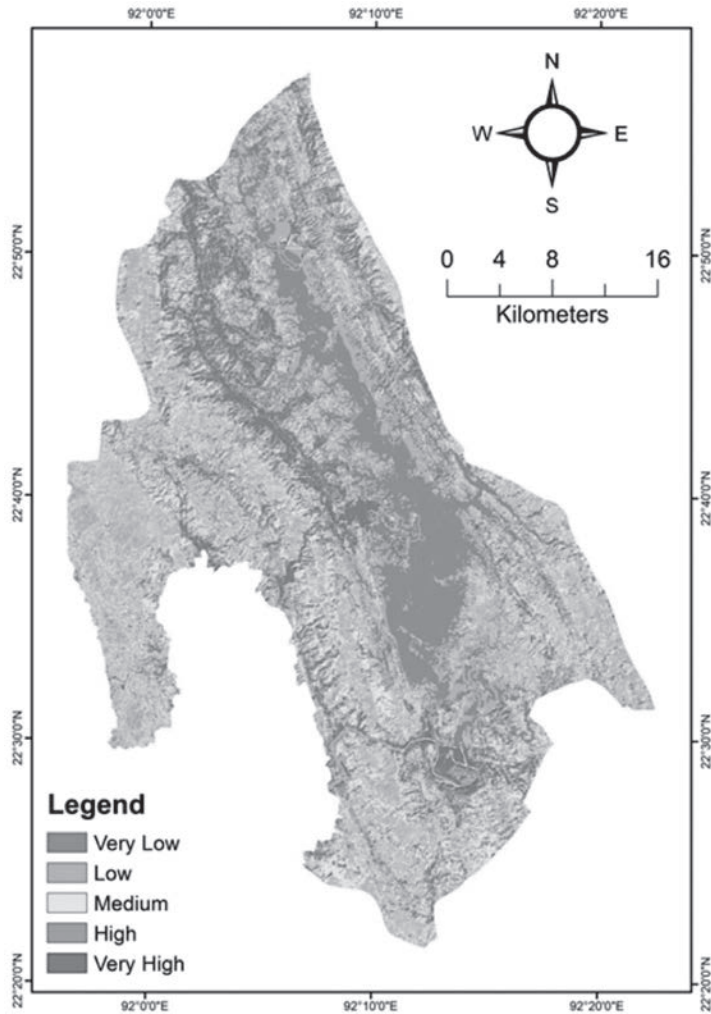
Figure 12: Landslide susceptibility map of the study area
Source: Compiled by authors, 2022

Generally, low susceptible classes contain fewer landslides comparing to the high susceptible classes. Maximum landslides occur in a small area and sparsely distributed over a study area. As a result, high landslide ratio should be concentrated in high susceptible zones. In the study area, very high susceptible zone contains 10.9% areas and 50.5% landslides (Figure 13). The ratio of landslides gradually decreased towards the lower susceptible zones and in the very low susceptible zone the landslide was absent. In the Rangamati Metropolitan Area, according to the LSM, 35.1% of areas are at high risk of landslides and 29.9% of areas are at moderate risk of landslides.
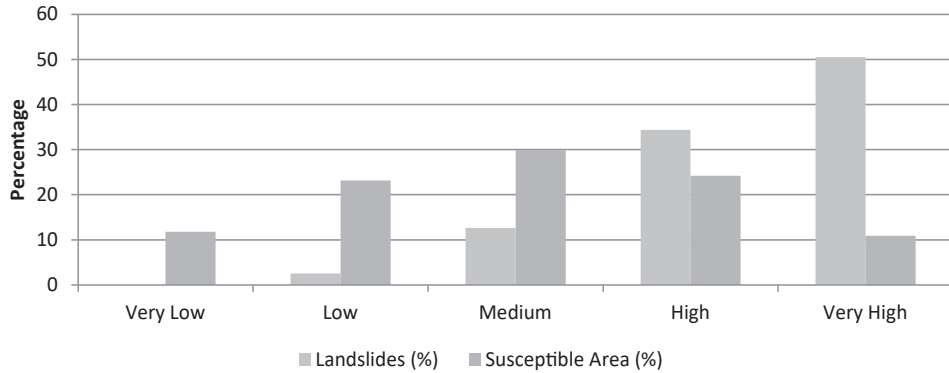
Figure 13: Percentage of Landslides in the susceptible classes of the LSM
Source: Compiled by authors, 2022

Discussion

The factors that had the most effects on landslides in the Rangamati Metropolitan Area were NDVI, geological groups, distance to road, and NDCI. The results demonstrated the influence of anthropogenic activity on the occurrence of landslides within this hilly region. In the Rangamati Metropolitan Area, the undivided Dihing and Dupi Tila formations exhibited the greatest influence on landslides. Tipam sandstone and Bhuban formation has also showed significant control on landslide. These geological groups contain higher sand in the top soil.

As elevation, distance to fault, and distance to road increased in the Rangamati Metropolitan Area, the frequency ratio of landslides decreased (Figure 14). Although the frequency of landslides tends to increase with increments in elevation, the

research region revealed the opposite tendency. Low proximity to road has a higher control on the landslide. Slope angle showed regular pattern evident in different hilly areas around the world. With increasing slope angle the likelihood of landslide occurrence is also increased.

Road construction in the hilly areas is responsible for this pattern. Roads are constructed in the low elevated areas on the hill slopes. But a higher slope angle exists near roads. This break of slope due to anthropogenic activity makes the slope unstable. Rangamati city is located over the Tbb and Tt geological units. These geological units are composed of sandstone and siltstone. These types of geological groups are highly sensitive to landslides. The anthropogenic activity over this geological unit makes the soil more permeable. The increased permeability increases the
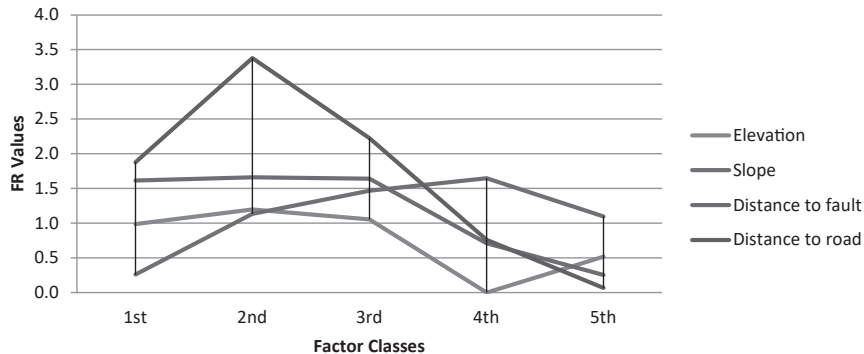
Figure 14: Trend of frequency ratio according to the increment of the factor classes
Source: Compiled by authors, 2022
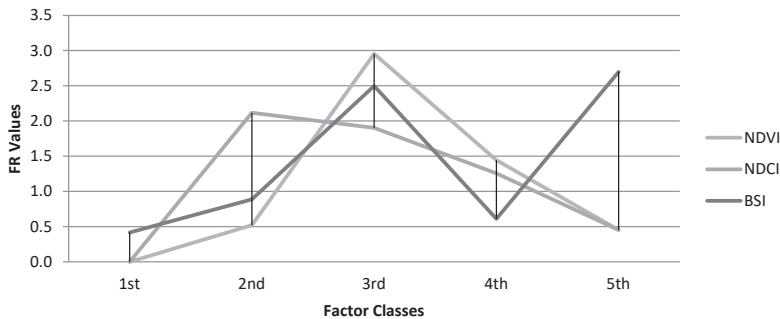
Figure 15: Trend of frequency ratio according to the increment of the factor classes
Source: Compiled by authors, 2022

infiltration rate during rainfall and makes the slope more unstable by decreasing shear strength.

In Rangamati, most of the landslide occurs in low NDVI areas (Figure 15). Because bare soil becomes more unstable during rainfall as its permeability is high. The BSI shows a similar result like NDVI. In Rangamati, most landslides occurred in medium vegetated areas. Especially, vegetated areas affected by human activity are more prone to landslides. Road construction also increases water permeability in the neighboring vegetated areas. Landslides occur in these areas during rainfall. In the Rangamati Metropolitan Area, landslides are very common in areas with low NDCI. Geological groups also depict similar patterns. The low clay ratio means high sand concentration. In Rangamati, sandstone and siltstone areas are more prone to landslides. The NDCI and BSI showed higher agreement in landslide analysis. In addition to the NDVI, both of these factors reveal substantial information on the type of landslide that occurs in the research area as well as its frequency. It is evident from the research that NDCI and BSI can be crucial in mapping landslide-susceptible areas even in the data-scarce and inaccessible regions.

Conclusions

The LSM of Rangamati Metropolitan Area has been prepared in the current research. The research also demonstrated the application of multispectral satellite indices in mapping landslide susceptible areas by engaging frequency ratio model. It is evident that the integration of the multispectral satellite indices with existing geological data and other relevant topographic factors can produce an accurate LSM. This integration in the current research provided valuable information about the application of NDCI as a proxy of geological group; because NDCI provides information about the ground soil condition (concentration of sand, silt and clay ratio) which has a significant relation to landslides. The relationship between conditioning factors and past landslides measure by frequency ratio model was used to predict the future landslide prone areas. In Rangamati Metropolitan Area, according to frequency ratio model, the highest impact to landslides was exhibited by NDVI, geology, distance to road, and NDCI. The ROC curve (ROC = 0.835) showed the acceptability of the map. It can be concluded from the research that besides the DEM processed data; multispectral satellite image processed data (NDVI, BSI and NDBI) also can be used in landslide research. By proper integration of multispectral satellite image indices with other landslide causative factors an accurate LSM can be produced. This research will help researchers to investigate and focus more on the multispectral satellite indices, besides other conditioning factors, for accurate landslide susceptibility mapping. The research will also help in landslide hazard investigation and mitigation, policy implication and planning in the study area.

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analysis, MSC; investigation, MNR, SS, and SA; resources, MSC, MNR, SS, and SA; data creation, MNR, SS, and SA; writing—original draft preparation, KHM, BH and MSC; writing—review and editing, KHM, BH and MSC; visualization, KHM, BH and MSC; supervision, KHM and BH; project administration, KHM and BH.

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Impacts of Kalna Bridge on land use, socioeconomic status and environment in Gopalganj district of Bangladesh

Sumaya Farzana[1], Md. Faruk Hossain[1*], Md. Fazlul Karim [2,3]

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

[2] State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University

[3] Department of Geography and Environment, Jagannath University, Dhaka, Bangladesh.

ARTICLE INFO	ABSTRACT
	The present paper demonstrates the impacts of Kalna Bridge on land use, socioeconomic status and environment in Gopalganj district of Bangladesh. Various development projects are taking place in various parts of the country. These development projects are important for the local context and these are benefitting people in different ways. However, many projects bring significant changes in land use, socioeconomic status and environmental conditions in that particular area. This research was conducted based on both primary and secondary data. Primary data were collected from satellite images and a survey of 200 households in the selected two unions, and secondary data, on the other hand, were collected from published documents. According to this study, the most significant changes occurred in built-up and agricultural areas between 2015 and 2022. Agricultural land has declined from 1,071.51 ha to 461.72 ha and built-up area has gone up due to rapid development in the area over the seven-year period. Majority of the respondents from both Kashiani (95%) and Ratail unions (92%) mentioned that local temperature has increased significantly. The socioeconomic status of the surveyed people in the study areas (Kashiani and Ratail) has changed due to construction of Kalna Bridge. The population of this area became benefitted more from this kind of development project. So, it is very important to consider the impacts on the environment, socioeconomic status, and land use change while executing any development project.

Introduction

To address the underlying vulnerability drivers and enable diverse communities, stakeholders, sectors, cultures, and regions to adapt to changing land use and socioeconomic issues, development action must not only accelerate change but also clearly demonstrate the underlying vulnerability drivers (Rashid et al., 2023). Bangladesh is an agricultural country and this sector plays a vital role in the overall development of this country. Bangladesh is going to become an upper middle-income country by 2031 and extensive development activities are one of the crucial components to achieve the goals (World

Bank, 2023). On the other hand, Bangladesh currently has a population approaching around 166 million and will add another 100 million before stabilizing, unless fertility can soon drop below replacement level (Haast & O'Brien, 2019). The agricultural area is being filled with sand and other construction materials, and trees are being cut down at an alarming rate to meet the demands of the growing population. Besides, communication system plays a leading role for the overall development of any country. The overall development activities of Bangladesh are being obstructed to a large extent due to the lack of direct communication system between the capital Dhaka and other remote areas of the country. In order to connect the capital with the southwestern districts of Bangladesh the Kalna Bridge project was inaugurated in 2015.

The people of the current research sites have made a living from agriculture, but the land use pattern has changed dramatically since the Kalna Bridge was inaugurated. The environment, socioeconomic conditions, and land use pattern in the surrounding areas have significantly changed since the bridge's construction began, despite the fact that the bridge will have a substantial impact on the region's communication systems. Therefore, the construction work put serious pressure on socioeconomic condition, environment and land use pattern in this area. As a result, the study area's livelihood alternatives are changing, with an increasing number of school dropouts and a growing demand for clean water and sanitation, causing health concerns. Theft and robbery have increased, affecting people's lives and livelihoods. Additionally, the conversion of agricultural land into built up area is one of the main issues the residents of the study area currently face but the local government have taken no enforcement action till now. Although the Kalna Bridge project's Environmental Impact Assessment (EIA) report discussed the impact on the environment during construction phase.

Land use refers to the plans, deeds, and contributions people make to a specific type of land cover in order to develop, modify, or maintain it (UNEP, 1999). Land usage includes both the goods and advantages derived from using the land and the human-performed land management 3 operations necessary to provide those goods and advantages (FAO, 2011). Chu et al. (2021) evaluated the land use and land cover (LULC) change and the socioeconomic impacts of Hangzhou Bridge construction using Random Forest method to quantify LULC changes before and after the construction of the Hangzhou Bay Bridge of China.

Development projects are causing gradual changes in many parts of Bangladesh and these have impacts on the local economy and environment in different ways (Dewan & Yamaguchi, 2009; Islam & Saker, 2016). LULC change is caused by human activities and it has been observed that areas near to roads underwent more LULC change and areas far away in remote areas underwent less LULC (Fonji & Taff, 2014). The government has made significant efforts over the past decade to improve the communication infrastructures of the nation; as a result, massive infrastructure projects have been undertaken without consideration for the effects on the environment (Faisal et al., 2018). LULC changes occur with the transformation and conversion of different land cover types and show the existing complex interactions between humans and the physical environment (Roger et al., 2011). However, a combination of remote sensing (RS) data and geographic information system (GIS) techniques help to study land cover changes at low cost and within less time (Ramamoorthy et al., 2016). Different studies were conducted focusing on LULC changes and these studies have observed different impacts such as land use change, environmental changes, socioeconomic changes etc. at various levels (Chen et al., 2017; Islam et al., 2018; Nahar et al., 2017). GIS and RS technologies, after all, become important tools for comprehending a multifaceted land use system in a particular area (Ahmed et al., 2023).

Objectives of the study

The objectives of this research are twofold. Firstly, this study quantifies the spatio-temporal changes of the study area due to Kalna

Bridge construction work as well as attempts to understand the land use dynamics from 2015 to 2022, in Gopalganj district of Bangladesh. Secondly, this study identifies the socioeconomic and environmental impacts of the study area due to commencement of various development activities from 2015 to 2022.

Materials and methods

In order to undertake this study, a number of procedures were followed. Desk research into relevant secondary data discovered in both published and unpublished documents, classifying satellite images and conducting questionnaire interviews with the surveyed households were the main methods used to collect primary and secondary data

Land use and land cover mapping

This study used Sentinel-2 and Landsat-8 images (Band 3, 4 and 8) in order to detect the land use dynamics in the past seven years of the surveyed
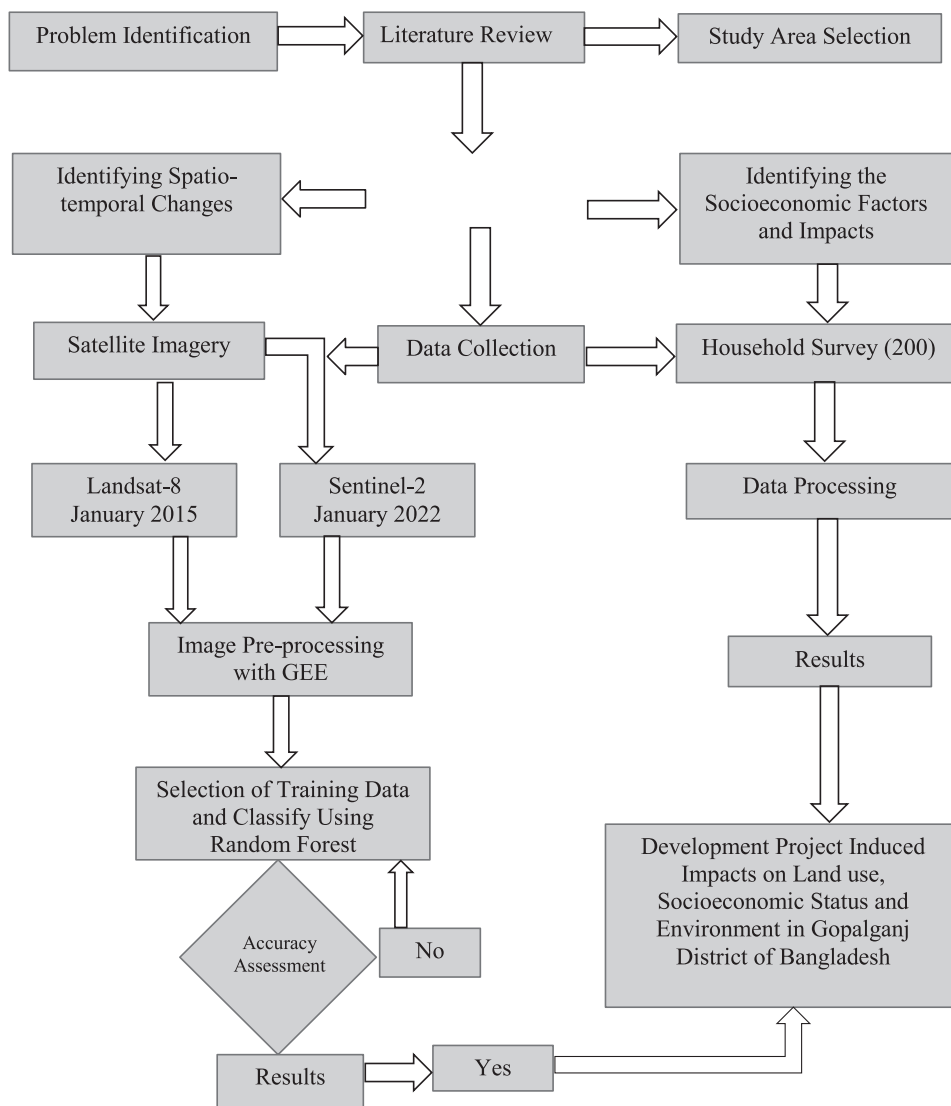
Figure 1: Methodological framework of this study

area. Using modern cloud computing platforms such as Google Earth Engine (GEE), which also provides the powerful computational power needed to address a range of societal and environmental concerns at large scales, multi-source data catalogue for geospatial analysis were used (Gorelick et al., 2017). Using GEE to access and analyze the Landsat image archives, the time series of detailed LULC classes from 2015 to 2022 were gathered.

Use of Random Forest (RF) nonparametric supervised classification algorithm (Breiman, 2001) has been well established for land cover classification (Belgiu & Drăguţ, 2016; Breiman, 2001; Colvocoresses, 1981; Halmy et al., 2015; Nguyen et al., 2020; Tokar et al., 2018; Wu et al., 2013). Training samples using a stratified random sampling method was selected. The sample points were collected for each class (Table 3). The sampling points that were chosen were 423 for vegetation, 410 for water bodies, 452 for agricultural land, 374 for sand, 417 for fallow land, and 203 for built-up areas. In total, 2,279 sample points were collected for the year 2022. A total of six LULC classes for this study were defined, (Table 3). In 2015 Sentinel-2 image was unavailable in the study area, so Landsat-8

image was used for image classification and 4 LULC classes was defined, (Table 4)

The training data for the land cover classification by visually interpreting high-resolution imagery at the locations of the training sample points was collected. Data collection was conducted using the "ee.ImageCollection([ee. Image(listS2022dataset.get(0))," For each point, the LULC class was identified for each year in the study period, if high-resolution imagery was available. RF algorithm with the function "ee. Classifier.smileRandomForest(300)" in GEE to classify LULC was used here. Two models were developed, one for Sentinel-2 data, and another for Landsat-8 data for the year 2022 and 2015, respectively. This number was chosen after testing the model performance with different numbers of trees (from 10 to 50) per class. Lastly, the models were used to classify LULC for each year by using the features of the particular year (Table 1).

In order to evaluate the contribution of each feature in enhancing the performance of the classifier, the variables from RF in GEE were estimated. To get insight into the problems and an understanding of the study areas and issues, an attempt was made to review available secondary documents. This included a review

Table 1: LULC classes in January 2022 (Based on supervised classification)

Level	Number of sample points	Description
Vegetation	423	Trees higher than five meters including deciduous forest and woodland.
Water body	410	River and fishpond.
Agricultural land	452	Cultivated land, paddy field, garden
Sand	374	Riverside sand and deposited sand for business purposes.
Fallow land	417	The land that was preparing for new crop after picking up crop is considered as fallow land.
Built-up area	203	Houses, bridge, shop, roads

Table 2: LULC classes in January 2015 (Based on supervised classification)

Level	Number of sample points	Description
Vegetation	874	Trees higher than five meters including deciduous forest and woodland
Water body	341	River and fishpond
Agricultural land	830	Cultivated land, paddy field, garden
Sand	45	Riverside sand and deposited sand for business purposes

Figure 2: Location of the surveyed households

of project documents and documents relating to the project, context, relevant news published in local or national newspapers, and area profile. The secondary documents provided a general overview of the context and area, project activities, and results; these helped to formulate an appropriate questionnaire and checklist for primary data collection through the field survey.

Household survey

The research made use of probability sampling to select the respondents for investigation. Samples were collected using simple random sampling. This helped to obtain the necessary data for the study with minimum cost and time. This study used structured questionnaires as a quantitative tool for collecting data. The sample size for this study was determined using Yamane's formula (Yamane, 1967), considering the number of households in the study unions and a precision level of seven percent (Table 3). The formula is given as:

$$n = N / (1 + N \times e^2)$$

Here,

n represents the sample size (number of households chosen for interviews).

N stands for the total households in the study unions.

e indicates the level of error.

Table 3: Distribution of sample size of surveyed household by union

District	Upazila	Union	Sample size (PPS*)
Gopalganj	Kashiani	Kashiani	100
		Ratail	100
Total of sample size			200

*PPS = Probability proportional to size

The research demonstrated the use of probability sampling to select the respondents for investigation. Samples were collected using simple random sampling. This study used structured questionnaires (SQ) as a quantitative tool for collecting field level data. The data collection was conducted based on the unions of Kashiani on 18 August 2022, and Ratail on 19 August 2022. A total of 50 household interviews were conducted in two selected unions of Kashiani Upazila using KoboCollect mobile survey data collection app. The Kalna Bridge project's construction directly affected the people who answered the survey.

Study area

This study was conducted in Kashiani and Ratail unions of Kashiani Upazila under Gopalganj district of Bangladesh. The location of Kashiani

Table 4: Demographic characteristics of the study area

Upazila	Union	Total population	Population density	Sex ratio	Percentage of literacy rate		
					Both	Male	Female
Kashiani	Kashiani	26,377	1,130	92	39.7	45.9	33.5
	Ratail	20,029	812	90	35.6	40.8	31.3

Source: Upazila Parishad, Kasiani, 2022

Table 5: Description of satellite data, operational land imager (OLI) and thermal infrared sensor (TIRS)

Data	Acquired date/year	Producer
Landsat 8 (OLI/TIRS)	January, 2015	USGS global land cover facilities
Sentinel 2	January, 2022	USGS global land cover facilities

and Ratail unions is latitude in between 23°05' N and 23°19' N and longitude in between 89°41' E and 89°56' E. These two unions are bounded by Moheshpur union in the north, Sajail union in the east, Fukura union in the south and Madhumati River in the west. Madhumati River is the main water channel runs through this study area. The study area belongs to tropical wet and dry climatic zone, and located at an elevation of 5.95 meters (19.52 feet) above sea level. The yearly temperature of the study area is 27.93°C which is 0.19 percent higher than Bangladesh's average temperature and receives 68.73 mm precipitation annually. The population of Kashiani union and Ratail union is 24,190 and 20,029, respectively, with 5,678 and 4,702 households (BBS, 2013). Kashiani union has high population density and literacy rate compared to Ratail union. Both overall and in terms of population density, Kashiani union has a larger population than Ratail union. Furthermore, it has a higher rate of literacy and a higher sex ratio.

Results and discussion

Land use and land cover mapping

The Random Forest (RF) method using GEE geometry (Point) for each of the six classes was applied by segregating points to the corresponding location in the classified images to assess the accuracy of the classified images of 2015 and 2022. For this study, the training area/reference data (total 4369 points) were randomly and
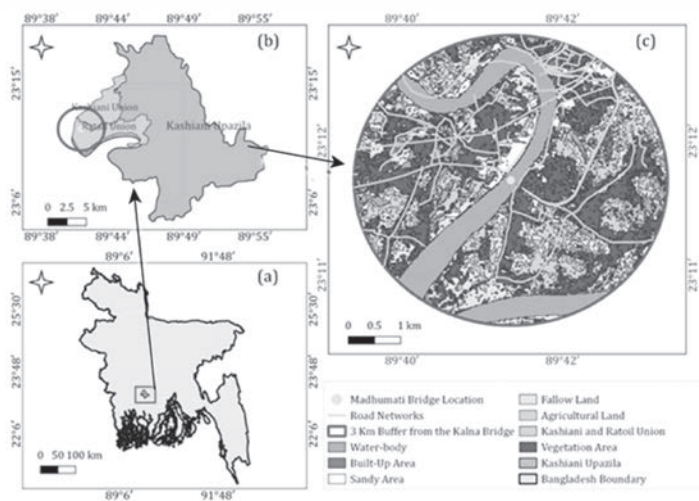
Figure 3: Map of the study area (Kashiani and Ratail unions)
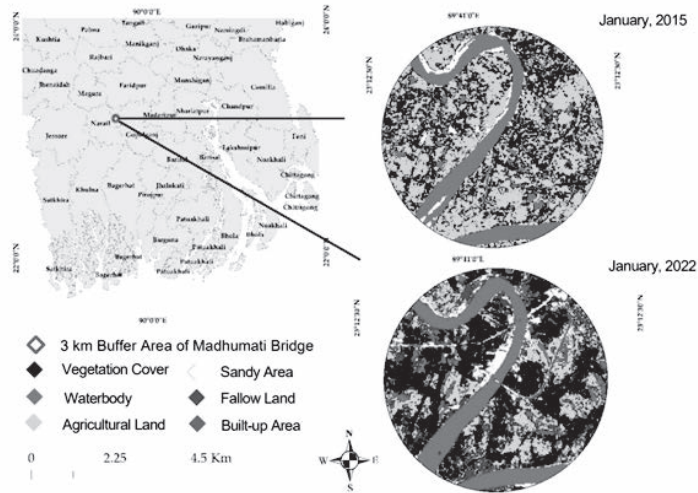
Figure 4: Land cover maps for the study area, classified into six major land cover classes: vegetation cover (green), agricultural land (light green), sandy area (white), fallow land (violet), and built-up area (red); at two time periods: 2015 and 2022.

manually selected to assess classification accuracy. The producer and user accuracy were obtained through a confusion matrix. Overall classification accuracy for 2015 and 2022 is 99.22% and 97.80% with Kappa Coefficient Index values of 0.98 and 0.97 respectively. Nowadays, improved image classification algorithms and satellite imagery with excellent resolution make it easy for researchers to conduct data mining 11 and monitoring of a broad range of target features on the ground. Machine learning (ML) classification has become a popular and efficient technique for RS applications, especially for land use/cover monitoring. ML classification has been used extensively for different research objectives in the recent past, due to its ability to deal with complex relations among variables coupled with high classification accuracy. Classification results of the classified images of Kashiani and Ratail unions in 2015 and 2022 are shown in Figure 4. By using visual interpretation, it is easy to interpret that the vegetation cover, agricultural land, built-up area and sandy area and the land classes of the study area have a dynamic (transition and conversion) relationship over the years. The Kalna Bridge project area in Kashiani and Ratail unions experienced the highest changes over the years. Based on the classification results,

there has been a notable increase in the built-up and sandy area over the past seven years.

Based on the image analysis of 2015 and 2022, the study area was primarily covered with agricultural land and vegetation, and the Madhumati river flowed through it. There was nothing concerning about the sandy area along the river. Due to the presence of vegetation cover, built-up areas and fallow land were not visible in satellite images. However, a significant change in land-use occurred in the same areas in 2022, and it accounted for a seven-year gap. The amount of built-up area, sandy area and fallow land had increased (Table 6). The amount of water bodies, vegetation, and agricultural land had been decreasing at an alarming rate. The Madhumati river's course had been somewhat changed. Fallow lands were shown to be more in quantity because crops were planted in January, during the winter, and were harvested then. Since the images were taken in January, a big amount of the land was still fallow because January was the month between harvesting and growing new crops.

It observed that in the last seven years, agricultural land decreased from 1,071.51 ha to 461.72 ha and vegetation cover reduced from 690.19 ha to 557.53 ha. Due to the interests of the influential groups of the study area, sandy

Table 6: Details of land use and land cover of the study area

Type	2015 (area hectares)	Percentage	2022 (area hectares)	Percentage
Agricultural land	1071.51	36.48	461.72	15.72
Built-up area	102.55	3.49	726.50	24.73
Sandy area	205.65	7.00	237.24	8.08
Vegetation cover	690.19	23.50	557.53	18.98
Water bodies	517.16	17.61	451.75	18.78
Fallow land	350.22	11.92	402.54	13.70
Total	2937.28	100.00	2937.28	100.00

Source: Field Survey, 2022

area also rose from 205.65 ha to 237.24 ha. The built-up area went up due to rapid development in the area, and it accounted around 21%. The Kalna Bridge is considered as an important factor for the overall socioeconomic and environmental changes of the study area.

Environment impacts in the study area

The residents of the study area have experienced heat waves, severe air and water pollution, water-logging during the monsoon season, high levels of daytime and nighttime noise pollution, defor-estation, extensive sand-filling of agricultural land, and other issues since the construction of bridge began at the study site. The effects on the environment are severely hurting the local population. People of the study area are facing various environmental problems due to the construction of Kalna Bridge project and sand business. The highest percentage of the respon-dents from both Kashiani union (95%) and Ratail union (92%) mentioned that local temperature has increased at an alarming rate. On the other hand, the lowest number of respondents from both Kashiani union (35%) and Ratail union (49%) highlighted that land pollution is taking place in the area. Noise pollution occurred in the study site and this issue was revealed by 70% and 82% of respondents, correspondingly (Figure 4). Moreover, air pollution, water logging and deforestation problems became challenging issues for the locals.

Various contributors are responsible for environmental impacts in the study area. The respondents highlighted some factors relating to environmental degradation in the surveyed area. The highest number of the respondents highlighted that making sand banks everywhere became a major environmental problem in both the unions, and the values were 88% and 75% in Kashiani union and Ratail union, respectively (Figure 5). There is also a significant problem with development projects lacking environmental protection measures in Kashiani union (82%) and Ratail union (70%). Lowest number of respon-dents opined that sound pollution by local vehicle is responsible for environmental problems in this area, and the values of Kashiani and Ratail unions were 63 and 58 respectively. Moreover, environ-mental conditions of this area are deteriorated due to other factors such as power practice by local influential people, damaging trees and over extraction of sand from rivers.
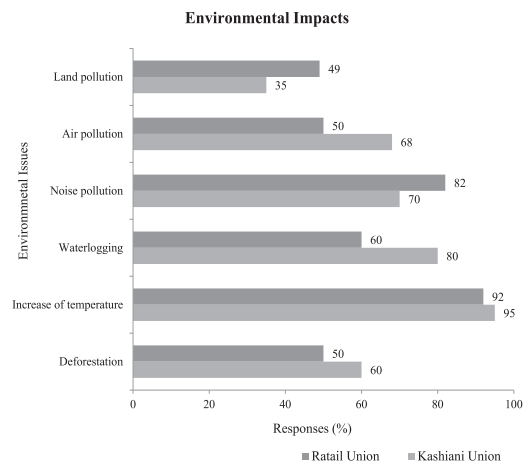
Figure 4: Environmental impacts faced by the local people
Source: Field Survey, 2022
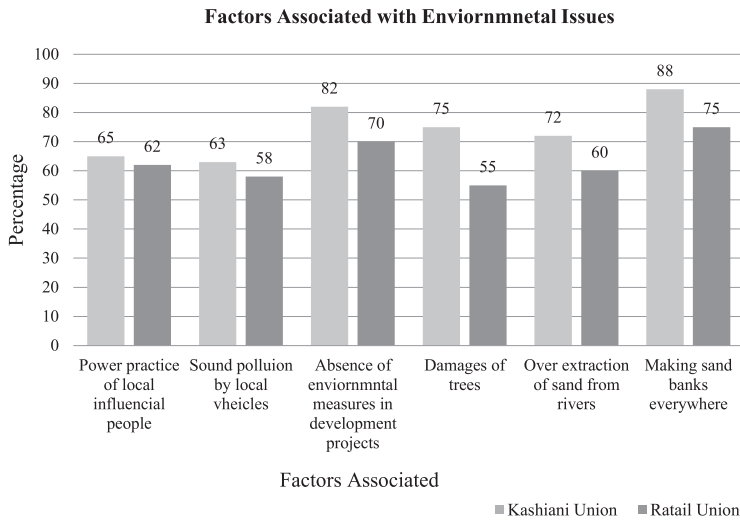
Figure 5: Factor associated with environmental problems in the study area
Source: Field Survey, 2022

To prevent environmental impacts, various measures need to be undertaken. A majority of the respondents from both Kashiani (92%) and Ratail unions (76%) spoke in favour of creating public awareness. Enforcement of laws to reduce the impacts was suggested by 82% and 70% of the respondents in Kashiani and Ratail, respectively. Stopping activities that cause environmental concerns, effective local management, and participation of diverse stakeholders were cited by respondents from both unions, Kashiani (55%) and Ratail (43%). The lowest number of respondents emphasized on the importance of encouraging tree plantation more (Figure 6). Furthermore, land owners are getting huge amount of money that is offered by the sand dealers while agricultural activities provide less money compared to sand business. This system should be stopped to recover agricultural land of the surveyed area.
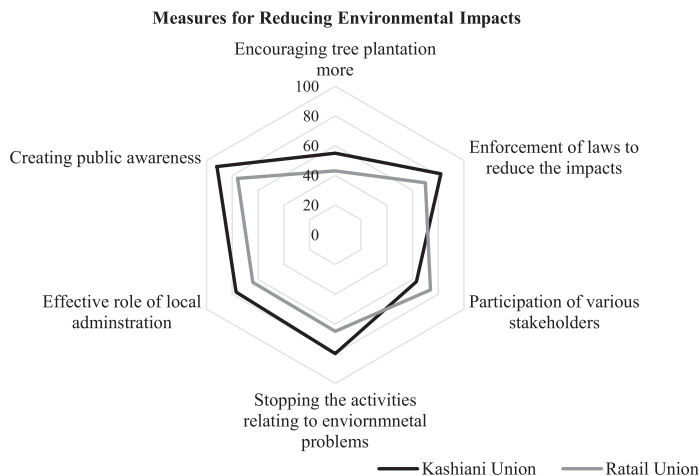
Figure 6: Measures need to be undertaken to reduce environmental impacts
Source: Field Survey, 2022

Factors Associated with Scocioeconomic Impacts
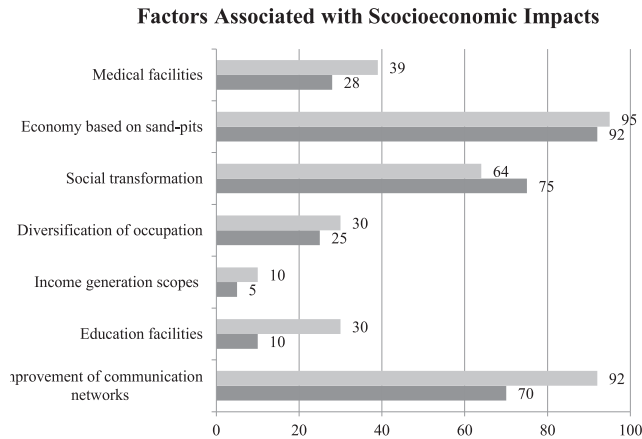
Figure 7: Factors associated with socioeconomic impact on the locals
Source: Field Survey, 2022

Socioeconomic impacts in the study area

The respondents to the survey mentioned a variety of socioeconomic impacts brought on by the building of the Kalna Bridge. The socioeconomic conditions of the residents of the study area (Kashiani and Ratail unions) are changing quickly. More than 90% of the respondents (95% in Kashiani and 92% in Ratail) mentioned that sand-pit economy was responsible for the rapid change in the socioeconomic conditions in the study area (see Figure 7), since this is the basis on which the business operates. The numbers of respondents from Ratail and Kashiani unions were 95% and 92%, respectively (Figure 7). The respondents also highlighted the need for improvement in the communication network (70% in Kashiani and 92% in Ratail). The respondents also emphasized on the social transformation, healthcare, education, and employment diversification, as well as the potential for income generation in both unions, all of which had an impact on the socioeconomic conditions in various ways.

The local population was greatly impacted by Kalna Bridge in both positive and negative manner regarding socioeconomic aspects. From the field survey it observed that health related risks became severe for 92% of the Ratail respondents and 85% of the Kashiani (Figure 8). People in the area are afflicted with a variety of diseases as a result of the area's air pollution caused by sand pits and crumbling roads. Lack of clean water and sanitation in these unions are visible, and 75% of the Ratail and 88% of the Kashiani union respondents mentioned this. Bridge has affected the local job market and the rate of literacy, for instance job type has been changed, people who were engaged in agricultural activities are doing other jobs like driving auto cars or other vehicles now and literacy rate is decreasing due to the poverty and availability of work but it has also brought about changes in the livelihood and deteriorated the security system. The influx of people and vehicles has made it difficult for the local police to maintain law and order, and the lack of proper infrastructure has made the area more vulnerable to criminal activities. Findings of the survey reveal that not a single respondent raised the issue of whether or not the bridge's construction had an impact on their income. Because the respondents did not focus on this issue, the majority of them own land and lease it to businessmen for sand deposition, generating a substantial annual income.

The dynamics of LULC types of the study area between 2015 and 2022 of Kashiani and Ratail unions were compared in Figure 4. The sandy area and built-up area were not noticeable in 2015 but these are observed more in 2022. Agricultural land declined around 21% and

built-up area increased approximately 21% (Table 6). Vegetation cover also declined about 5% from 2015 to 2022. But over time, sandy area, water bodies, and fallow land decreased. Since January is the month between harvesting and planting new crops, a significant portion of the area is still uncultivated. This is evident from the images taken during that month.

Conclusion

The livelihood conditions of Kashiani and Ratail unions of Gopalganj district were highly dependent on agricultural activities before the construction of Kalna Bridge. There has been a decline in agricultural activities in the study area, following the bridge's construction. The Kalna Bridge project's construction appears to have been a significant factor in declining of agricultural lands within the study locale in recent years. In order to improve the nation's communication network, the Bangladeshi government built the Kalna Bridge in the present study area. A number of noteworthy factors including high labor costs, disease outbreaks, and natural and environmental consequences, contributed to the decline in agricultural activities in the study area. This research revealed that over 67.16 ha of agricultural land was converted into sandy area and 94.37 ha of agricultural land was converted into built-up area in between 2015 and 2022. In this study, based on the quantitative analysis, the socioeconomic and environmental impacts due to the commencement of Kalna Bridge project were identified. Using satellite imagery and RF image classification techniques, the generated spatio-temporal maps of vegetative and agricultural land cover change area helped to identify the factors contributing to the decline in vegetation and agricultural land area between 2015 and 2022. The government need to adopt policies to protect the agricultural land and vegetation cover of the project areas in meeting the development goals as the largest amount of the export earning comes from agricultural products. This kind of research has good potential to promote sustainable development goals related issues from the local to national level. Furthermore, policymakers, planners, researchers, development partners and other relevant stakeholders may find the research findings useful as well.

Limitations

The use of Landsat 8 OLI and Sentinel-2 satellite imagery has been found to be insufficient in accurately portraying the evolution of settlements. It is suggested that very high resolution (VHR) satellite imagery would be a better choice to achieve the desired accuracy in future research. Another limitation is that the respondents did not show much interest for providing proper information during the field survey.
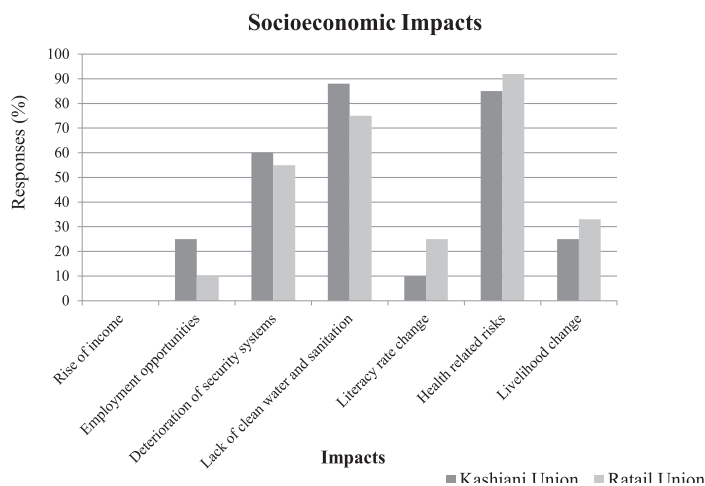
Figure 8: Socioeconomic impacts on the locals
Source: Field Survey, 2022

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Transforming rural community through fertilizer optimization of climate resilient, early maturing, high yielding banana cultivar (Grand Naine)

Nisat Tasnim[1*], Md Estiak Islam[1], AHM Rahat Hossain[2], Mohammad Abdul Kuddus[1]

[1]Thengamara Mohila Sobuj Songho (TMSS), Shibganj, Bogura, Bangladesh

[2]Palli karma Sahayak Foundation (PKSF), Dhaka, Bangladesh

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ABSTRACT

This study was conducted in the supervision of Palli Karma-Sahayak Foundation (PKSF), funded by the World Bank, an environment friendly project named "Sustainable Enterprise Project (SEP)". Under this project, a subproject which is "Promotion of Ecologically Cultivated Safe Banana" carried by Thengamara Mohila Sobuj Songho (TMSS), collaborator organization of PKSF. The project area was Shibganj Upazila of Bogura district, is the largest banana production region of Bangladesh. Low soil fertility, high rates of fertilizer application, low yields and quality are major problems in intensive banana cultivation in Shibganj area. A field experiment was conducted to determine the optimum management practices, promoting a high yielding, climate resilient variety of banana (Grand Naine/ G9) for changing the traditional way of cultivation. Soil nutrient requirements, yield and fruit quality were determined. Application of lime and optimum amount of phosphorus fertilization was found to increase soil pH and nutrient availability and increase banana yield. The experiment consisted of five treatments namely T_1: 100gm phosphorus/ plant, T_2: 200gm phosphorus/plant, T_3: 300gm phosphorus/plant, T_4: 400gm phosphorus/plant, T_5: 500gm phosphorus/plant. It was recorded that the plant height (167.98cm), girth of pseudo stem (65.34cm), number of leaves (18.34). These vegetative parameters indicate the maximum yield (55ton/ha) compared to other local variety of banana. Creating awareness with the aid of project on the potential benefits of utilizing disease free tissue cultured banana and adapting low-cost tissue culture technology significantly boost banana production in Shibganj regions and country as a whole.

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Introduction

Banana is one of the leading fruit crops and considered as the "Apple of paradise". It is also known as 'Adam Fig' (International tropical fruits network, 2016). The name 'Banana' comes from the Arabic word meaning finger (BananaLink, 2016). By nature, banana is very nutrient feeder crop due to its size, growth rate, nutritional value,

rooting pattern, and phenomenon of its bud differentiation which have positive relationship with the yield. In Bangladesh, banana is a very popular fruit and cultivated almost everywhere around the year. It occupies an important position among the fruits of the country. It is a commercial fruit, but in Bangladesh, it is grown in a limited area commercially. The major banana producing districts of the country are Narsingdi, Bogura, Gazipur, Rangpur, Natore, Pabna, Faridpur, Chuadanga, Kushtia. Besides, Chattogram, Rangamati, Sylhet, Netrokona, Moulvibazar, Khagrachhari are the wild variety cultivated districts. Bangladesh produces one million tons of banana annually (Hossain, 2014).

Bogura district, situated in the heart of northwestern region of Bangladesh, especially Shibganj Upazila is known as a big hub of banana production. After meeting up local demand, banana produced in this area are sent to the other part of Bangladesh. However, the banana farmers of Shibganj area cultivate bananas in the traditional way. The conventional method of propagation is used in production of bananas. Using sucker is very slow process resulting in low production because a banana plant produces only 5-10 suckers in its lifespan (Singh et al., 2011). In addition, spread of diseases and pests through banana suckers as a planting material is a major drawback in the conventional method of propagation (Langat et al., 2013). Consequently, there is a limited supply of clean planting materials. Banana growers obtain suckers from their existing fields which are already attacked by Sigatoka and Panama (Major disease of banana) virus. The farmers use chemical fertilizer at an extreme rate for higher production but result in low productivity, environmental pollution, and increase of production cost and so on.

Sufficient knowledge and positive attitude are highly required in an individual towards improved management practices to make mentally strong to adapt new variety and management practices. Generally, the development of new practice is not a major problem now a day, but the main problem exists today is that of diffusion and adaptation of these practices by the banana growers. The adaptation process is the mental process through which an individual passes first hearing about an innovation to its final adaptation.

Community consultation is very effective process for adapting new technology. The banana farmers of Shibganj village were influenced in providing training, group discussion, forum meeting, seminar, billboard, poster and so on through SEP project. The villagers came to know about the early maturing, high yielding tissue culture variety (G9) thus helps not only the economical solvency but also produce safe healthy banana.

Project interventions
According to Soil Resource Development Institute (SRDI), the amount of nitrogen (%) and zinc is very low besides the phosphorus amount is higher than the optimum range in the Shibganj region. But the banana growers apply chemical fertilizer in guesswork result in imbalance of micronutrients in the soil compound. It affects not only the soil physical property but also reduces the growth and yield of plants.

Iron and zinc deficiency appears due to extreme use phosphorus. It is hard for plants to uptake iron, zinc and other macronutrient because the extra phosphorus disrupts their natural process. Root development is granted by adequate P doses, besides increasing water and nutrients uptake that contribute to fruiting (Attia et al., 2009) Phosphorus deficiency inhibits the

Table 1: Comparison of chemical properties between Shibganj soils with ideal one

Element	Optimum range	Remain in Shibganj soil
Nitrogen (%)	0.271-0.36	0.06
Phosphorus(μg/g)	15.76-21	96.97
Potassium(μg/g)	0.271-0.36	0.22
Sulfur (μg/g)	22.51-30	27.74
Zinc (μg/g)	1.35-1.8	0.80
Boron (μg/g)	0.451-0.60	0.22
p^H	6.0-6.5	5.7
Organic matter	3.41-5.5	1.12

Source: Soil Resource Development Institute, Bogura, 2023

translocation of carbohydrates within the plant results from less plant growth and a purple color lesion appears on the margins of the leaves (Kaiser et al., 2018). Excessive N fertilization has caused low N use efficiencies and serious environmental problems (Cui et. al., 2016; Zhu et. al., 2016). Therefore, rational N fertilization strategies must be considered for achieving high crop production and sustainable agro ecosystem.

Good agricultural practices (GAP)

Good agricultural practices (GAP) are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products". GAP are particularly important in the banana industry, not only for sustainability of production and minimization of environmental impact, but also to ensure that harvesting, packaging and transport activities are conducted in hygienic conditions in order to deliver safe and good quality fruit to consumers.

No farmers received training on GAP for banana production at the study area. They have been farming for a long time learning from their parents and neighbors. They did not ever test their soil health. A high dose of chemical fertilizer is being used, don't follow crop rotation and perform mulching/ intercropping. Due to lack of proper knowledge on the integrated pest management (IPM) system, they apply a high dose of chemical pesticides even just before harvesting. It is a health hazard for the human body. Farmers do not perform any processing, cleaning, storing, and packaging of bananas. Even most of farmers do not use appropriate personal protective equipment (musk, gloves, goggles) while applying pesticides.

Before planting banana saplings, it is important to test the chemical properties of soil to know the present condition of micronutrient and uptake capacity. The most important project activities are to provide the facility of soil test. To aware the rural banana growers about the importance aspects of soil test, adopting modern technologies, uses of fruit bagging instead of chemical spraying to prevent insects attack by the facilitation of skill development training and to create environmental awareness adopting environmental practices at the time of cultivation by the facilitation of environmental awareness training. Most of the farmers of the study area applied the organic manure during land preparation, and the chemical fertilizers like urea, potash and DAP were applied @ recommended dose following the report of soil testing.

According to the annual report of Upazila Agriculture Office of Shibganj Upazila (2022) that 600 ha of land is occupied for banana cultivation every year and the average yield is 35 tons/ha which is comparatively low than the previous year. Lack of disease resistant and climate friendly variety was the root cause of this reduction of yield. It was the crying need to introduce a new variety. The SEP project team tried to take risk to innovate a disease resistant tissue cultured variety named 'Grand Naine'

Figure 1: Soil test report and fruit bagging practice

(*Musa Acuminata*), Cavendish subgroup of the AAA (triploid) group. Grand Naine literally translates from French as "large dwarf". Lack of genetic diversity makes this variety disease and toxicity resistance. It is high yielding, fastest growing, excellent keeping quality in ripen fruits.

Ecological farming

The ecological farming method is a very new concept for Bangladeshi farmers. No farmers in the project area had a clear idea about this method and do practice in their field. This is the best way of getting safe food and earning a premium price. Ecological farming is a crop production technique respecting the rules of nature. Ecological farming maximizes the use of on-farm resources and minimizes the use of off-farm resources, its farming that seeks to avoid the use of chemical fertilizers and pesticides.

Ecological banana farming, the entire system that means plant, animal, soil, water, and microorganisms are to be protected. By ecologically growing bananas, uses natural materials to feed the plant and produce edible bananas without chemicals and pesticides. Nutrient management through organics plays the main role in maintaining soil health due to the build-up of soil organic matter, beneficial microbes, and enzymes, besides improving soil physical and chemical properties (Babalad & Kumara, 2010). To achieve sustainable soil fertility and crop productivity, the role of organic manures and other nutrient management practices like the use of fermented organic nutrients are becoming popular among farmers. These fermented liquid organic fertilizers contain in addition to nutrients, numerable microorganisms, and growth-promoting substances which help in improving growth, metabolic activity, and resistance to pests and diseases.

The below organic fertilization practices were being implemented in Banana plantations to improve the necessary nutrient content of the soil;

- Intercropping: Planting seasonal crops (Cabbage, Cauliflower) between banana rows increased the fertility of the soil. Land gave a return before the banana crop is ready.
- Water conservation- By building terraces to keep water in the field, mulching crops, and planting cover crops, as long as they are not competing with banana plants were practiced to preserve moisture in the plantation.
- Soil conservation- Applying compost in the planting holes of Banana trees and adding organic manures afterward improved the growth and productivity of plants. Soil was protected against erosion as soil moisture was conserved.

Harvesting management

The harvesting standards may vary place to place, season, transport distance and the end use of the fruit. The fruit may be harvested fully matured stage for short distance transport; the fruit may be harvested at 90% maturity level for long distance transport. The fruit may be

Figure 2: Practicing intercropping system in the field

Figure 3: Harvesting and packaging of banana

harvested at 75% maturity level again; the fruit are harvested for table purpose at fully matured and yellow banana is preferred. Irrigation of banana plantations are being stopped well in advance of the harvest date, preferably a week, so as to facilitate drying of the soil for movement of labor, harvesting, loading, etc. The bunches are kept for minimum 15 minutes after harvesting for carrying to cease the latex flow and bunches are not be allowed to come into contact with soil by keeping them on polythene sheet or banana leaves.

Farmers of the study area, sell the banana on the orchard itself. Usually, the traders come to the farm, harvest the quantity of banana required, load it in the vehicle (usually truck) and transport it to the destination. Earlier at the time of transporting banana no packaging materials are used but at present the farmers of the study area are covering at the time of transporting banana by the banana leaves. This might reduce physical injury to the banana fruits.

Waste management and bio-fertilizer production
We all know that the banana is a persistent plant but the fruit is available all around the year. After the successful harvest of bananas, the whole plant becomes a byproduct which ultimately for about 80% of the countries goes into waste (Prity, 2020). In all around the banana producing countries, farmers usually cut down the whole stem of the banana plant for the fruit and let the new younger plant grow for another yield. This makes the whole stem and the inflorescence all to be gone for waste. After the harvest of the fruits the whole plant- leaves, stem, and rhizome is left in the field for natural degradation, which takes months together. However, these wastes can

be utilized for cellulase production (Baig *et al.*, 2003). In this study area, all farmers after the harvesting, they left the trees on the field which is caused for environmental pollution. They did not have any knowledge or training on how to recycle this waste.

Under SEP project, the farmers of Shibganj have some basic knowledge about environment pollution created by their traditional methods of banana cultivation and how to recycle waste after harvesting. The farmers of the study area now following a good environmental practice like they dig a pit on a corner of the banana field and after harvesting banana they are dumping the banana waste at the pit. Thus, the environmental pollution is reducing and also getting the bio-fertilizer that produces at pits. In the study area, waste collection points both at cluster (8 units) and market site (2 units) have been constructed as a grant. The farmers also dump banana waste, biodegradable waste in it and use the bio-fertilizer in field those are produced from waste collection points.

Banana plant parts (leaves, pseudo stems), generally disposed as waste. These huge volumes of waste biomass are either disposed in the agricultural fields by burning on site or disposed off along the roads or railway tracks which cause environmental problems. These practices also result in loss of valuable nutrients present in the plant biomass.

Fiber management
Shibganj Upazila of Bogura district is famous as a big hub of banana production. Generally, the farmers here after the harvest of the fruits the whole plant (leaves, stem, and rhizome) left in the

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Figure 4: Pit beside in the banana field

Figure 5: Waste collection point for producing bio-fertilizer

field for natural degradation. Thus, environment pollution occurs and bad odor disseminate.

A young micro entrepreneur Md. Bokul Hossain (35) from Arjunpur, Shibganj had so much interested to do new items. Under SEP project, he received two lakh takas as common service loan from TMSS and getting an exchange visit at Snigdha Banana Fiber Co. Ltd., Madhupur, Tangail. He bought two fiber crushing machine from there and started to produce banana fiber from the waste banana stems named M/S Bokul Fiber and Vermicompost Plant. He became succeed through fiber production

and new employment had been created. Eight employees work at his microenterprise. He is selling the fiber at the rate of Tk. 140 per kilo. Many handicraft items like table matte, glass lid, pen holder, key ring, bags are produced from the banana fiber and trying to make further more new items.

Demonstration effect

The moderate height (6-7 ft.) allows easy harvesting and excellent wind protection. On 24 October, 2022, The Sitrang cyclones shows a devastating damage in agriculture sector specially banana field. The local variety banana plants were

Table 2: Amount of produced bio-fertilizer

Ingredient (kg)	Amout of produced bio-fertilizer
Banana leaves (250 kg)	56 kg
Banana leaves (100 kg) + Pseudo stem (150 Kg)	87 kg
Banana leaves (50 Kg) + Pseudo stem (100 kg) + Cow dung (150 kg)	168 kg

Waste banana stems — **Producing fiber from waste banana stems through crusher machine** — **Sun drying of fiber**

Table matte, glass lid, pen holder, key ring produced from banana fiber

Figure 6: Different handicrafts produced from banana fiber

collapsed abruptly due to their height, comparatively less damage was shown in Grand Naine (G9) field, average two plants were affected from three plots out of 45 demonstration plots. The responses of the nearby farmers of the G9 demonstration plot had been increased drastically after this incidence and seeing the result of higher yield, climate resilient compare to other local variety. From 10 G9 demonstration plot under SEP-banana, about 31 nearby farmers collected 2,188 G9 saplings and started cultivation at their own field.

Economic indicators i.e., gross expenditure, gross returns, net returns of Grand Naine demonstration plot (1 ha) are presented in Table 3. The data clearly revealed that, gross expenditure was Tk. 524,500/ ha and the net return was Tk. 1,237,831/ ha which was two times higher than gross expenditure.

G-9 banana is one of the most commonly cultivated Cavendish bananas. These are the high yielding among all the banana varieties which is introduced to India from Israel. It is the solid green fruit with high export value and

Figure 7: Showing the comparative effect of cyclones of Grand Naine to the local variety

Table 3: Calculation of income expenditure G9 demonstration plot (ha/Tk.)

Sl. No.	Expenditure items demo. plot	Tk.	Comments
1.	Land cultivation	5617/-	
2.	G9 tissue culture sapling plantation	1,54,500/-	3090 p * 50/-
3.	Irrigation	13,480/-	
4.	Weed control	80,878/-	
5.	Fertilization	90,920/-	
6.	Fungicides & pesticides application	26,435/-	
7.	Bamboo stick for support	71,330/-	
8.	Bagging of fruits (banana)	81,440/-	
Gross expenditure (B)		**5,24,500/-**	
9.	Banana sale	16,50000/-	3000 p * 550/- (Av)
10.	Sapling sale (from the field)	1,12,331/-	
Gross return (A)		**17,62,331/-**	

economically highly profitable.

According to Table 4, it was shown that the net return of Grand Naine variety for one hectare land was Tk. 974,233 which was comparatively high than Anupom and Champa varieties. However, farmers get benefited to cultivate Grand Naine and produce disease free sucker which is suitable for spreading this tissue culture variety.

Nutrient quality of G-9 and other banana varieties

It is essential to know the nutritional and biochemical composition of different banana varieties. Bananas and plantains are the fourth most important food crop in the world after rice, wheat and maize. The consumption of fruits especially banana is known not only to promote general good health but also lower the risk of various chronic diseases, such as heart diseases, stroke, gastrointestinal disorders, certain types of cancer, hypertension, age-related macular degeneration, cataract of the eye, skin conditions,

lowering of low-density lipoprotein (LDL) cholesterol, and improved immune function. To promote healthy eating lifestyle, the USDA recommends filling up half the plate with fruits and vegetables, because these provide a good amount of dietary fibers, certain vitamins (*e.g.* ascorbic acid, folic acid, and vitamin A precursors), many minerals (*e.g.* potassium, magnesium, iron, and calcium), and many other important phytochemicals having strong anti-oxidative properties.

The fresh ripen banana of three varieties were tested in the lab of the Institute of Food Science and Technology (IFTS) under Bangladesh Council of Scientific Research and Industrial Research (BCSIR). The report is given below.

According to the Table 5, protein, total sugar, zinc, fat, iron, fiber composition of Grand Naine is comparatively higher than other varieties. On the other hand, carbohydrate, energy, potassium, magnesium composition is lower than other varieties.

Table 4: Comparative chart of income expenditure of different bananas (per hectare)

Land amount	Variety	No. of planted tress	No. of fruiting tress	Sales price (per Ghaor/ Chari)	Total sales price (Tk.)	Total production cost (Tk.)	Net return (Tk.)
1 hectare	Champa	2471	2000	380/-	7,60,000/-	2,37,090/-	**5,22.910/-**
	Anupom	2471	1500	550/-	8,25,000/-	2,95,783/-	**5,29,271/-**
	Grand Naine	3090	3000	500/-	15,00000/-	5,25,767/-	**9,74233/-**

Table 5: Comparable composition of fresh ripen banana of three banana varieties

Variety	Protein (%)	Total sugar (%)	Energy (Kcal/100g)	Carbohydrate (%)	Zinc (mg/100g)	Fat (%)	K (mg/100g)	Mg (mg/100g)	Fe (mg/100g)	Fiber (%)
Grand Naine	1.50	19	89	20.56	0.6	0.07	477.92	33.48	3.34	2.01
Anupom	1.41	7.63	105	24.62	0.3	0.02	504.63	52.21	0.28	0.07
Champa	1.21	10.93	101	23.81	0.22	0.01	697.31	47.83	0.13	0.08

Methodology

This experiment was conducted at Shibganj Upazila under Bogura district. Shibganj is located between Latitude 24º54′ & 25º 08′ north and Longitude 89º 10′ & 89º 28′ east.

Baseline study

The baseline survey pursued both quantitative and qualitative approaches for collecting information about the status of the project target group (banana farmers). A questionnaire was used to collect key information such as age, income, income sources, expenditure, product production, selling, environment and health, and safety situation, etc. Qualitative and quantitative approaches were used to understand the overall scenario of the target group. Besides, some techniques were applied such as verbal interviews and informal conversations to find out the depth of knowledge on banana farming and environment and health and safety situation. Statistical formulas and tools were used to analyze the collected information.

Study area and sample size setermination

Simple random sampling has used to determine the study area. There are different ways to determine the sample size. In our study, the sample size determination formula has used for a finite population ('known'). The formula is given below:

$$S = \frac{X^2 NP\,(1\text{-}P)}{d^2\,(N\text{-}1) + X^2 P\,(1\text{-}P)}$$

Where:

S = *Required Sample size*
X = *Z value (e.g. 1.96 for 95% confidence level)*
N = *Population Size*
P = *Population proportion (expressed as decimal) (assumed to be 0.5 (50%)*
d = *Degree of accuracy (5%), expressed as a proportion (.05); It is a margin of error.*

In our study, the total population was 2000. We used this formula and determine the sample size. $S = 322$

$$S = \frac{1.96^2 \times 2000(1-.5)}{d^2 \times (2000-1) + 1.96^2 \times .5 \times (1-.5)} = 322$$

So, our sample was 322. From the selected 322 samples have considered 176 members were male and 146 members were female.

A structured survey questionnaire was developed for the target group. Question guidelines were developed to collect information about the target group and analyze the present scenario. Questionnaire field test was done to finalize the questionnaire. The main goal of the questionnaire field test was to identify the actual situation and easy to understand the target group.

Soil testing, experimental design and field management

Soil sample of the experimental plot were taken from the top 0-15 cm and bulked together to get a composite sample. The composite sample was taken air dried for four days, sieved through a 2.00 mm sieve and analyzed for the chemical properties (Table 1) in SRDI, Bogura. The land was applied lime for the balance of the pH level according to the recommended doses. Then plot was ploughed for three times, harrowed and irrigated. A complete randomized block with three replications with each treatment was set up. The experiment consisted of five treatments namely T_1: 100 gm phosphorus/plant, T_2: 200 gm phosphorus/plant, T_3: 300 gm phosphorus/plant, T_4: 400 gm phosphorus/plant, T_5: 500 gm phosphorus/plant.

The germfree tissue culture banana seedlings were transplanted with (6ft×6ft) spacing. After ¾ weeks, 10 representative plants were selected at the first row and tagged for observation and

Table 6: Effect of Phosphorus fertilization on the vegetative characteristics of Grand Naine variety banana

Treatment	Plant height (cm)	Pseudo stem girth (cm)	No of leaves
T_1	150.56	60.25	16.65
T_2	152.78	60.43	17.98
T_3	167.98	65.34	18.34
T_4	145.54	56.43	15.43
T_5	140.89	54.32	15.76
S. Em.	0.39	0.67	0.89
LSD (P=0.005)	1.24	2.67	2.13

T_1: 100gm phosphorus/plant, T_2: 200gm phosphorus/plant, T_3: 300gm phosphorus/plant, T_4: 400gm phosphorus/plant, T_5: 500gm phosphorus/plant

data collection throughout the experimental period. All observations on growth characters viz., plant height, girth of pseudo stem, number of leaves, number of hands per bunch, number of fingers per hand, number of fingers per bunch, inflorescence length, finger weight, bunch weight, days taken to planting to flowering, days taken to flowering to harvesting were recorded from tagged banana plants. The height of plants on shooting stage was measured from above ground level up to the angle between the youngest first and second leaf axis. The girth of the plant was measured from 30 cm above level at monthly intervals up to shooting. The fruits were considered to be ready for harvest when the angular girth of skin of fruit disappeared, and color turned from dark green to light green. Yield of banana in tons per hectare was calculated by multiplying the average bunch weight with the total number of plants per hectare.

All the data collected were analyzed using analysis of variance with the aid of Panse and Sukhatme (1967), significant means were separated using least significant difference (LSD) at 5% probability level.

Result and discussion

Data represented in Table 6 showed that various treatments differed in respect of different vegetative characteristics. The tallest plants (167.98 cm) with maximum pseudo stem girth (65.34 cm) were produced in T_3 treatment, whereas, smallest plants (140.89 cm) with least pseudo stem girth (54.32 cm) were recorded in T_5 treatments. This increase in height and girth of pseudo stem might be due to the improvement of physical

Table 7: Effect of phosphorus fertilization on the production cost of Grand Naine (G9) banana

Treatment	Yield (tons/ ha)	Monetary returns (Tk./ha)	Cost of fertilizer (Tk./ha)	Cost of cultivation (Tk./ha)	Total cost (Tk./ha)	Net profit (Tk./ha)	B:C ratio
T_1	45	806550	115775	258953	374728	431822	1.1
T_2	50	810337	120665	258953	379618	430719	1.1
T_3	55	918750	139779	258953	398732	520018	1.3
T_4	44	812337	158797	258953	417750	394587	0.9
T_5	43	820550	165750	258953	424703	395847	0.9
SE.m	0.78						0.015
LSD (P=0.05)	2.34						0.043

T_1: 100gm phosphorus/plant, T_2: 200gm phosphorus/plant, T_3: 300gm phosphorus/plant, T_4: 400gm phosphorus/plant, T_5: 500gm phosphorus/plant

properties of soil, optimum amount of fertilizer uptake which was manifested in the form of enhanced growth and higher carbohydrates production as explained by Nayyer et al. (2014).

During the time of emergence of inflorescence, the maximum number of leaves (18.34) were counted in applying 300 gm phosphorus per plant banana plant (T_3), on the contrary lowest number of leaves (15.76) were recorded when per plant of banana was given 500 gm phosphorus (T_5). The increase in vegetative growth and other parameters might be due to the production of more chlorophyll content with the inoculation of nitrogen fixers. Increased number of leaves might have increased the photosynthetic activity resulting in higher accumulation of carbohydrates.

Table 7 showed that application of 300 gm phosphorus fertilizer per plant recorded highest yield (55 tons/ha), monetary returns (Tk. 918,750/ha), net profit (Tk. 520,018/ha) and benefit cost ratio (1.3) which implies banana growers gets maximum profit by applying optimum amount of fertilizer. The lowest benefit cost ratio 0.9 which indicates farmers apply extra amount of phosphorus, as a result total cost of production is higher than the profit.

Conclusion

The farmers of the study area had no knowledge about modern technologies for banana cultivation. They were following the traditional practices. They were using excessive chemical fertilizer and pesticides which contaminated the water and soil. They have also faced various health hazards due to the lack of proper knowledge and training. By considering all the issues the farmers under this project get agricultural training (skill development under modern technologies), environmental awareness and certification training, business development and certification training, use of organic fertilizer, minimum use of chemical fertilizer as per report of soil testing, use of fruit bagging instead of insecticide spraying. Proper motivation and financial aid would help the micro-entrepreneurs to produce safe bananas which increased their income and living standard.

It was recorded that the plant height, girth of pseudo stem, number of leaves was maximum in the plants supplied with 300 gm phosphorus per plant with earliness in flowering and flowering to harvesting of bunch as compared to others. These vegetative parameters indicate the maximum yield (55 tons/ha) compared to other local variety of banana at Shibganj Upazila.

Adaptation strategies through changes in farming practices, cropping pattern and use of new technologies will help to ease the negative impact of climate change and get more profitable healthy tissue culture variety. Banana leaf biomass amended with cow dung is a good feed substrate for vermicomposting which showed promising results of waste mineralization and earth warm growth. Last but not least, production of fiber from banana plants can be open a new window in the value chain and play a significant role in our microenterprise.

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Assessing the impacts of government subsidies on people's livelihood in Kushtia district

Farjana Akther Lubna[1], Md Rahedul Islam[1*]

[1]Dept. of Geography and Environment, Pabna University of Science and Technology, Pabna, Bangladesh

ARTICLE INFO	ABSTRACT
	Bangladesh is experiencing drastic socio-economic development through the social equity. The government provides various social and financial subsidies to the marginal people. The main objective of the study is to look into the relationship that exists between government subsidies and profitable growth in the quarter of the Kushtia. The primary data was collected through the questionnaire survey and focused group discussion. The Operations of the LM and Granger- F tests have been used to determine the unproductive relationship between government subventions and their goods on individualizes. Before doing this, the government subventions with and without structural discontinuities are examined for the presence of non-stationary using unit root tests. To determine whether these two variables partake in the same stochastic trend, the co-integrated test is used. The periodic time series data from 2015-16 to 2022–23 are covered by the analyses. It has been determined through analysis that profitable progress in non-stationary is what drives government subventions rather than the other way around. Thus, in Bangladesh's frugality, there's a unidirectional unproductive relationship between government subventions and fiscal progress. Also, it has been discovered that both variables parade order 1 integration with and without structural discontinuities, although they don't carry complementary dependence on each other for the profitable development of the Kushtia quarter frugality. Retrogression analysis has also been performed to probe the statistical relationship between the short-term profitable impact and government subventions. The results of the t-test and F-test indicate that there's little correlation between the government subventions and profitable growth. This demonstrates unequivocally that the government subventions have no perceptible impact on Bangladesh's profitable growth individual testing revealed that the residuals are typically distributed with a mean of zero, that the residuals aren't bus-identified, that there's no suggestion of heteroscedasticity, and that the short-run model doesn't contain autoregressive tentative heteroscedasticity.

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Introduction

Bangladesh is one of the world's least developed nations. As a less advanced nation. The government of Bangladesh allocates enormous sums of money for subsidies to support economic development on an annual basis. It was discovered that the government's subsidies for this sector were Tk. 402.6 million in 2015–16, but they

increased to Tk. 612.6 million in 2022-23. Thus, it can be said that, in Bangladesh, the government subsidies for the fiscal year 2022-23 will be 52.161 times greater than those for the fiscal year 2015-16. Thus, we are left wondering if the government subsidies are applicable correctly or not. Besides, it is necessary to understand whether the massive amount of government subsidies are contributing significantly to economic development. For this reason, I have decided to look at the causal relationship that exists over the long term between government subsidies and how they affect people. The Granger F-test and Lagrange Multiplier test are used to examine the causal relationship between economic impact and government subsidies. It is crucial to look at the integration sequence before doing the causality checks. For this reason, an additional attempt has been made in this work to determine whether the variables, the economic impact, and the government subsidies have a unit root. Any modifications to the series are transitory and have immediate effects if the variable lacks a unit root. If not, any shocks to it will be long-lasting and have an impact over time. Unit root tests are a class of econometric procedures that are used to test for non-stationary a variable. It is commonly known that when variables incorporate stochastic trends, standard regression analysis techniques can produce extremely misleading conclusions (Granger & New bold, 1974; Stock & Watson, 1988). Regression results are spurious, in particular, if the dependent variable and at least one independent variable have stochastic trends and if they are not co-integrated. An analysis of the existence of a stochastic trend in the variables is required to determine the proper model specification. It is common knowledge that a variety of factors, such as political and ideological disputes within political parties, changes in government policy, policies and viewpoints of various foreign aid organizations, such as the World Bank, ADB, and EU, as well as policy shifts within aid countries, have an impact on their livelihood and government subsidies in the Economical sector. Because of this, an additional attempt has been made in this article to determine whether

the non-stationary outcome is susceptible to structural fractures. Here, the Pivot-Andrews technique has been used to search endogenously for the breakpoint and test for a unit root in the variables rather than arbitrarily selecting a breakpoint based on pre-test analysis of the data. Co-integrated tests are also used to determine whether a pair of variables shares the same stochastic trend. This study uses regression analysis to investigate the statistical relationship in the short run between the economic impact and government subsidies. Based on the time series data covering the years 2015-16 through 2022–23, all analyses were conducted.

Objectives of this study

The objective of the study was to assess the government subsides impacts on the poor people in Kushtia district of Bangladesh. Therefore, the specific objectives are as follow:

- To identify the people under the government subsidies;
- To assess the impact of the subsidies on people; and
- To evaluate the beneficial subsidies from the government.

Scopes and significance of this study

The study can assist in determining the kinds of subsidies that have the greatest positive effects on livelihoods. The study can help to raise awareness of government efforts and their effects on individual livelihoods by disseminating the findings to the local community. This study is important because it sheds light on the dynamic interaction that exists between government interventions and the livelihoods of people living in Kushtia. In addition to adding to academic knowledge, the results will give policymakers useful information that they can use to improve subsidy programs and better meet the changing requirements of the community.

Literature review

Zafar et al. (2023) claim that six sections make up the organization of the paper. A conceptual foundation for the link under investigation in this study is presented in the second section.

The trend of input subsidies in comparison to public farm investment is examined critically in the third section. The data and methodology are explained in depth in the fourth section. The study findings and discussions are presented in the fifth section. The last portion offers a brief synopsis and pertinent policy recommendations. (Shadman Zafar, 2023)

In fisheries management, subsidies are frequently accused of encouraging overfishing and an increase in fishing capacity worldwide. Due to the widespread calls from scientists for the elimination of "harmful" subsidies that artificially boost fishing profitability, members of the World Trade Organization have agreed to do just that. The case for outlawing damaging subsidies is based on the supposition that fishing will become unprofitable in the absence of subsidies, encouraging certain fishermen to leave and discouraging others from joining. These claims stem from open-access governance systems in which entrance has eliminated profits. However, many contemporary fisheries operate under limited-access policies that set capacity limits and ensure financial gains even in the absence of subsidies. (Wanga et al., 2023) (Kaiwen Wanga, 2023)

Saeediankia et al. (2023) argue that Iran's growing subsidy program affects social and economic institutions in a variety of ways. The subsidy was employed as a method to curb price increases and inflation before the revolution, but the desired results were not achieved for social, economic, and technical reasons. Then it was the implementation of the basic items rationing scheme and the subsidy payments. Subsidies were used as a means of achieving social fairness and income redistribution following the revolution. (Afsaneh Saeediankia, 2023)

Wunderlich and Kohler (2023) claim that subsidies to farmers are increasing. These subsidies may be funded by consumer fees (CSE), taxpayer transfers (PSE), or a combination of the two. Farm subsidies increase the quantity and hence lower the cost of some agricultural commodities, which may have an impact on food costs. The purpose of this study is to determine whether these subsidies can help to explain why

obesity rates are rising globally. We evaluate the various effects on overweight (BMI above 25 to 30) and obesity (BMI above 30) using data on farm subsidies and obesity from the OECD and FAO, and by separating the two models. Regression research suggests that farm subsidies may be too low to have an impact on overweight or obesity and that it would be more effective to combat rising obesity nationally rather than attempting to continue do a cross-country basis. (Anne C. Wunderlich, 2022)

In China, the aging population presents an extraordinary issue. Health insurance programs, socioeconomic position, social support, and family dynamics are some of the barriers that prevent people from accessing healthcare and have resulted in an unequal distribution of government health subsidies for the elderly. Utilizing benefit incidence analysis, the distribution of government health subsidies for the elderly by income quintile was investigated. In 2008 and 2013, the concentration index was computed in both rural and urban areas. (Chen & Wang, 2020) (Mingsheng Chen, 2020)

Paula et al. (2023) describe, when taken as a whole and as economic entities with distinct objects of activity, Romania's agriculture is a significant sector of the country's economy that guarantees the income from activities that are dependent on the object of activity. However, the financial outcomes of Romanian agricultural holdings are contingent upon the subsidies they get, which have the potential to significantly increase their profitability. (Stoicea Paula, 2023)

Research methodology

This study focuses on the government subsidies and economic development in Kushtia district spanning over a time period about 8 years from 2015-16 to 2022-23. This study based on primary data which were collected from Kushtia district by questionnaire survey and FGD. The samples of collected data are around 210. Data has obtained on variable, the sample data are divided into different kinds of subsidies such as about 82 people –old age subsidies, 47 people –widow subsidies, 33 people –Disability, 24
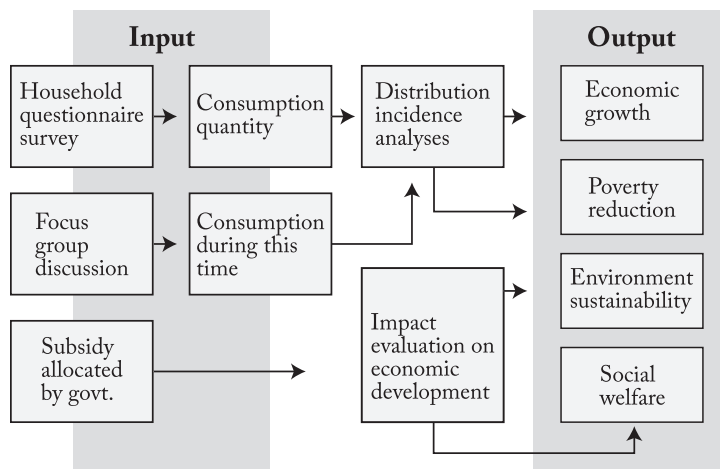
people –During pregnancy and 20 people are getting others subsidies. The impact of subsidies are identified across different sector based on qualitative and quantitative analyses using the age, gender, occupation, annual income, health condition and the amount of subsidies.

A desk methodology was used in this investigation. Primary data collection is a popular term used to describe a desk study research design. In essence, this involves gathering data using al-ready available resources, ideally because of its lower cost when compared to field research. Because the data was readily available through online journals and libraries, our current investigation examined previously published studies and publications. A key analytical technique is used to compare data between different categories to recognize relationship by using different types of methods.

Identified structural break point: On this table, I have confined the analyses to the structural break point which show the most beneficial sector of government subsidies where the age is independent variable. Actually the government subsidies and economic impact are affected by different factor. From table 1, we see that the strong structural break point for government subsidies are Model(B) which determine the age of 66-70. On the other hand, the strong structural break point for economic impact on their livelihood are Model(A).

Table 1: Results of quantitative analyses for detecting break point in the series of economic impact and government subsidies in different sectors at Kushtia district.

Age	Government subsidies on different sector			Economic impact on peoples livelihood		
	Model(A)	Model(B)	Model(C)	Model(A)	Model(B)	Model(C)
5-10	0.098346	0.239214	0.342782	0.453767	3.675342	0.453788
11-15	0.675890	0.918500	1.298221	0.865328	3.453788	0.564223
16-20	1.675890	0.678542	0.105678	0.546387	2.456723	1.765990
21-25	0.875849	0.340589	2.456548	3.453799	1.674789	1.564238
26-30	0.231678	1.231122	1.984322	2.765789	0.785324	2.876534
31-40	0.558900	2.893099	0.124228	2.546312	0.675328	0.674211
41-45	0.211954	0.198001	0.665677	0.453790	0.987634	0.546667
46-50	0.345678	0.123001	0.321789	0.675342	0.543789	0.657880
51-55	0.787985	0.120112	0.787478	0.564280	0.453780	0.123324
56-60	0.455670	2.768333	0.676523	2.453689	0.546223	3.756367
61-65	0.897896	0.831455	2.453578	1.457823	0.564244	0.876922
66-70	0.123722	3.567123	2.453687	1.564328	1.234567	0.566722
71-75	0.522901	0.194522	1.675840	2.786319	0.781230	1.435678
75-80	0.881368	0.089623	0.780230	0.764267	0.546329	0.129549

Result and discussion

Demographic characteristics

Bangladesh governments may target subsidies based on various demographic factors to address social or economic objective. From the primary data survey we received the demographic information about the subsidiary needed people.

Demographics	Groups	Frequency	Percentage (%)
Subsidies sector	Old age subsidies	82	40
	Widow- subsidies	47	19
	Disability	33	17.5
	During- Pregnancy	28	12.5
	Others	20	11
Gender	Female	135	64
	Male	75	36
Age	1-15	17	7.45
	16-30	28	12.32
	31-45	42	22
	46-60	53	27.67
	61-75	70	31.22
Occupation	Employed	37	17
	Unemployed	173	83
Monthly income	less than 3000	65	31
	3000-5000	72	42
	5000-7000	54	21
	7000-10000	19	6

Now the primary observation of Government subsidies and its economic impact are presented graphically below

From the figure, we can see the percentage of subsidies type and economic impact in the Kushtia district. In the subsidies type, 40% old age subsidies which are the largest percentage subsidies in the Kushtia district. On the other hand, during 2017 the most economical impact on their livelihood and also near about 2023 in the Kushtia district.

From Figure, we can see the percentage
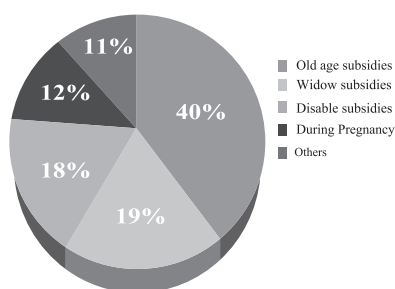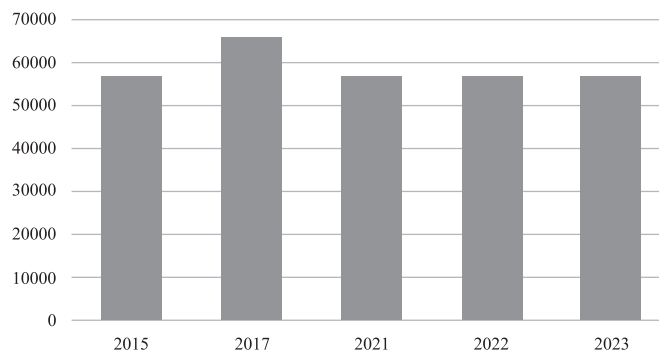
Figure 1: Subsidies types and economic impact on people in the Kushtia district
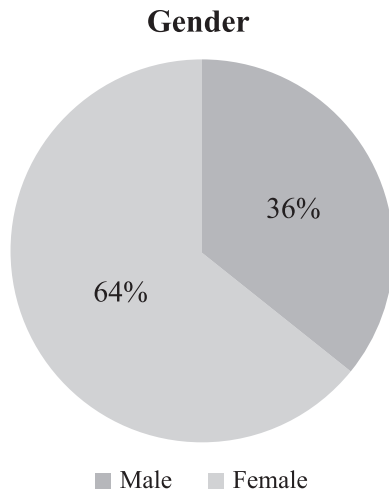
Gender

Figure 2: Gender purpose to divide govt. subsidies

of male people is less than the percentage of females. So, now I have found out that a large number of female people get more benefits from government subsidies in the Kushtia district.

Now to primarily observe to show the diagram, the people get how much amount of government subsidies in below:

In Figure 3, series 1 shows how much people get different types of subsidies, and series 2 shows how much amount of subsidies they get. Now we can see the old age subsidies, widow subsidies get fewer amounts than disabled and during subsidies. Agriculture and other subsidies are more average than others.

From provisional data % of people who benefited from this kind of subsidy in the Kushtia district:

There we can see the people of Kushtia benefit from this subsidy such as food, agriculture, shelter, education, healthcare, tube-well, and others. The maximum benefit people get from food is 21%, and the minimum is tube-well which is only 8%.

Econometric analysis

The main econometric analysis entails determining whether an underlying co-integration relation exists and whether the Economic Impact and government subsidies include a unit root. Any innovations to the series are temporary and have immediate effects if either of the two series lacks a unit root. If not, any shocks to it will be permanent, resulting in long-term effects. Unit root tests are a class of econometric procedures that are used to test for non-stationary a variable. Next, we talk about unit root tests.

Unit root tests without structural breaks

It is commonly recognized that when variables incorporate stochastic trends, standard regression analysis techniques can produce extremely deceptive conclusions (Granger & New bold, 1974;

Amount of different types of subsidies
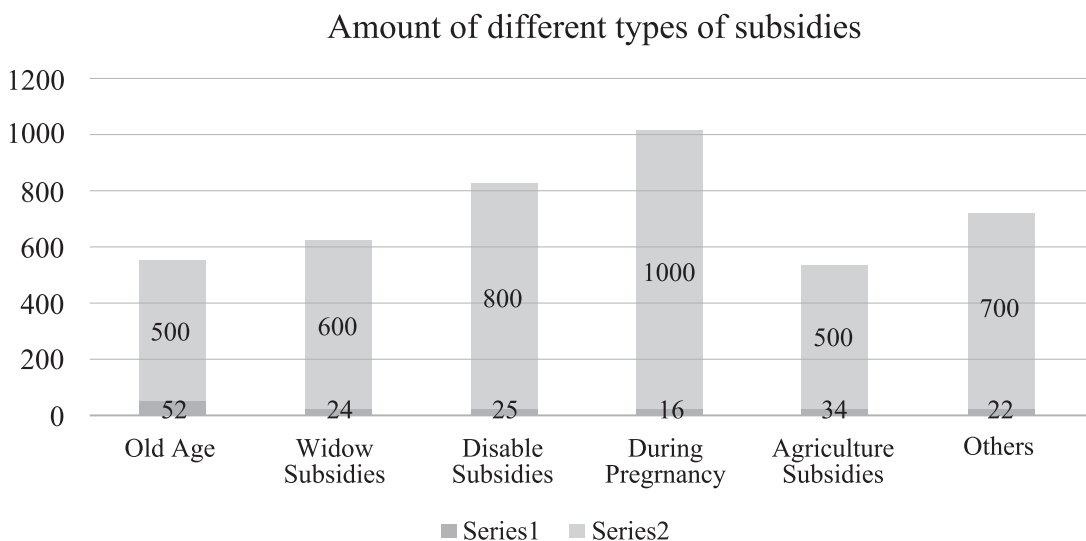
Figure 3: Given the amount of subsidies from govt.
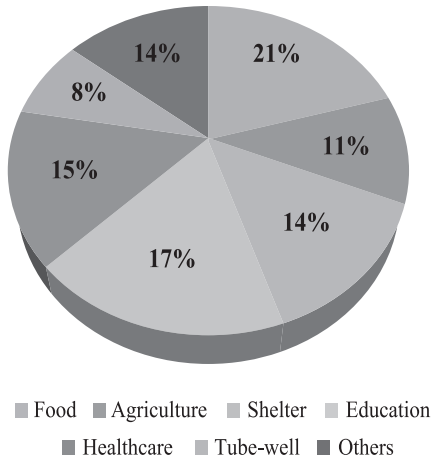
Figure 4: People benefited from govt. subsidies

Stock & Watson, 1988). Regression results are spurious, in particular, if the dependent variable and at least one independent variable exhibit stochastic trends and are not co-integrated (Granger & New bold, 1974; Phillips, 1986). Investigating the existence of a stochastic trend in the variables is necessary to determine the proper model specification. Several econometric methodologies have been used here to test for the stationary of agricultural production and the government subsidies on the agricultural sector. To determine if each variable has a stochastic trend or not, the Dickey-Fuller and the Augmented Dickey-Fuller tests are used. The following three instances of the Dickey-Fuller test have been examined in this study.

Condition 1: Constant and trend terms are included in the equation

$$\Delta X_t = \alpha_0 + \alpha_1 t + \theta X_{t-1} + u_t \qquad (1)$$

Condition 2: Only the constant term is included in the equation

$$\Delta X_t = \alpha_0 + \theta X_{t-1} + u_t \qquad (2)$$

Condition 3: No constant and trend terms are included in the equation

$$\Delta X_t = \theta X_{t-1} + u_t \qquad (3)$$

and for the Augmented Dickey-Fuller Test, the following equations have been considered

Condition 1: Constant and trend terms are included in the equation

$$\Delta X_t = \alpha_0 + \alpha_1 t + \theta X_{t-1} + \sum_{i=1}^{m} \emptyset_i \theta X_{t-i} + u_t \qquad (4)$$

Condition 2: Only the constant term is included in the equation

$$\Delta X_t = \alpha_0 + \theta X_{t-1} + \sum_{i=1}^{m} \emptyset \Delta X_{t-i} + u_t \qquad (5)$$

Condition 3: No trend and constant terms are included in the equation

$$\Delta X_t = \theta X_{t-1} + \sum_{i=1}^{m} \emptyset \Delta X_{t-i} + u_t \qquad (6)$$

Here, X_t is the series under investigation, Δ stands for first difference and the lagged difference terms on the right-hand side of the equations are designed to correct for serial correlations of the disturbance terms. The lagged differences are selected by using the AIC and right-hand criteria. If $\theta = 0$, the series

X_t contains a unit root and therefore a (1) process governed by a stochastic trend. Since the estimated θ does not have the usual asymptotic distribution, the values tabulated by MacKinnon (1991) are used; these values are more accurate than the ones originally tabulated by Dickey-Fuller (1987) and Fuller (1976).

According to Table 2, the unit root null hypothesis for both variables cannot be rejected at the (3-5%) level of significance, according to the estimated results of the DF and ADF tests. The null hypothesis of no co-integration is rejected, if the value were below -3.50; and not rejected if the value were above <1. Consequently, it can be said that neither of the variables is stationary. This series' creativity will endure and benefit Bangladesh's economy in the long run. As a result from the Table 2, DF and ADF test determined that Government subsidies bear economic development at Kushtia district in a short run.

Table 2: The DF and ADF test result for Unit Root

	DF Test			ADF Test		
	Condition 1	Condition 2	Condition 3	Condition 1	Condition 2	Condition 3
Economic impact	-3.24695	0.33176	-1.24356	-1.34569	1.00345	2.94117
Govt. subsidies	-3.32877	-2.64042	1.50265	-3.45265	-2.56885	1.29743

Co-integration tests

The analysis that came before it aids in demonstrating that the government subsidies, economic impact, and series are non-stationary, meaning that each series has a unit root on its own. The question is whether these series follow a similar pattern, preventing the gap from widening indefinitely. As a result, I've carried out an additional investigation utilizing co-integration approaches. Economic time series modeling now has more flexibility thanks to the concept of co-integration among variables. Two variables are co-integrated of order (1, 1), according to Engle and Granger's (1987) definition, if each variable is stationary in initial differences (integrated of order 1) but the linear combination of the variables is stationary in level (integrated of order 0). In general, a collection of variables is co-integrated of order d, b) if at least one linear combination of order (d-b) occurs, but each variable is integrated of order d separately. Like other studies, I have concentrated on the scenario when d = 1 and b = 1. In this case, I also performed the ADF and PP tests for the second unit root; Table 6 reports the results of these tests, which show that the second unit root is rejected in each series. Therefore, it is appropriate to perform the co-integration analysis because it is evident that all the series are processes. Here, the X_t (1987) test (1990) is used to check for co-integration.

The co-integrated test results for different pairs of series are given in the following table 2. Residual based tests results for co-integration between different pairs of variable are given in Table 3.

On the Table 3, there firstly the dependent variable economic impact and independent variable government subsidies measure the condition which sh ows the variation between the values. On the other hand, there the dependent variable government subsidies and independent variable economic impact measure the condition which shows a negative value of this test. The findings of both studies confirm that government support for their livelihood does not generate Economic development; rather, government subsidies are a result of economic development. Therefore, it may be concluded that government subsidies have little impact on Bangladesh's economic development. This demonstrates unequivocally that corruption exists in Bangladesh and that government subsidies to the industry are not being used effectively for livelihood development.

Regression Analysis for Time Series Data

Economics' time series data sets are a valuable source of information. To investigate the economic relationship between changes in agricultural production and government subsidies to the industry, I have performed a regression analysis in this section. The parameters value for estimating the economic relationship between agricultural production and government subsidies in the agricultural sector have been estimated in this section. The following is the regression equation:

$$\Delta Eco_t = \alpha_0 + \alpha_1 \Delta Sub_t + u_t$$

Where, Eco_t: indicates Economic impact in logarithmic at time t, Sub_t: indicates government subsidies in logarithmic at time t and Δ stands for the first difference. Here I regressed the first difference of Economic impact to the first difference of government subsidies because all the series are non-stationary, so if we regress economic conditions on other macroeconomic variables, the usual t and F tests are not valid, and the regression results are spurious. Diagnostic tests for normality, serial correlation, heteroscedasticity, and autoregressive conditional heteroscedasticity have been also conducted. All the results are given below

Table 2 shows that while government subsidies have a short-term favorable impact on people, they are not statistically significant. On the Table 4, the findings of the T-test and F-test indicate that there is little correlation

Table 3

Engle-Granger test		
Dependent variable (Economic impact), Independent variable (Government subsidies)		
Condition 1	Condition 2	Condition 3
-3.38312	-1.95547	2.29486
Dependent Variable (Government Subsidies), Independent Variable (Economic Impact)		
-0.24679	-3.66501*	-3.09091*

Table 4: Parameter estimates of the regression equation

Variables	Dependent variable$_t$)			
	Parameters value	S.E. of coefficients	Test value	P value
Constant	0.00580	0.0072226381	3.84149	2.00683359
ΔSub_t	0.00678	0.0190214442	1.09128	1.9447832
F-test			1.0002	1.4547323

between government subsidies and economic development. This demonstrates unequivocally that government subsidies have no appreciable impact on Bangladesh's economy. The results of the Jarque- Bera (JB) test show that the residuals have a normal distribution with a mean of zero. There are the result of T-test, F-test, and P value are not equivalent to zero so the variables of the series government subsidies and its economic impact on beneficiaries livelihood in Kushtia district is very low.

Conclusion

The long-term effects of the government subsidies on the economy as well as the effects of the government budget have been discussed in this study. It is evident from the graphical display that both series show an upward trend throughout the sample period. Therefore, an empirical examination has been conducted using modern economic methodologies to determine whether these trends stem from the positive drift term of a random walk. Initially, it was discovered that the stationary hypothesis had been uniformly rejected for both the series with and without breakpoints using the DF and ADF tests. We can therefore deduce that any invention of these series will be long-lasting and impactful. The test findings corroborate the assertion that there is no second-order unit root in these series. These series are integrated into order 1, thus. I have used a whether test to determine the co-integrated relationship between several pairs of variables. Government subsidies are found to be co-integrated with the level of economic impact based on the results of the Engle-Granger test; however, the results of the Phillips and Ouliaris test show that this relationship is maintained when a constant term is added to the model. Thus, it can be concluded that the stochastic

trend shared by these two series is the same. The findings of both studies show that there is no co-integration between the amount of government subsidies received by the different sector of people and its economic development. Consequently, it may be said that while each series has a unit root on its own, they do not all follow the same stochastic trend. Thus, it may be said that there isn't an equilibrium relationship between economic impact and government subsidies over the long term. Therefore, it can be concluded that there is no mutual correlation between the two variables and government subsidies and economic progress. The Granger F-test and the La-grange Multiplier test are used in this study to determine the causal relationship between government subsidies and health effects. My test results confirm that the influence of government subsidies on individuals does not lead to economic development. This suggests that, in Bangladesh, government subsidies do not significantly contribute to economic development; rather, it has been discovered that these subsidies are pushed by the people. To further explore the relationship between the change in impact and short-term government subsidies, I have also performed a regression analysis in this paper. According to the projected results, government subsidies for all sectors have no discernible effect on the economically viable to the people and are not adequately utilized, which suggests that corruption exists in the subsidies sector in the Kushtia district. After doing a diagnostic check, it was discovered that the residuals are normally distributed with a mean of zero, that they are not auto-correlated, and that the White test did not reveal any heteroscedasticity. There is also no autoregressive conditional heteroscedasticity in the short-run model.

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Role of social media on users' belief in health regarding prevention of COVID-19: A case of Rajshahi University students

Md. Uzzal Hossain[1*], Siddiqur Rahman[1], Bijoy Krishna Banik[1]

[1]Department of Sociology, University of Rajshahi, Rajshahi, Bangladesh

ARTICLE INFO	ABSTRACT
	Amid the context of the COVID-19 pandemic, social media has emerged as a critical tool for efficiently disseminating healthcare information and fostering communication between governments and citizens. This descriptive survey research focuses on the global progression of COVID-19, with a specific emphasis on Bangladesh. Despite existing research acknowledging the dual impact of social media on mental health, including issues such as social media fatigue due to information overload, there is a noticeable gap in comprehensively exploring its effects on health beliefs and subjective well-being (SWB) during the pandemic. To address this gap, the present study employed a descriptive survey research design and utilized a simple random sampling technique in selecting a sample of 200 participants. Five-point Likert scale was used to measure dependent variable and subsequent analysis involved descriptive statistics such as frequency counts and percent. The results gleaned from this study highlight a significant number of individuals deriving tangible benefits and knowledge from social media. They utilized it as a tool for self and societal protection against COVID-19, particularly in the context of lockdown situations. Furthermore, findings underscored a positive correlation between the intensity of social media use and health beliefs, as well as subjective well-being. In summary, the judicious use of social media emerges as a contributing factor in enhancing health beliefs and fostering subjective well-being. Consequently, it is advocated for the prudent use of social media for accessing accurate information and call for measures to combat the dissemination of fake news. This research underscores the importance of leveraging social media as a valuable resource for promoting public health and well-being, especially in the midst of global crises like the COVID-19 pandemic.

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Introduction

In late December 2019, the emergence of the highly contagious coronavirus disease 2019 (COVID-19), caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), set off a global crisis with profound

impacts on various facets of society. The World Health Organization (WHO) officially declared it a pandemic in March 2020, signaling its widespread and severe consequences. Within nearly a year, the virus infected approximately 660 million individuals and tragically claimed the lives of 6.7 million people (WHO, 2021). In response to the escalating crisis, nations worldwide implemented stringent measures to curb the virus's transmission, including economic shutdowns, the suspension of international flights, and the enforcement of strict movement restrictions. This collective global effort aimed to control the spread of the virus and safeguard public health.

Presently, vaccines stand as the primary tool for curtailing the virus's spread and preventing severe symptoms. However, the COVID-19 pandemic poses a serious threat to human mental health or subjective well-being. According to the WHO, maintaining positive mental health is crucial for individuals to transition from pandemic-induced fear to normal life patterns.

To address the fear induced by the COVID-19 pandemic, preventive measures based on proper health behaviors have been imperative. These behaviors include actions that support health and prevent vulnerability to viruses, such as using hand sanitizers, frequent hand-washing, maintaining personal hygiene, using protective measures like face masks, practicing social distancing, and staying at home. Notably, these behaviors have been widely promoted on various social media platforms, which have become the primary source of information related to COVID-19 (Laato et al., 2020).

Furthermore, social media's role in knowledge acquisition during the pandemic has been crucial. (Sheth, 2020; Dutta, 2020) posited that social media facilitates knowledge gain. Therefore, understanding knowledge acquisition patterns and social media intensity during the pandemic is of primary concern. Additionally, exploring the impact of knowledge gain on users' health beliefs, encompassing perceived threats and expectations, requires thorough examination. While existing studies have delved into the effects of social media on user fatigue and subjective well-being

(SWB), a holistic perspective can offer deeper insights into this multifaceted issue.

Adapting to a new situation is both difficult and time-consuming. When economic and cultural aspects of people are also added to this, the environment becomes more complex. The coronavirus has created such a situation. Although the proliferation of social media has reduced the time and money spent on obtaining information, the role or impact of social media on awareness of the coronavirus still warrants re-evaluation. Because most people around the world are users of Facebook or any other or multiple social media. Therefore, the present study was undertaken to: i) learn the patterns of knowledge gain and their impact on social media intensity; ii) investigate the effect of social media have on user's health belief regarding perceived threats and expectations; and iii) explore how to sustain the benefits of social media effectively.

Theoretical framework

Built upon the foundation of our study is the stimulus-organism-response (S-O-R) model, originating from environmental psychology. Within this model, the premise is that all elements of the environment act as external stimuli, influencing individuals' internal cognition and emotions, consequently leading to distinct behavioral responses (Laato et al., 2020).

Within the framework of this study, the stimulus will be designated as the acquisition of knowledge on social media, the organism will be recognized as the level of engagement with social media, and the responses will encompass health beliefs, social media fatigue, and subjective well-being.

Knowledge gain on social media

The acquisition of knowledge through social media stands out as a significant benefit. According to Chuang and Liao (2022), Barker et al. (2013) identified two categories of knowledge gain on social media. Firstly, there is focused knowledge gain, where users actively seek information or intentionally acquire specific knowledge. Secondly, incidental knowledge gain takes place when users search for information on
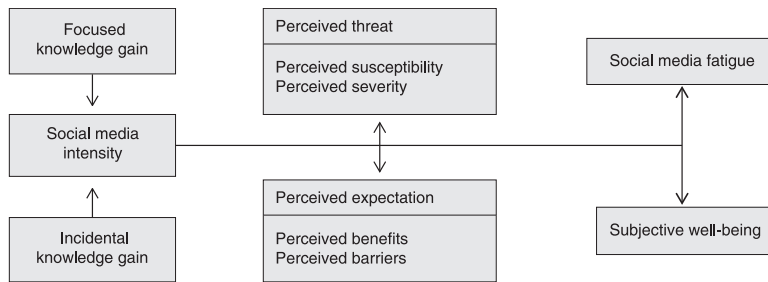
Figure 1: Theoretical framework

social media and inadvertently come across additional information or acquire new knowledge.

Social media intensity

Social media intensity, indicating a user's level of activity and engagement with social media platforms, is a crucial aspect (Chuang & Liao, 2022). This intensity plays a significant role in establishing and sustaining a user's social capital. Studies, such as Ellison et al. (2007), have highlighted a robust association between the use of platforms like Facebook and the maintenance of social capital, covering both bridging and bonding aspects. Additionally, social capital empowers individuals to leverage resources, encompassing the ability to organize groups, nurture personal relationships, and access valuable information from others.

The Health Belief Model

The Health Belief Model, designed to elucidate patient behavior concerning illness or the potential risk of falling ill (Grodner, 1991; Grosser, 1982), serves as a foundational framework. Originating in the 1950s, it posits that positive factors enhance pro-health behaviors, while negative factors diminish or inhibit them. Therefore, individuals must, for the adoption of healthcare behaviors or mitigation of disease risk, (1) perceive susceptibility to the disease; (2) believe that the disease would have a negative impact, at least to some extent, on their life; (3) acknowledge that adopting specific behaviors is beneficial in reducing susceptibility or, if already afflicted, mitigating its severity; and (4) overcome significant psychological barriers crucial for successful prevention or treatment (Maiman & Becker, 1974; Rosenstock, 1974).

In the context of the COVID-19 pandemic, the HBM has been employed to identify factors shaping people's attitudes towards public policies. It considers both demographic and psychological variables in understanding individual perceptions. Demographic factors such as age, gender, and educational background, along with psychological variables like personality traits and peer group pressure, are taken into account by the HBM (Wong et al., 2020).

Perceived susceptibility

Perceived susceptibility, defined by Champion (1984), refers to an individual's personal assessment of their likelihood of contracting a disease. It signifies their belief in their vulnerability to infection (Chuang & Liao, 2022). In practical terms, individuals tend to take measures to safeguard themselves against COVID-19 only when they perceive the potential for being infected with the virus.

Perceived severity

Perceived severity, as outlined by Champion (1984), is an individual's assessment of a disease's consequences, encompassing both medical aspects such as death, disability, or pain, and social aspects like effects on social relations, work, or family life. This perception indicates the extent to which individuals are concerned about the medical and social implications of a disease (Chuang & Liao, 2022). For instance, the well-known seriousness of COVID-19 is universally acknowledged. The infection risk exists for everyone, irrespective of race, gender, or age, given the confirmed cases worldwide. COVID-19 can lead to severe lung damage, known as pulmonary fibrosis, and may result

in death. Furthermore, even those who are not infected with COVID-19 have still been affected by the pandemic.

Perceived benefits

The successful completion of a task hinges on the evaluation of its benefits. In the aftermath of the emergence of the coronavirus, people have been introduced to numerous health rules and regulations, many of which prove challenging for individuals to adhere to correctly. Additionally, misinformation can lead to confusion rather than providing benefits. In this regard, individuals find it much easier to adopt specific behaviors in adverse situations if they can assess the advantages or benefits of those behaviors.

Perceived benefits, as emphasized by Champion (1984) and Chuang and Liao (2022), relate to an individual's perceptions regarding the effectiveness of various actions taken to counteract a disease threat. In the context of protecting themselves against COVID-19, individuals engage in pandemic prevention behaviors, such as acquiring relevant information about the pandemic and adhering to the instructions of relevant authorities.

Perceived barriers

Perceived barriers, as elucidated by Chuang and Liao (2022), involve an individual's perceptions regarding potential negative aspects of specific health-related actions. In the assessment of health actions, individuals typically conduct a cost-benefit analysis, taking into account both positive and negative aspects. Amidst the COVID-19 pandemic, routine preventive activities such as checking body temperature, hand washing, wearing masks, practicing social distancing, and monitoring case footprints are perceived as time-consuming and inconvenient. Additionally, individuals may experience discomfort and frustration when they are aware of pandemic-related information but observe others not adhering to appropriate disease prevention behaviors.

Furthermore, the repeated preaching of rules and regulations to prevent the coronavirus has led many people to view them as excessive and absurd. Consequently, one aspect of this research aims to determine whether individuals have encountered obstacles such as sarcasm, jokes, or mockery while adhering to these rules and regulations.

Social Media Fatigue and Subjective Well-being

Social media fatigue

The word 'boredom' is familiar to us, but it has taken on a new dimension thanks to social media. With the increasing use of social media, there is a corresponding rise in depression, anxiety, and mental turmoil among people, particularly noticeable among the youth of the present generation. Frustration arises from various factors, including misinformation, bullying, ID hacking, and harassment on social media. Additionally, people experience frustration by comparing themselves with others on these platforms. In summary, social media has given rise to a new type of depression that occurs specifically through its use.

Fatigue arises when individuals engage in activities requiring prolonged energy expenditure and motivation. Actions exceeding one's cognitive and physical capacities can lead to pressure, weakness, and eventual physical or psychological fatigue. There are two distinct types of fatigue: psychological and physical fatigue. Psychological fatigue involves adverse cognitive conditions resulting in pathological stress, boredom, or anxiety. Physical fatigue influences an individual's psychological state and induces conditions like physical imbalance, eye fatigue, or muscle fatigue (Eidelman, 1980).

In the realm of social media, user fatigue can be understood as a subjective and multidimensional experience involving adverse emotional reactions. Social media fatigue occurs when individuals become weary of social media content or have an excessive number of friends and contacts on these platforms. This fatigue is characterized by information overload and social overload, creating feelings of stress and tiredness (Chuang & Liao, 2022).

Subjective well-being (SWB)

Subjective Well-being (SWB) is characterized as an individual's affective and cognitive evaluation of their overall life. Typically, optimal SWB is associated with a high level of life satisfaction, positive emotions, and a low level of negative emotions (Chuang & Liao, 2022).

The coronavirus is a new experience for us. People around the world have likely never before collectively faced such a crisis of extreme uncertainty. Businesses have been significantly impacted, leading to the closure of many private institutions. Various factors such as layoffs, irregular salaries, restrictions on going out, excess information on social media, and the spread of misinformation about the coronavirus can disturb people's tranquility. In our study, we aimed to understand how much social media use has affected the mental peace and well-being of people during the coronavirus period.

Methodology

For data collection at the University of Rajshahi, the social survey method was employed, utilizing a self-administered questionnaire distributed to students who were active users of social media. The questionnaire consisted of two parts: the first part used for collection of basic information about the respondents, while the second part focused on the fundamental research objectives. A 5-point Likert scale was employed, ranging from 1, indicating "strongly disagree," to 5, representing "strongly agree." To ensure clarity and accuracy, the questionnaire was translated into Bengali.

The well-designed questionnaire was distributed to respondents residing in six residential halls of Rajshahi University, selected following simple random sampling technique. The collection aimed for a total of 200 valid questionnaires. After the collection of data, completion, IBM SPSS 22.0 was utilized for descriptive statistics to profile the sample.

Result and discussion

However, the HBM has faced criticism for neglecting external structural variables, such as governmental coercion, as factors influencing individual behavior. Given the scarcity of studies in the context of Bangladesh, this research aims to investigate the role of social media in shaping users' health beliefs to prevent the spread of COVID-19, utilizing the HBM framework. This approach seeks to provide a more comprehensive understanding of the factors influencing compliance with pandemic guidelines, particularly in the Bangladeshi context. The model recognizes various contextual factors, including internal elements related to individuals such as demographics and psychology.

This section, organized into two segments under the following subheadings, unveils the results and discussions derived from the study:

Section A. Presentation of demographic data

Table 1 highlights the significance of age as a crucial factor in comprehending individuals' perspectives on specific issues. Age is influential in shaping participants' views, considering its impact on social, economic, and mental aspects. Notably, the age group 21-23 exhibits the highest participation at 42.5 percent in this study, suggesting greater familiarity and usage of social media within this demographic.

Table 2 indicates that 52.6% of participants strongly agree with the role of social media in raising awareness about COVID-19, emphasizing trust, reachability, speed, and ease. Additionally, 37% agree that, social media sites provided adequate health related information and they trust upon them. The acquisition of knowledge through social media stands out as a significant benefit and we find the result here which is supported our statements. To raise awareness among the people, social media- off course- played very important role in corona period.

Social media intensity refers to one's own engagement and the level of activation for those engaged with social media. Here, the findings indicate that overall 56.67% of users are highly connected with social media usage, and they would not be happy in case of a decline in social media. Moreover, 26.33% of people also agree that social media has occupied a part of their life.

Table 1: Age of the respondents

Age	Frequency	Percent (%)
18-20 years	75	37.5
21-23 years	85	42.5
24 years and above	40	20
Total	**200**	**100**

The result exposes that social media have been becoming a part of everyday life to the maximum users' and they feel unrest sometimes when they have not logged into the social media sites.

In many respects health awareness depends on whether people could perceive susceptibility and severity in some specific health related cases. In this section, the data reveals that a substantial 60% of respondents strongly agree that they could perceive the susceptibility and severity of their health risk during the COVID-19 period. Additionally, 28% agree with this perception, that means social media help them to perceive susceptibility and severity in the case of Covid-19 pandemic.

Within the context of the Health Belief Model, perceived benefits emerge as a crucial component. Notably, a substantial 57.75% of respondents believe that they benefited significantly by acquiring diverse information from social media during the COVID-19 pandemic. Furthermore, 31.75% agree that they also derived benefits from social media. The information of social media paid very much attention to the users' in Covid-19 period. Here, the result shows that social media provided various information about corona virus and the maximum users benefited from those information.

The findings indicate that a combined 46.4% of respondents strongly agree, while 28% agree that they perceive barriers hindering them from taking preventive steps during the COVID-19 pandemic. Notably, barriers such as information overload, time consumption for obtaining information, and deriving enjoyment from others are identified as primary obstacles. A small percentage of respondents, 7.8% hold an opposing view, and 14.4% were unable to identify barriers at all. The identification of barriers is a crucial aspect of this study, representing a noteworthy finding.

The results reveal that a substantial 56.67% strongly disagree with the notion that they experienced fatigue from using social media during the pandemic, indicating that they did not feel any tiredness, boredom, or disinterest in new information. Additionally, 25.67% share a similar sentiment. A neutral stance is held by 9.33%, and some users assert that they did experience fatigue from social media during the pandemic situation. A pivotal aspect of this study sought to understand if individuals experienced any fatigue from using social media during the pandemic.

Table 8 illustrates that a significant 58.67% of participants strongly agree that their online social life conditions were very satisfactory, and they felt content. Additionally, 28% agree with this sentiment, while 6.33% remain neutral. The perception of subjective well-being is a crucial factor for users of social media, such as Facebook. We notice that based on responses of participants, social media had not affected negatively on users' mental peace and subjective

Table: 2 Knowledge gain on social media

Statements	SA	A	N	D	SD	Total
Social media are aware to people during COVID-19	60%	32%	0%	8%	0%	100%
Social media give an accurate information to the people during COVID-19	67%	25%	1%	3%	4%	100%
Social media create trust in society	15%	70%	2%	9%	4%	100%
Through the social media reachability is more easiest to provide information, when movement of people is not possible	55%	35%	0%	7%	3%	100%
Social media gives faster and easier communication to the society	66%	23%	0%	7%	4%	100%
Total Group Responses	**526**	**370**	**6**	**68**	**30**	**1000**
Total Percentage	**52.6%**	**37%**	**0.6%**	**6.80%**	**3%**	**100%**

Table 3: Social media intensity

Statements	SA	A	N	D	SD	Total
These sites are a part of my everyday activities.	56%	31%	4%	6%	3%	100%
I feel unrest when I have not logged into these sites for a while.	51%	22%	10%	7%	10%	100%
I would feel disappointed if these sites are no longer.	63%	26%	5%	2%	4%	100%
Total Groups Responses	**340**	**158**	**38**	**30**	**34**	**600**
Total Percentage	**56.67%**	**26.33%**	**6.33%**	**5%**	**5.67%**	**100%**

well-being and it is very important that the excess information or misinformation could not create mental pressure on users'.

B. Discussion of the findings

In the battle against COVID-19, efforts to curb the spread have emphasized key guidelines like social distancing, sanitization, and mask-wearing (Patma et al., 2020; Zeb et al., 2020). Despite the global acknowledgment of these measures, individuals often deviate from pandemic mandates for various reasons (Gaber & Elsamadicy, 2021). Notably, there's a substantial research gap focusing on why governments struggle to ensure compliance with lockdown policies (Abbas et al., 2021; Nguyen & Ha, 2021). Recognizing the pivotal role of understanding, predicting, and influencing population behaviors for healthcare providers (Pham et al., 2020), the Health Belief Model (HBM) emerges as a psychosocial framework to predict factors influencing individual practices (Nutbeam et al., 2010).

Initially, during the COVID-19 pandemic, social media emerged as a crucial means to remain connected with the world, bridging physical separations. Unlike the 1918 flu pandemic, there was no comparable source for communication and raising public awareness for self-protection and societal well-being. In the 21st century, social media's substantial role in disseminating news and combating misinformation during the pandemic is evident. In this critical situation, having a trustworthy information source on social media and governments making rapid, informed decisions are crucial for managing uncertainty at societal and mental levels.

This pandemic experience marks the first foray into such crises for many social media users, highlighting its significant role in the digital realm. It facilitates communication, news dissemination, and responses across sectors like education, training, and health treatment through new tools and techniques on social platforms.

The study confirms the influence of knowledge gain on social media intensity. In contrast

Table 4: Perceived susceptibility and severity

Statements	SA	A	N	D	SD	Total
I think there was a great chance for me to get infected with Covid-19 during the corona period	62%	28%	0%	8%	2%	100%
I regard that I had a big chance than others of holding COVID-19 infection.	55%	17%	3%	15%	10%	100%
I am greatly worried about infected COVID-19 during the pandemic.	60%	30%	0%	6%	4%	100%
I think if I infected COVID-19 during the pandemic would jeopardize my career.	65%	33%	0%	2%	0%	100%
If I infected COVID-19 in the pandemic would worsen my economic security.	58%	32%	4%	5%	1%	100%
Total Groups Responses	600	280	14	72	34	1000
Total Percentage	60%	28%	1.4%	7.2%	3.4%	100%

Table 5: Perceived benefits

Statements	SA	A	N	D	SD	Total
Gaining information about COVID-19 can prevent future problems during the pandemic.	54%	36%	1%	7%	2%	100%
I have acquired a lot of information about COVID-19 during the pandemic.	61%	35%	0%	3%	1%	100%
Those information about COVID-19 could help me elude COVID-19 transit during the pandemic.	53%	26%	15%	6%	0%	100%
I would not be so worried about COVID-19 because I got information about COVID-19 during the pandemic.	63%	30%	2%	4%	1%	100%
Total Groups Responses	**462**	**254**	**36**	**40**	**8**	**800**
Total Percentage	**57.75%**	**31.75%**	**4.5%**	**5%**	**1%**	**100%**

to Barker et al. (2013), who explored knowledge gain from social media in the context of social capital affinity, our research posits that health-related knowledge actively contributes to increased social media intensity during the pandemic. This study validates the reciprocal relationship between social media intensity and knowledge gain, emphasizing the potential for positive feedback loops.

The existing studies on the effects of social media have often focused solely on adverse outcomes, such as social media fatigue (Cao & Sun, 2018; Hwang et al., 2019; Liu et al., 2021; Pang, 2021; Tandon et al., 2021) or exclusively on positive outcomes, such as SWB (Huang et al., 2021; Keutler & McHugh, 2021; Wen et al., 2021; Zhao, 2021). In contrast, our study delves into both the positive and adverse influences of social media, providing a more comprehensive

understanding of its role during the pandemic. While prior research on social media has frequently associated various overloads with social media fatigue, this study reveals that social media fatigue is not a concern in the context of constructive applications, such as focused or incidental knowledge gain. This suggests that knowledge gain may not suffer from the problems of overload and fatigue during the pandemic. Additionally, given that social media intensity positively influences SWB, social media emerges as a potent tool for acquiring knowledge related to COVID-19 prevention. this study extends previous research associated with the Health Belief Model (HBM) (Ashoori et al., 2020; Moghadam et al., 2020) by highlighting the positive effects of social media use on individuals' health beliefs. The findings underscore the potential of social media to positively shape

Table 6: Perceived barriers

Statements	SA	A	N	D	SD	Total
Gaining information about COVID-19 had bothered me during the pandemic.	58%	42%	0%	0%	0%	100%
The information that I gained about COVID-19 is a time-consuming process.	40%	45%	10%	4%	1%	100%
My family and relatives would rebuke me when I searched knowledge about COVID-19 during the pandemic.	70%	20%	4%	0%	6%	100%
The information about COVID-19 would require starting a new habit, which is difficult for me during the pandemic.	64%	33%	3%	0%	0%	100%
I am frightened I would not achieve information about COVID-19 during the pandemic.	0%	0%	0%	35%	65%	100%
Total Groups Responses	**464**	**280**	**34**	**78**	**144**	**1000**
Total Percentage	**46.4%**	**28%**	**3.4%**	**7.8%**	**14.4%**	**100%**

Table 7: Social media fatigue

Statements	SA	A	N	D	SD	Total
Sometimes, I grasp sick when using social media.	5%	10%	15%	20%	50%	100%
Sometimes, feel depressed when using social media.	6%	4%	8%	25%	57%	100%
I realize detached in whether new things are occurring on social media.	0%	0%	5%	32%	63%	100%
Total Groups Responses	22	28	56	154	340	600
Total Percentage	3.67%	4.67%	9.33%	25.67%	56.67%	100%

people's perceptions and beliefs related to health during the pandemic.

Looking ahead, social media's quality is anticipated to improve, expanding its presence and significantly contributing to various social and economic sectors. This evolution is expected to reduce costs and enhance work efficiency, aligning with the world's increasing demands.

Conclusion

This research explored the impact of social media on individuals' perceptions during the COVID-19 pandemic. Using the social survey method, the study identified a key factor: the acquisition of health belief-related knowledge, influencing the intensity of social media engagement and subsequently shaping psychological states, including SWB and social media fatigue.

The study affirmed the crucial role of social media in acquiring knowledge to effectively combat the COVID-19 pandemic and contribute to sustained subjective well-being. Specifically, it revealed that both focused and incidental knowledge gain heightened social media engagement. Moreover, increased social media engagement played a role in strengthening users' health beliefs related to perceived susceptibility, severity, benefits, and barriers.

Importantly, the study found that higher social media intensity was associated with improved subjective well-being among users, without causing significant social media fatigue. Respondents highlighted the convenience of accessing timely information and news about COVID-19 at both national and international levels through social media platforms. This rapid access to relevant information played a crucial role in safeguarding both physical and mental well-being during the emergency situation.

This study emphasizes the crucial role of social media platforms in disseminating valuable information and raising awareness, particularly in the context of the COVID-19 pandemic. The effectiveness of these platforms in providing authenticated and trustworthy information during crises, such as the ongoing pandemic, establishes a precedent for their potential utility in various disaster scenarios. The insights gleaned from this study also provide valuable perspectives on individual and societal behaviors in emergency situations, particularly during a pandemic. The tools and mechanisms utilized to disseminate authentic and trustworthy information during the COVID-19 pandemic, especially amid lockdowns, have proven highly effective.

Table 8: Subjective well-being

Statements	SA	A	N	D	SD	Total
My online social life on social media is close to ideal in most respects.	55%	36%	4%	2%	3%	100%
The ambience of my online social life on social media is excellent.	61%	23%	5%	0%	11%	100%
I am pleased with my online social life on social media.	60%	25%	10%	4%	1%	100%
Total Groups Responses	**352**	**168**	**38**	**12**	**30**	**600**
Total Percentage	**58.67%**	**28%**	**6.33%**	**2%**	**5%**	**100%**

The emergence of new tools within social media platforms during this crisis holds promise for their continued usefulness in diverse sectors such as education, business, disaster management, and political communication. This indicates an opportunity for social media companies to direct their innovative capacities towards developing tools and techniques that can address social, economic, and environmental challenges. Furthermore, we advocate for the responsible and positive use of social media to enhance health beliefs among users. As a recommendation, we emphasize the importance of utilizing social media as a platform for disseminating accurate knowledge and preventing the spread of misinformation and fake news. This not only protects individuals from potential harm but also contributes to the overall well-being of society. Essentially, our recommendation underscores the need for leveraging social media as a force for genuine and reliable information dissemination, fostering a positive impact on various aspects of life.

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