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Editor: Oliver Tirtho Sarkar & Dr. Hamidul Huq

Preface

This proceeding is a combination of selected papers from the 5th International Conference on Sustainable Development, which was organized by the Institute of Development Studies and Sustainability (IDSS) on February 19-20, 2022 online. The aim of the conference was to identify the ways to achieve sustainability and share empirical knowledge based on research, practice, and education. This theme emphasizes the strong foundation that is provided by using research to inform everyday practices, policies, and research approaches. The conference provided opportunities to interact with prominent leaders in the field and greatly expand on your global network of scholars and professionals. We received 103 papers from this conference and published the best 19 papers as conference proceedings. We express our deep gratitude to all academics, scientists, economists, environmentalists, development practitioners, social activists, researchers, scholars, and policy analysts who contributed to the 5th International Conference on Sustainable Development of United International University (UIU). Our heartiest gratefulness to the Royal Netherland Embassy, Dhaka, for their kind sponsorship of this conference. And also, we are very thankful to other sponsors for various support to make this conference successful. We gratefully acknowledge the cooperation of the reviewers, composers, designers, and all others who sincerely extended help and cooperation in making it possible to publish the proceedings.

Hamidul Huq, PhD, WUR

Convener

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Urban green-space availability and recommended plantation area in Dhaka South City Corporation (DSCC) using RS-GIS

Syed Hafizur Rahman[1] and Mahfuzul Islam[2]

Abstract

Urban green-spaces (e.g., a park, surrounding a monument, public playground, riverside footpath, or lakeside) are well-managed regions of a city that acts as purifier against the polluted environment. From the environmental and health perspective, experts suggest having 15 to 20% green space area in a city. This study was aimed to evaluate the amount and distribution of urban green-space (both sparse and dense) in the Dhaka South City Corporation (DSCC) with a landmass of 99.2856 Km2 and recommend available places for the plantation and create new green-spaces on-demand. Administratively, DSCC has been divided into ten zones consisting of seventy-five wards. In this study, they were divided into four geographical sectors. Satellite imagery of Sentinel-2B was used with the "minimum-distance" algorithm in the QGIS 3_18_3 to classify the land use of DSCC where the accuracy was measured and tested by error matrix and kappa value as the method of the land-use classification map. After that, Google-Satellite-Images and Open-street-map were used in QGIS 3_18_3 to find out available areas to recommend the place for creating new green-spaces. The study demonstrated that about 39.19% of Dhaka south city corporation was covered with vegetation. Among them, 31.20% are sparse vegetation. Only 7.99% dense green-space area was available in the whole Dhaka South City Corporation. In the sectoral view, the sparse vegetation cover in the North-west, West-south, South-east, and East-north were 28.66%, 16%, 36.45%, 42.62% and dense vegetation were 5.05%, 0.74%, 6.59%, and 19.90%. In the zone scenario, the arrangement of zones according to the dense green-space area was 3<4<5<2<10<9<1<8<6<7. The study showed that West-south, North-west, and South-east sectors of DSCC had a very low amount of dense green area, more specifically all the zones of DSCC except zone 6 and 7 had a green area of less than 10% which is below standard. To overcome this situation places like water-bodies, roadsides, riverbanks, lake-sides, graveyards, local and public parks should need to put under the plan of creating new green-space. The sparse vegetation area should be turned into dense vegetation, and where the space was very tough to manage, roof-top gardening could be a nice way to approach focusing wards by wards of DSCC. Around 14.87 Km2 area had been pointed out in the recommendation all around the DSCC, where 2.55 Km2 in the West-south, 6.58 Km2 in the South-east, 4.14 Km2 in the North-west, and 1.59 Km2 in the East-north sectors that were available to make the dense green zone.

Keywords: Urban green space, sparse vegetation, dense vegetation, RS-GIS, Dhaka South City Corporation, Land use.

1. Introduction

Urban green spaces are well-managed regions of a city that acts as a purifier against the polluted environment. As there is no specific definition of green space, urban green spaces may include places that have formed naturally, but may also include specific types of urban greenery, such as parks, surrounding greenery of a monument, public playground, riverside footpath, or lakeside, street trees, and may also include ‘blue space’ which represents water elements like

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ponds, rivers, lakes, wetlands, etc. Ultimately, they can depend on particular environment-health pathways under consideration.

When the discussion is about the green space in the area like cities, the question about the size or area of the green space comes around by itself. As cities are the most compact area with lots of roads, buildings, traffics and people, it is very much necessary to determine a minimum standard for the green space in the city to keep it habitable. On this concern looking around some of the urban green area standard, it is found that these standards are divided into some categories. Like, a standard percentage for the green space in a city or minimum standard green area per capita, or standard walking distance from the presence of the green space in a city.

By searching for the total area standard for the green space in a city, it can be seen that under the SDG goal 11.7, Sustainable Development Solutions Network (SDSN) suggests to have a minimum of 45% of a city area as the public open space. Where street can occupy 30% of the area and green space will cover around 15% area (UN-Habitat, 2013). At some other sources, these minimum standard has been set around 20 % (Rahman and Zhang, 2018). Where these areas of green space should be well distributed as it would fulfill the demands like, every neighborhood would have the access to green zone in between five minutes walking distance. Within a 2 Km distance there should be at least one green space with a minimum area of 20 ha or 0.02 Sq. Km and 100 ha and 500 ha area of green space for each 5 and 10 Km. When it comes to the point of area per person, we can see different standards in different parts of the world. According to World Health Organization (WHO), 9 m2 area will be there in a city for each person which will be accessible to them (Thompson et al., 2016). In Europe, the city of London provides 40 m2 per person. In USA, cities like Washington provides 38 m2/person, and Los Angeles provides 48.5 m2/person. Among the South Asian countries, India has a standard of 8 m2 and Pakistan has the standard of 5.2 m2 (M. R. Maryanti et al., 2016). Unfortunately, there is no specific standard for our country and due to the shortage of land area and unplanned urbanization, most of the cities of our country cannot maintain the global standard which is 9m2 per capital. But there are estimated green spaces for individual cities. In Dhaka, according to Dhaka Metropolitan Development Plan, 1995 by RAJUK recommended only 0.16 acre for every 1,000 population (Dhaka, 1997), which means around 0.52m2 green space for each person.

Dhaka is the capital of Bangladesh that holds a remarkable history of more than 400 hundred years. The city was first pronounced as the capital of Bangla by the Mughal Empire in 1608, as it was the 12th most powerful city in that period. From then the city has passed through the colonial period, the Pakistan period, and now the independent Bangladesh period. The city bears the proof such buildings, monuments, roads, bridges here and there those carry the history themselves of this long journey. In 1977 Dhaka was redesigned as a metropolitan of Bangladesh with 50 different wards. Due to population growth and massive urbanization the city was divided into two different administrative regions which are Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC). Our study region is Dhaka South City Corporation, which has a land area of 109.251 Km2, which is into 10 different zones and those are consists of a total of 75 wards. The river Buriganga flows to the west-south boundary of the city and the Balu River lies at the eastern boundary. Narayanganj and Keraniganj are situated in the south and Dhaka North City Corporation is placed to North according to the position of Dhaka South City Corporation. The population of Dhaka South City Corporation was more than 120 million in 2020.(DSCC, 2021b, DSCC, 2021a)

The goal of this study is to calculate the total green space area and suggest available area and ways to create new green space on demand

2. Materials and Methods

2.1 Study area

Dhaka south city corporation (DSCC), one of the parts of two of the capital of Bangladesh, Dhaka, is situated between 90.3474E to 90.5137E and 23.661N to 23.7823N. The city acts as an individual city corporation from 2011 with 5 zones and 57 wards.(DSCC, 2021b) Till now, DSCC has 10 zones and 75 wards that cover a land area of 109.251 Km2 and carry around 120 million people.

2.2 Data Collection

The 10 m resolution Sentinal-2B high resolution imagery has been used in the study. The imagery was collected from the USGS earth explorer website (https://earthexplorer.usgs.gov/). The photo was taken on 7th November 2020, when the sky remains comparatively clear than other times of the year, and the time is in the dry season in Bangladesh as the temporal shift of the waterbodies is minimum at this time. The path and row were 134 and 44. The details about the satellite imagery are given in the Table 2. 1 (System, 2015).The shape file of Dhaka South City Corporation has been collected from the authority (Dhaka south city corporation). In the shape file, the region was divided into 10 zones and 75 wards.

Data Acquired	*Used Band name*	*Sensor*	*Band number*	*Sentinel-2B*		*Resolution (meters)*	*WRS Path and Row*	*Cloud Coverage*
				Central wavelength (nm) – 2	Bandwidth (nm) – 2			
7-11-2020	Blue	MSI	2	492.1	65	10	137/44	<10%
	Green	MSI	3	559	35	10	137/44	<10%
	Red	MSI	4	665	30	10	137/44	<10%
	Vegetation Red Edge	MSI	5	703.8	15	20	137/44	<10%
	Vegetation Red Edge	MSI	6	739.1	15	20	137/44	<10%
	Vegetation Red Edge	MSI	7	779.7	20	20	137/44	<10%
	NIR	MSI	8	833	115	10	137/44	<10%
	SWIR – Cirrus	MSI	11	1376.9	30	60	137/44	<10%
	SWIR	MSI	12	1610.4	90	20	137/44	<10%

Table 2. 1: Bandset data of sentinel 2B

2.3 Image classification

The Study was done by doing the supervised classification of Sentinel-2B imagery. QGIS 3.18.3 software was used to run the process. Semi-automatic classification plugin has been used with the "minimum distance" algorithm in the supervised classification. Minimum distance algorithm was a famous method and found suitable to conduct the land use classification(Ukrainski, 2017). Band set 2 to 12 were used except 9 & 10 in the process. Different virtual band sets were used to distinguish different features of the land, e.g. band set 8, 3 & 2 were used to identify the vegetation area as the vegetation reflects the near infrared light more than others. Then the region of interest (ROI) polygons for each categories were taken on the basis of NDVI values (System, 2019). The categories of the land use and their NDVI value ranges are given in **Table 2. 2**.

2.4 Accuracy assessment

Accuracy assessment of the classified image was arranged by the semi-automatic classification (SCP) plugin of QGIS 3.18.3. The google satellite image was used as the reference map for the

real-world comparison with the classified image which provides a high-resolution image of the real world. Simple random sampling method was used to randomly select region of interest

CATEGORIES	NDVI RANGE	DESCRIPTION
WATERBODIES	< .06	Physiographic units those hold water in them. Like; ponds, rivers, lakes, wetlands, etc.
BUILT-UP AREA	0.14-0.21	These are the areas which are occupied by human made structures, like, buildings, roads, monuments, bridges, etc.
SPARSE VEGETATION	0.22-0.46	Very low vegetation that covers only 10 to 50 % of their surface area, e.g. herbs, shrubs, scattered trees.
DENSE VEGETATION	0.47-0.99	Very high vegetation especially large amount of trees that cover more than 50% of their surface area, e.g. parks, forests.
BARE SOIL	0.061-0.14	The surface areas which is mainly naked soil without any kind of other physiographic units.

Table 2. 2 : Categories of land use classification, NDVI range and description

(ROIs) points from the classified map (Congalton, 2001). Total 476 points were collected in the QGIS software. Each point was compared with the Google satellite image, which represents the real world. For the calculation of accuracy, overall, user and producer accuracy were calculated, and the kappa coefficient was determined. Overall accuracy [%] = 84.7434 & Kappa hat classification = 0.7739

2.5 Shape file management

The shape-file of the Dhaka South City Corporation has been divided into four sectors. These are North-West (zone 1 and 2), North-East (zone 6 and 7), South-West (zone 3, 4, and 5), and South-East (zone 8, 9, and 10), these four sectors consisted of 10 zones. These zones have consisted of 75 wards, which are the smallest administrative boundary units (**Error! Reference s ource not found.**). All these shape-file regions were used to clip out the respective areas from the classified map to calculate the sparse and dense vegetation areas. The area was calculated using the classification report method under the semi-automatic classification plugin. To recommend the available area for creating green space, QGIS 3.18.3 software was used. The google satellite image and Open Street Map were used as references for the free space. To find out the free space for creating the new green area, polygons were drawn manually and calculated the accumulated area from them.

3. Finding

3.1 Green space status

RS-GIS exploration of the land use of Dhaka south city corporation has projected out the amount of sparse and green vegetation in the area. As a whole, the study area has an amount of 30.97 Km^2 covered with sparse vegetation which stands at 31.2%, and 7.93 Km^2 dense vegetation which stands at 7.99% of the total area. Figure 3. 1 illustrate the land use of Dhaka South City Corporation.

This result has been further evaluated according to the different sectors, zones, and wards. The results from the study are being discussed below;

3.1.1 Northwest Sector

The northwest sector consists of two zones that are zone 1 and 2. The average sparse and dense vegetation presence in this sector is 28.66% and 5.05% respectively (Table 3. 1). In Zone 1,

sparse vegetation is 33.22% with an area of 3.78 km^2 and dense vegetation is 7.11% and 0.81 Km^2. Zone 1 consists of 7 wards. The percentage of sparse and dense vegetation in these wards are given in Table 3. 1: Land use in the Northwest sector under five categories. In Zone 2, sparse vegetation is 24.31% with an area of 2.84 km^2 and dense vegetation is 3.08% and 0.37 Km^2. Zone 2 consists of 12 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 3**.

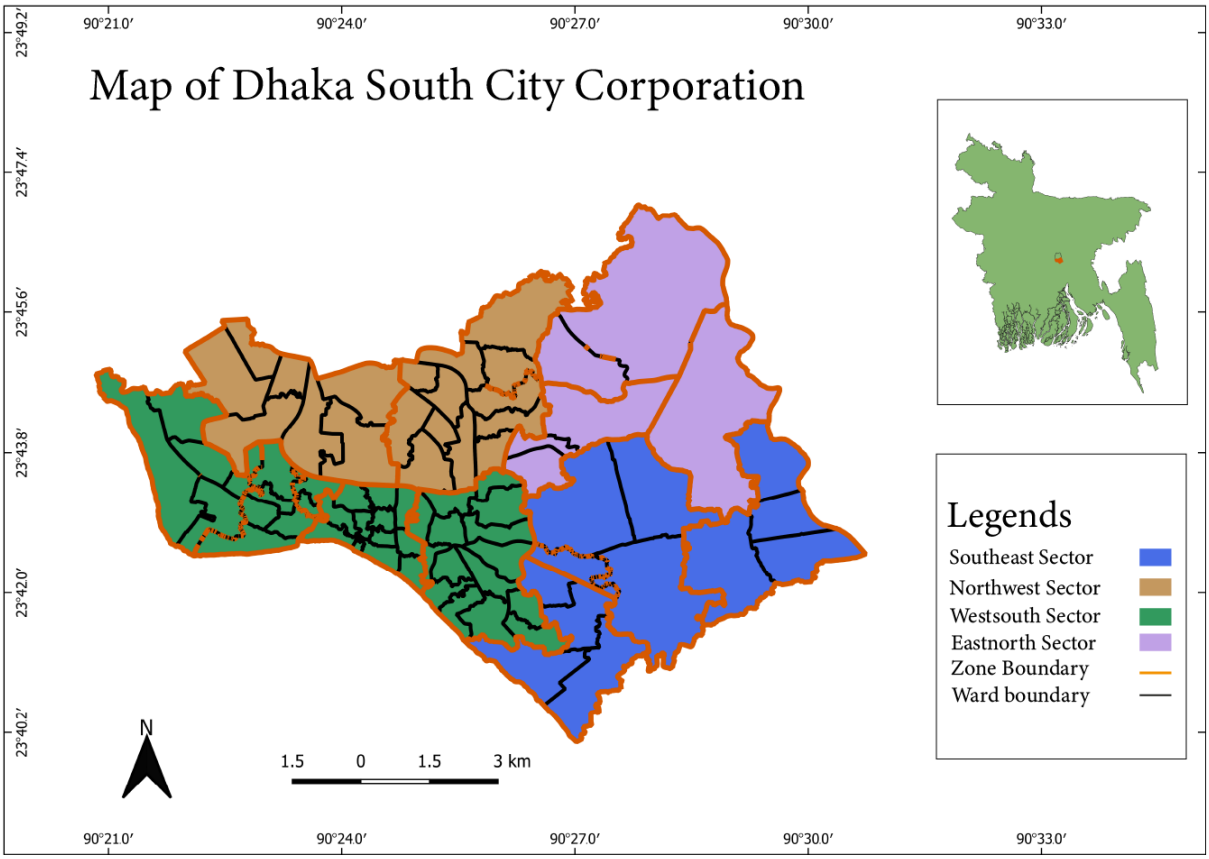


Figure 2. 1: Shapefile of the base map (DSCC) used for the study

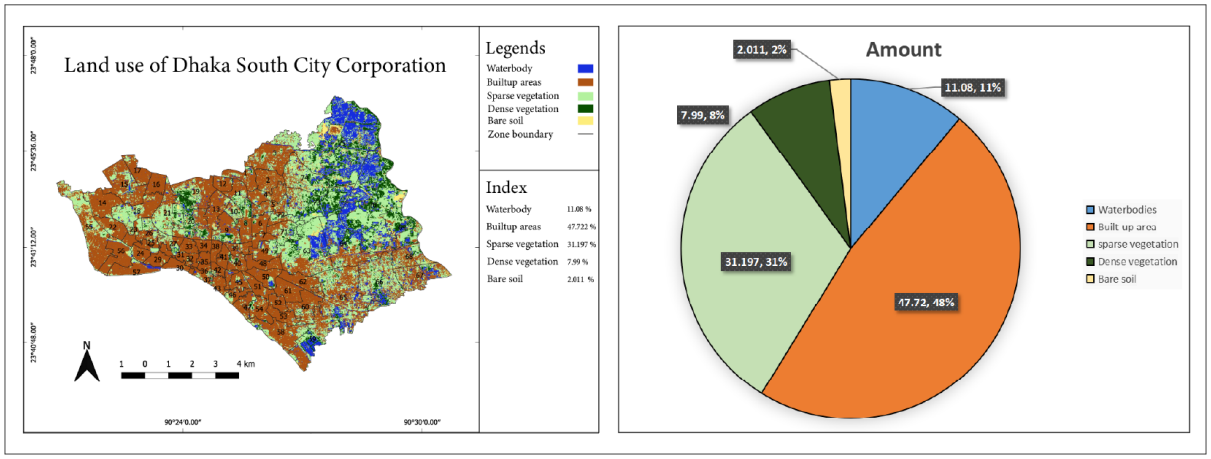


Figure 3. 1: Land use of Dhaka South City Corporation

Category	Percentage	Area m^2
Water bodies	4.502168219483921	1048600
Sparse vegetation	28.658709372719077	6674900
Dense vegetation	5.050019320767678	1176200
Built-up area	60.53024773517668	14098100
Bare soil	1.2588553518526469	293200

Table 3. 1: Land use in the Northwest sector under five categories

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
15	Dhanmondi	20.49917986	0.815711309
16	Kathal Bagan	0.865542456	0
17	Sobhanbag, Shukrabad, Kolabagan, PanthoPath	11.23406303	0.036083714
18	Dhaka college & new market area	48.27715557	1.966668453
19	Mouchak, Baily road	28.05609018	10.12372835
20	Ramna Park, Shegun Bagicha, High Court area	37.19889727	22.17652642
21	Dhaka University Area	57.2647076	4.568557574

Table 3. 2: Sparse and dense vegetation percentage in different wards of zone 1

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
1	Khilgaon	18.2732803	1.848385587
2	Goran	10.73428749	0.041485169
3	Ansarbag, Aftabnagar	33.19802731	1.251896813
4	Bashabo, Wahab Colony, Mother Tek	18.74278518	0.283345577
5	AhmedBag, RazarBag	29.82223694	1.15932428
6	Mugdapara	13.8577379	2.322973406
8	Komlapur	23.86804657	12.17119448
9	Motijheel	22.61310782	8.980972516
10	Motijheel	59.54779494	4.678755317
11	Shahidbag	36.7554662	5.667253079
12	Malibag bazar road, Matijhil, Malibag, Bakshi Bag, GulBag, Shanti Bag, Indrapuri	7.220789526	0.35707201
13	Chameli Bag, Aminbag, Rajarbag Police line, Old Paltan GPO, Baitul Mukarram Stadium (Swimming pool, Sport Council), Outer Stadium, Bijay Nagar, New Paltan, Old Paltan Line, Traffic Police Barack, Police Hospital & C and B Field, Shantinagar and Shantinagar Bazar Area.	12.80107047	0.303300624

Table 3. 3: Sparse and dense vegetation percentage in different wards of zone 2

3.1.2 West-south sector

The west-south sector consists of zone 3, 4 & 5. The average sparse and dense vegetation presence in this sector is 15.999% and 0.74%, respectively (**Table 3. 4**). In Zone 3, sparse vegetation is 21.88% with an area of 2.39 $km^{2,}$ and dense vegetation is 0.28% and 0.03 Km^2. Zone 3 consists of 12 wards. The percentage of sparse and dense vegetation in these wards is given in **Table 3. 5**. In Zone 4, sparse vegetation is 7.94% with an area of 0.3 $km^{2,}$ and dense

vegetation is 1.10% and 0.043 Km^2. Zone 4 consists of 11 wards. The percentage of sparse and dense vegetation in these wards is given in **Table 3. 6**. In Zone 5, sparse vegetation is 12.296% with an area of 1.10 km^2 and dense vegetation is 1.15% and 0.103 Km^2. Zone 5 consists of 15 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 7**.

Category	Percentage	Area m^2
Water bodies	2.7089861518245226	643200
Sparse vegetation	15.99868593955322	3798600
Dense vegetation	0.7400013477543044	175700
Built-up area	79.2037299100374	18805500
Bare soil	1.3485966508305536	320200

Table 3. 4: Land use in west-south sector under five categories

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
14	Neemtola, Jigatola, Hajaribag Tenary area, Shikary tola Slum,Shonatongor	12.47234105	0
22	Hajaribag, Kalunagar, Bot tola	15.12417994	0
23	Azimpur, Nababgonj	27.69776665	0.292214569
24	Lal Bag, Amligola	10.97055616	0
25	Lalbag	25.08007687	0
26	Eden College area	39.95187901	2.45187901
27	Dhakesshori Mondir, Hosseni Dalal	36.58947368	0.021052632
28	Churi Hatta	2.078298695	0
29	Islam Bag	4.50090018	0
55	Hasan Nagar, Gudara Ghat	32.95867983	0.233887734
56	Rasulpur, Islamnagar, Kamrangi Char,Rupnagar	12.25796615	0.007623113
57	Momin Bag, Ashrafabad, Nurbag, Muslimbag, Rahamatbag	9.939788767	0

Table 3. 5: Sparse and dense vegetation percentage in different wards of zone 3

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
30	Chakbajar, Babubazar, Badamtoli.	1.15792067	0
31	Jail Road, Tara Mosjid	26.82156553	6.316264381
32	Jindabajar, Koshaituli	3.06923626	0
33	Neemtoli, Bongshal	2.459770115	0.022988506
34	Siddik Bazar, Alu Bazar, Nazira Bazar	1.222222222	0
35	Nayabazar, Malitola, Nababpur	0.23400936	0
36	Ray Shaheb Bazar, Shakhari Bazar, Tati Bazar	4.082636498	0
37	Bangla Bazar, Patuatuli	21.21212121	2.59373395
38	Kaptan Bazar, Thatari Bazar	1.38213463	0

42	Dholai khal, KoltaBazar, lakhsmi Bazar	10.19367992	1.087325858
43	Shyam Bazar, kagojitola, Forashganj,Dalpotti	8.168507578	0.282558438

Table 3. 6: Sparse and dense vegetation percentage in different wards of zone 4

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
7	Manik Nagar	7.845060064	0.073547438
39	Hat Khola, Tika Tuli	13.05816135	0.318949343
40	Dayaganj	15.27372263	4.835766423
41	wari	3.864623828	1.211982621
44	Kolutola, Shutrapur	6.044624746	0.851926978
45	Dhupkhola	15.48846803	0.09375586
46	Mil Barack, Gendaria	21.87852788	0.293519982
47	FaridaBad	12.74682652	0.070521862
48	Sayedabad, North Jatrabari	2.59667737	0
49	Golapbag	30.44276458	2.181425486
50	Jatrabari	10.02967359	1.721068249
51	Mir Hajirbag, Dolairpar	6.280487805	0.015243902
52	Janata market	3.696343402	0
53	Shyampur	7.492148946	0.314042171
54	Jurain	14.85020938	2.995812305

Table 3. 7: Sparse and dense vegetation percentage in different wards of zone 5

3.1.3 South-east sector

The south-east sector consists of zone 8, 9 & 10. The average sparse and dense vegetation presence in this sector is 36.45% and 6.59% respectively (**Table 3. 8**). In Zone 8, sparse vegetation is 42.58% with an area of 3.67 km^2 and dense vegetation is 9.83% and 0.85 Km^2. Zone 8 consists of 4 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 9**. In Zone 9, sparse vegetation is 39.40% with an area of 5.23 km^2 and dense vegetation is 5.91% and 0.785 Km^2. Zone 9 consists of 4 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 10**. In Zone 10, sparse vegetation is 22.86% with an area of 1.55 km^2 and dense vegetation is 3.79% and 0.256 Km^2. Zone 10 consists of 4 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 11**.

Category	Percentage	Area m^2
Water bodies	12.763745101938987	3658000
Sparse vegetation	36.45413530686374	10447500
Dense vegetation	6.585645846200013	1887400
Built-up area	41.555097298259206	11909400
Bare soil	2.641376446738057	757000

Table 3. 8: Land use in south-east sector under five categories

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
66	Dogair	48.0489311	7.113241391
67	Tengra, Golakata bridge	32.36529586	2.805580045
68	Hazi Nagar, Balur Ghat	35.86874338	4.483592923
69	Demra Police Station, Mirpara Mosque	47.71775758	25.06892678

Table 3. 9: Sparse and dense vegetation percentage in different wards of zone 8

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
62	Shanir Akhra	8.629130967	0.132598939
63	Matuail waste treatment plant, Mridhapara	51.01288697	8.105473394
64	Konapara, Dharmikpara	37.3152479	8.843155597
65	Matuail, Tushardhara	36.93282895	3.245066967

Table 3. 10: Sparse and dense vegetation percentage in different wards of zone 9

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
58	Shyampur	23.36570593	1.822263993
59	Mohammadbag, Pagla	31.82936172	8.503689367
60	Rayerbag	19.65669989	0.726744186
61	Dania	2.622986504	0

Table 3. 11: Sparse and dense vegetation percentage in different wards of zone 10

3.1.4 East-north sector

The east-north sector consists of zone 6 & 7. The average sparse and dense vegetation presence in this sector is 42.62% and 19.89% respectively (**Table 3. 12**). In Zone 6, sparse vegetation is 41.09% with an area of 7.73 km^2 and dense vegetation is 19.36% and 3.64 Km^2. Zone 6 consists of 3 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 13**. In Zone 7, sparse vegetation is 48.61% with an area of 2.32 km^2 and dense vegetation is 22.02% and 1.02 Km^2. Zone 7 consists of 3 wards. The percentage of sparse and dense vegetation in these wards are given in **Table 3. 14**.

Category	Percentage	Area m^2
Water bodies	23.956690576724153	5651000
Sparse vegetation	42.61586203388106	10052400
Dense vegetation	19.894948364450325	4692900
Built-up area	10.877380407318851	2565800
Bare soil	2.6551186176256127	626300

Table 3. 12: Land use of east-north sector

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
70	Demra, Nalshata	42.8781822	22.47396381
74	Nandipara	54.9796748	12.24593496
75	Trimohini area	36.2736423	18.4326955

Table 3. 13: Sparse and dense vegetation percentage in different wards of zone 6

WARD NO.	NAME OF AREA	SPARSE VEGETATION (%)	DENSE VEGETATION (%)
71	Manda	48.5875176	11.14969498
72	Manda	55.88458618	6.511009871
73	Begun Bari, Dokhingaon	47.42647059	28.23026647

Table 3. 14: Sparse and dense vegetation percentage in different wards of zone 7

From the data of sparse and dense vegetation in Dhaka south city corporation, it is clear that the distribution of green space in the city is neither equal nor in a balance. In the sectoral view, only the east-north sector has a sufficient amount of dense vegetation (19.89) which can represent green space. But in the other three sectors which are northwest (5.05%), west-south (0.74%), and south-east (6.59%) way below the minimum standard that is 15 to 20% of the total area. The picture becomes clearer at the ward level. 17 wards in the city that contain no dense vegetation at all. 22 wards contain less than 1% and the other 27 wards contain less than 10% dense vegetation of their total area.

3.2 Recommendation

It was an approach to find some available space to create a green zone or dense vegetation in the city to enhance the amount of green space in the city. The area which was low in dense vegetation was prioritized in the process. The availability of space in each sector is given in **Table 3. 15**. Besides, a huge amount of land area is covered by the building in the Dhaka south city corporation (47.7%), where rooftop gardening could be a good solution for green space enrichment. Especially in these areas where both shortages of available space for green space and scarcity of dense vegetation are present. Roadside planting and plantation around the water bodies, especially the rivers and lakes, could be a nice way to improve the city's green space. Another excellent approach would be turning the sparse vegetation area into dense vegetation, if that is possible then the scarcity of green space could be extricate in many wards.

SECTOR	AREA (KM^2)
EAST-NORTH	1.59
NORTH-WEST	4.143
SOUTH-EAST	6.58
WEST-SOUTH	2.55

Table 3. 15: Land area of recommendation for new green space

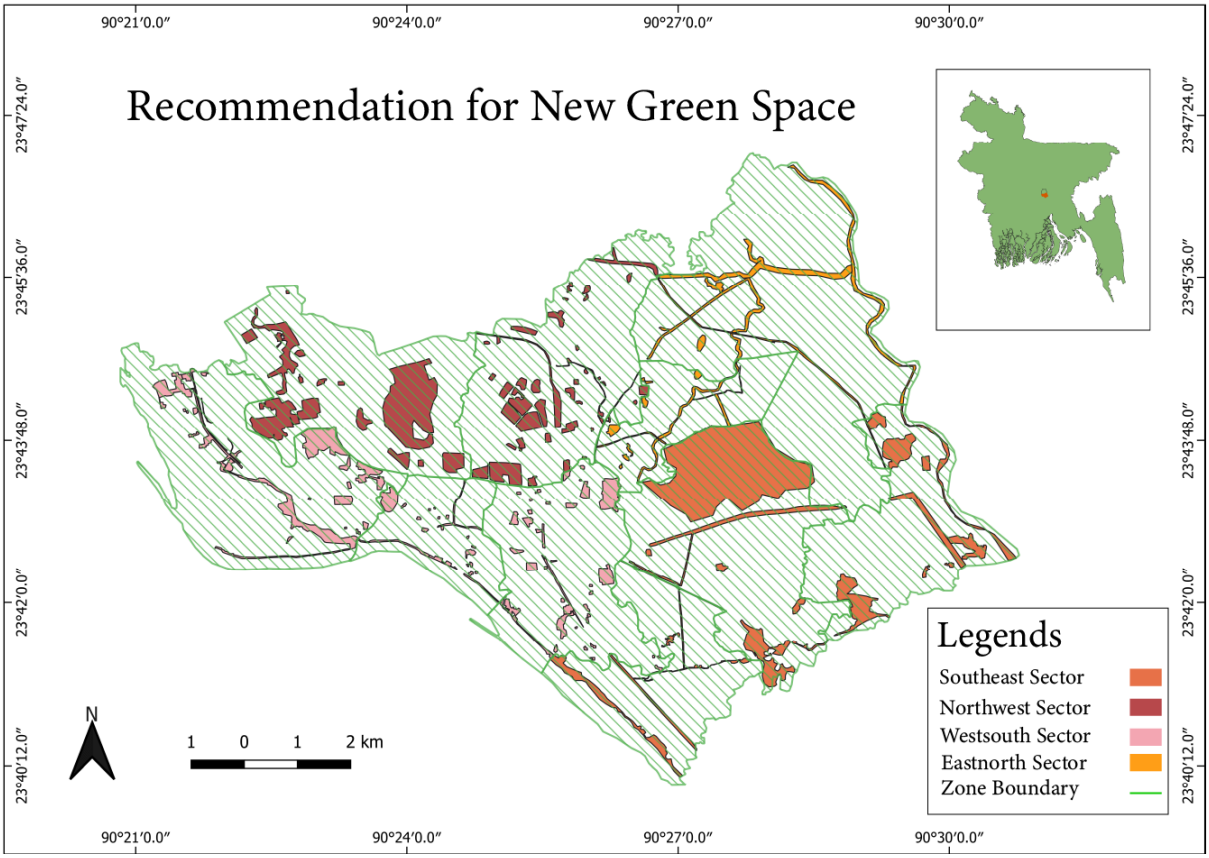


Figure 3. 2: Map of Recommended area for new green space in different sectors

4. Conclusion

From the findings of this study, the amount of total green space in Dhaka south city corporation is way below the standard, which is 7.99%. Besides, another big concern is that the green space all over the city is not properly distributed. 65% of green space is situated in the east-north sector which is more than two-thirds of the total.

To make the environment of the city suitable to lead a healthy life and control the pollution that is created by daily activities, the amount of green space in Dhaka south city corporation must need to improve. And to improve this situation, necessary steps should be taken as soon as possible. In this process, an urban development plan at the wards level could bring better results than considering the whole city as one.

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%E0%A6%A2%E0%A6%BE%E0%A6%95%E0%A6%BE-%E0%A6%A6%E0%A6%95%E0%A7%8D%E0%A6%B7%E0%A6%BF%E0%A6%A3 [Accessed 24th February 2022].

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Feasibility And Sustainability Analysis Of Vertical Farming In Dhaka City

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Abstract

Rapid urbanization, unreliable road networks, and loss of arable land are only a few reasons why vertical farming (VF) should be considered in a city like Dhaka. However, with VF, there are concerns regarding resource use and energy requirements. When considering Dhaka in this multivariable equation, it can raise questions about the feasibility of a vertical farm in a stressed Metropolitan. The objective of this study was to use Life Cycle Assessment (LCA) to see if a vertical farm in Dhaka would yield feasible results. Three leafy vegetables- mainly Basil, Lettuce, and Bok Choy- have been considered for the study. The sample farm itself has been considered as the system boundary to conduct LCA. The only concern is the significant energy footprint. While still in the research and development stage, this farm shows great potential for improving the nutritional value of food in the city. With investments in green technology and energy, vertical farms show great potential to further explore the untapped potential of closing the gap in the existing supply chain.

1. Introduction

It is no surprise that our existing agricultural systems are busy battling a plethora of challenges. These range from volatile production, pricing, and the environmental burden from crop intensification, to name a few (World Economic Forum, 2015). With the existing business-as-usual practices of agriculture- biodiversity losses and eutrophication is set to exceed what was proposed by the planetary boundaries (Pimbert and Anderson, 2018). This is where vertical farming is expected to ease off some of the environmental pressures. With precise systems to control the growth of crops, vertical farms reduce the pressure on land, water for irrigation, and the need for intensive fertilizer, herbicides, and pesticides (Molden, 2007). More importantly, vertical farming also provides a practical solution to the loss of arable land due to climate change, which is estimated at a 10% loss for every 1°C increase in atmospheric temperature (Despommier, 2010).

The growing number of vertical farms across the world is indicative of a growing audience of farmers and consumers who are more environmentally conscious. Noticeable numbers of farms have been seen in the USA, Japan, Germany, the UK, Taiwan, Singapore, and more (Piechowiak, 2022). A striking similarity across these farms is that they mainly produce vegetables. An advantage of growing vegetables this way in cities is that the supply chain is shorter, meaning city dwellers get produce that has high nutritional value (Despommier, 2013). However, these farms are based mainly in developed nations, with sufficient money and technology to carry out large-scale projects. The traction for vertical farming needs to pick up speed in developing countries, where multiple challenges hinder the growth of such ventures.

For countries like Bangladesh, agriculture brings forth a lot of competition with the land. Industrialization and urbanization are key factors for the loss of agricultural land, and it has been reported that agricultural land has declined from 87.69% in 2000 to 83.53% in 2010 (Rahman, 2017). One can assume that this decrease in land will only increase as time goes by, leaving vertical farming as the only route left for farming. Locally appropriate technology for vertical farming can address this issue of land loss and the losses of crops that occur due to

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natural disasters and the effects of unpredictable weather changes like high temperatures, erratic rainfall, and droughts (Haroon, 2021).

While the scale is smaller than expected, there is a vertical farm present in the capital city of Bangladesh. Dhaka, with its bustling metropolitan and ever-increasing urban population, is home to a small pilot vertical farming project. This paper looks into the feasibility of the vertical farm and aims to look at its footprint on Dhaka's environment. The robust tool of Life Cycle Assessment (LCA) has been utilized to unravel the picture of this vertical farm for Dhaka city. Such a study will also shed light on the future of what farming may look like in megacities in developing countries.

2. Methodology

Life cycle assessment (LCA) is a widely used tool that helps evaluate a product's or service's environmental performances throughout its entire life cycle determining environmental hotspots (Hauschild, 2018). The methodology of LCA is highly recognized in the agriculture and food sector to determine the sustainability of the food production and processing system (Djikman, 2018). The assessment of this study is based on one production cycle (4 months) from a pilot vertical hydroponic farming system in Dhaka, producing 8000 plants in one cycle. The system produces three types of leafy vegetables, including lettuce, bok choy, and basil, sold to local supermarkets and retailers.

2.1 Goal and scope definition

The goal of this study is to evaluate the sustainable practices of a vertical farm and assess its feasibility for the city of Dhaka. The analysis shows to what extent this type of vertical hydroponic farming system can produce nutritious high-yield vegetables with lower environmental impacts, thereby contributing to a more sustainable food system.

2.1.1 Functional unit and system boundary

The functional unit considered for this study is 8000 leafy vegetables delivered to retailers. This is the same assumption as mentioned in the methods of Romeo et al., (2018) and Martin et. al, (2019) where the lettuce was considered a substitute for leafy vegetables due to their nearly identical functionalities. Figure 1 depicts the system boundary of this study, where the blue dotted line represents the vertical farm.

A cradle-to-gate analysis was performed considering the product cultivation and transportation to the retailers. The analysis also includes capital goods such as steel, PVC, and other parts but only till the stage of making the inventory. Since the system architecture for growing the crops remains the same, their footprint was not considered as the same structure would be used to produce many lots of produce. In this study, the pesticide emission has been omitted since the entire cultivation process is conducted in a pest-free and controlled environment. The fertilizer emission is considered zero since the nutrients are recirculated in the water bath throughout the production cycle, with no fertilizers being used in an aerosol form.

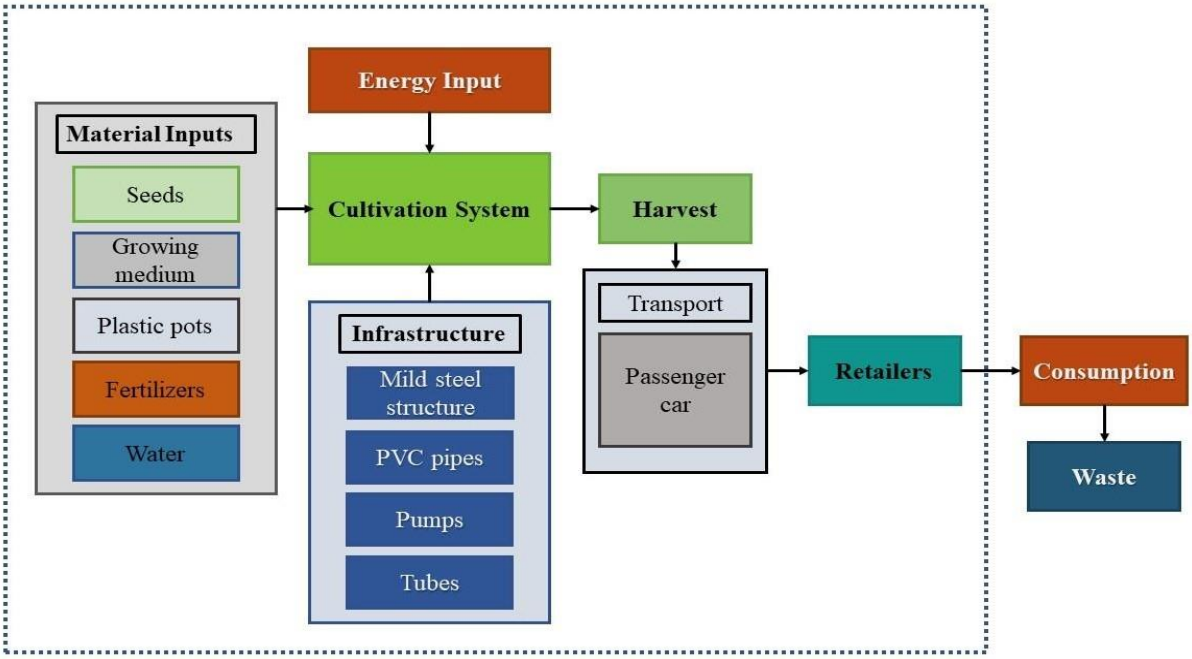


Figure 1: System boundary for the study

2.1.2 Impact Categories The life cycle impact assessment was performed using Simapro 8 software and ReCiPe 2016 methodology for the Midpoint level. The water stress index or WSI was calculated using the Hoekstra et al 2012 (Water Scarcity) V1.03 method to get an idea about the water footprint of the vertical farm. Given the very small scale of the vertical farm, this study looked at 7 indicators- global warming, freshwater eutrophication, terrestrial acidification, terrestrial ecotoxicity,

freshwater ecotoxicity, mineral resource scarcity and fossil resource scarcity. The small scale, as well as pilot project-based farm, was justified sufficiently to overlook sensitivity analysis for the time being.

3. Results and Discussion

3.1 Life cycle inventory

The Life Cycle Inventory was developed following one production cycle of the vertical farm, which lasts for 4 months. The farm is located in an abandoned building that was later refurbished to convert it to a vertical farm. The area covered by the farming system stands at 185 m2 . the seeds for the leafy vegetables are sourced from the local market, which is then transported to the vertical farm where they are germinated.

The inventory was developed after a field visit to the farm and observing their working conditions. The 185 m2 is divided into three rooms where the developers have created a very controlled environment using air conditioners, CO2 cylinders, water tanks as well as 400 LED lights for lighting. The leafy vegetables are grown in PVC pipes which stand on a structure made from mild steel (MS) angles. During one production cycle, the farming system remains operational for 24 hours in a day, but the LED lights operate for 12 to 14 hours per day to stimulate real daylight hours plants use for photosynthesis. The vertical farm runs throughout the year, allowing for 3 production cycles per annum.

While the vertical farm supplies their leafy vegetables to multiple clients, the distance from the farm to the client clusters do not exceed more than 15km. As a result, the transportation footprint was not calculated due to its really small footprint.

3.2 Life cycle impact assessment

The findings from the life cycle impact assessment are summarized according to their impact categories in Table 1.

Impact category	Unit	Value
Global warming (GWP)	kg CO2 eq	4798.761
Freshwater eutrophication (FE)	kg P eq	0.060213
Terrestrial acidification (TA)	kg SO2 eq	12.75595
Terrestrial ecotoxicity (TT)	kg 1,4-DCB	9281.281
Freshwater ecotoxicity (FT)	kg 1,4-DCB	3.206202
Mineral resource scarcity (MRS)	kg Cu eq	9.281755
Fossil resource scarcity (FRS)	kg oil eq	1946.171
Water stress indicator (WSI)	m^3	27832.39

Table 1: Results of Life Cycle Impact Assessment of the vertical farm

From the values, we can clearly see that the most concerning impacts are those of global warming, terrestrial ecotoxicity and fossil resource scarcity. Upon closer inspection of global warming and fossil resource scarcity, categories that have the highest value, we can see that the biggest contributors for these impact categories are due to the PET cups the farm uses to sow the seeds and the source of electricity which happens to be the national grid, where fossil fuels reign supreme. An elaborate breakdown is shown below in Figure 2.

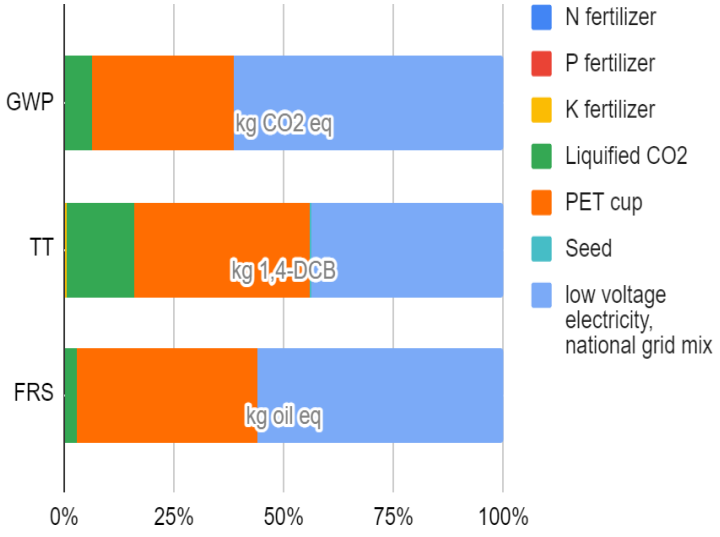


Figure 2: Impact contributors for GWP, TT, and FRS

All agricultural systems emphasize the amount of water they use and what stress it leaves on the environment. In the case of this farm, the water stress index stands at 27832.39 m3. However, this water can easily be regenerated in a short period of time which is why the stress is lower than what the value might suggest.

When compared to traditionally growing leafy vegetables data sourced from Romeo et. al., 2018 our study shows that vertical farming in an urban setting reduces environmental burden significantly. This can be compared simply looking at the water consumption, global warming, and the risk of eutrophication (Romeo et al., 2018).

3.3 Limitations of the study

The most predominant limitation of this study lay in the small scale of the vertical farm. The values for fertilizers and electricity allocation were extracted from Martin et al., (2019) and calculated for the 8000 plants for this study due to the lack of sufficient data from the vertical farm. Additionally, the PET cups used for sowing the seeds and growing the leafy vegetables are beyond the scope of this study as they are left at the hands of consumers for its management.

4. Recommendations

While the farm in our study is a pilot project and has successfully attracted buyers, we have noticed certain areas where principles of circularity can be implemented. First and foremost, many of the buyers from the vertical farm are involved with the food and restaurant industry. This industry is known to have a significant portion of their resources end up as food waste. By looking into the organic matter of this food waste, this can be utilized to make compost which can help the farm increase their yield (Martin et al., 2019).

The use of fossil fuels is the biggest reason why the footprints for global warming and fossil resource scarcity are high. This can easily be resolved by looking into renewable energy, e.g., solar energy. From the results, we have noticed that a significant percentage of waste and toxicity concerns arise from the use fo PET cups to grow vegetables. So, once the vegetables leave the farm, these cups get mismanaged. Thus, by connecting consumers with adept collection and recycling facilities, these PET cups can be managed better, and scope of circularity also get enhanced. With all of these in mind, for urban environments, vertical farms are a great initiative to better ensure food security and better nutrition. The way this farm has been designed, old buildings and unused spaces can be easily converted to small-scale vertical farms with high outputs. As a result, the supply chain will be shortened, ensuring food security remains high in the metropolitan.

5. Conclusion

This study looked at a pilot vertical farming project in Dhaka and carried out a Life Cycle Assessment to better understand the footprint such farming activities have on a bustling metropolitan. The study found that the most concerning impacts left in the environment are those of global warming, terrestrial ecotoxicity, and fossil resource scarcity. The biggest contributors are PET materials and the use of fossil fuel derived electricity. Better recycling and use of renewable energy will reduce these impacts and bring forth opportunities of circularity.

Acknowledgements

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3:3:2 - A Sustainable Urban Development Model: Transforming Dhaka into a Sustainable Mega-City

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Abstract

The ever-bustling Dhaka city, that stands as one of the most densely populated mega-cities reveals itself as the capital city of Bangladesh to the world. Dhaka is an extremely polluted city that struggles to grasp sustainability as a working concept in the grand scheme of moving forward. However, if sustainability is kept outside the equation, this city will fall flat on its growth due to socio-economic instability, health hazards, impending natural disasters, and climate change. Hence, even though it is challenging to implement sustainability, it should be promoted in the framework of the administration. However, there is an acute shortage of sustainable urban development models for Dhaka city, which concurrently explores the social, environmental, and economic aspects, the three core components of sustainability. This paper proposes a novel sustainable urban development model for Dhaka city named "3:3:2". In this model, we have identified three core pillars along with three sub pillars under each core pillar. Moreover, those three sub-pillars are further classified into two categories which, in entirety, correspond to the 3:3:2 model. The core pillars here are redefined as "Social Egalitarianism," "Environmental Stability," and "Economic Well-Being." This paper has further scrutinized and integrated sustainability implementations of proper infrastructure, modern waste management, cleaning of rivers, and a gradual shifting to cleaner fuels, greener alternatives, and affordable and sustainable housing. Moreover, quality education, improving human rights, planned expansion, and incentives for green development are the topics that have further been integrated into the model. In essence, the model is formulated by combining the core concepts from numerous noteworthy literatures in a comprehensive form that paves a more straightforward path for our upcoming challenges regarding sustainability. The challenge is approachable only if skillful and efficient involvement of all relevant parties is ensured.

Keywords: Sustainability, Urban Development, Environmental Stability, Social Egalitarianism, Economic Well-Being.

Introduction

Sustainability is an ongoing buzzword which has seen its use for almost every aspect in modern-day activities, starting day-to-day life activities to how the world runs at whole. The Mega-city Dhaka, which is the capital of Bangladesh, has an astounding population of 21,741,000, which takes it up to the 6th position as the most densely inhabited city worldwide (29029 people/sq. km) (Wright, Facts and Cities, 2022). Megacities are defined as cities with population arbitrarily larger than 10 million (megacity, 2022). It is one of the fastest-booming mega cities around the world (Roy et al., 2018). Development is always a concern whenever the talk of mega cities comes into the equation. The buzzword of Sustainable development thus comes here. The monumental report "Our Common Future" put forward the quintessential definition, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (2022). For a mega-city, this development is challenging to say the least. These reasons include high

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population, rapid urbanization, uneven urbanization, poverty, poor living standards (Roy et al., 2018). There is also environmental pollution, poor infrastructure and services, inferior solid waste management that comes in the equation (Rana and Parves, 2011). There is a big concern on how existing administrative framework does not accommodate sustainability into the equation when it comes to urban planning (Roy, 2009).

The growth of this city is not happening in a sustainable manner (Rana and Parves, 2011). This can be understood by looking at some major indicating factors. For example, when AQI (Air Quality Index) is measured in Dhaka compared to other countries as shown in figure 1 (World Air Quality Index (AQI) Ranking | AirVisual, 2022), it stands as the most polluted city in the world, which is also estimated to cause severe harm to the citizens' health. When looking at the astonishingly low healthy vegetation; we can see how it is declining over the years, as shown in figure 2 (Nawar et al., 2021). All these give us a vague idea of how unsustainable Dhaka is and is going to be in the coming years if nothing is done about it.

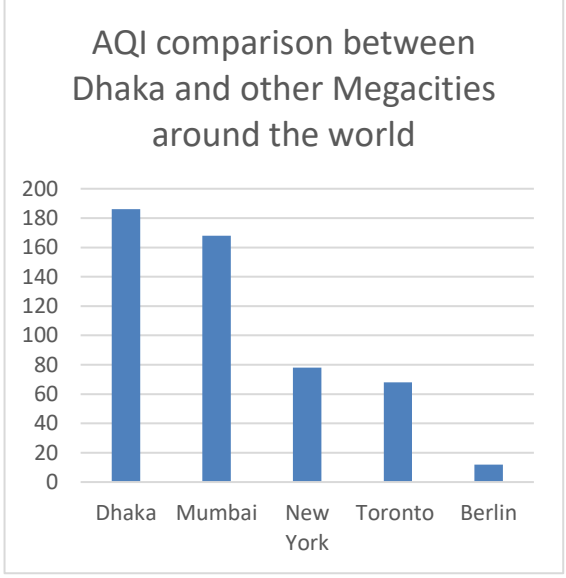


Fig.1.*World Air Quality Index (AQI) Ranking (Year 2022)* (World Air Quality Index (AQI) Ranking | AirVisual, 2022)

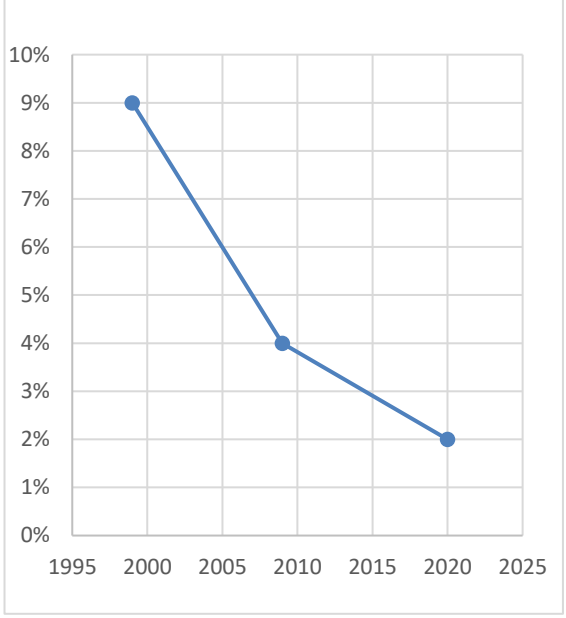


Fig. 2. Healthy Vegetation in Dhaka during 1999-2020 (Nawar et al., 2021)

These factors only explain a minor part of a more diverse problem. Sustainability is a concept that encompasses all of life and livelihood. This paper will follow us through a model that will create a pathway to solve the entire issue.

Literature Review

In the existing literature, specific sustainable urban development models do not exist specifically for the overall development of Dhaka city. Most of the existing literature tend to focus on a niche aspect of sustainability while some show various analysis about how sustainability can be implemented in a wider scale. For instance, Rana and Parves (Rana and Parves, 2011)showed us a comprehensive plan considering the difficulties that lie within the issue. Roy et al. (Roy et al., 2018) explained the challenges that are to be faced due to urban sprawl while he further formulated a plan (Roy, 2009) to combat it while also discussing about sustainable urbanization. There is research on Sustainable urban development for the slum areas (Sinthia, 2013). Rana and Parves showed various challenges and strategies for sustainable urban development in Bangladesh (Rana and Parves, 2011) but their research was based on the

entire urban prefecture in Bangladesh, while this work focuses specifically on Dhaka. Murad et al. Showed a fascinating prospect for sustainable urban development in Dhaka (Murad et al., 2021). Furthermore, Greener adaptations for urban development is precisely evaluated by Zinia and McShane (Zinia and McShane, 2018). Sufian presented an interesting model of Solid Waste Management in Dhaka. Various studies analyzed how energy can be made sustainable where one study (Islam, 2016) showed how sustainable energy and solid waste can be complementary. Another study (Bahauddin et al., 2014) showed us a model for sustainable urban infrastructures. Moreover, research (Zafarullah and Rahman, 2002) showed how human rights can be integrated into Bangladeshi civil society and further research (Naser et al., 2019) showed how climate change and governance affects human rights. Transport is a complex factor in Dhaka, which needs Sustainability in its perimeters (Labib et al., 2014). Various researchers formulated various sustainable urban development models based on their region. Another research (Byomkesh et al., 2012) showed the prospects of Greenery in Dhaka. There has been various literature that can be used to link with social sustainability considering the prospect of women empowerment, minority rights, freedom of speech, and expression. All such existing literature will be combined in this paper.

Sustainable Urban Development Model and our Approach

All the existing prevailing literature combined and formulated into a sustainable urban development model (Fig:3). Models are simplified abstractions of reality that can be used to tackle a complex problem (model, 2022). Urban development and management are a complex topic by itself. When sustainability is put forward alongside it, it becomes even more convoluted. Various researchers worldwide have put forward wonderful models and frameworks encompassing sustainable urban development (Tang and Lee, 2016.) Sustainable Urban Development (Rasoolimanesh et al. 2011) can be made more comprehensive and feasible sustainable urban development using city development strategies. This proposed model uses a three-layer model which can gradually and simply expresses how sustainability can be implemented in the urban development of Dhaka city. In the next section we will elaborately explain our methodology to formulate our model.

Methodology

In this paper, a model is formulated that encompasses the sustainable development journey in Dhaka city. Various secondary research sources are used to combine information to formulate the model. Finally, what we end up with is an integrated model which gleams at the futuristic sustainable aspect of urban development. Before formulating the model, the current issues regarding urban development are addressed. Then the new solutions are combined and put forward in the model.

The model uses various layers to put forward the idea. Inside the innermost layer there stands the name of the model; named as Sustainable Urban Development Model Dhaka (3:3:2 Model) where the three main components (Duran et al., 2015) of sustainability are mentioned. These components are named as Environmental Stability, Social Egalitarianism, and Economic Well-Being. In the second layer, each of those components are further divided into 3 categories that explain the various sides of sustainable urban development. In the 3rd layer all the second layer categories are further divided into 2 sub-categories for each of the categories:

1. Environmental Stability: Protecting the environment is an important part of sustainable development. The environmental aspects of urban development are integrated in this model into 3 sub-pillars:

1.1 Solid Waste Management: The solid waste management situation in Bangladesh occurs in a unsustainable dumping into landfills solution. But a comprehensive look at Solid Waste Management Modeling (Sufian and Bala, 2007) shows the management step by step. That can be simplified into 2 categories: First comes the recycling Solid waste as Energy (Islam, 2016) and other materials (Sufian and Bala, 2007). This should be complementary with general solid waste management procedures that are to be all-round in aspects of home and industries around Dhaka city referred as "Home and Industrial Solid Waste Management". These two categories comprise of Solid Waste Management and they work intertwined with each other like the proposed model (Sufian and Bala, 2007) of Solid Waste Management of Dhaka City.

1.2 Urban Green Development: In this model, Urban Green Development refers to developing and reinvigorating the green spaces around the Dhaka city in a urban development perspective. This is then simplified into 2 categories in the final layer. First comes the Allocation of Green Spaces and Rooftop Farming. Green Spaces are to be prioritized in the expansion of new urban areas (Byomkesh et al., 2012) planned in the upfront to tackle the severe lack of healthy vegetation (Nawar et al., 2021). The existing illegal urban infrastructure should be replaced with healthy greenery. This should come with the spread of Rooftop farming among the inhabitants. Now, the next step forward would be Incentives to prevent Deforestation and river filling. By deforestation, this paper is referring to the loss of vegetation and green areas around the city. Incentives could include laws that prevent people from taking away the green and rewards for those making the city green (Zinia and McShane, 2018).

1.3 Pollution Control: Several steps are to be taken to control pollution in this city. Dhaka is one of the most polluted cities in the world; the steps here would push the city in the right direction. In the first category, it is mentioned as Cleaning rivers, Canals and Land Waste around Dhaka. Dhaka is home to hazardously polluted rivers like Brahmaputra, Turag, and others. The pollution runs from the canals, so that is to be prioritized too. Industries are to manage their wastes as explained in 1.1, the existing land waste needs to be cleaned and manpower needs to increase in this sector. Newer technologies and approaches should be taken accordingly, slowly restoring the water quality (Whitehead et al., 2018) (Yin et al. 2021) Secondly, the category of Cutting Carbon Emissions is put in the model as the other category. As said before, it needs to be a high priority as Dhaka is time and time again considered as the most polluted mega-city in the world. The best ways to start doing this is by promoting energy efficiency and clean energy. This refers to an increase in overall use of renewable and banning inefficient energy driven unlicensed vehicles all over Dhaka. The overall power grid needs to be optimized for a better electricity based efficient energy use in all the sectors (Sikder et al., 2016), one step at a time.

2. Economic Well-Being: This comprises of all the elements that ensures the economic sustainability of this city. Economy sustains humans and distributes the resources among everyone. Sustainable Economy of this city is then formulated into 3 sub-pillars:

2.1 Sustainable Green Finance: In short, Green Finance refers to the financial activities done with the consideration of minimizing the damages to the environment while protecting and reinvigorating it (Lindenberg, N., 2014). This section has two categories that broadly make it easier to deal with green finance. These are split as Sustainable Production and Sustainable Consumption.

2.2 Planned Urban Expansion: Dhaka is expanding in a rapid rate. All of that expansion needs to be planned according to sustainability in mind (Roy et al., 2021). Now this expansion would Include two things broadly: Green Infrastructure Development and Sustainable

Transport System Planning. Proper Green Infrastructure is projected to decentralize the congestion and reduce the unsustainability markers of the city. The new infrastructure made for all purposes needs to be sustainable (Bahauddin, 2014). The current solar-powered Metro-rail is a step in the right direction, but there should be more low investment options, like road networks and updating the existing road networks using overpasses. There could also be promotion of cycle lanes and eco-friendly vehicles.

2.3 Sustainable Energy Use: This is the final sub-pillar which includes the categories of "Increase Renewable Energy & Optimize Supply Grid" and "Promote Innovation in Energy-Sector". Energy use is a complicated issue for developing countries like Bangladesh. But steps are to be taken at one point. That is because of Dhaka being one of the most polluted cities has the worst air pollution (World Air Quality Index (AQI) Ranking | AirVisual, 2022) due to the use of non-renewable fossil fuels for energy in inefficient infrastructures (Sikder et al., 2016).

3. Social Egalitarianism is just as important in sustainability (Zafarullah et al., 2002). In Dhaka, Civil Rights, Sustainable Healthcare and Impartial Stable Government are the elements of social sustainability in our model.

3.1 Sustainable Healthcare: Healthcare is an extremely important aspect for sustainability that needs to be managed well considering various issues as a bustling city in a developing country (Jahan and Chowdhury, 2014). In this model, this includes the efficiency of human resources in medical sector and Enhance Quality in Government Hospitals. This covers up the criterias that healthcare sector demands in Bangladesh. In Dhaka, just like any other cities, there is a lack of manpower in public health sector. Government subsidies should increase on creating more employment in this sector.

3.2 Civil Rights: Civil rights refer to equality and anti-discrimination under the law (civil rights Definition, Types, Activists, History, & Facts, 2022). First of this category is to enhance quality education and basic rights for all. In basic rights, there is education, food, water and shelter. Dhaka has a long way to go regarding this improving the infrastructure. This needs to come at a all- round aspect by both infrastructural development and policy updates. Ensuring Gender Equity and Minority rights and freedom of speech also fall under this category. Women's rights need to continue to improve by increasing their participation in all sectors (Banks, N., 2013) as gender equality is often considered as a prerequisite for sustainability (Johnsson-Latham, 2007). While urban development is underway, the rights of women and minorities of all backgrounds are to be respected by ensuring proper employment and safety. Social Welfare organizations could be promoted in each area under urban development where the inhabitants will be able to feel comfortable exercising freedom of speech. To ensure this, Laws regarding freedom of speech needs to be updated (Khan, A.R., 2021) and ensuring protection against hate crime for ethnic and religious minorities (Chaney and Sahoo, 2020), alongside LGBTIQ population (Chaney et al., 2020) must be ensured. Finally, women and minorities should have Business community and investment programs for the improvement of their living standards (Murad et al., 2021).

3.3 Impartial Stable Government: The governance of Bangladesh needs to be Impartial and stable; this would include eradication of political violence and Green Governance (Rana and Parves, 2011). A stable government with less corruption which skillfully tackles sustainability is of utmost importance (Naser et al., 2019).

All of these factors are then combined into figure 3 and then we have our desired Model.



Fig.3. 3:3:2 – A sustainable urban development model.

In the next section the expected outcomes and possible improvement directions are discussed.

Expected Outcomes and Possible Improvement Directions

Models help anyone and everyone be able to comprehend a complex scenario. Our model is specifically designed in such a way that common people would be able to learn from it. After-all people are the driving force in development. Thus, if our common residents in Dhaka get to know about Sustainable development in Dhaka specifically then it would be great for all of us. By following the guidelines and protocols by the scientists and integrating them in the administration in the city would enable sustainability as the issues of environment is slowly handled.

In this section we will discuss the benefits of the successful implementation of the proposed model in the context of Dhaka:

1. Protecting Environmental Stability: When environment is focused, Dhaka will have a cleaner air and will not be one of the most polluted cities in the world. This will occur as the steps in the model is expected to reduce the pollution by improving the pollution indexes (Pollution in Dhaka, 2022). Protecting the environment will also improve the public health and livability (Rana and Parves, 2011). Waste management will also improve the environment (Sufian, and Bala, 2007) and possibly produce ways to obtain cleaner fuel (Islam, 2016). Green Spaces and rooftop farming prospects will help ensure the betterment of environment (Byomkesh et al., 2012).

2. Ensuring Economic Well-being: Ensuring the well-being of economic is the biggest indicator of a decent living standard of a country. Improving the economic aspects of urban development has wide range of benefits (Murad et al., 2021) including the prospects for economic benefits for all in the long run due to sustainable production and consumption. The improving green infrastructure would allow the inhabitants to receive benefits as higher employment, better standard of living in all regards. Better housing and Transport would ensure stable economic growth while Sustainable energy use would open up new horizons in all the sectors.

3. Exercising Social Egalitarianism: The prospect of social egalitarianism in urban development is often overlooked. Yet in both explicit and implicit cases, social sustainability needs to be maintained. This model could ensure the betterment of social standard of living for the poor and underprivileged, as it focuses on basic rights for all. This would include the access to clean water, quality education, affordable housing, and child protection. The underprivileged minorities would also be able to gain certain rights due to the protective laws and business unions they can create in a sustainable city. Women's rights will be ensured by their equal participation in sustainable grounds (Johnsson-Latham, 2007).

In other words, this model will ensure an acceleration and initialization in sustainability as a part of urban development in terms of Dhaka city.

There exist some limitations to this model. Firstly, as it is a simple model made easier for common people to understand, simplification might make it seem as if some points are missing. Because one can straight up say that Safe and Sustainable Water supply is not present there but it actually exists under the civil rights in the subclass of basic rights for all. Also, by dividing the pillars and creating a 3:3:2 model, it is seen that some elements are overlapping with each other, which might cause confusion. Thus, there are some obvious weaknesses to this model. In the next and final section, the conclusion is written.

Conclusion

Dhaka stands as a city of dreams for millions of Bangladeshis. The dire situation Dhaka faces in this world where implementing sustainability is like a race of time that must be addressed. Sustainability prevents the impending disasters the city might face in future. The wellbeing of citizens should always be the top priority for urban development and only sustainability can ensure that. Thus, urban development must put forward all the necessary components of sustainability and implement them one by one, as shown in our model. This will drive Dhaka to a cleaner, healthier and sustainable future where the inhabitants can enjoy the environmental stability while maintaining their economic wellbeing in an egalitarian Society. The dream won't translate to reality if proper steps are not taken. Sustainability is the only viable step, moving forward.

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Measuring Rural Poverty Using Multidimensional Poverty Index: A Case Study in Khulna

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Abstract

This article is designed to measure acute poverty from the multidimensional poverty index perspective. As, the targets under the first goal of SDG: 'end of poverty in all its forms everywhere' emphasize poverty reduction at different magnitudes by the year 2030, poverty alleviation has become a key area to work on. The Multidimensional Poverty Index (MPI) approach can be the best measure of monitoring the target of the first goal of the SDG. We considered two rural Unions of Khulna Districts in Bangladesh as there is a high poverty level in the Khulna District with an HCR of 30.8% below Upper Poverty Line. Dumuria sub-district is not different from Khulna, where the poverty level is also high (i.e., 33.9%). Climate-induced shocks can be considered the major influencing factor for high level of poverty as these events frequently occur, damage livelihood assets, and create stress in many dimensions of daily life among the inhabitants. The unidimensional measure of poverty, like the head count index, does not show the severity of poverty. To address this fact, this article intends to develop a multidimensional poverty index for measuring acute poverty. The quantitative research approach has been adopted, and we have selected a total of 319 households as the sample size. The questionnaire survey was used to collect household data which was collected from two Unions such as Sarappur and Sovna of Dumuria sub-district. To construct MPI, 19 indicators have been considered under three major dimensions such as health dimension (6 indicators), education (2 indicators), and living standard dimension (11 indicators). The household-based approach has been used and a household is considered multidimensionally poor when it is found to be deprived in more than or equal to one-third of total dimensions. The result found that 57.4% of the total population is multidimensionally poor (i.e., 174 households). These poor households are experiencing 52.3% of deprivation from total weighted indicators. The adjusted MPI score that we have found is 0.30, which indicates these two unions are deprived of 30% of the total potential deprivation.

Moreover, the poverty cut-off justifies 19.75% of total households are in vulnerable conditions to become MPI poor (0.2<=k< 0.33), whereas 9% of total households are experiencing extreme multidimensional poverty (k>=0.67). This severe magnitude of poverty is caused mostly by the lack of minimum years of schooling among at least one of the members of each household, lack of school attendance for the children who are supposed to go to school under the education dimension, malnutrition, food coping, food diversity under health dimension; lack of accessibility to a minimum area of cultivatable land, insufficient cash saving, flooring material under living standard dimension. This article provides a background for different actors, including NGOs, communities, local government, and central government organizations, to make community-level poverty alleviation planning effective and make them realize the areas where resource allocation is needed. The donors or government can take MPI as a poverty monitoring tool for tracking the poverty reduction process in different countries.

Keywords: Rural Poverty, SDGs, Multidimensional Poverty Index, Headcount Index, Intensity Index, Khulna

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1. Introduction

Being labeled 'No Poverty', the sustainable development goal-1- 'End poverty in all its form everywhere' have such targets by 2030 as- eradicating extreme poverty, reduce at least by half the proportion of men, women, and children of all ages living in all its dimensions; achieve substantial coverage of the poor and vulnerable, ensure that poor and vulnerable have equal rights to resource and services; build the resilience of the poor and reduce exposure and vulnerability to climate-related extreme events (United Nations, 2022). Before the SDGs, MDGs also targeted to reduce extreme poverty by half of the total and it was attained ahead of time. So, reducing poverty has been a major part of international policy for a long time (Sydunnaher, Islam and Morshed, 2019).

The income or consumption poverty measures are well-practiced worldwide based on World Bank's dollar-a-day headcount ratio (Hanandita and Tampubolon, 2016). Yet, poverty cannot be well defined only by income or consumption as it is reflected from a society's economic, political and social deprivation (Bhuiya et al., 2007). Thus, poverty is the inadequacy of food where a school-going child is going to work to get rid of hunger, poverty is not having a place to sleep, access to school to gather knowledge, affordability to meet the doctor. Poverty is unemployment or lack of income and the reason, therefore, having fear for the future. It is malnutrition or losing a child from a chronic illness. It is a lack of proper management of WASH as well. Poverty is a stress-induced from the absence of capability of progress out of the unwanted situation, at the same time it is a risk of falling into that unwanted situation in the near future because of not having livestock, savings, assets, capital at different levels (i.e., social, human, natural). Hence, poverty has to be perceived as a multidimensional phenomenon (Bhuiya et al., 2007). Strategies in poverty reduction often emphasize income generation activities for the target group. Even after recognizing the non-income dimensions of poverty, it has not been seen that non-income dimensions are being monitored and evaluated well after the implication of poverty reduction schemes. Thus, it has become tough to make the answer of whether a particular program is successful or not or how successful the program is in the non-income perspective of poverty. This problem might be derived from not having easy tools to measure poverty's multidimensionality. (Bhuiya et al., 2007)

The Human Poverty Index (HPI) was being measured since 1997 by Human Development Reports (HDRs) to address multiple non-income aspects that contribute to poverty which is consequently replaced by the Multidimensional Poverty Index (MPI) in 2010 (Alkire and Santos, 2014). A multidimensional poverty index where all the dimensions have been merged into one and based on a single cut-off value poverty measurement method is introduced by Alkire and Foster. People who are failed to get a certain level of need, resource or are unable to function a minimum standard of living are objected to be identified in this method (Alkire and Foster, 2011; Sydunnaher, Islam and Morshed, 2019). Thus, it is designed to measure acute poverty, acknowledging several aspects simultaneously. In other words, it measures the people who are experiencing multiple dimensions. Both headcount ratio or incidence of multiple deprivations and intensity of the deprivations are measured here.

This paper uses 19 indicators under three major dimensions to measure the MPI of Sarappur and Sovna unions of Dumuria Upazila of Khulna. These major dimensions are- health, education, and living standard. The following section of the papers will explain the study area, data collection, selected dimensions and indicators for the MPI, and the construction of MPI; analysis and findings with concluding remarks.

2. Methodology

2.1 Study Area

Dumuria upazila of Khulna district has been considered as our study area. The largest upazila of Khulna in terms of the population consists of 14 unions, 205 mauzas, and 241 villages. It is located between 22°39' and 22°56' north latitudes and between 89°15' and 89°32' east longitudes. There are 71,909 households with an average size of 4.2. Among the general households, 11.1% live in a pucca house, 20% in semi-pucca, 67.6% in kutcha, and the remaining 1.3% live in jhupri house. Sarappur and Sovna are the two of the fourteen unios that have been chosen for the case study. According to the population and housing census 2011, Sarappur and Sovna have respectively 4122 and 4806 households; 16,101 and 19,708 population (Bangladesh Bureau of Statistics, 2022)

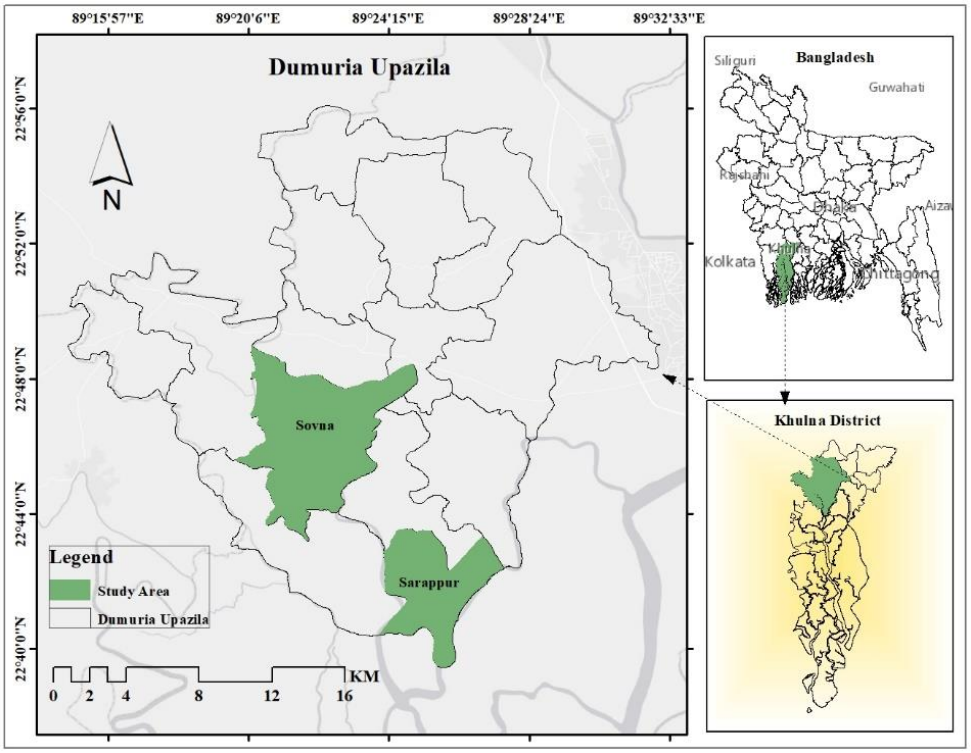


Figure 1: Study Area

2.2 Indicator Selection for MPI

The globally introduced (among 109 countries) MPI of 2011 has three dimensions made up of ten indicators. The then Millennium Development Goals or MDGs was a basis being an international consensus to set up the deprivation cut-offs for each indicator. Deprivation cut-off is basically the minimum level of satisfaction is to be observed for each indicator. After that, MDGs have been followed by SDGs with similar goals and targets regarding poverty reduction, validating the acceptance of MPI as a tool for poverty measurement. These three dimensions are- Health, Education and Living Standard where two indicators-nutrition, child mortality belong to health dimension; years of schooling, school attendance- belong to education dimension and cooking fuel, sanitation, water, electricity, floor, assets belong to a living standard dimension. This set of ten indicators is almost the only combination of indicators that has data availability across the 100 countries of the globe (Alkire and Santos, 2014).

Our study area is the smallest administrative and local government unit in Bangladesh, the

union. The regional or national MPIs- one of the two major broad categories of MPI measure is based to address local realities better based on locally most available data. Likely the Alkire-Foster method, we have considered the same indicators under the education dimension (Table 01). Considering the local context of Sarappur and Sovna, four more indicators- child labor, food coping, food diversity, prevalence of fever or diarrhoea added to the health dimension and electricity indicator has been excluded, on the contrary, newly added indicators- both value of productive asset and number of non-productive assets, number of sources of income, gender empowerment of female adult member, access to cultivatable land, income, cash saving- have been newly added under the living standard dimension (Table 01).

Health Dimension: The global MPI has two indicators under the health dimension where the first one is about nutrition. This information is tough to extract directly from a household. Checking Body Mass Index (BMI) whether it is below the minimum standard of 18.5 or not for adults, and comparing weight to the national median for children, are practiced globally to measure malnutrition. In our study area's context, this indicator has been measured by BMI for children knowing their height and weight and knowing if there any woman is suffering from anemia. Malnutrition is a barrier in front to achieving a cognitive, healthy, and strong physical society. Additionally, to support a better understanding of our context, food coping strategy, food diversity- have been measured by knowing whether less than two strategies are there or not among the predetermined nine strategies and whether they take less than six items of food or not. The prevalence of diarrhoea or fever in the last month, the incidence of child laboring on a regular basis, having an autistic child or child with chronic illness, or incidence of a child dying- helped to understand the local community's health condition in a more dynamic way.

Education Dimension: In this dimension, there are two indicators- the years of schooling and the school attendance. According to the deprivation cut-off, at least one member must have completed five years of schooling. Therefore, if no member has at least five years of schooling, all the household members will be counted as deprived. Similarly, if a household has any school-age (6-14) child who does not attend school, all the members will be considered deprived. On the contrary, a household with no school-age child will be considered as non-deprived in this indicator. Thus, the demographic structure of households of a certain study area will be reflected as the educational attainment of that community.

Living Standard Dimension: Both values of productive asset and number of non-productive have been measured. Besides the undertaken global indicators and their cut-off, the newly added cut-offs are- A household has less than two income sources, less than 33tk of daily income, less than 1000tk of cash saving. A portion of the questionnaire is dedicated to assessing women's empowerment. If, less than 75% of all the questions under that portion are answered positively by any female adult member, all the member of that household is considered as deprived in the gender empowerment of the female adult member indicator. In our taken study area, a massive agricultural dependency is observed according to the census data which has made the necessity of inclusion of access to cultivatable land indicator. A household is deprived of this indicator if it has any marginal farmer who has no cultivatable land or less than 2.5 acres of cultivatable land. Indicators under this dimension are all about having entitlements and their ability to function these entitlements and bring the ultimate wellbeing.

Maj. D	Indicator	Deprived if…..
Health	Child Labor	Any child ('early childhood'- 3 to 8, 'middle childhood'- 9 to 11, 'adolescence'- 12 to 18) is affiliated with any labor work.
	Child illness or mortality	Any child has died in the family. Any child having autism or chronic illness.
	Nutrition	Any adult or child for whom there is nutritional information is malnourished. Any woman is suffering from anemia.
	Food coping	Having less than 2 strategies among 9 coping strategies in a week
	Food diversity	One takes less than 6 items of food in a week
	Prevalence of fever or diarrhea	He/she had fever or diarrhoea in last 30 days
Educa-tion	Years of schooling	At least one person in the household has not completed five years of schooling
	School attendance	Any school-age child is not going to school in years 6 to 14
Living Standard	Improve sanitation	The household lacks adequate sanitation or shared among more than one nuclear family.
	Safe drinking water	The household does not have access to clean drinking water or clean water within 30 minutes walking distance (roundtrip)
	Flooring	The household has a dung, dirt or sand floor
	Cooking fuel	The household cooks with charcoal or dung
	Value of productive asset	Value of the productive asset is less than 10000 Tk
	Number of Non-productive assets	Less than four
	Number of sources of income	Less than two
	Gender empowerment of female adult member	The asked questions are answered positively less than 75% by female adult member
	Access to cultivatable land	No cultivatable land or, Marginal farmer having less than 2.5 acres of cultivable land
	Income	Income is less than 33 Tk per day
	Cash Saving	It is less than 1000 Tk

Table 01: Determinants of Multidimensional Poverty Index Table

(Source: Based on Dumuria upazila's socioeconomic profile as well as the global standard of MPI indicators (Alkire and Santos, 2014; Sydunnaher, Islam and Morshed, 2019)

2.3 Questionnaire Preparation and Data Collection

A structured questionnaire has been developed to survey the households at the studied two unions- Sarappur and Sovna. The questionnaire had several parts including demographic profile (i.e., age, sex, occupation, number of children). Health (i.e., child illness or mortality, nutrition, anemia, prevalence of fever or diarrhoea), education (i.e., education level, school attendance) living standard (i.e., food, drinking water, sanitation, cooking fuel, flooring material, asset).

Household is considered as the unit of analysis. Households that are surveyed are randomly sampled. Thus, a total of 319 households have been surveyed, with 149 from Sarappur and 170 from Sovna.

2.4 Construction of MPI

Deprivation cut off: Described in Table 01, a person is considered deprived in a certain indicator when his or her achievement is below the mentioned cut off in the same indicator. The ongoing SDGs, national and international policy and agreement, the local culture of the study area, empirical evidence- are the basis of setting deprivation cut-off.

Indicator's weight: In our MPI calculation, likely the globally practiced MPI all the dimensions have been equally weighted which means each dimension has a weight of 1/3. The indicators within a dimension are also equally weighted. Thus, in our considered indicators, each indicator under the heath dimension got 1/18, indicator under education dimension got 1/6, and indicator under living standard dimension got 1/33. It is to be noted that- Say, indicator i weight as wi, $\sum_{i=1}^{d} w_i = 1$

Poverty cut-off: A person's deprivation is assigned first as per his deprivations in all the indicators within all the dimensions. The deprivation score is calculated by taking the weighted sum of the number of deprivations, so it lies between 0 and 1. The deprivation score increases with the inclination of the number of deprivation incidences and vice versa. If deprivation is not observed in any indicator, it gets 0 in that particular indicator. It can be written as,

ci= w1I1+ w2I2+ w3I3+……wnIn

Here, ci is the deprivation score; In is 1 where it is observed to be deprived, it will be 0 if it is not deprived and wn is the weight given to the indicator n.

Poverty cut-off is the basis to consider a person MPI poor. Generally, it is noted as 'k' value. If a person's deprivation score is equal to or greater than (ci>= k) poverty cut-off, that person is considered to be MPI poor. In, MPI this poverty cut-off is 1/3 which means when a person is found to be deprived in equal to or greater than 1/3 of total indicators (weighted) is considered as MPI poor. To check the different magnitude of poverty, in this paper different poverty cut-off has been reclassified. Hence, a person with 20% to 32% deprivation of total indicators has been considered as vulnerable to MPI poor; when this value is 67% or more is being said the person is having extreme poverty. The robustness of MPI can be measured by differentiating different poverty cut-offs.

Computing the MPI: MPI is basically the integration of two key parts- headcount index, intensity index. Headcount index is basically the proportion of MPI poor to the total population whereas intensity index refers to the proportion of deprivation to total weighted indicators. The headcount index is expressed as,

H= q/n

Here, H is the headcount index, q refers to the number of total MPI poor and n is the total population. The average deprivation score or intensity index is basically the breadth of the poverty is expressed as,

$$A= \frac{\sum_{i=1}^{n} c_{i(k)}}{q}$$

Where A is the intensity index, ci(k) refers to the deprivation score which has satisfied the poverty cut-off of k of 0.33 and q is the total number of MPI poor.

Hence, $MPI = H \times A$

3. Analysis

3.1 MPI Result

From Table 02, we see 57.4% of the total population are MPI poor. Against this number, 567 among 1331 are found to be non-poor. These non-poor groups also consist of vulnerable groups who are likely to be fallen into multidimensional poverty in the near future. Against 174 MPI Poor households, 145 are found to be non-poor. The headcount index of 0.574 implies 57.4% of the total population of Sarappur and Sovna unions are found to be MPI poor.

The next part, intensity index of 0.523 indicates- among these 1331 people from 319 surveyed households 764 people who are MPI poor are deprived of 52.3% of total weighted indicators. The MPI score of 0.30 reflects people from the study area are deprived of 30% of the total potential deprivation. MPI score is basically the adjusted score by combining both incidence and intensity. Hence 30% can be derived from- a) There is a society where 30% of the total population are deprived of 100% of total weighted indicators; b) where 100% of people are deprived of 30% of the total weighted indicators. In our findings, we draw in Sarappur and Sovna unions-there are 57.4% of the total population who are experiencing 52.3% of total weighted indicators.

Total Household	Total Non-poor	Total Poor	Total Non-poor Household	Total Poor Household	Headcount Index	Intensity Index	MPI
319	567	764	145	174	0.574	0.523	0.30
	42.6%	57.4%	45.45%	54.55%	57.4%	52.3%	30%

Table 02: MPI Summary

3.2 Deprivation score across different poverty cut-off

From Table 03, poverty cut-off has been classified across different values from 0 to 1. Around, 23.07% of the total population is nowhere near multidimensional poverty nor acute poverty (k< 0.2). 264 people from 64 households are at risk of falling into multidimensional poverty (0.2<=k<0.33) which covers 19.53% of the total population. MPI is basically the tool for measuring acute poverty. 1/3 of poverty cut-off is to find out these people who are experiencing acute poverty. Thus, the range of k value from 0.33 to 1 is for those people who are experiencing acute poverty. In our analysis, we classified this acute poverty into two groups- General MPI Poor (0.33<=k<0.67), Extreme MPI Poor (k>=0.67).

47.78% of people are experiencing general multidimensional poverty which covers 636 people from 146 households whereas 9.61% of people are experiencing extreme multidimensional poverty which covers 128 people from 28 households (Table 03).

MPI Score	Number of Household	Number of Population	Percentage of Total Population	Cumulative Percentage	Magnitude of Poverty
<0.20	81	307	23.07%	23.07%	Not MPI Poor
0.2-0.32	64	260	19.53%	42.6%	Vulnerable
0.33-0.39	40	178	13.37%	55.97%	MPI Poor
0.40- 0.49	47	208	15.63%	71.6%	MPI Poor
0.50- 0.59	40	170	12.77%	84.37%	MPI Poor
0.60-0.66	19	80	6.01%	90.38%	MPI Poor
0.67-0.79	14	67	5.03%	95.41%	Extreme MPI Poor
0.80-0.89	10	45	3.38%	98.79%	Extreme MPI Poor
>0.89	4	16	1.20%	99.99%	Extreme MPI Poor
Total	**319**	**1331**			

Table 03: Deprivation score across different poverty cut-off

3.3 Deprivation count across the Indicators

Figure 2 represents the deprivation count as per all the nineteen indicators. The most deprived indicator we found is cash saving. Among 319 surveyed household 235 are found to be deprived in this indicator which means these 235 households has no minimum cash saving of 1000tk. As the maximum household of the study area belongs to katcha household, Sand is often founded as a flooring material. In this indicator 213 households have been founded as deprived. The local economy is much dependent on agricultural activities as per the census data but the grief is 170 of the total surveyed households is founded not having minimum accessibility to cultivatable land. The households carry a minimum a farmer does not have a minimum of 2.5 acres of cultivatable land. These farmers are considered marginal farmers. Against the massive deprivation in these indicators, deprivation in child illness or mortality, child labor is quite lower. Subsequently, 30 and 42 households are deprived of these two. This indicates children are affiliated with any labor works as well as the incidence of losing a child from chronic illness are not seen frequently which are found to be the lowest deprived indicators among all nineteen, the prevalence of fever or diarrhoea is also found to be less than 100, although this number is 89. Sanitation and safe drinking water have a similar deprivation count ranging from 80 to 90. We observed there is a common use of tube-well among the community. Maximum households do not have their own tube-well for safe drinking water, still, the distance of getting this common or shared tube well is within 30minutes. Most of the surveyed households appeared with more than 33tk of income per day. Except for 56 households, the remaining households have more than four non-productive assets (i.e., tv, bicycle, mobile phone).

Deprivation count does not reflect the share of contribution to the overall deprivation score as well as MPI. Hence, a higher deprivation count will not contribute higher to overall MPI all the time. Rather it is important to secure a lower deprivation count in those indicators where the number of indicators is relatively low than other dimensions (i.e., indicators under the education dimension). In other words, to secure a lower MPI as well as deprivation score, it is important not to be deprived in the higher weighted indicators (i.e., years of schooling, school attendance).

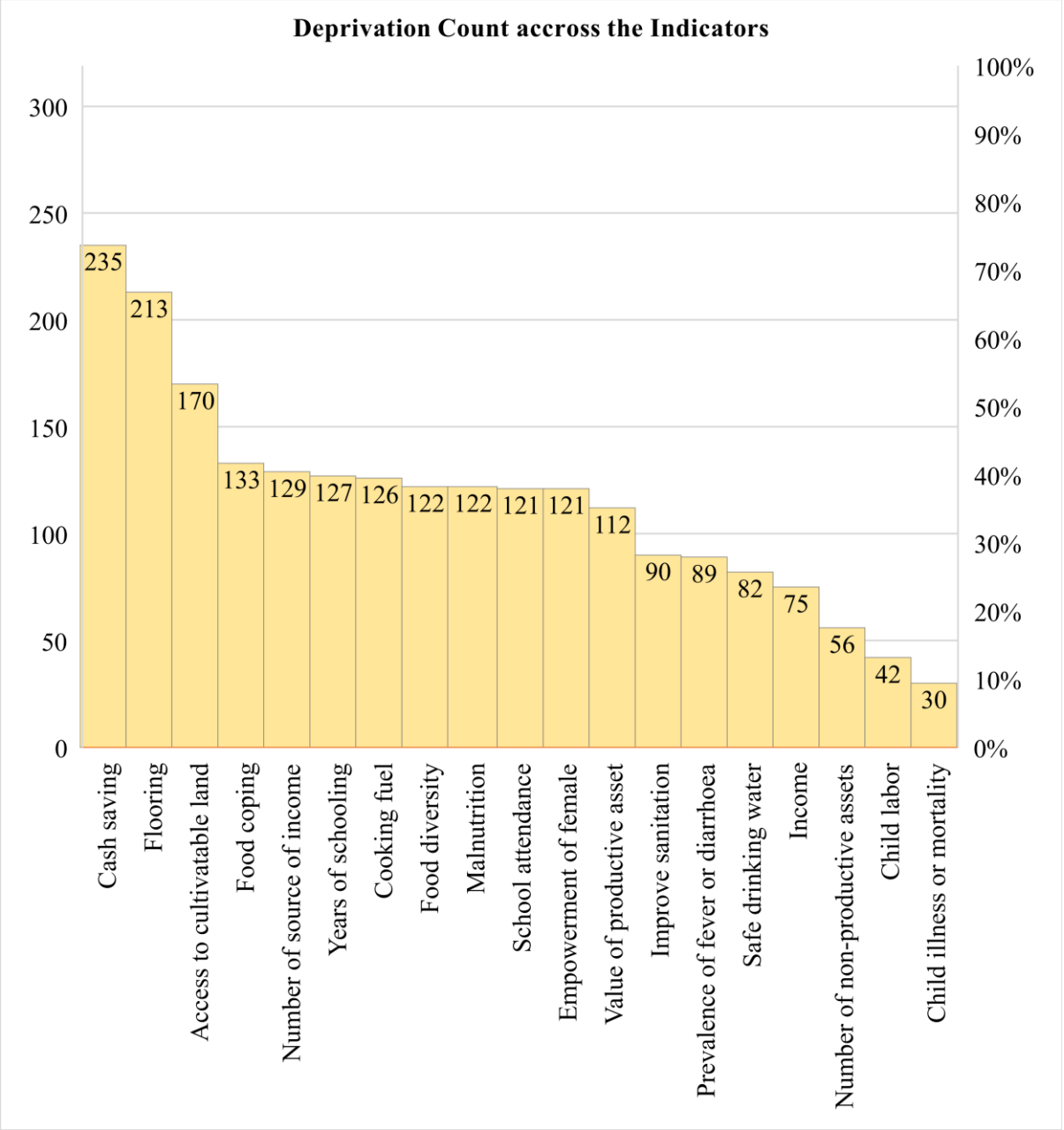


Figure 2: Deprivation count across the Indicators

3.4 Contribution of each Dimension and Indicators to total Deprivation score

The most contributed dimension to the overall deprivation score as well as the intensity index is the education dimension. Among 399.46 of total deprivation score ($\sum_{i=1}^{n} c_{i(k)}$), this dimension has shared 167.83 which is 42.01% (Figure:3) of total. The most weighted indicators are here under this dimension. In the deprivation count analysis, we did not find years of schooling nor school attendance as the most deprived count indicators but still, this dimension contributed most to the overall deprivation score because of its indicator's higher weight. Two indicators have contributed equally (Table: 04), 21% each. In MPI, dimensions are weighted equally. Hence, indicators under each dimension are weighted equally based on their dimension's weight. The education dimension contains the lowest number of indicators, making these indicators the most expensive. Thus, despite not having the highest deprivation count, these two contributed most to the overall deprivation score and intensity.

The second most deprived dimension is the living standard dimension. This has contributed

almost 32% to the total deprivation as well as the intensity index. The highest number of indicators belonging to this dimension got the lowest weighted indicators of 1/33. Thus, despite having the highest deprivation count indicator cash saving, it has contributed only 4.9% to the overall deprivation score (Table: 04) which is similar to flooring material and access to cultivatable land as well. Except for 75 households, we have seen people's income is well over the 33tk per day line. Similar to this, most of the households we found had more than four non-productive assets. These have contributed the lowest to the overall deprivation score among all nineteen indicators. As per the deprivation count, we observed living standard dimension contains the most deprived indicators. But being the lowest weighted indicators among all three dimensions, its contribution to the overall intensity is second highest.

The lowest contributed dimension is the health dimension. Though we have observed that more than 1/3 of our surveyed households struggle with food coping, food diversity, and nutrition. These indicate, people have fewer food items to enjoy, thus they are having fewer strategies to cope with. They were asked about foods containing protein, carbohydrates, and vitamins- most of the children of these households were found to be malnourished or women in these households suffer from anemia. These three indicators contributed most from the health aspect. The other three have much lower contribution, especially since working child and child mortality have not been seen frequently. The prevalence of fever or diarrhoea was also found to be less than 1/3 of the total surveyed household.

The interesting findings, we must mention are that in the education dimension more than 1/3 of the surveyed household is having at least a child (6-14) who is not going to school but is supposed to. But, in the health dimension, the frequency of households having a working child (3-18) is only 42. This observation interprets children who are not going to school are not affiliated with any income-generating activities as well. So, this common age group is roaming their time aimlessly need to send to school immediately to improve the scenario of the community. Similarly, despite a lower incidence of child mortality, the number of households with malnourished children is quite higher.

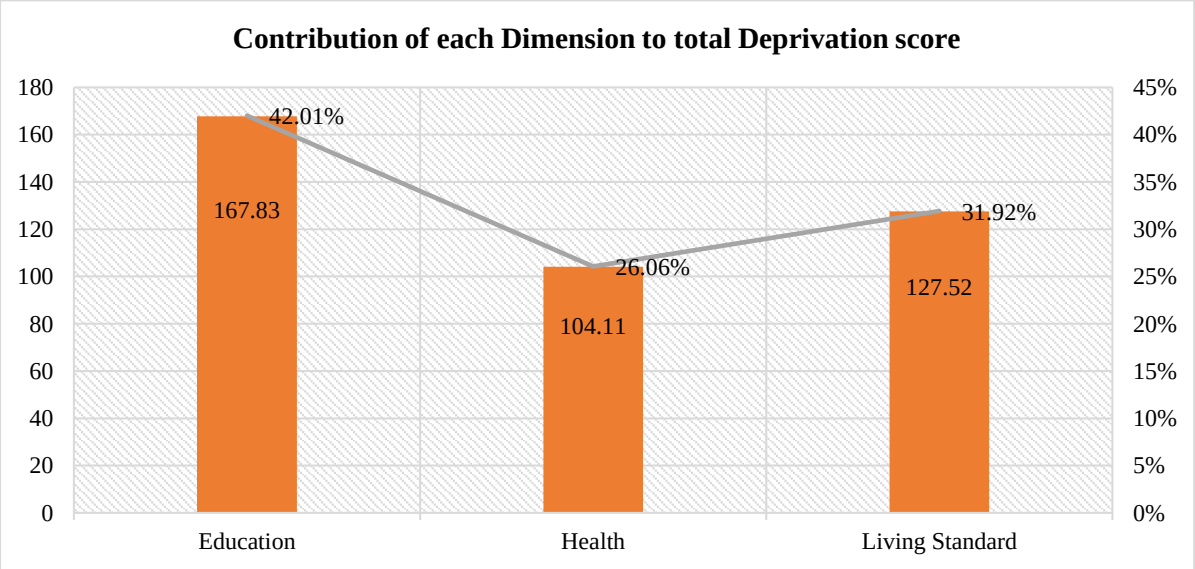


Figure 3: Contribution of each Indicator to total Deprivation score

Indicator	Deprivation score	Share to overall intensity
Child Labor	9.33	2.34%

Child illness or mortality	7.17	1.79%
Nutrition	20.56	5.15%
Food coping	27.83	6.97%
Food diversity	21.22	5.31%
Prevalence of fever or diarrhea	18	4.51%
Years of schooling	84	21.03%
School attendance	83.83	20.99%
Improve sanitation	8.67	2.17%
Safe drinking water	7.45	1.87%
Flooring	17.12	4.29%
Cooking fuel	12.67	3.17%
Value of productive asset	12.52	3.13%
Number of Non-productive assets	5.27	1.32%
Number of sources of income	10.73	2.69%
Gender empowerment of female adult member	11.18	2.80%
Access to cultivatable land	16.24	4.07%
Income	6.06	1.52%
Cash Saving	19.61	4.91%

Table 04: Contribution of each Indicator to total Deprivation score

4. Conclusion

The paper has introduced MPI as an effective poverty measurement tool with descriptive statistical analysis. Poverty has to be measured in a better way for better policy intervention. In developing countries like Bangladesh, acknowledgment of the multidimensionality of poverty is not often seen in policy formulation and social research (Chowdhury and Mukhopadhaya, 2014). Undertaken 19 indicators are both income and non-income parameters helped to portray the poverty story of Sarappur and Sovna unions of Dumuria upazila of rural Khulna in a better way. This MPI approach is different from traditional income-based poverty measurement. Hence, the breadth of poverty is measured here which will make the reader understand how poor the poor are. The MPI analysis showed that the community is deprived in 30% of the total potential deprivation that could have been experienced, 57.4% of the total population is found to be MPI poor and this MPI poor are deprived in 52.3% of the total weighted indicators.

One of the limitations of this paper is that this paper did not address the spatial attributes (i.e., distance from workplace, distance from education, distance from medical) which is being practiced nowadays (Sydunnaher, Islam and Morshed, 2019). Another one is, people do often not find themselves comfortable answering questions relevant to their income and saving. There is a tendency not to tell their actual saving to the people they do not know. This is one of the reasons that results in the highest deprivation count in cash saving indicator.

Finally, this paper incorporates the methodology developing critical insight into poverty measurement. Hence, MPI will be practiced more in the national poverty measures, will be exercised in poverty reasoning, will be practiced in the public debates. Besides, the findings will directly help in local development policy and resource distribution. Thus, efficient allocation of resources and development projects can be ensured.

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participated in the survey.

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Flood Risk Assessment of a Proposed (100 MWAC) Solar Power Plant in Sonagazi, Feni and Formulation of Mitigation Measures

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1. Abstract

The Government of Bangladesh has prioritized the development of the country's power industry and is committed to providing energy to all inhabitants by 2021. The 8th Five Year Plan's renewable energy ambitions also include a target of 10% clean energy generation by 2021. Keeping line with this, the study mainly focuses the flood risk in coastal belt region where several power development projects are planned to be initiate. To determine the flood risk and accordingly formulate the mitigation measure a 100 MWAC Grounded Solar Power Plant has been proposed which is located at Sonagazi, Feni District. A Two Dimensional hydrodynamic model has been developed using Delft3D FM to assess the flood hazard both for base and future climate change scenarios. The model was simulated considering normal tide, sea level rise and combination of sea level rise and storm surge. Simulation result showed that for combined effect of sea level rise and storm surge the whole study area goes under water where the surge height becomes 6.25m and 6.50m for 0.2m SLR and 0.4m SLR respectively. In case of landfall during spring tide and considering 1.5m sedimentation the surge height increases to 7.30m and 7.50m for 0.2m SLR and 0.4m SLR respectively. As a part of structural measure a sea-dyke and three marginal dykes with a crest level of 9.5mPWD, 8.8 mPWD. 8.8 mPWD and 8 mPWD has been proposed. Regulators (3 vents and 5 vents) at outlet and culverts at Inlet has been proposed to assure the smooth passage of upstream flow. Canal re-excavation is also proposed where the volume has been found approx. 3,45,180 m3. A 200m X 200m internal water reservoir with a depth of around 3.5m has been proposed to accommodate the access water during extreme rainfall event. Land formation level has been suggested to increase up to 6.5 mPWD for extra safety during the normal flooding condition. After finalizing the measures, hydrodynamic model outcome- considering suggested mitigation measures brings fully flood free condition inside the study site. The strategies if implemented will help to overcome the flood risks and will help in implementing better flood management in the study area.

Keywords: flood risk assessment, climate change, solar power plant, feasibility

2. Introduction:

Government of Bangladesh has started overhauling the power sector in order to ensure that all citizens have access to electricity by 2021. It is currently focusing its efforts on solar and wind energy development, which contribute to the country's renewable energy production. Keeping line with these a study area has been considered at Sonagazi Upazilla, Feni where grounded solar power plant has been proposed to be constructed. The area is highly dynamic intertidal floodplain, where recurrent tidal flooding causes morphological changes in estuaries and rivers. The objectives of the study are,

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- Site specific “Detail Flood Modelling” to assess the future flood risk for extreme events”.
- Formulating mitigation measures considering the flood model outcomes from base and future Scenario
- Assessing the internal water management system within the Study area and checking the adequacy of sea dike and marginal dikes
- Finalizing the mitigation interventions to reduce the flood risk within the focused area where grounded solar power plant is planned to construct.

3. Overall Approach and Methodology:

Approach of the study includes, collection of relevant primary and secondary data. Field survey was conducted to collect land topography and river cross sectional data. Time series rainfall data was collected from BMD, water level and discharge data was collected from BWDB. The datasets were analyzed and prepared as per model format. Secondly, the 2D hydrodynamic model was developed for the study area and simulated for different climate change scenarios. The model was also simulated considering the suggested mitigation measures to check its applicability. Based on the simulation outcome, flood risk assessment was conducted and some preliminary mitigation measures were identified accordingly. Figure 1 shows the overall approach of the study.

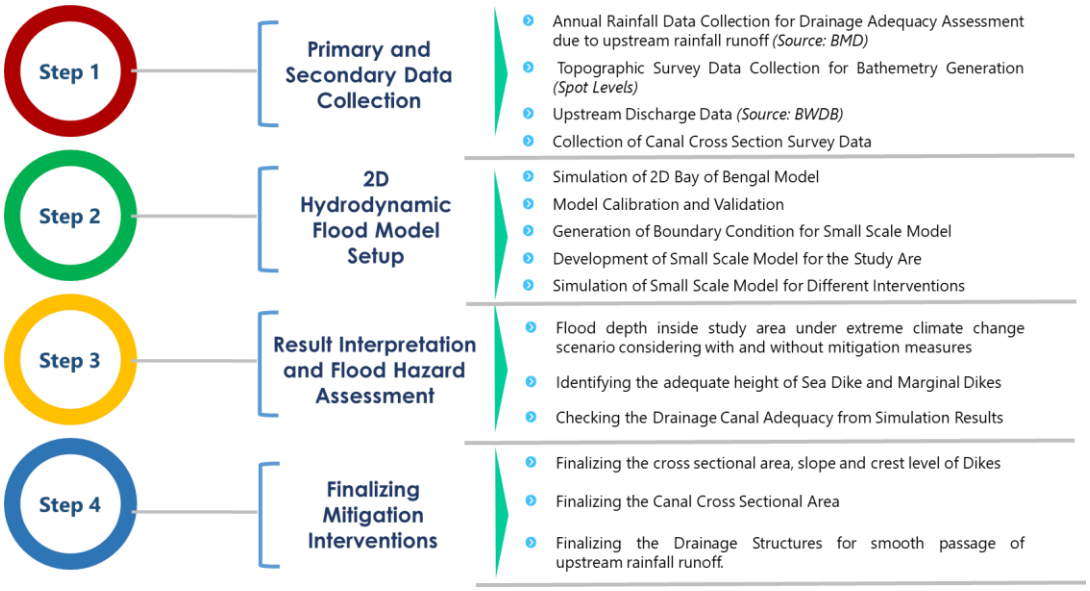


Figure 1: Overall Approach of the Study

3.1 Development of Flood Model:

A large scale 2D hydro-dynamic model has been developed to generate the boundary conditions for small scale model. The boundary conditions for the model are shown in table 1.

SL	Boundary Type	Boundary Location	Type of Data	Source
1	Upstream	Hardinge at Ganges	Discharge	BWDB
2		Bahadurabad at Brhmaputra	Discharge	BWDB
3		Bhairab Bazar at Upper Meghna	Discharge	BWDB
4	Downstream	Deep Sea at Vishakapatnam	Astronomic Tidal Constituents	TPXO 8.0 Global Inverse Tidal model

Table 1: Boundary Conditions for Developing Model

After defining the boundary condition the model is then calibrated and validated against the observed water level data. The calibration and validation result was found at satisfactory level. Figure 2 shows the sample results of Calibration and Validation.

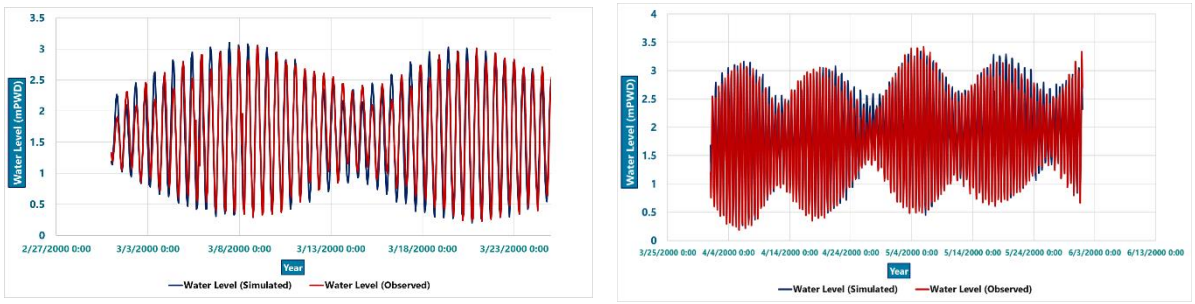


Figure 2: Sample of Calibration and Validation Result

The grid size of the large scale model has been taken varying from 100 m to 500m grid. Bathymetry of the deep-sea portion has been taken from the General Bathymetric Chart of the Ocean (GEBCO19) and the bathymetry in the lands and rivers portion of Bangladesh has been generated based on the National DEM and BWDB cross sections of rivers and estuaries. Figure 3 shows the large scale developed model.

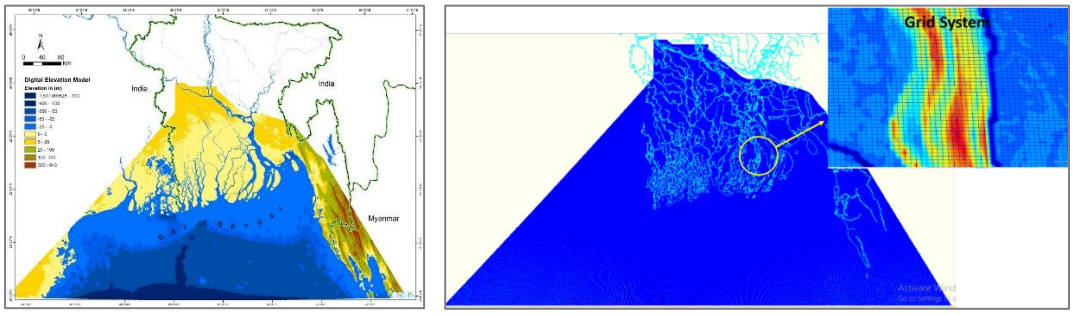


Figure 3: Grid Size for Small Scale Model

As the developed large scale model has comparatively coarser grid size to assess the impact of flood hazard within the study area, a small-scale model with comparatively finer grid size has been developed using the same tool-Delft3D Flexible Mesh. The grid size for the small scale model has been set to 30m X 30m (for Khals) and 50m X 50m (for flood plains) considering both the computational requirements and ensuring smooth connection with the large scale Model. The grid size for small scale model is illustrated as figure 4,

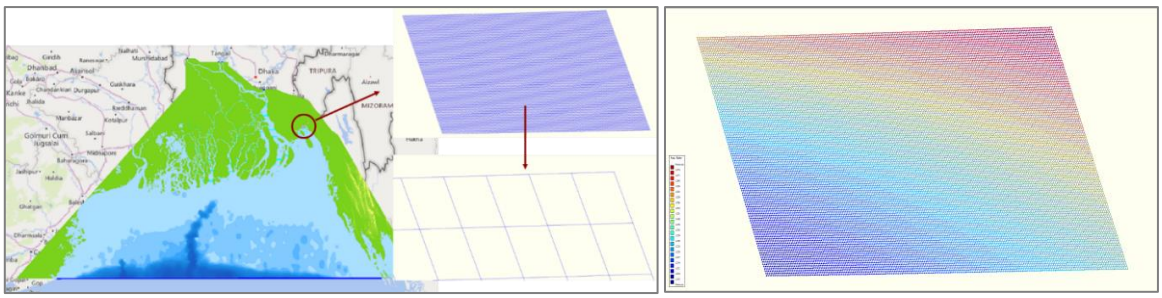


Figure 4: Grid Size for smaller Domain Model

3.2 Drainage Adequacy Assessment:

The drainage adequacy has been assessed by delineating the catchment and calculating the peak discharge of the canals. The discharge has been calculated considering both 25 and 50 year return period. The overall approach of catchment delineation is shown as figure 5.

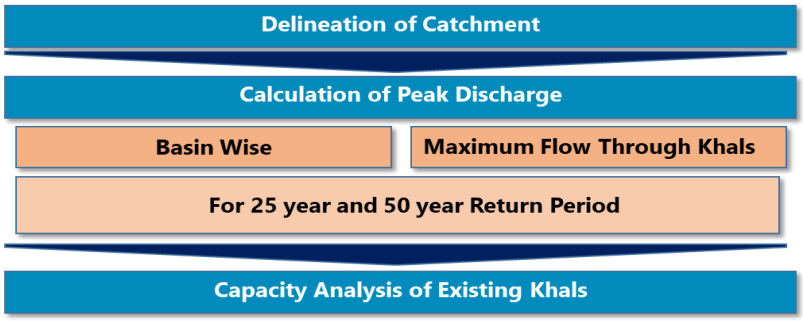


Figure 5: Catchment Delineation Process

From the catchment delineation, the total inflow and outflow within the study area has been found 49 m3/s and 59.5 m3/s respectively. Considering the rainfall event, the study area will generate 9 m3/s of additional runoff for 13.5 mm/hour rainfall event. The 49 m3/s of inflow has been found distributed over Sonagazi Khal, Khal 2, Khal 3 and Khal 4 receiving as 33 m3/s by two branches, 2 m3/s, 5 m3/s and 9 m3/s respectively. Similarly, total outflow is found to be carried out by two outlets, one is of Sonagazi Khal and another is the Khal 3, as 36 m3/s and 23.5 m3/s respectively. Following figure 6 shows the schematic diagram drawn in not to the scale to illustrate the design runoff quantity estimation.

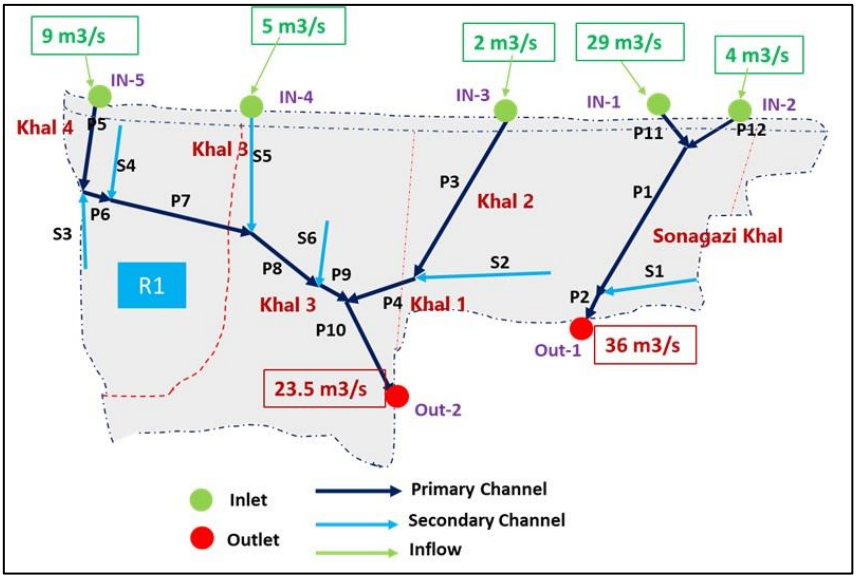


Figure 6: Schematic Diagram of Estimated Design Runoff Quantity in the Project Area

3.3 Development of Future Climate Change Scenarios:

After estimating the runoff flow, drainage adequacy assessment has been performed to check the capacity of existing reaches of canals. The all major reaches have been found inadequate considering the design storm event i.e. 100 year return period single day rainfall. For simulating the following scenarios have been developed to assess the flood risk within the study area. Table 2 shows the developed scenario for model simulation.

Scenario ID	Scenario Type	Considered Parameter	Considered Value	Objective
SC1	5 year Return Period Tidal Flood	Normal Coastal Tide	Average Year Tidal Flood	To assess the impact of tidal intrusion during the spring tide
SC2-1	Sea Level Rise	Only Sea Level Rise	0.2m (Year 2050)	To assess the impact of Sea Level Rise irrespective of any Cyclonic Event
SC2-2			0.4m (Year 2080)	
SC3	15 Year Return Period Extreme Storm Surge	1991 Cyclone	15 year Return Period	To assess the impact of Extreme Cyclonic Event Irrespective of Sea Level Rise
SC4-1	Sea Level Rise + 15 year Return Period Extreme Storm Surge	Sea Level Rise and 1991 Cyclone	• SLR: 0.2m (Year 2050) • Cyclone: 1991 (15 Year Return Period)	To assess the Combined impact of Sea Level Rise and Extreme Cyclonic Event
SC4-2			• SLR: 0.4m (Year 2080) • Cyclone: 1991 (15 Year Return Period)	
SC5-1	Sea Level Rise +15 year Return Period Extreme Storm Surge Landfall at Spring Tide	Sea Level Rise and 1991 Cyclone	• SLR: 0.2m (Year 2050) • Cyclone: 1991 (15 Year Return Period)	To assess the Combined impact of Sea Level Rise and Extreme Cyclonic Event if it makes landfall during spring tide
SC5-2			• SLR: 0.4m (Year 2080) • Cyclone: 1991 (15 Year Return Period)	
SC6-1	SLR+ 15 year Return Period Extreme Storm Surge Landfall at Spring Tide+1.5 m Sedimentation in the D/S due to Musapur Closure	Sea Level Rise and 1991 Cyclone Making Landfall During Spring Tide and Sedimentation due to Musapur closure	• SLR: 0.2m (Year 2050) • Cyclone: 1991 (15 Year Return Period)	To assess the Combined impact of Sea Level Rise and Extreme Cyclonic Event if it makes landfall during spring tide inclusive of 1.5 m land formation as intertidal area in the downstream of the area due to sedimentation
SC6-2			• SLR: 0.4m (Year 2080) • Cyclone: 1991 (15 Year Return Period)	

Table 2: Developed Scenarios for the Simulation of the Developed Coastal Flood Model

4. Result and Discussion:

After simulation of developed model for different scenarios, flood hazard assessment has been performed based on the inundation depth and extent statistics. Apart from inundation depth and extent, maximum surge height in case of cyclone and storm surge-based scenario is also recorded. The summary outcome of the flood hazard assessment for different scenarios are shown in table 3.

Sl No.	Scenario ID	Inundated Area (Sq.km) under Different Flood Depth Class					% of Total Area Inundated	Max. Surge Height (mPWD)
		F0 (<0.3m)	F1 (0.3-0.9m)	F2 (0.9-1.8m)	F3 (1.8-3.6m)	F4 (>3.6m)		
1	SC1	0.4	0.6	0.6	0.1	0.0	45	-
2	SC2-1	0.5	0.7	0.7	0.2	0.0	59	-
3	SC2-2	0.8	1.1	0.9	0.5	0.0	90	-
4	SC3	0.0	0.8	1.8	1.1	0.1	100	6.00
5	SC4-1	0.0	0.6	1.8	1.3	0.1	100	6.25
6	SC4-2	0.0	0.1	1.9	1.6	0.1	100	6.50
7	SC5-1	0.0	0.0	1.7	1.9	0.2	100	6.90
8	SC5-2	0.0	0.0	1.2	2.2	0.3	100	7.13
9	SC6-1	0.0	0.0	0.6	2.7	0.5	100	7.30
10	SC6-2	0.0	0.0	0.2	2.9	0.6	100	7.50

Table 3: Developed Scenarios for the Simulation of the Developed Coastal Flood Model

Though all the developed scenarios have been simulated but the most extreme scenario (SC6-2) has been considered for formulating the mitigation measures to ensure the flood protection even in extreme cases. The inundation depth and extent for considered extreme scenario is illustrated as figure 7.

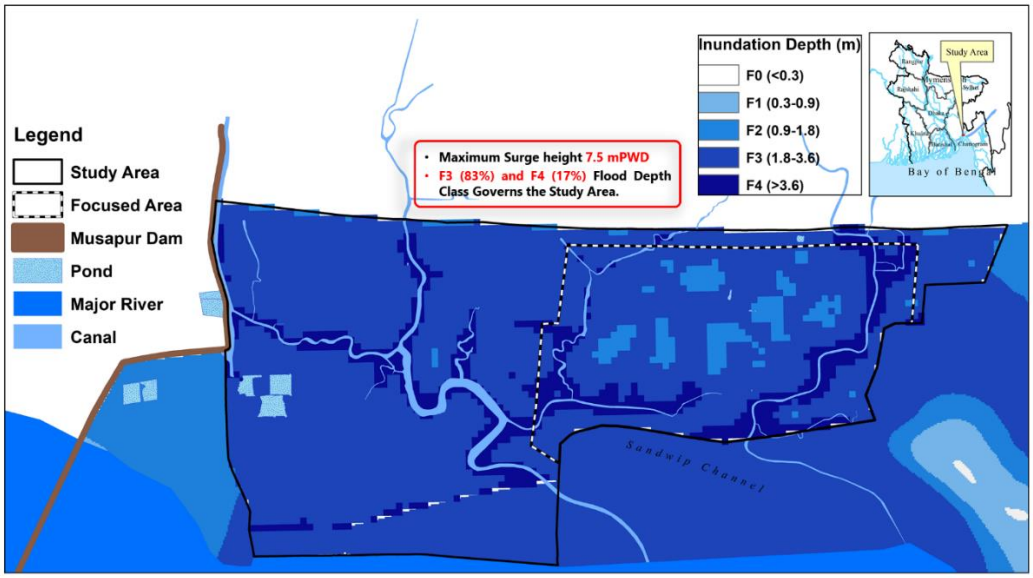


Figure 7: Inundation Depth and Extent for 0.4m SLR, Extreme Cyclone Making Landfall during Spring Tide and 1.5m Sedimentation in Downstream (SC6-2)

4.1 Formulating Mitigation Measure:

From the inundation depth and extent statistics it is evident that, almost entire study region is vulnerable and goes under water due to extreme cases. For formulating the mitigation measures a focused region from the entire study area has been selected where two major drainage canals have been detected. To ensure the smooth passage of upstream water and reduce the flood risk for considered extreme scenario following structural measures have been formulated.

- Formation Level: Considered existing formation Level for the focused region
- Construction of Dikes:
  - Sea Dike along Southern Boundary of Focused Area.

Top Width	Bottom Width	Length	Avg. Sill Level	Crest Level	Earth Filling Volume	Side Slope
6.5 m	71.5 m	2400 m	3 m PWD	9.5 m PWD	Approx. 608400 m^3	1:7 in Sea Side, 1:3 in country side

Table 4: Design Sections of Sea Dike

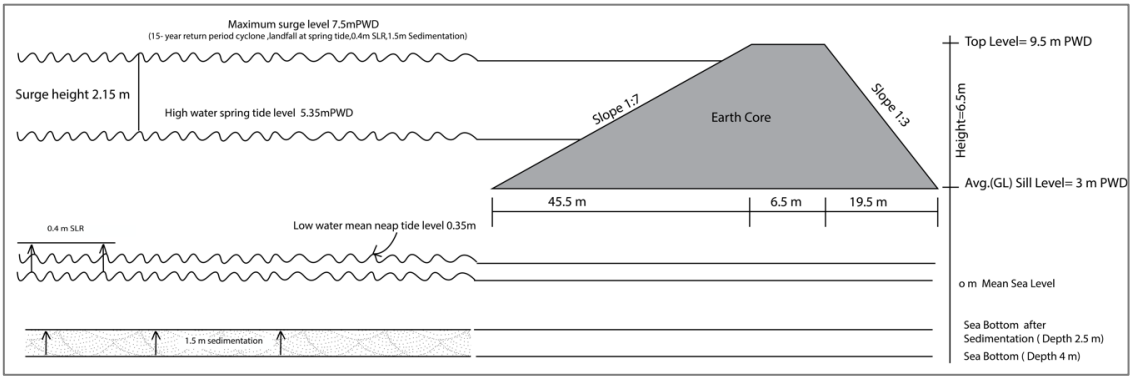


Figure 8: Schematic Section of the Proposed Sea Dike

- Western Marginal Dike or Flood Wall over Marginal Dike

Top Width	Bottom Width	Length	Avg. Sill Level	Crest Level	Earth Filling Volume	Side Slope
6.5 m	35.3 m	1090 m	4.5 m PWD	8.8 m PWD	Approx. 1,09,349 m^3	1:3 in both sides

Table 5: Design Sections Western Marginal Dike

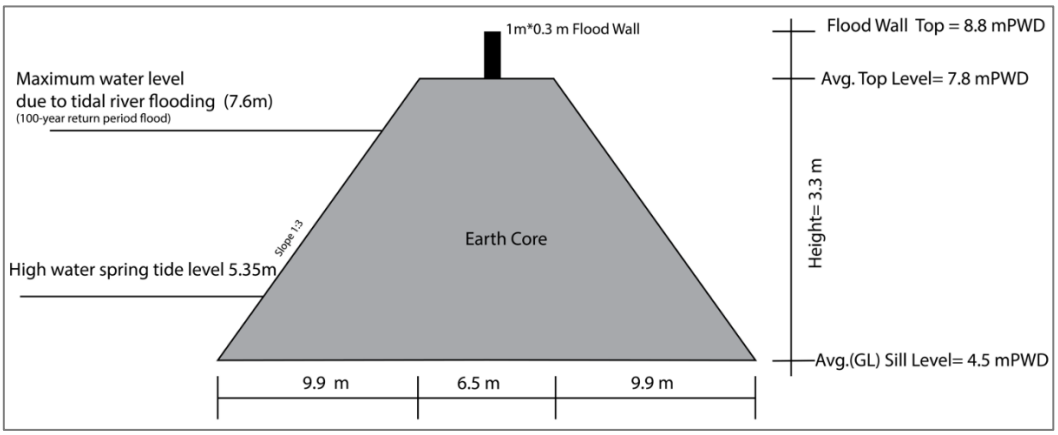


Figure 9: Schematic Section of the Proposed Western Marginal Dike

- Eastern Marginal Dike or Flood Wall over Marginal Dike

Top Width	Bottom Width	Length	Avg. Sill Level	Crest Level	Earth Filling Volume	Side Slope
6.5 m	35.3 m	440 m	4.5 m PWD	8.8 m PWD	Approx. 44,141 m^3	1:3 in both sides

Table 6: Design Sections Eastern Marginal Dike

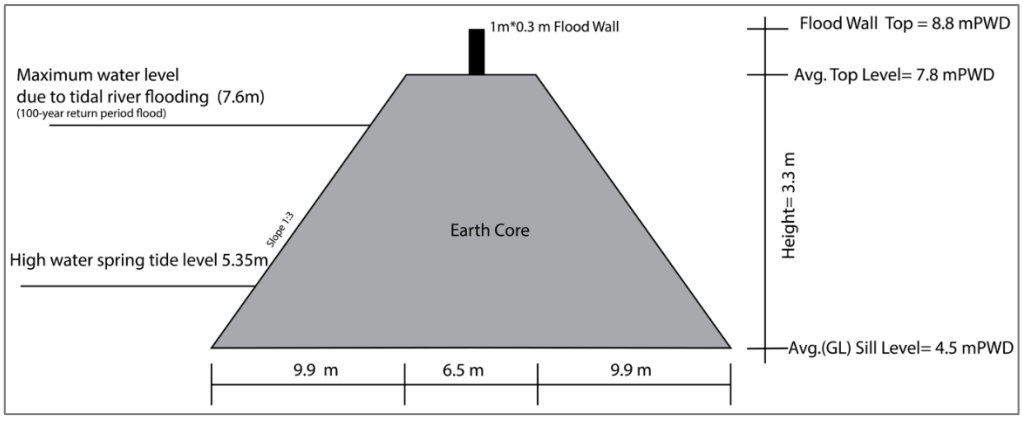


Figure 10: Schematic Section of the Proposed Eastern Marginal Dike

- Northern Marginal Dike

Top Width	Bottom Width	Length	Avg. Sill Level	Crest Level	Earth Filling Volume	Side Slope
6.5 m	30.5 m	1640 m	4.0 m PWD	8.0 m PWD	Approx. 1,21,360 m^3	1:3 in both sides

Table 7: Design Sections Northern Marginal Dike

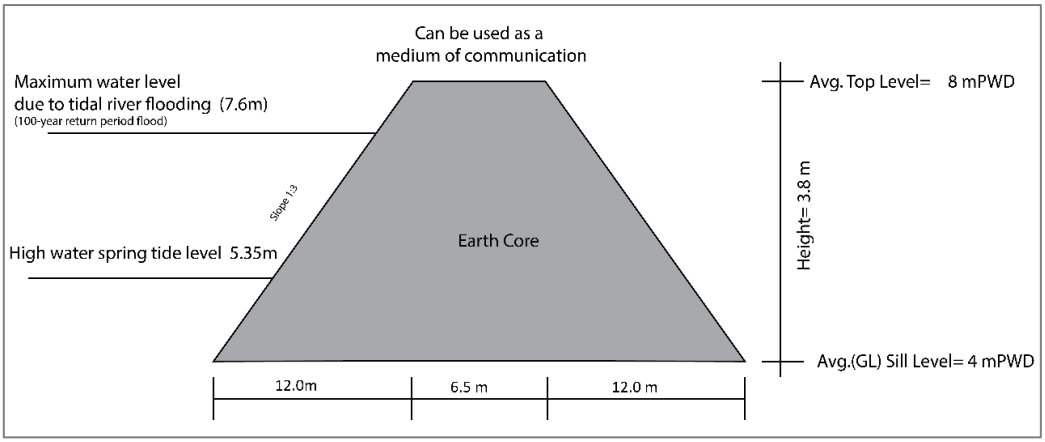


Figure 11: Schematic Section of the Proposed Northern Marginal Dike

- Re-excavation and Re-alignment of Khals

In order to ensure the smooth passage of upstream water, both the major canals namely "Khal 2" and "Sonagazi Khal" needs re-excavation work. The required depth and cross-sectional area for the canals are given in table 8. Figure 12 shows the proposed cross-sectional schematic diagram of the canals.

Khal Name	Top Width	Depth	Side Slope	Sill Level
Sonagazi Khal	27m	3.8m	1:2	2.6
Khal 2	25m	2.5m	1:2	3.3

Table 8: Design Cross Sections of Proposed Canals

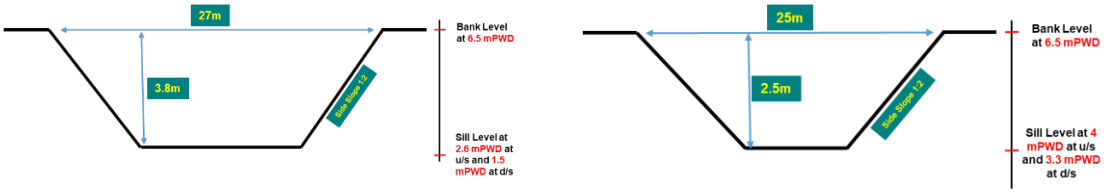


Figure 12: Schemetic Digram of "Sonagazi Khal" and "Khal-2"

- Inlets:

Establishment of box culverts for Inlet 1 and 2 as shown in Figure 13 and Figure 14 respectively and the location is shown in final layout Figure 17.

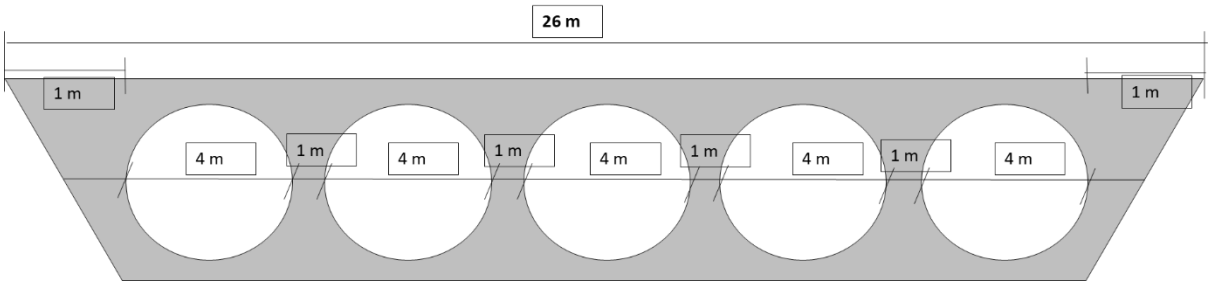


Figure 13: Proposed Section of Box Culvert at Inlet 1

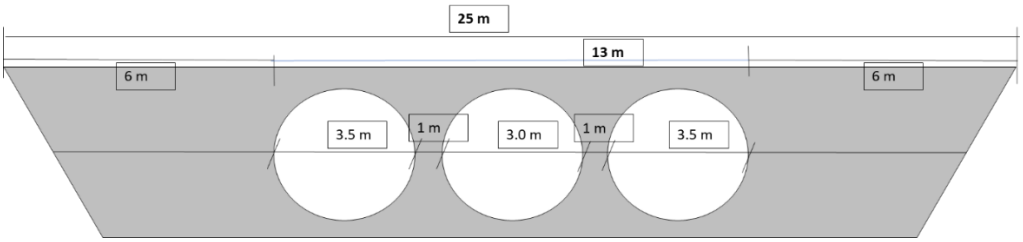


Figure 14: Proposed Section of Box Culvert at Inlet 2

- Regulators:

Two regulators at two major canals have been suggested to ensure the smooth flow of upstream rainfall runoff and tidal inflow from the Bay of Bengal. The design sections of proposed regulators are shown in table 9.

Khal Name	Number of Vent	Area	Sill Level	Remarks
Sonagazi Khal	5 vent	1.5m X 2m	1.5 mPWD	10-15 degree angular flap gate in sea-side
Khal 2	25m	1.5m X 2m	3.3 mPWD	10-15 degree angular flap gate western side of the focused area

Table 9: Design Sections of Proposed Regulators

- Proposed Water Reservoir

A 200m X 200m X 3.5m reservoir has been proposed to retain water during heavy rainfall event. The earth excavation volume for the reservoir has been calculated and identified approx. 1,40,000 m3

4.2 Simulation of Model with Mitigation Measure:

After formulating the structural measures considering the inundation extent for future extreme scenario, a site specific model is than developed and simulated again with these structural measure to identify whether the measures are adequate or not. Initially the site specific model has been simulated considering the existing land topography of the focused area where almost entire area becomes flooded. To eliminate this risk, the land topography of focused area has been elevated more upto 1.5 mPWD. Considering the raised land topography, the model is then again simulated and this time the entire focused area becomes flood free. Figure 15 and 16 shows the flooding condition for both situation.

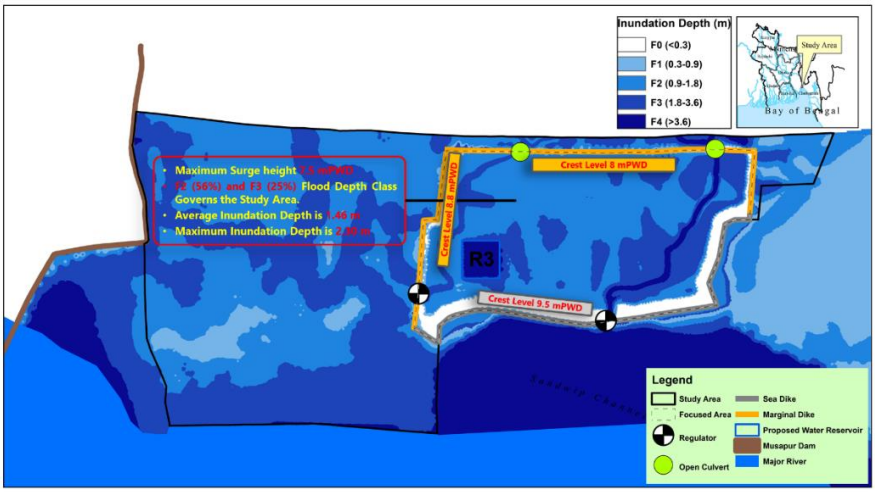


Figure 15: Simulation Result of Flood Model with Mitigation Measure (Existing Land Elevation)

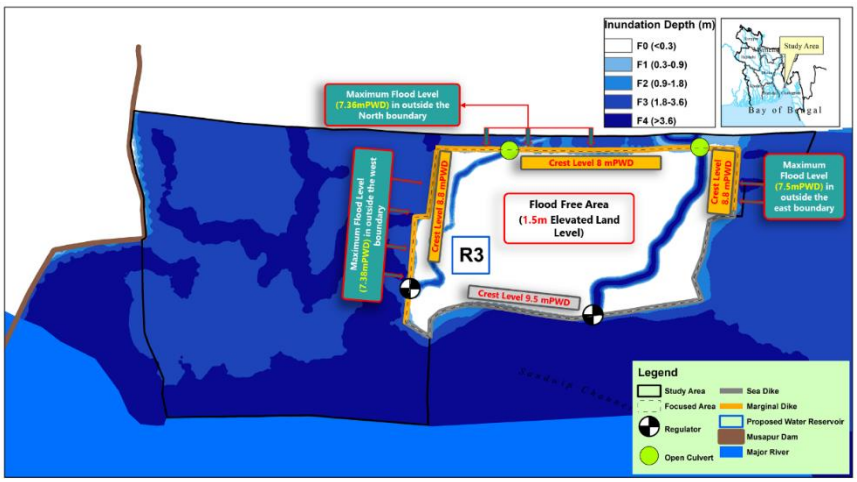


Figure 16: Simulation Result of Flood Model with Mitigation Measure (1.5 mPWD Raised Land Elevation)

4.3 Finalizing Mitigation Measures:

According to the simulation results of developed model with mitigation scenario, height of the dikes, canal cross-sectional area, reservoir volume and all other aspects are found adequate. The formation level is suggested to be raised up to 6.5 mPWD by increasing the existing formation level 1.5 mPWD which will help in better future sustainability and minimizes future flood risk. The finalized mitigation measures are shown in figure 17(in scale), where the total usable area for installing proposed grounded solar power plant has been estimated.

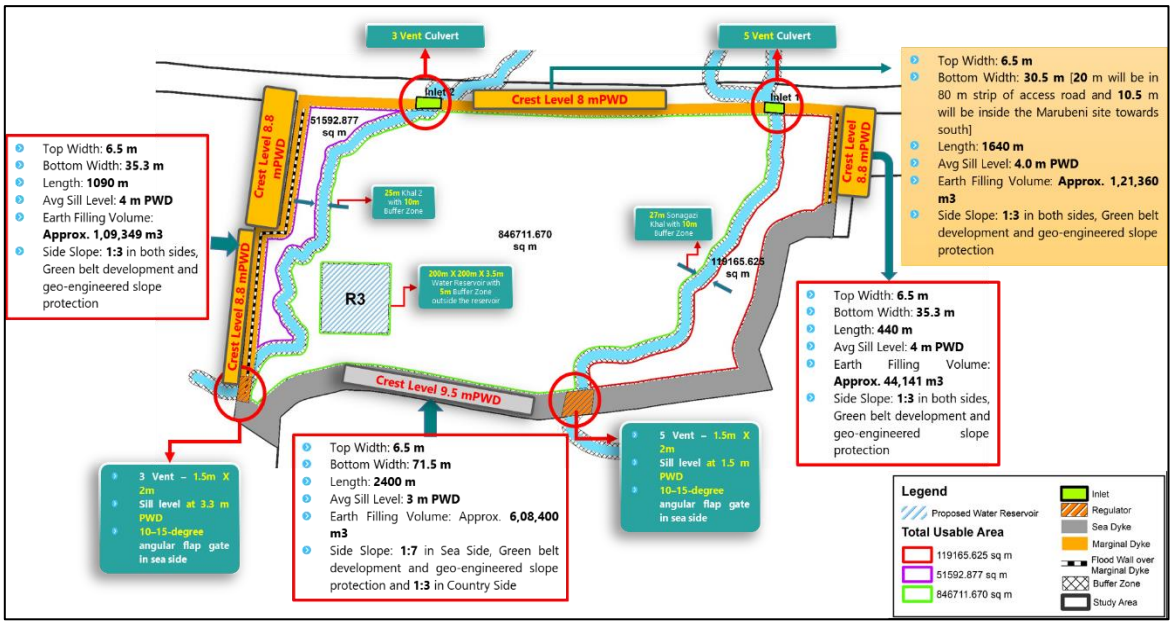


Figure 17: Simulation Result of Flood Model with Mitigation Measure (1.5 mPWD Raised Land Elevation)

5. Conclusion:

The preliminary flood mitigation measures have been proposed to sustain the development initiatives in coastal belt, based on the outcome of a site specific flood model. While simulating the model, runoff estimation has been done using rational formula instead of using rainfall runoff module. So for better result, the runoff module is need to be included. The preliminary cross –sectional drawings of sea-dike, marginal dike and open culverts are all based on the simulation result. So, detail design and drawings for each intervention is needed to be

performed during the implementation work for better sustainability. Further detail study is also suggested during the implementation phase. The overall mitigation measures are formulated keeping in mind that this will help to protect an inter tidal area near coastal belt for development projects and reduce the flood risk of the overall area during extreme events.

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The Role of Co-management in Climate Change, Disaster and Pandemic Nexus

Md. Mahfuzul Islam[1]

Abstract

The recent COVID-19 pandemic has affected the world and due to climate change impacts, such as extreme weather events (excessive heat, droughts, flooding, cyclones, storms and heavy rainfall) the effects would be twice during a pandemic. While calls are being made to deal with the linkages between climate change, disaster and pandemic it is time to deal with an integrated policy, co-management which would be the potential to build the resilience of the community by addressing regulations, participation, partnership, knowledge and learning resources. The purpose of this paper is to develop an integrative framework of the interaction between climate change, disaster and pandemic by addressing the role of co-management strategies during a catastrophe. The study integrates insights from climate change adaptation, disaster risk reduction and pandemic studies to provide a fresh perspective on needs and priorities in co-management strategies. This research contributes to the growing literature examining how co-management is the best fit for reducing climate change impacts and disaster risks while pursuing dual goals of social well-being, economic and environmental sustainability. This research covers a gap in the cross-cultural evidence existing in the literature and proposes the integration of the concepts of climate change adaptation, disaster risk reduction, public health, pandemic and co-management towards sustainable livelihood and community resilience.

Keywords: climate change adaptation, disaster risk reduction, resilience, pandemic, COVID-19

Introduction

Climate Change Vulnerability, Adaptation and Resilience

Vulnerability is frequently discussed in conjunction with climate adaptation. Adaptation (to climate change) is described by the IPCC (2014) as "initiatives and strategies to lessen the vulnerability of natural and human systems to actual or predicted climate change consequences." The process of adjusting to the existing or anticipated effects of climate change is known as climate change adaptation. Along with mitigation, it is one of the strategies to respond to climate change. Adaptation in human's attempts to mitigate or avoid harm and take advantage of opportunities; in natural systems, humans may act to aid adjustment. Figure 1 illustrates that how climate change impacts on our socioeconomic livelihood. It also explains the linkages between vulnerability, hazards and exposure where risk certainly emerged. In this diagram how the governance and adaptation and mitigation policy can be taken to reduce climate change vulnerability and risk as well.

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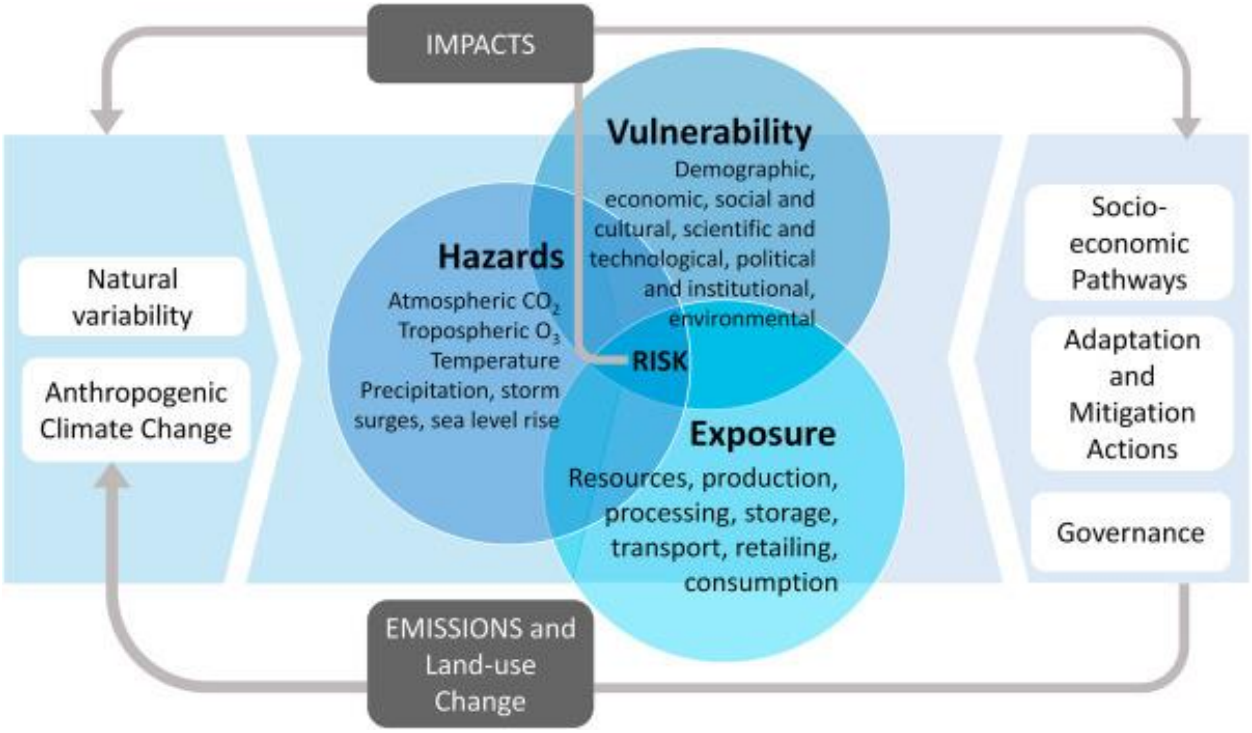


Figure 1: IPCC (2014)

Climate resilience refers to a society's, economy's, and ecosystems' ability to cope with a potentially dangerous event, trend, or disturbance. The primary purpose of climate resilience development is to reduce the climate vulnerability that communities, governments, and countries confront today as a result of climate change's numerous consequences. Climate resilience methods are currently being implemented at all levels of society and encompass social, economic, technological, and political solutions. The main goal of developing climate resilience is to lessen the climate vulnerability that communities, governments, and countries face today as a result of climate change's multiple repercussions.

Case of "Amphan"

Figure 2 illustrates that the case study of Amphan. As cyclone Amphan was the fiercest tropical cyclone ever originated in the Bay of Bengal, Bangladesh had done a massive evacuation activity by evacuating around 2 million coastal people in only 14,636 shelters compromising the COVID-19 risk issue (Appadurai, 2020). Due to the risk of COVID-19 pandemic and subsequent nationwide lockdown. The COVID-19 outbreak risk greatly affected the life and livelihood of the coastal people of Bangladesh (Lima et al., 2021). Moreover, the cyclone is a common phenomenon for coastal people, but COVID-19 is an unprecedented event. So, when a category 5 cyclone was about to hit the coastal areas of Bangladesh, people had to take the daunting decision of risking life by staying at home or risking infection by evacuating to a crowded safe place (Alam and Chakraborty, 2021).

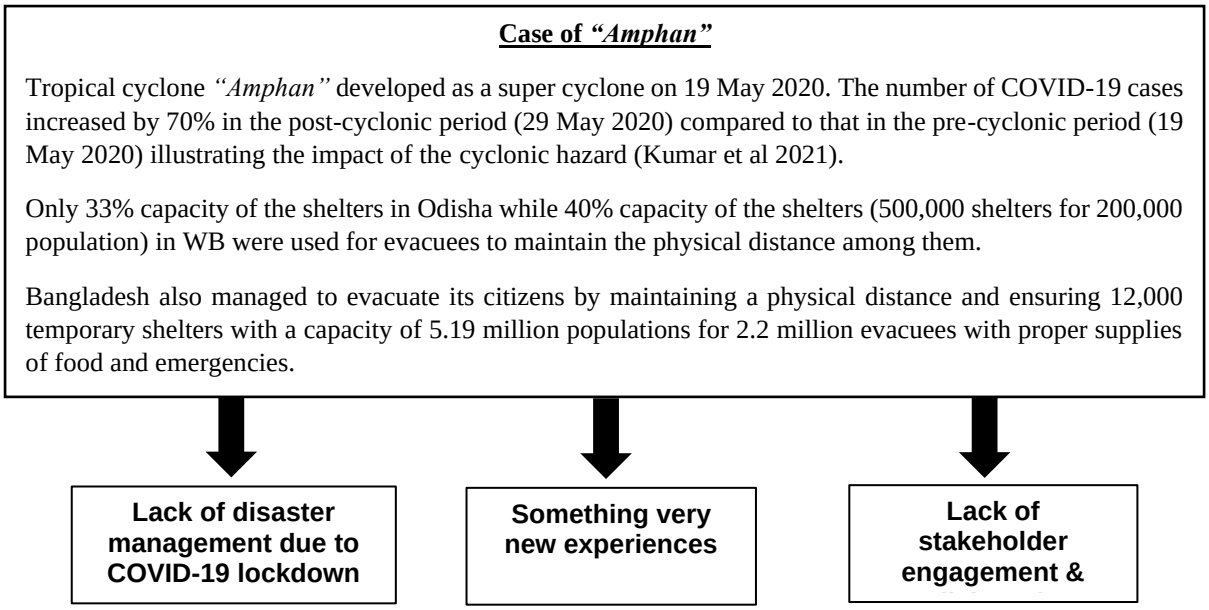


Figure 2: Indication of Vulnerability during a Superstorm occurs during COVID-19

Impacts on disadvantaged groups

Climate change and poverty are inextricably linked because impoverished people in low-income areas and developing countries around the world are disproportionately affected by it. Because of their increased exposure and vulnerability, those in poverty are more likely to suffer the negative effects of climate change. Vulnerability refers to how vulnerable a system is to the negative effects of climate change, such as climate unpredictability and extremes, or how ill-equipped it is to cope with them (Maja and Ayano 2021, Nyiwul 2021).

Climate change has a significant impact on human health, the economy, and human rights, all of which have an impact on environmental inequity. Low-income people and communities are more vulnerable to environmental risks and pollutants, according to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), in the year of 2014. They also have a harder time recovering from climate change's effects; which takes longer for low-income communities to be rebuilt after natural disasters.

When compared to non-indigenous peoples, climate change has a disproportionate impact on indigenous peoples around the world. These consequences are especially noticeable in terms of health, the environment, and communities. Indigenous peoples all across the world have developed ways and passed down traditional knowledge to cope with climate change. As representations of self-determination, these knowledge systems can be advantageous to both indigenous and non-indigenous populations in coping with climate change.

Gender inequality often means that women are more vulnerable to the negative effects of climate change. This is due to the gender role, especially in developing countries. That is, women often depend on the natural environment for their livelihoods and income. Climate change often puts more strain on women than men by further reducing women's already restricted access to physical, social, political and financial resources, and existing gender. May exacerbate inequality.

Nexus between Climate Change, Disaster and Pandemic

Figure 3 illustrates that the "triple threat and extreme vulnerability". It is basically the integration of three types of risks. Specifically, during a pandemic if any natural hazard occurs that time the communities are facing very vulnerable situation that time they are unable to handle the situation. For instance, during COVID-19, any natural disaster occurs (extreme weather events, cyclone, earthquake, tsunami, wildfire) and also due to climate change people are facing incredibly threatening condition which causes huge economic losses, damaging social life and even sometimes in a life threat. That is why the current paper is naming "the real superstorm" because of the extreme threating conditions.

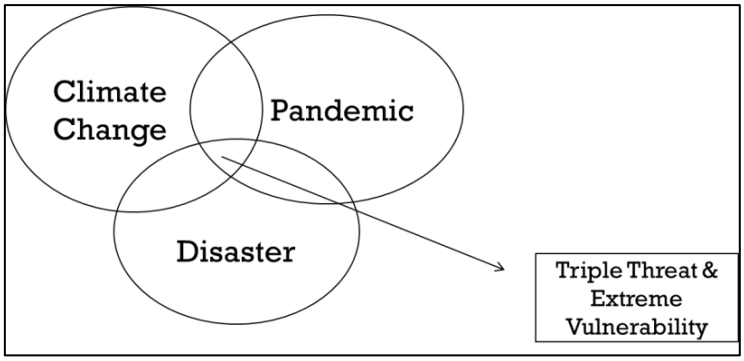


Figure 3: Triple Threat and Extreme Vulnerability

According to Savari and Zhoolideh (2021), extreme climatic condition is making the people into real trouble which also affecting the agriculture, farming and sources of income specially them whose are relying on the nature (fisherman, farmer). Ultimately, the loss of agriculture and farming activity, it would impact on the national economy, price inflation would be much higher and it would effect on the middle and lower income group. Poverty and hunger would be drastically emerged and it would become a massive famine due to the "triple threat and extreme vulnerability". For this reason, this paper is emphasizing on triple threat (climate change, disaster and pandemic) (Rahman et al 2021).

Role of Co-management as Community-based Adaptation towards Resilience

Co-management is a governance system that blends state control with local, decentralized decision-making and responsibility, enhancing the strengths of each individual body while mitigating its weaknesses (Dahlet et al 2021). Co-management includes components such as resource management, some form of collaboration between public and private players, and the partnership is not a static state but rather a process that unfolds over time (Carlsson and Berkes 2005). Certain pre-conditions in the external environment frequently need co-management (When calamities strike, individuals typically collaborate to solve the problems, and the answers frequently result in some change.) In this way, a disaster acts as a necessary pre-condition for co-management success, boosting the possibility that stakeholders will see co-management networking as a viable option (Cahyanto et al 2021).

Figure 4 illustrates that a framework for climate change, pandemic and disaster towards sustainable livelihood based on co-management strategies. In this framework, the co-management strategies effectiveness is indicating that the "triple threat and extreme vulnerability" would be much lesser if there is an existence of the holistic approach among central and local government along with the stakeholders' engagement (civil society, local community, commercial and public sector) are necessary to establish the resilience of sustainable livelihood (Garcia Ferrari et al 2021).

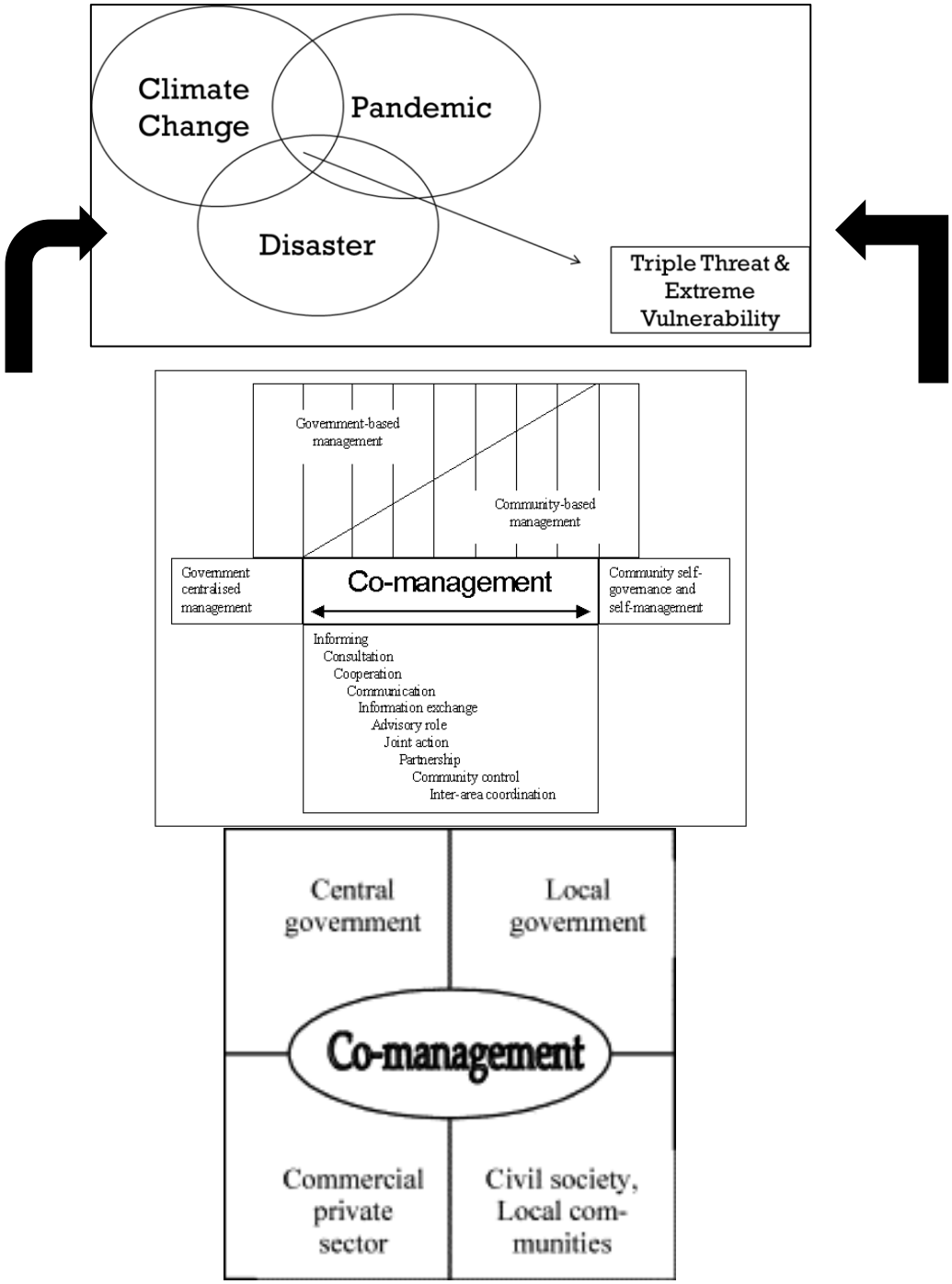


Figure 4: Framework for Climate Change, Pandemic and Disaster towards Sustainable Livelihood based on Co-management

Figure 5 illustrates that co-management initiatives should be combination of four types of crucial initiatives which are – vulnerability and risk assessment, stakeholders' engagement, joint action, mitigation and adaptation.

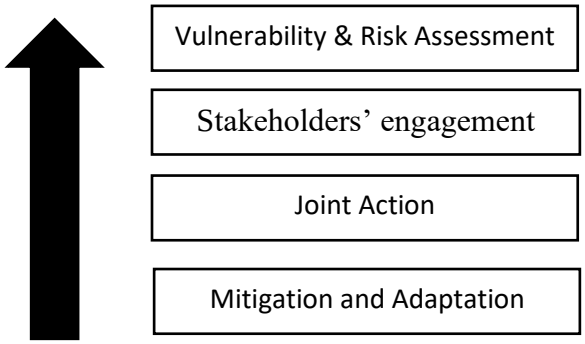


Figure 5: Co-management strategy to address "triple threat"

Conclusion

Bangladesh is facing a difficult situation, as it must deal with COVID-19 community transmission without any significant health infrastructure, policy, or legislative institutions in place to battle a pandemic. At the same time, the country is vulnerable to natural calamities such as floods, cyclones, landslides, and other natural disasters. While the globe struggles to achieve 100% COVID-19 immunization, social and behavioral sciences are the best hope for significant insights into how to manage the pandemic and its consequences (Alam and Chakraborty, 2021).

- To address the holistic climate change impacts with natural disaster during pandemic
- Co-management must be implemented nationwide and beyond boundaries.
- All sectors must be in a platform for the betterment of society and social well-being.
- Preparedness is necessary, simultaneously adaptation strategies should be implemented to reduce this extreme threat.

The Government and non-governmental organizations (NGOs) were accountable for good disaster management, but there were no community-based groups in charge of natural hazard management (Basnayake et al 2021). Because the relevant authorities pay insufficient attention to natural catastrophe management, the "triple threat" has had a hidden but crucial socio-economic impact. Creating community-level organizations to manage disasters and climatic extreme weather events during a pandemic is critical.

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Monitoring & Evaluation (M&E) for National Adaptation Plan Process in Bangladesh

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Abstract

Ministry of Environment, Forest and Climate Change is executing Formulation and Advancement of the National Adaptation Plan (NAP) Process in order to establish institutional arrangements and a coordinated strategy for mid- and long-term climate change adaptation investment. The NAP includes a national Monitoring and Evaluation (M&E) system for tracking adaptation progress towards achieving goals, deciding the efficacy of implemented interventions in reducing the desired level of risk, and assessing adaptation priorities. Beside this, the United Nations Framework Convention on Climate Change (UNFCCC) recognized adaptation monitoring and evaluation as an important step in the process of adapting to climate change, as it facilitates Parties to better understand climate risks, improve the effectiveness of adaptation measures, and increase accountability under the UNFCCC. Over the last decades, Bangladesh has made significant progress in combating climate change, establishing itself as a global leader in adaptation. Climate action has received a significant financial investment in the country, and the subject of climate change is constantly being mainstreamed into national planning and policy procedures. It is imperative to verify if adaptation measures are successful in building resilience and lowering vulnerability of climate-affected people in Bangladesh to guarantee proper use of limited resources. Furthermore, exhibiting increased transparency in climate action will aid in attracting international climate funds. While many government agencies in the country have used a variety of frameworks with varying degrees of success, there is still a pressing need to build a comprehensive, national framework for adaptation monitoring and evaluation (M&E). This paper devises strategies to develop an effective and transformative M&E framework to facilitate the National Adaptation Plan (NAP) process in Bangladesh.

Keywords: M&E, National Adaptation Plan, UNFCCC, Climate Change, Bangladesh

1. Introduction

Bangladesh is considered one of the most climate-vulnerable countries due to ensuing natural calamities and slow onset adversities. The changing climate regime, compounded with Bangladesh's unique geographical position, puts significant influence on the country's economy and progress toward sustainable development. Coastal tropical cyclones, monsoon flooding, flash floods, droughts, and other climate induced hazards are causing catastrophic losses in many socio-economic sectors. According to Germanwatch's 2021 Global Climate Risk Index (CRI), Bangladesh ranks seventh on the list of countries most vulnerable to climate destruction, while emitting only 0.56 percent of global emissions that are affecting our climate. Evidence shows that Bangladesh suffered economic losses worth $3.72 billion and witnessed 185 extreme weather events due to climate change from 2000 to 2019. Despite the bombardment of exacerbated climate adversities, Bangladesh has steadily progressed, both in terms of stamping its mark on the world economy and as a pioneer in addressing climate change adversities through efficient adaption strategies. Bangladesh has received international acclaim for developing and implementing climate change adaptation plans. Bangladesh's effective

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climate adaptation began with the National Adaptation Program of Action (NAPA) in 2005. Following the updating of NAPA in 2009 and the subsequent establishment of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), climate adaptation measures in the following decade were further streamlined and enhanced. In light of addressing both short-and long-term climate change uncertainties for water resources management, Bangladesh has recently formulated the 100 years' strategic delta plan. Mujib Climate Prosperity Plan (MCPP, 2021) has been developed as a leader of Climate Vulnerable Forum (CVF) countries. However, institutional arrangements and a coordinated strategy for mid- and long-term climate change adaptation investment are not yet in place. In order to meet this gap Formulation and Advancement of the National Adaptation Plan (NAP) Process is being executed by the Ministry of Environment, Forest and Climate Change, financed by the Green Climate Fund (GCF) and supported by United Nations Development Programme (UNDP). The NAP includes a national Monitoring and Evaluation (M&E) system for tracking adaptation progress towards achieving goals, deciding the efficacy of implemented interventions in reducing the desired level of risk, and assessing adaptation priorities. Monitoring and evaluation promote accountability and transparency in public spending, ensuring effective resource utilization for achieving adaptation goals. It will provide stakeholders and policymakers with information relative to achieving perceived targets and outcomes while portraying the current status of target achievements. Without an effective M&E structure, resources might be spent inefficiently and could be disbursed in projects that are not consistent with the adaptation strategies and priorities. NAP is providing a framework for monitoring adaptation implementation in the country. The national M&E of NAP may be integrated as one of the key components of the national MRV system. At the same time, the M&E system will act as a tool for monitoring, evaluating, and reporting the achievement of the implementation targets via a set of monitoring indicators. Adaptation M&E at the national level can eventually help report national contributions to the United Nations Framework Convention on Climate Change (UNFCCC), especially towards the Paris Agreement's global adaptation agenda. It can also assist countries in reporting on their progress toward achieving the Sustainable Development Goals (SDGs), especially SDG 13 on Climate Action and the Sendai Framework's targets and indicators.

This study primarily focuses on the key role, principles, resources, indicative output, framework, management and institutional arrangements, challenges, revision, updating and reporting process of monitoring and evaluation in relation to the implementation of the National Adaptation Plan (NAP) by using available secondary sources on adaptation M&E. This study also reviews the existing monitoring and evaluation system in Bangladesh. This paper devises strategies to develop an effective and transformative M&E framework to facilitate the National Adaptation Plan (NAP) process in Bangladesh by following the guidelines provided by Least Developed Countries Expert Group(LEG) and integrating the climate objectives mentioned in the BCCSAP, NAPA, the Five-Year Plan, Perspective Plan, Bangladesh Delta Plan etc.

2. Objectives

The specific objectives of this study are as follows:

a) Providing a critical review of existing M&E initiatives in Bangladesh and M&E system adopted in NAPs of developing countries
b) Identifying challenges and need of adaptation M&E in Bangladesh
c) Conceptualizing a M&E framework for NAP in Bangladesh

3. Methodology

This study was conducted through available secondary resources such as relevant literatures, publications relevant technical reports, news articles, existing M&E initiatives in Bangladesh, National Adaptation Plans of developing countries submitted under UNFCCC, international guidelines etc. regarding M&E of NAP. The methodology for this study can be divided into three steps: reviewing relevant literatures, assessing challenges and need and then conceptualizing a M&E framework for NAP in Bangladesh.

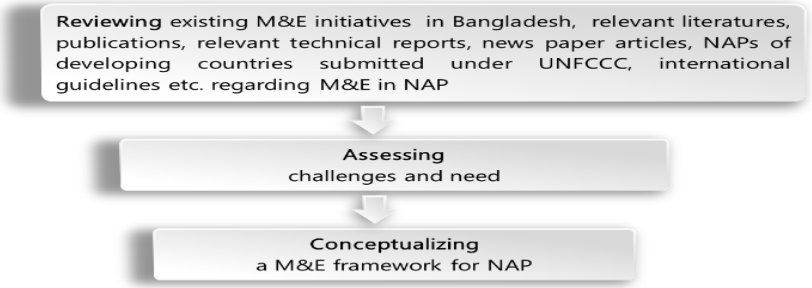


Fig. 1: Methodological approaches of this study

4. Policy landscape for supporting M&E in Bangladesh

Understanding the policy and legal framework context is essential to assess adaptation challenges, goals, and the theory behind adaptation in priority sectors. For this study policy documents like National Adaptation Programme of Action (NAPA, 2005), Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009), Third National Communication (TNC, 2018), Bangladesh Delta Plan 2100, Climate Fiscal Framework (CFF, 2020), Second Perspective Plan 2041, National Development Framework: The Eight Five Year Plan (8^{th} FYP), Climate Financing for Sustainable Development, 2021-22, Mujib Climate Prosperity Plan up to 2030 etc. has been reviewed. Both NAPA and BCCSAP did not mention any appropriate framework for adaptation M&E. BDP 2100 highlighted a solid M&E effort for sound implementation of the BDP 2100 in the context of Adaptive Delta Management. The CFF emphasizes designing the projects in line with the thematic areas, programs, and actions mentioned in the BCCSAP while preparing the project proposal. SPP 2041 emphasizes an effective monitoring and evaluation system that will be strengthened from production to processing and delivery for enhancing export and building the confidence of international buyers regarding products safety and nutritious value. The CFSD recognizes the importance of the M&E system to track financial progress and ensure transparency. Inclusion of result-based framework in sector action plans, introducing national priority indicators in perspective plan and five-year plan, developing M&E framework for BDP2100, the emphasis of MRV for tracking the progress of GCF country program and NDCs would certainly complement the NAP M&E process.

5. M&E Initiatives and Entities in Bangladesh

Efforts have been made to understand the functionality of exciting M&E initiatives and entities like SDG tracker, annual performance agreement, Implementation Monitoring and Evaluation Division (IMED), Planning Division, Ministry of Planning, Bangladesh Bureau of Statistics (BBS), Bangladesh Climate Change Trust (BCCT). It has been found that there are no such existing dedicated adaptation M&E initiatives in Bangladesh as we have seen in foreign developing country's NAP. Even though MoEFCC, a dedicated ministry for climate change, lacks separated proper adaptation M&E. The current M&E template of BCCT is primarily focused on tracking the financial and physical progress of their interventions, with no

provisions for measuring their impact or results. Yet initiatives related to SDG monitoring through SDG trackers, involvement of BBS and BCT for collection of a large set of SDG indicators data would certainly complement the NAP M&E process.

6. M&E focus for Foreign NAPs

30 countries have been submitted their National Adaptation Plan under UNFCCC so far, of which 20 documents are in the English language. These 20 documents of different countries have been reviewed to identify various components of their adopted M&E system. Most of the countries adopted the M&E system in an overarching way. The NAP of Suriname, Kenya, Nepal, Burkina Faso, Cambodia, Fiji, Armenia, and Ethiopia recognize an effective M&E system that may provide information relevant for adaptation and track their NAP implementation.

Country	Approach
Kenya	Indicator-based system using outcome and process-based monitoring, reporting and verification (MRV) of actions under the indicators measured at the national and county levels. Agriculture and livestock are both sectors for which prioritized adaptation actions to be monitored are proposed.
Suriname	Highlights the six (6) overarching strategic priorities which require action regardless of the sector in which action is taken the geography of whether hinterland or coastal or urban or rural. Their first strategic outcome is Institutional arrangements, policies, and capacities to lead and coordinate national and sub-national climate change adaptation.
Fiji	Adopted a simplistic monitoring system developed in the United Kingdom by Adaptation Sub-committee in 2015 to track progress with the NAP's implementation using traffic light colors as the basis for summarizing progress (ideally based on a PFP's assessment).
Nepal	Programme-level indicators (based on Pilot Program for Climate Resilience – PPPCR) core indicators). Indicator system piloted for eight climate change projects and indicators linked to National Adaptation Programmes of Action (NAPA) priorities; matched by individual project-level indicators. 149 sub-national 'environmentally friendly' indicators for different sectors (including climate) and scales (household to district).
Suriname	Sets out tables for monitoring activities, outcomes, and impacts with specific lists of objectives, anticipated results, performance indicators, data sources, data collection methods, data collection frequencies, and entities responsible for data collection for each of the National strategic priorities of the National Adaptation Plan.
Cambodia	Adopts a twin-track method to assess how good national institutions manage climate risks through institutional readiness indicators and how effective climate actions reduce vulnerability or lower carbon emissions through impact indicators.
Armenia	Includes macro level monitoring, disaggregated sectoral or geographic and micro level outcome indicators at both the outcome and process level in their accountability, evaluation, and monitoring system.

Tab. 1: Approaches of M&E in foreign NAPs

7. International Guidelines for M&E of NAP

Necessary direction has been derived to conceptualize adaptation M&E in the NAP process by reviewing some international guidelines for M&E of NAP. Efforts have been made to review 'Technical guidelines for the national adaptation plan process' by LEG (2012), 'Adaptation made to measure: A guidebook to the design and results-based monitoring of climate change adaptation projects' by GIZ (2013), and 'Tracking adaptation in agricultural sectors' by FAO (2017).

LDC Expert Group (LEG) issued 'Technical guidelines for the national adaptation plan process' in 2012, as part of the UNFCCC process, to Parties and relevant organizations in response to the mandate given to the LEG by the COP. This guideline provides examples of practical methods and tools to establish a monitoring and evaluation system of adaptation needs and measures and plans to iteratively address emerging markets based on lessons learned from countries already developing adaptation M&E. This guideline suggests four steps that include a plan for monitoring and evaluation, with a method for data collection and ongoing compilation and synthesis of new information on impacts and vulnerabilities to be used in updating the NAPs. The NAP Technical Guidelines recommend the following steps to establish an M&E system from the outset of a NAP process.

1. Monitoring the NAP process
2. Reviewing the NAP process to assess progress, effectiveness and gaps
3. Iteratively updating the national adaptation plans
4. Outreach on the NAP process and reporting on progress and effectiveness

GIZ published 'Adaptation made to measure: A guidebook to the design and results-based monitoring of climate change adaptation projects' in 2013, aiming at government representatives, donors, and non-governmental organizations involved in planning and implementing adaptation projects. It is also intended as a reference source for national and international organizations, NGOs, and research bodies that require a practical framework for the results-based design of adaptation interventions and verification of the results achieved. This guidebook offers practical advice to the questions "What characterizes an adaptation project?" and "How can adaptation results be measured?" It proposes the following five steps to design adaptation projects and their results-based monitoring systems based on the theory of change.

1. Adaptation context
2. Contribution to adaptation
3. Theory of change
4. Indicators and baseline
5. Operationalization

The publication on "Tracking Adaptation in Agricultural Sectors – Climate Change Adaptation Indicators" by FAO (2017) outlines the importance of tracking adaptation in the implementation of the Paris Agreement. It provides a flexible and consistent indicator framework for tracking adaptation in agricultural sectors, including agriculture, forestry and fisheries and aquaculture at the national level. The framework is based on recognizing that adaptation should be tracked by analyzing different indicators across agricultural sub-sectors. National decision-makers and planners can use the framework provided in this document in

farming sectors and other stakeholders, including development partners, research institutions and adaptation practitioners, involved in tracking adaptation progress by customizing it at the local level; granular data are available.

8. Challenges and Need of Adaptation M&E

Implementation of adaptation M&E in Bangladesh comes with many challenges as climate change adaptation actions are affected by uncertainties and focus on valued objectives. The first challenge is to maintain coherence between local adaptation M&E systems, respond to very specific circumstances, and report at national and global levels. Lack of knowledge and understanding on climate change adaptation and low levels of awareness regarding the importance of measuring the effectiveness of adaptation interventions are also significant challenges. Limited coordination amongst different stakeholders is also a challenge for developing a successful M&E framework for climate change adaptation projects in Bangladesh. Lack of consistent baseline data on climate change, limited accessibility of data, inconsistencies in data formats, complexities regarding the ownership of data, lack of MIS for collection, storage, and retrieval of data also hinder implementing appropriate adaptation M&E process. There is a significant knowledge gap and technical inadequacies when it comes to implementing and coordinating adaptation M&E. This leads to focusing on monitoring financial and physical progress without substantial considerations for assessing desired impacts of the adaptation project.

In this regard, there is a continuous need to integrate local M&E systems into NAP M&E, enhance coordination amongst relevant skate holders, improve knowledge and understanding on climate change adaptation, enhance skills on applying M&E tools and approaches, raise awareness regarding the importance of measuring adaptation success, provide technical inadequacies in terms of data collection and management skills and ensure availability of necessary infrastructure (hardware and software). For this, existing M&E initiatives like SDG trackers, Bangladesh Bureau of Statistics (BBS) monitoring system, proposed result-based framework in sector action plans, national priority indicators in perspective plan and five-year plan, project implementation monitoring by IMED, developing M&E framework for BDP2100, the emphasis of MRV for tracking the progress of GCF country program and NDCs can be integrated with NAP M&E. Appropriate approach and methodology for measuring adaptation effectiveness can be developed by using a threefold system to monitor, evaluate, and report adaptation progress. The first tier for the national level (Tier 1) can be the very concise and simplistic summary of the planning level M&E outcome. The second tier (Tier 2) for planning level M&E can be the summary of program or project level. The third tier (Tier 3) for program or project level M&E can track against a specific program or project. SMART (exact, measurable, achievable, relevant, and time-bound) indicators can be selected for outcome/ result-based framework keeping consistency with existing national priority and SDG indicators. Besides this, coordination and engagement amongst relevant stakeholders for knowledge sharing and data harmonization can be enhanced.

9. Conceptual M&E Framework for NAP in Bangladesh

This study proposes a threefold system to monitor, evaluate, and report adaptation progress. The first tier is for the national level (Tier 1), the second tier for planning level (Tier 2), and the third tier would be for program or project level M&E (Tier 3). The M&E report of national level will be the very concise and simplistic summary of the planning level M&E outcome, and the planning level M&E will be the summary of program or project level M&E. The Tier 1 and Tier 2 will track progress against strategic actions and Tier 3 against specific program or project.

It proposes a traffic light color-based simplistic M&E system for the national level and outcome or result-based M&E system for the planning and program levels. It also recommends selecting SMART (specific, measurable, achievable, relevant and time bound) indicators for outcome/ result-based framework, keeping consistent with existing national priority and SDG indicators.

Process-based M&E analysis may include input, activity and output related indicators which reflect the quantity, quality and timeline of the input or resources provided, utilization of the resources and amount of goods or services produced directly by the adaptation actions respectively. In contrary, outcome or result based framework may involve indicators related to outcome or impact to monitor and assess the medium-term results or broad long-term changes and effectiveness of adaptation actions toward the ultimate goal. However, gradual efforts should be made in the medium and longer-term to develop a combination of process and outcome or result-based M&E system for Tier 3 M&E following the 'Theory of Change' principles.

A Climate Change Wing (CCW) of MoEFCC can be established to hold the stewardship of the NAP M&E system with the sole responsibility of preparing to compile and submit the Tier 1 and Tier 2 M&E reports. The IMED can be responsible for preparing the summary Tier 3 M&E report collecting data and information of proposed outcome-based indicators from relevant multi-sectoral stakeholders from national and local levels.

Responsible entities or agencies for implementing NAP will be in-charge of collecting data relevant to process and/ or outcome-based indicators of a program or specific intervention or project for tracking adaptation progress internally following a comprehensive process or/and outcome-based framework. Responsible implementing agencies will provide the collected/ monitored data and information to IMED as a national implementation monitoring and evaluation agency to track adaptation program or project level M&E for physical and financial progress from Government's end. Coordinating bodies from MoEFCC will keep liaison with IMED to summarize the Tier 1 and Tier 2 M&E. NSCC and NEC, NAP will, regularly, guide the national level actors upon analysis of M&E report for further update and/ or revision of NAP actions. In contrast, IMED would guide the local level actors for the update or correction to tackle any implementation barrier ensuring robust transparency and accountability, including finance-related matters. The data collection of monitoring indicators and evaluations should be done monthly. Many of the proposed indicators may not have any baseline data or developed systems to collect the data in an organized way. In this regard, MoEFCC and IMED jointly develop a standardized protocol for data collection, sharing, process, storing, upload, update, and user right by/among key stakeholders. The provision of outsourcing such activities may also be explored in the above aspects to make the NAP M&E system operational.

A sophisticated dynamic web-based M&E system can be developed to support the data collection, monitor, update and generate Tier 1, Tier 2, and Tier 3 reports with appropriate weighted aggregation techniques using values of selected indicators for a timeline established through a comprehensive study. The proposed web-based M&E system will need to collect, upload, process, or update data in the developed standard result-based framework by/among the relevant stakeholders under the data protocol and mandated by the proposed legislation. The initial framework should include baseline data and set major targets for indicators against each strategic action for Tier 1 and Tier 2 and against each program/specific project for Tier 3, respectively, in different future timelines i.e., 2030s, 2041s and 2050s to track the progress of M&E. Later interim targets will also be set for sub-yearly or yearly timeline by the concerned national focal to keep up the strive for achieving the major targets of NAP. The aggregation should follow the bottom-up approach i.e., Tier 3 report will give input to Tier 2 report and

Tier 2 report will culminate the Tier 1 report. Existing similar initiatives such as SDG trackers, BDP2100 M&E tool, or MRV tool of NDC may be coordinated with the tool.

Furthermore, NAP envisages launching an appropriate external evaluation mechanism parallel to internal M&E of adaptation actions. External evaluation would facilitate verification of M&E, enhanced transparency, and auditory process of NAP progress and outcome, opening a wide window of climate investment through international climate funds bilateral or multilateral development partners. Proper communication strategies are advised to be brought in place to report and inform M&E outcomes to global NAP platforms such as UNFCCC or Conference of Parties.

Tier 1: National Level M&E

The simplistic national level M&E will use indicators based on three traffic-light colours, i.e., **RED**, **AMBER,** and **GREEN,** as follows:

- Strategic action not implemented/lack of progress in delivering actions (**RED**)
- Strategic measure partially implemented/some progress in providing activities (**AMBER**)
- Strategic move fully implemented/significant strides in delivering activities (i.e., completed or on-track) (**GREEN**)

The implementation status and threshold for the above three criteria can be set based on proposed weighted aggregation techniques generating progress status in percentages of 0 to 100, amalgamating the Tier 2 M&E report status. For example, the following figure includes simplistic indicator and its status if 'Ensure protection against climate change variability and induced natural disasters' is a goal of NAP.

Strategic Actions	Simplistic Indicator and its Status
Goal 1: Ensure protection against climate change variability and induced natural disasters	
SA 1.1: Combat cyclonic storm surge, sea-level rise, and salinity intrusion	Not implemented or lack of progress Partially implemented or progressed Fully implemented or significantly progressed

Tab. 2: Exemplary summary status reflecting the current tentative situation of strategic actions in Tier 1

Tier 2: Planning Level M&E

The following table provides some possible outcome-based frameworks and examples of potential indicators for planning level M&E system at Tier 2:

Strategic Actions	Outcome	Possible Indicators
Goal 1: Ensure protection against climate change variability and induced natural disasters		
SA 1.1: Combat cyclonic storm surge, sea-level rise, and salinity intrusion	Outcome 1: Increased adaptive capacity of human, natural, and economic systems to reduce risk and vulnerabilities and ensure protection against climate change-induced disasters in coastal areas	1. Affected areas or exposure to different climate change-induced hazards (storm surge, sea-level rise, salinity intrusion) 2. Measurement of discharge, water level, salinity in designated locations 3. Measures regarding infrastructure development (embankment height, regulator nos., etc.) 4. Vulnerable population 5. Loss and damages due to climate change-induced slow onset and extreme events (coastal area) 6. Household-level potable drinking water facility 7. Per capita freshwater availability in saline prone areas etc.

Tab. 3: possible outcome-based frameworks and examples of potential indicators for planning level M&E system at Tier 2

Tier 3: Program or Project Level M&E

The following table illustrates the process and result or outcome-based framework for a program or project level M&E (Tier 3) following 'Theory of Change':

Goal	Program	Process	Outcome	Possible Indicators
Goal 1: Ensure protection against climate change variability and induced natural disasters	SA 1.1: Promote extension of Climate-Smart Agriculture (CSA) practices			
	Program 1: Improve Irrigation Water Efficiency	Input: • Guidelines for installation of buried pipe and water-saving technologies • Strengthen extension services Activity: • Extension of Water Saving Technologies like AWD • Installation of Buried Pipes etc. Output: • Irrigation water efficiency increased	Outcome: • Agriculture productivity increased for the Boro crop • Emission from agriculture practices decreased • Resilience enhanced for the crop sector	• Boro crop production • Irrigation water efficiency • Coverage of buried pipe • Groundwater level • Emission from agriculture etc.

Tab. 4: Process and result or outcome-based framework for a program or project level M&E (Tier 3)

10. Revision and Updating of NAP

As climate change appears in diverse ways, with varying implications over time, the NAP should be considered a living document with a planning horizon through the 2050s and at least 5 five-year updating/revision cycles. As a result, the strategy must be evaluated, amended, or updated in an iterative manner after a set period of time has passed through effective and regular

M&E. It necessitates the adoption of feasible mechanism that takes into account past adaptation difficulties, new adaptation issues, social and environmental changes, new policies, and national and international government pledges, among other things. Reviews, revision, and updates may be carried out in the following ways:

- **A regular review and significant update** at the end of each five-year implementation cycle by incorporating the lessons learned during the earlier five years of implementing the NAP to increase the plan's effectiveness to tackle uncertainties posed by climate change and maximize the country's gains' resilience sustainable development.
- **A mid-term review and minor revision** at the end of the half implementation cycle aims to determine the progress made and make necessary changes.
- **Ad-hoc reviews and revision** may be conducted based on the contexts triggered by factors such as addressing sudden natural extremities or unfavorable country situations, entirely undesirable adaptation process and outcomes, the effectiveness of adaptation measures, variations observed compared to initial climate projections, changes in the vulnerability of development sectors, etc.

Every 2.5 years, a summary progress report on the NAP implementation process can be generated by CWC, MoEFCC in coordination with IMED compiling the M&E review report and recommendations for any revision or update. The report may comprise information on the following issues:

- New findings on climate change and vulnerabilities in Bangladesh,
- Position of the country to reducing anticipated risks and enhancing resilience,
- Progress and obstacles in achieving goals and indicators,
- Recommendations for future steps and measures.

11. Discussion and Conclusion

Bangladesh has made significant progress in combating climate change, establishing itself as a global leader in adaptation. Climate action has received a significant financial investment in the country, and the subject of climate change is constantly being mainstreamed into national planning and policy procedures. To ensure proper utilization of these limited resources, it is important to verify whether adaptation efforts are being successful in enhancing resilience and reducing the vulnerability of climate affected communities in Bangladesh. Without an effective M&E structure, resources might be spent inefficiently and could be disbursed in projects that are not consistent with the adaptation strategies and priorities. Proposed conceptual approach will establish necessary building blocks and hence mark a step in the right direction by enhancing coordination amongst relevant stakeholders in the country and building their technical and institutional capacity.

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Emphasis on Environmental Sustainability in Bhutan's Philosophy of Gross National Happiness (GNH): A Study Keeping Focus in the Present Context of Bangladesh.

Shosunth Chandra Sarker[1], Tarnima Warda Andalib[2], Dil Rowshan Zinnat Ara Nazeen[3]

Abstract

Environmental sustainability, as a development paradigm, has evolved with significant magnitude in the development discourse since 1980s and especially with the introduction of 'Brundtland Report' in 1987 that suggests to promote economic growth keeping natural resources well protected for the future. Termed as 'sustainable development' the 'Brundtland Report' becomes the base of development globally and as the time progresses strong consensus has remarkably been developed among the development thinkers worldwide that the indiscriminate pillage of environment has to be stopped anyhow and that the countries worldwide have to make the constrained use of natural resources in their pursuits of promoting economic advancement. A small country like Bhutan has been conducting almost the same strategy over the years and successfully promoting economic growth slowly but constantly and preserving ecological balance simultaneously through its development policy of Gross National Happiness (here after GNH) even before the introduction of 'Brundtland Report'. Basically comparative in nature, this study keeps its main focus on how the issue of environmental preservation has so firmly been prioritized in Bhutan in undertaking any development initiative and how the issue of environment at present is highly ignored in Bangladesh for keeping its sole focus on economic growth and its negative consequences in the lives of people in Bangladesh. This study is qualitative in nature that has been developed through a robust content analysis of the relevant secondary data substantiated by qualitative interview of five scholarly participants in in-depth manner with semi structured questionnaire. This paper argues that Bangladesh needs to keep focus more on preserving its natural resources and take the insights of Bhutan's philosophy of GNH in setting its development strategy. And the study findings can contribute to the policy makers of Bangladesh to a significant extent that the pace of economic growth can be fostered keeping natural resources well protected that Bhutan has successfully doing over the years.

Key Words: Bangladesh, Bhutan, Brundtland Report, Economic Growth, Environment, GNH,

1. Introduction

Sustainability is obviously not new a concept and people always to some extents feel that their persistence is embedded strongly on the resilience of ecological balance (Dreze and Sen, 2013:41). However, this very issue of sustainability emerged with profound significance with the introduction of 'Brundtland Report' in1987 that suggests going for gaining economic growth without causing any negative impact on environment. Since then, environmental sustainability becomes an integral part of development and in the Rio Declaration in 1992, for instance, where

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178 countries participated, it was stated that economic growth has to be incorporated with environmental sustainability (ibid,p.27). However, Bhutan, a small and poor country in South Asia has been following the very spirit of sustainable development over the years and has had quite remarkable success in promoting economic growth and protecting its environment applying the development philosophy of GNH which hardly got any attention towards the development thinkers in the global arena. Under the shrinking state of natural resources worldwide and especially for the countries like Bangladesh that has been under serious threat of natural calamities, Bhutan can be a glaring testimony how the economic growth of a country can be fostered in parallel with environmental harmony. As the time progresses, GNH has already got considerable attention in the global development discourse. The disaster in natural environment in Bangladesh has now been a burning issue and despite the variations in different dimensions- population density, governance practice, etc- Bangladesh can take the different insights from Bhutan. The present study seeks to analyze this less focused issue and find out the answer to the questions- How does Bhutan succeed to preserve its natural environment in line with economic growth? How can Bangladesh be benefitted taking insights from Bhutan in minimizing its loss of natural resources keeping the pace of economic growth upwards?

This paper progresses in several spheres. Along with the introductory analysis, first section analyses the theoretical aspects of Sustainable Development and GNH. The second section discusses the research methodology. The third section explains the study findings followed by the contribution of the study with a concluding analysis and necessary recommendations in the fourth section.

1.1 Review of the Literature

1.1.1 Concept of Sustainable Development

As alluded in the prior, the concept of sustainability somehow inherent in human thought (Dreze and Sen, 2013:41) and Coomer, (1979) for instance, defines sustainable development:

> *The sustainable society is one that lives within the self-perpetuating limits of its environment. That society…is not a 'no growth' society…It is rather, a society that recognizes the limits of growth…[and] looks for alternative ways of growing* (Sharmin 2021:39).

World Wildlife Fund (WWF) and UNEP in the World Conservation Strategy (IUCN-UNEP-WWF, 1980) put definition:

> *Sustainable development is the maintenance of essential ecological processes and life support system, the preservation of genetic diversity, and the sustainable utilization of spices and ecosystems* (ibid ,p.42)

The concept, however, took a new turn with the perceived crisis caused by World War (WW) II that brought the challenge for the governments worldwide to meet the minimum basic needs of people. The world think tanks led by USA asked the governments worldwide to concentrate on economic growth for the survival of people through the scientific skill and knowledge (Sharmin, 2021:33). Industrialization was cited as synonymous to development (ibid).In so doing, the pace of economy was, obviously, fostered to a significant extent in many areas of the world but that economic development was mostly achieved at the cost of indiscriminate destruction of the natural resources. Environmental activists along with concerned international institutions such as World Wildlife Fund (WWF) since 1950s began to raise strong voice on the point that the economic growth through the reckless disaster of environment would not sustain (Beder,2005) and people had to pay high cost of it (Sharmin, 2021:37).As the time progressed, the concept of

environmental sustainability became more stronger and in response to the constant appeals of the environmental activists, a commission was formed by United Nations under the Norwegain Prime Minister Gro Harlem Brundtland in 1983 and the Brundtland Report, 'Our Common Future' was issued in April 1987 that promoted the term of sustainable development in larger scale and is still the most unanimously accepted definition on sustainable development (Jepson 2004, Sharmin 2021:47) and the definition is:

Development that meets the needs of the present without compromising the ability of future generations

(World Commission on Environment and Development, WCED,1987,cited in Sharmin, 2021:40).

1.1.2 Concept of Environment in GNH

GNH as a development philosophy was first coined by the 4th king of Bhutan Jigme Singye Wangchuck in 1970s (Ura et.al. 2012: 6). Influenced profoundly by the Buddhist philosophy of encouraging people to concentrate for material and spiritual development with equal emphasis (Mancall2004 cited in Duncan, 2010: 169), environmental sustainability has been one of the key aspects of all sorts of development initiatives in GNH.

The core principle of GNH is development with values and the Bhutanese grow up with such a strong bondage with nature that environmental ecstasy is an inseparable part of their long-practiced values. There is no single cited definition on GNH. However, the definition as follows, is mostly cited on GNH:

"*Gross National Happiness (GNH) measures the quality of a country in more holistic way [than GDP]and believes that the beneficial development of human society takes place when material and spiritual development occurs side by side to complement and reinforce each other*"

(Ura, et.al.2012: 7).

GNH, in the prior, was rested on four pillars - sustainable and equitable socio-economic development, and environmental conservation, preservation and promotion of culture and good governance – and all the pillars are connected firmly with the issue of environmental conservation. These four pillars have later been included into nine domains such as psychological wellbeing, health, education, culture, time use, community vitality, good governance, ecological diversity and resilience, and living standard, (Ura, et.al.2012: 7-8). Each of the nine domains has specific indicators (shown in the graph as follows).

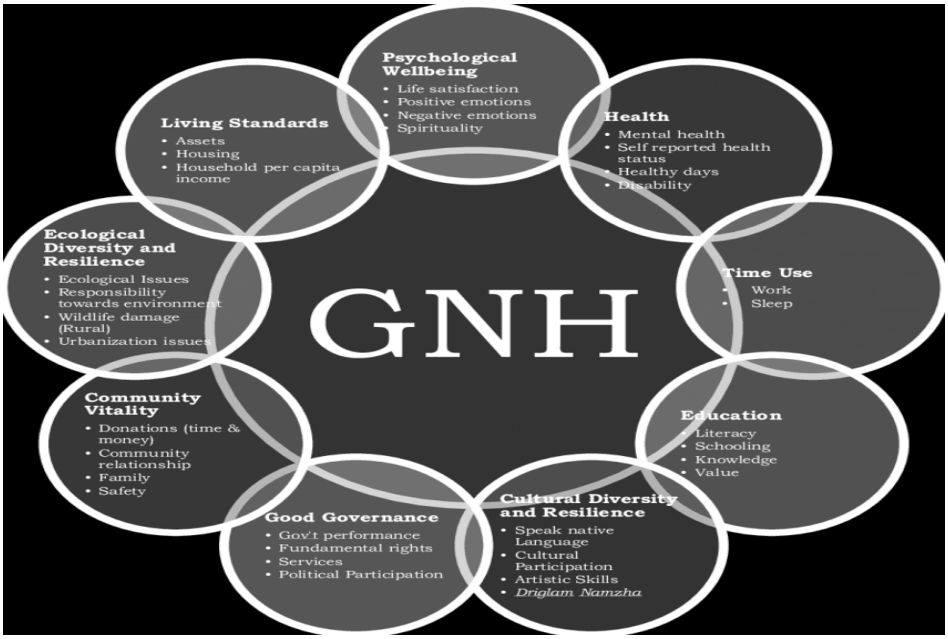


Figure 1: Source (Ura et al 2012:13)

Along with ecological diversity and resilience, all the domains of GNH are concerned with the issue of sustainable environment either in one way or in other. And Bhutan has hardly deviated from its development philosophy of GNH and that is adopting economic policy taking the issue of environmental preservation into well consideration.

2. Research Methodology

This study is qualitative in nature that we have developed through a robust content analysis method of the reliable secondary data concerning sustainable development and GNH and the state of environment in Bangladesh. Many scholars such as Islam (2015:32) have stated that qualitative study is an effective way to have an in- depth understanding of human conducts and the factors that direct that particulars behaviors. Content analysis-analysis of relevant data-including scholarly articles, books and various news portals-both national and international- is applied here with careful attention to get the required data to understand the state of environment in both Bhutan and Bangladesh. As far as the study of GNH is concerned, GNH survey reports of

2010 and 2015, various documentaries which are found in different YouTube channels, online journals, e-Books etc are analyzed carefully. We have also interviewed five individuals who are specialized in the arena of environment, public policy, development, politics, and law. The interviewees included Dr. Sabbir Ahmed, Professor, Department of Political Science and General Secretary of Asiatic Society Bangladesh, Dr. Prabal Barua, an environmental scholar and Program manager of YPSA –a well known NGO, Mohammad Abdul Khaleque, a senior lawyer of Bangladesh Supreme Court, Talat Mahmud, a researcher, writer and media personality and Nazrul Islam, a PhD researcher and Executive Director of an NGO-READI. Taking all the data as a whole, the study has been conducted to make the paper a successful one.

3. Sustainable Environment in Bhutan

Environmental harmony has always been very special towards the Bhutanese. The Bhutanese grow up in the lap of nature and this bondage between man and nature has deeply been influenced by the spirit of the Buddhism that "a tree is the nourisher of all life forms, symbolizing longevity, health, beauty and even compassion" (The Diplomat, 2016).The government formulates development policy in the way that it does not cause any negative impact on environment and people are equally responsible to treat nature with utmost care and passion.

3.1. Emphasis on Environment in Constitution of Bhutan

The Constitution of Bhutan has empowered people as the sole owner of the natural resources of Bhutan. In the Constitution of Bhutan (2008) Article 5(1) it is stated that "Every Bhutanese is a trustee of the Kingdom's natural resources and environment for the benefit of the present and future generations and it is the fundamental duty of every citizen to contribute to the protection of natural environment". The government is committed to take all the necessary measures to protect the environment with highest priority and Article 5 (4) directs that "Parliament may enact environmental legislation to ensure sustainable use of natural resources and maintain intergenerational equity and reaffirm the sovereign rights of the State over its own biological resources". Article 5 (3) seems to be the mere reflections of the Bhutanese commitment towards environment that "The Government shall ensure that, in order to conserve the country's natural resources and to prevent degradation of the ecosystem, a minimum of sixty percent of Bhutan's total land shall be maintained under forest cover for all time."

3.2 People's Involvement in Environmental Preservation

The hallmark of Bhutan's phenomenal success in preserving environment is people's responsible attitude towards nature. People consider nature as the inseparable part of their lives and obey the constitutional direction of protecting the natural resources from any destructive activities. The Constitution, for example, directs to protect at least sixty percent forest land of the total country and the country has surprisingly much more than that -71% (Reza and Mollah, 2019:7).The world community has been familiar with their spiritual love towards nature when they planted 108,000 trees to welcome the newborn Prince on 6 March 2016 throughout the country where thousands of citizens from all classes of life participated in that historical moment with an enthusiastic mode (The Diplomat, 2016). This also bears the sign of inclusiveness in terms of environmental sustainability in Bhutan.

3.3 Governance and Environment in Bhutan

Governance that stands for active participation of different classes of people in any sort of development initiative can be observed quite remarkably in Bhutan. The government has a strong monitoring mechanism to protect the environment and make survey to assess the state of the country's natural resources. Two surveys have been conducted in the recent past-2010 and 2015-on people living in all the 20 districts of Bhutan. Conducted on 7142 people, GNH Survey 2010 identified 84.4% as highly responsible to save the environment (Ura et.al, 2012:31). 2015 survey report also suggests that 84% people's attitudes nature have somehow been pro-environment oriented (GNH Survey Report, 2015:211). Dr. Sabbir Ahmed, Professor, Department of Political Science and General Secretary of Asiatic Society Bangladesh argues in his interview with the authors that "People's responsible attitudes towards environment and environment-centric development policy work as the key factors of Bhutan's success in preserving its natural resources".

The issue of environmental sustainability has highly been prioritized in Bhutan. Bhutan, obviously, has the pressure of increasing population, need of promoting industrialization, extreme poverty, and hunger and so on but it makes the conscious use of its natural resources so that the development project does not pose any threat to the environmental sustainability. As Dr. Prabal Barua, Program Manager of YPSA-a well known NGO in Bangladesh- and environmentalist in his interview with the authors argues that "Bhutan has many environmental problems and climate change vulnerability which hammering its economic growth. But it has strong management for the implementation of environmental laws and strategies and people are benefitting with the strategies". A documentary of BBC (2012) found the existence of tiger in four thousand feet above in Bhutan (Reza and Mollah, 2019:7) which suggests the sign of enriched bio-diversity oriented environment in Bhutan. Any act that may cause negative impact on environment is strictly prohibited there. For example, smoking in public place is a punishable crime in Bhutan and people do not use any sort of chemical fertilizer in land for cultivation. And the outcome is that Bhutan is the only carbon negative country in the world (ibid).The most mentionable aspect of Bhutan's success is that it has equally kept the pace of its economic growth moving in line with environmental preservation. The poverty rate decreased to 8.2% in 2017and the increasing rate of income disparity in Bhutan has been absolutely marginal (Tobden 2019 cited in Reza and Mollah 2019:7).The per capital income increased from USD 1864 to USD 3360 during 2009 to 2018 (World bank 2018, cited in Reza and Mollah2019:7)). Education and health service are free there (Zimba 2012 cited in Reza and Mollah 2019:7). This economic advancement resembles with the very goal of sustainable development that stands for meeting the present material needs of people keeping the environment well preserved for the future.

3.4 Environmental Sustainability in Bangladesh

The Constitution of Bangladesh, has equally empowered people as the sole owner of the country including natural resources as Article 7A (1972) states that "All powers in the Republic belong to the people, and their exercise on behalf of the people shall be effected only under, and by the authority of, this Constitution". And the state is assigned to take all the necessary measures to protect the natural resources. Article 18A (1972) states that "The State shall endeavour to protect and improve the environment and to preserve and safeguard the natural resources, bio-diversity, wetlands, forests and wild life for the present and future citizens".

The practice, however, does not match with the theory. The percentage of forest land is getting declined horribly over the years. There is indiscriminate pillage of natural resources everywhere under different excuses including expansion of industrialization, establishment of various infrastructures, and pressure of increasing population and so on. As such it has been a daunting task for the government to preserve the environment facing all the challenges as Professor Dr. Sabbir Ahmed argues "The government policy of growth based development leads the extinction of natural resources in many ways. Lack of proper planning is also a vital factor for the degradation of environment and Bangladesh can look at the ways Bhutan succeeds to involve people in preserving the country's environment". Nazrul Islam, a PhD researcher and Executive Director of an NGO-READI-, too argues in his interview with the researchers that "Public awareness is absolutely frustrating and we, the majority people, hardly think how we are destroying our environment and causing disaster to our natural forests. Development projects also are not undertaken taking the issue of environment with due attention".

The outcome of people's irresponsible attitude towards environment is that the percentage of forest land decreased to 7-9% in 2018 from16% in 1980 (Das,2019:524).There is a lack of proper monitoring in the state policy and the issue of environmental sustainability remains less focused in different dimensions. Until 1995 there was no binding obligation to follow the Environmental Impact Assessment (EIA) (Khan 2020:300). The government in the recent times takes the issue of EIA with much importance. However, in many cases and especially in terms of mega projects such as the Rampal Power Plant, the issue of EIA has been ignored. Department of Environment, for instance, has allowed establishing nearly 200 industrial units in the Sundarbans which is an ecologically critical zone (ibidP.316).

3.5 Consequences of Environmental Degradation in Bangladesh

The result of ignoring environment on people is somewhat daunting. Bangladesh has already lost a huge amount of its natural resources. The number of rivers has come down to 200 from 700 (The Dhaka Tribune, cited in Khan and Rahman 2020:2) due to the indiscriminate defilement of rivers. The air of Dhaka is absolutely polluted and Dhaka is considered as one the most polluted cities in terms of air quality (The Dhaka Tribune, cited in Khan and Rahman 2020:2). According to the Global Climate Risk Index (CRI) 2020, Bangladesh is one of the most vulnerable countries in case of climate change (Reza and Mollah, 2019:7).

Bangladesh loses 20 thousand cores taka simply for air pollution every year (Country Environment Analysis 2018, cited in Reza and Mollah, 2019:15). 28 percent of all deaths of people in Bangladesh are caused by environment pollution (World Bank 2018:8, cited in Khan and Rahman 2020:2.). Sound pollution in Dhaka city is now three times more than the tolerable limit which is putting public health at tremendous risk (The Independent, November 4, 2021).The root causes of it are the huge gathering of people in Dhaka city and inescapable sounds from construction work and carelessness of people towards sound pollution (Ibid). Mohammad Abdul Khaleque, a senior lawyer of Bangladesh Supreme Court in his interview with the researchers argues that "The polluter pay principle has to be implemented strictly. Otherwise, the irresponsible attitude of people towards environment cannot be stopped anyhow." Talat Mahmud, a researcher, writer and media personality in his interview with the researchers argues that "The government initiatives to protect the environment are not enough to face the extreme challenges of environmental preservation in the real field. The laws also are not time worthy. A massive social movement is needed where civil society has to play the most dynamic role. And Bhutan can be an iconic example for us." The situation is, in fact, absolutely alarming. As per the report of the Intergovernmental Panel on Climate Change (IPCC) with the rise of just one meter rise in the sea level, approximately 16% total land of Bangladesh may go under water (cited in Uzzaman 2014;108).The Ministry of Environment (MoE) states that Bangladesh is losing 1.81% GDP annually due to climate change that may rise to 2.5 percent after 2030(Ibid) and if it does happen, it would cause a profound negative impact in the very existence of people's lives in Bangladesh.

4. Conclusion and Recommendations

The capitalist modernity that primly focuses on material riches has deeply penetrated in the mind of majority modern people in Bangladesh and modern people's attitudes towards environment are mostly narrow (Carson, 1962:41). What Schumacher (1973:4) has mentioned that people hardly feel their inherent bondage with environment in the modern times, seems to be applicable remarkably in terms of the modern people in Bangladesh. The environmental sustainability in

Bangladesh has now been at tremendous stake. The economic needs of people have to be met and the task is absolutely challenging for Bangladesh for its huge population density. However, the environmental issue can in no way be ignored for that as the effects of climate change can demolish a huge amount of land from the country and according to World Bank (2018:8) nearly 28 percent people in Bangladesh die every year only for environment pollution and most of them are poor and marginalized people (Khan and Rahman 2020:2.).

The disaster of forest land on the plea of removing poverty would not sustain as the poor people ultimately become the worst victims of environment pollution. Rather Bangladesh should concentrate more on how to foster the pace of economic growth with the conscious use of natural resources ensuring the active and spontaneous involvement of people into the whole process as Bhutan has quite successfully doing over the years. The task is obviously far challenging for Bangladesh due to the pressure of huge population. But Bangladesh can take the insights from Bhutan and formulate policies taking the issue of environmental sustainability into well consideration. And for that, a mass social movement is needed with the active participation of all classes of people in the society and obviously civil society has to play a very dynamic role in raising awareness among people for saving the environment for the next generations and we have to preserve what Dreze and Sen, (2013:41) state:

> *the air we breathe, the water we drink, and the epidemiological surroundings in which we live.*

And in so doing, we have some specific recommendations:

- Planting two trees in the suitable places if one tree has to be cut for any development project;
- Selecting a particular day for planting trees in any national holiday throughout the country with the spontaneous participation of all classes of people;
- Ensuring a green atmosphere in every educational institution;
- Providing lessons to the students about the importance of environment from the primary level;
- Developing the monitoring system especially in the grass-root levels;
- Following the polluter pay principle strictly; and
- Developing a mass social movement to raise awareness of people regarding the disastrous effects of environment pollution and media and civil society have to play the most dynamic role for that; and

Above all, we have to love our natural resources for our own existence and for the welfare of our next generations and for that the philosophy of plain living and simple thinking has to be promoted that people can develop in the close harmony with nature what Bhutan has successfully doing through its development philosophy of GNH.

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Spatial and Temporal Variability of Rainfall over Bangladesh during 1981-2020

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Abstract

This paper analyzes the spatial and temporal variability of rainfall in Bangladesh from 1981 to 2020 using the satellite daily rainfall data. 12 weather stations of Bangladesh like eastern (Sylhet, Srimangal, Cox's Bazar, Teknaf), central (Dhaka, Mymensingh, Barisal, Patuakhali), and western (Rajshahi, Rangpur, Jessore, Khulna) were selected to represent the country. The spatial and temporal rainfall characteristics were determined by Precipitation Concentration Index (PCI), Rainfall Anomaly Index (RAI), and Standardized Precipitation Index (SPI) using R programming, and rainfall trends were determined by using the Mann-Kendall trend test then predicting the data by geostatistical interpolation method Kriging and IDW. The results showed that PCI values were higher in the eastern region and have strong seasonal influences, whereas lower PCI values were mostly observed in the central region of Bangladesh. The spatial distribution of rainfall showed that the coastal zones of Teknaf and Cox's Bazar received more rainfall and were sensitive to disaster-prone zones. Drought index results RAI and SPI showed that the frequency of drought is repeated in the western zones. The Mann-Kendall trend test reveals that the significance of monotonic annual rainfall trends increase in Sylhet, Cox's Bazar, Teknaf, Patuakhali, and Rangpur regions and decrease in Srimangal, Dhaka, Mymensingh, Barisal, Rajshahi, Jessore, and Khulna. These changes may have a deleterious effect on rain-fed agriculture in Bangladesh. Furthermore, PCI, RAI, and SPI can serve as warning tools for disaster control and water resource management.

Keywords: precipitation concentration index, rainfall anomaly index, standardized precipitation index, rainfall trend analysis, geostatistical interpolation, Bangladesh.

1. Introduction

Rainfall is a very important factor in Bangladesh's economy which is directly or indirectly related to agriculture because almost 80% of people live in rural and depend on the economic growth of agriculture in Bangladesh (Rahman, 2008; Shahid, 2010a). There is a close relation between rainfall change and rice production. Most of the climatic factors affect the variation of rice production. Aman rice production depends on rainfall and it is planted during the monsoon. Rainfall variability is a risk for Aman and Aus rice because increasing rainfall creates extreme floods or decreasing rainfall creates extreme drought (Hussain AM., 1996). And some natural calamities like tornadoes, tropical cyclones, tidal surges, etc. are also caused due to climate change which occurs in rainfall variation (Eckstein and Kreft, 2020). During the monsoon, the annual average rainfall is estimated that 70-85% which varies from 70% in the eastern to about 85% in the western (Talchabhadel et al., 2020). The northeastern part and southeastern part of Bangladesh is very important for agricultural, crop production, fisheries, forestry, water management, hydro energy, etc. And the overall temperature varies from 32oC to 10oC in the eastern part of Bangladesh (Ahmed and Kim, 2003; Shahid, 2012a). Characteristics of renewable water resources in a particular region largely depend on the rainfall patterns (Ramamasy, S. and Baas, 2007). On the other hydrological hazard risk such as

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floods and drought are also correlated with extreme deficiencies in rainfall (Choudhury and Rahman, 2015; Geographer, 2017).

Spatial and temporal rainfall variability of rainfall has an enormous impact on the renewable eater resource and hazard occurrence. There is not a single work to investigate the frequency of variability of rainfall patterns in Bangladesh. In this study, the rainfall characteristics of three rainfall indices Precipitation Concentration Index (PCI), Rainfall Anomaly Index (RAI), Standardized Precipitation Index (SPI) were proposed by Oliver (1980), Van Rooy (1965), and Tom Mckee (1993) respectively, were used to explore rainfall variability of eastern, central and western parts of Bangladesh. Mann-Kendall trend test was used to explore the trend of rainfall time series over Bangladesh. And finally, geostatistical interpolation methods such as Kriging and IDW were used to predict the spatial and temporal rainfall variability in Bangladesh.

This study can explain spatial and temporal rainfall variability, seasonal rainfall variation, and daily and monthly rainfall heterogeneity within a year which can furnish an applicable framework for decision-makers for regional planning, agriculture, renewable water resources, and disaster management in Bangladesh.

2. Materials and Methods

2.1 Data

In this study, daily rainfall data from 1981 to 2020 were collected from 47 meteorological stations, and the data set was provided by Bangladesh Meteorological Department (BMD). But long term daily rainfall data like over fifty years are available at 19 stations (1958-2017) and above this station, only 12 stations were selected which are divided into three zones: eastern (Sylhet, Srimangal, Cox's Bazar, Teknaf), central (Dhaka, Mymensingh, Barisal, Patuakhali), and western (Rajshahi, Rangpur, Jessore, Khulna) to represent whole Bangladesh. Collected satellite time series rainfall satellite data contains no percentage of missing values so that data are rearranged and analyzed by Precipitation Concentration Index (PCI), Rainfall Anomaly Index (RAI), and Standardized Precipitation Index (SPI) through R programming language, and rainfall trends were determined by using the Mann-Kendall trend test then predicting the data by geostatistical interpolation methods like Kriging and IDW and represented through maps in ArcGIS 10.5.

2.2 Methods

2.2.1 Precipitation Concentration Index (PCI)

In this study, PCI is defined by Oliver (1980) and was modified by De Luis (1987) for the temporal feature of the rainfall distribution within a year and used as a criterion of hydrological hazard risks such as floods and droughts. PCI is expressed as a percentage according to the following formula:

$$PCI = 100 \times \frac{\sum_{i=1}^{12} Pi^2}{\left(\sum_{i=1}^{12} Pi\right)^2} \quad (1)$$

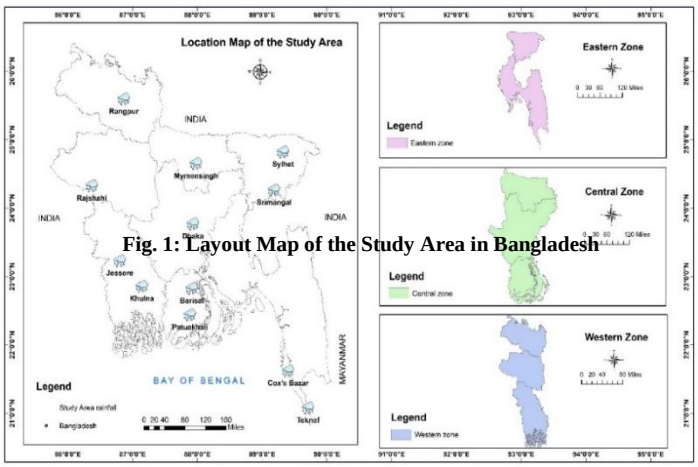


Fig. 1: Layout Map of the Study Area in Bangladesh

Where Pi = precipitation of ith month within a year. According to Oliver (1980) different annual PCI values are categorized into different classes. When the annual PCI value is below 10 indicates the rainfall is uniformly distributed throughout the year, and if the value is from 11 to 15 it indicates rainfall is moderately concentrated and would be irregularly distributed when the ranges from 16 to 20. If the PCI value is over 20 it indicates significant irregular rainfall distribution.

2.2.2 Rainfall Anomaly Index (RAI)

The Rainfall Anomaly Index (RAI) is defined by Van Rooy (1965) and assimilated a categorize procedure to allocate magnitudes to positive and negative anomalies. RAI is expressed according to the following formula:

$$RAI = 3\left[\frac{N-\bar{N}}{\bar{M}-N}\right], \text{ for positive anomalies} \quad (2)$$

$$RAI = -3\left[\frac{N-\bar{N}}{\bar{X}-N}\right], \text{ for negative anomalies} \quad (3)$$

Where, N = recent monthly/yearly rainfall (mm); $\bar{N}$ = average monthly/yearly rainfall of the historical series (mm); $\bar{M}$= average of the ten highest monthly/yearly rainfall of the historical series (mm); $\bar{X}$= average of the ten lowest monthly/ yearly rainfall of the historical series (mm). When the RAI value is above 4 it indicates the extremely humid area throughout the year, and if the value is 2 to 4 indicates a very humid area when the ranges from 0 to 2 it indicate the humid area and the value is from -2 to 0 it indicates the dry area, from -4 to -2 it indicates the very dry area and if the value below -4 it indicates the extremely dry years in the studied area.

2.2.3 Standardized Precipitation Index (SPI)

The Standard Precipitation Index (SPI) is a statistical indicator proposed by Tom Mckee (1993) which is used to evaluate the meteorological drought trends, soil moisture, and rainfall conditions for any time scale based on the probability of precipitation (McKee TB, Doesken NJ, 1993). SPI is expressed according to the following formula:

$$SPI = \frac{Xi-Xm}{\sigma} \quad (4)$$

Where, Xi = precipitation for the station, Xm = mean precipitation, and σ = standardized deviation. When the SPI value is above 2 it indicates an extremely wet area, if the value is from 1.5 to 1.99 it indicates very wet, if the ranges from 1.0 to 1.49 are moderately wet, if the ranges from -.99 to .99 are near normal, when the ranges in between -1.0 to -1.49 is moderately dry, if the ranges from -1.5 to -1.99 are severely dry and the ranges are less than -2 it indicates an extremely dry area.

2.2.4 Mann-Kendall (MK) trend test

The non-parametric Mann-Kendall was suggested by Mann et al. (1945) and Kendall et al. (1956). The Mann-Kendall Trend Test is used to determine whether a time series of hydro-meteorological variables has a monotonic upward or downward trend and it works for all distributions. In the MK trend test, the data values are estimated as an ordered time series. The MK test tests, whether H_0 is the null hypothesis or no monotonic trend to reject and accept the alternative hypothesis (H_1) or Monotonic trend is present. If x_1, x_2, x_3 ….. x_i represents n data points where x_j represents the data point at time j. Then the MK statistics S is-

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(xj-xk) \quad (5)$$

Where, sgn(xj-xk) = $\begin{cases} +1, \text{if } \theta = (xj - xk) > 0 \\ 0, \text{if } \theta = (xj - Yk) = 0 \\ -1, \text{if } \theta = (xj - xk) < 0 \end{cases}$

The probability associated with S and the sample size, n, is then computed to statistically quantify the significance of the trend. The S is considered to be normally distributed when n≥8 and its mean and variance can be computed as follows:

$$E(S) = 0 \quad (6)$$

$$Var(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{n} ti\ i\ (i-1)(2i+5)]}{18} \quad (7)$$

Where ti indicates the number of data in the i^{th} tied group. Finally, the standardized test statistics Z can be computed as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0 \end{cases} \quad (8)$$

A positive Z value shows an increasing trend, while a negative value shows a decreasing trend. At 99% and 95% significance levels, if $|Z| > 2.575$ and $|Z| = 1.96$the null hypothesis of no trend is rejected.

2.2.5. Spatial interpolation

Kriging is the latest geostatistical procedure (statistical model) that creates an estimated surface from a scattered set of points with z-values.

$$Z(s) = m(s) + e(s) \quad (9)$$

Where the attribute value of Z(s) is at the spatial position s, m is the deterministic trend that doesn't depend on the location s of the observations, and e(s) is the auto-correlated error. Kriging is used in this study for the interpolation of point data to prepare the raster maps of various rainfall parameters. Inverse distance weighted (IDW) interpolation regulates cell values using a straight weighted combination of a set of sample points.

3. Results and Discussion

3.1 Spatial and temporal patterns of the Precipitation Concentration Index (PCI)

The results showed that the PCI values increased in the eastern parts of Bangladesh at around 18 then gradually decreased in the western parts on average at 17 and finally central parts around 16 of the study area. The coefficient of variation (CV %) was also calculated for understanding the spatial and temporal variability between the years. Higher values of CV% of PCI in the Patuakhali region of Bangladesh mean that the seasonal variability of rainfall in the region is high.

Station Name	St ID	PCI	CV%	Categorization
Sylhet	41891	15.38	7.17	Moderate rainfall distribution
Srimangal	41915	15.10	7.79	Moderate rainfall distribution
Cox's Bazar	41992	20.22	11.93	Irregular rainfall distribution
Teknaf	41998	21.04	11.53	Significant irregular rainfall distribution
Dhaka	41923	15.25	7.78	Moderate rainfall distribution
Mymensingh	41886	15.80	6.37	Moderate rainfall distribution
Barisal	41950	16.40	11.66	Irregular rainfall distribution
Patuakhali	41960	17.28	12.42	Irregular rainfall distribution
Rajshahi	41895	18.00	10.79	Irregular rainfall distribution
Rangpur	41859	17.81	9.72	Irregular rainfall distribution
Jessore	41936	15.81	9.63	Moderate rainfall distribution
Khulna	41947	16.80	11.42	Irregular rainfall distribution

Tab. 1: The Spatial Patterns of PCI Values With Their Coefficient of Variation in Bangladesh From 1981 to 2020

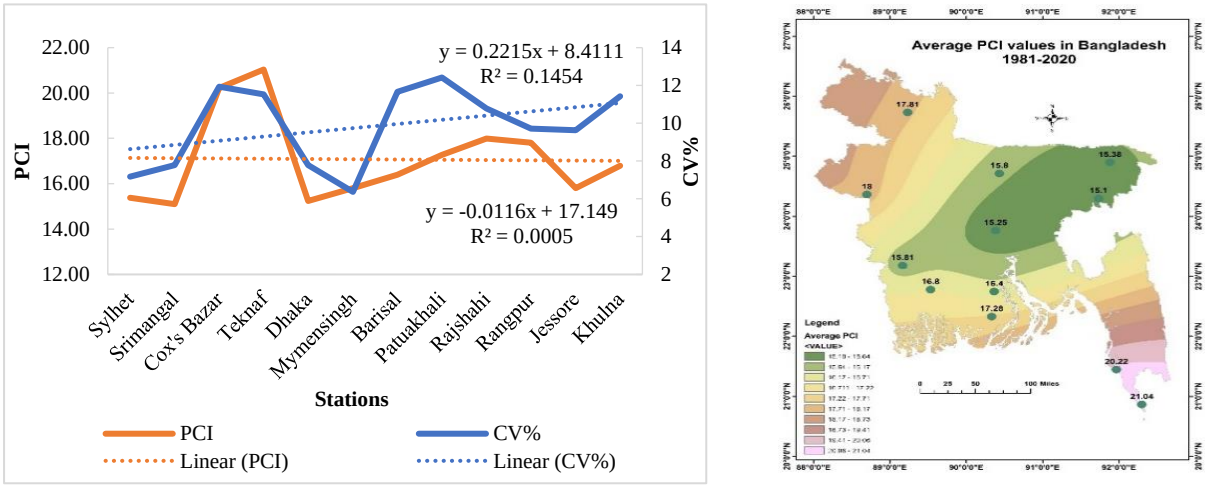
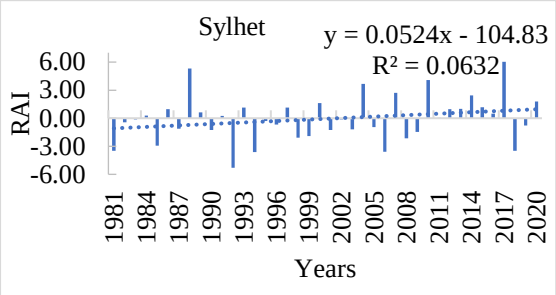
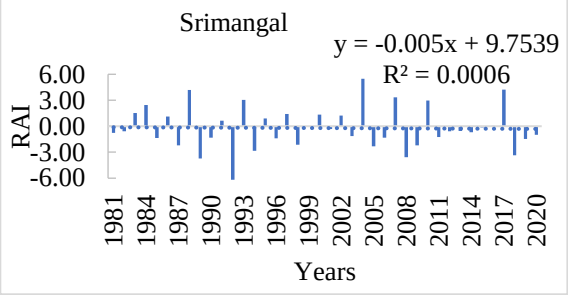


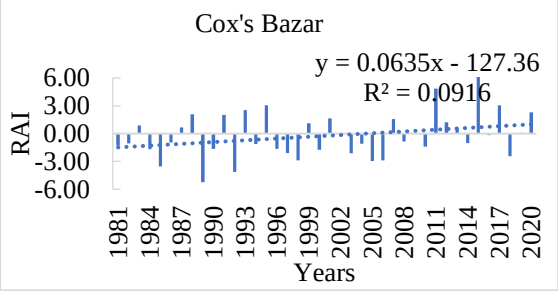
Fig. 2: Spatial and Temporal Distribution of PCI Value in Bangladesh Over 1981-2020

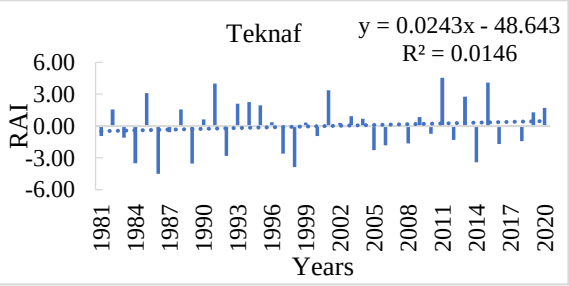
3.2 Spatial and temporal patterns of the Rainfall Anomaly Index (RAI)

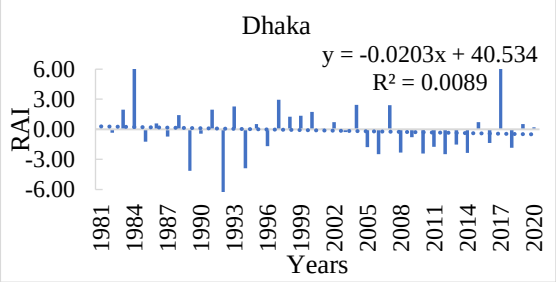
From the temporal-spatial distribution of rainfall data at 12 weather stations in Bangladesh from 1981 to 2020 RAI was calculated. In this study, the results showed positive and negative values in the year. RAI value increased in the western zones more than in the other zones.

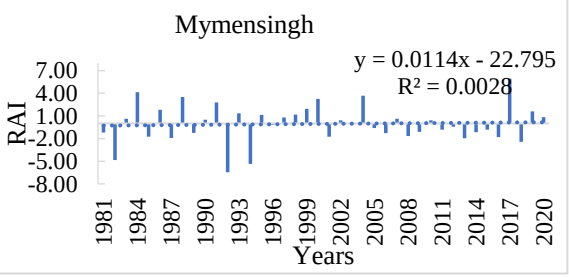


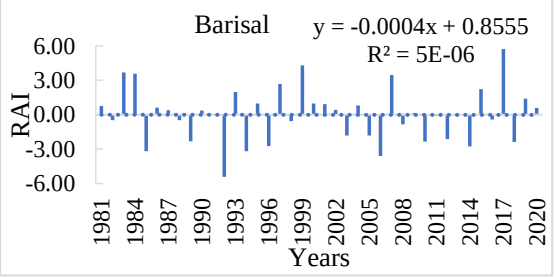


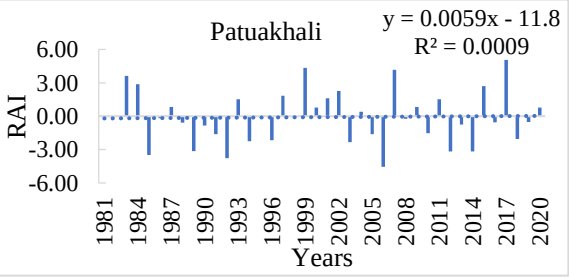


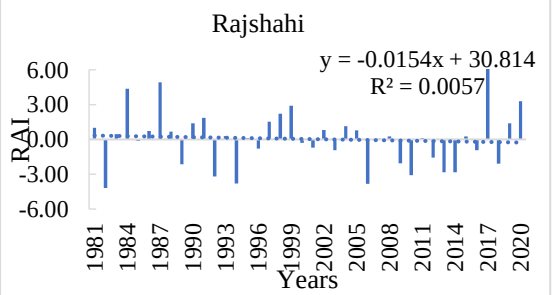


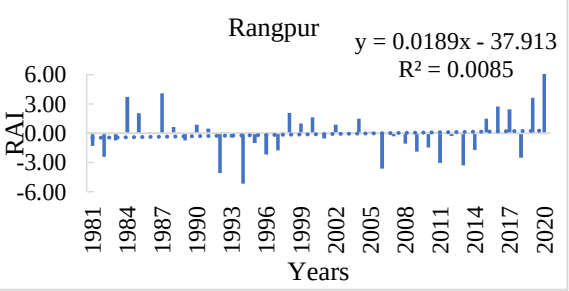












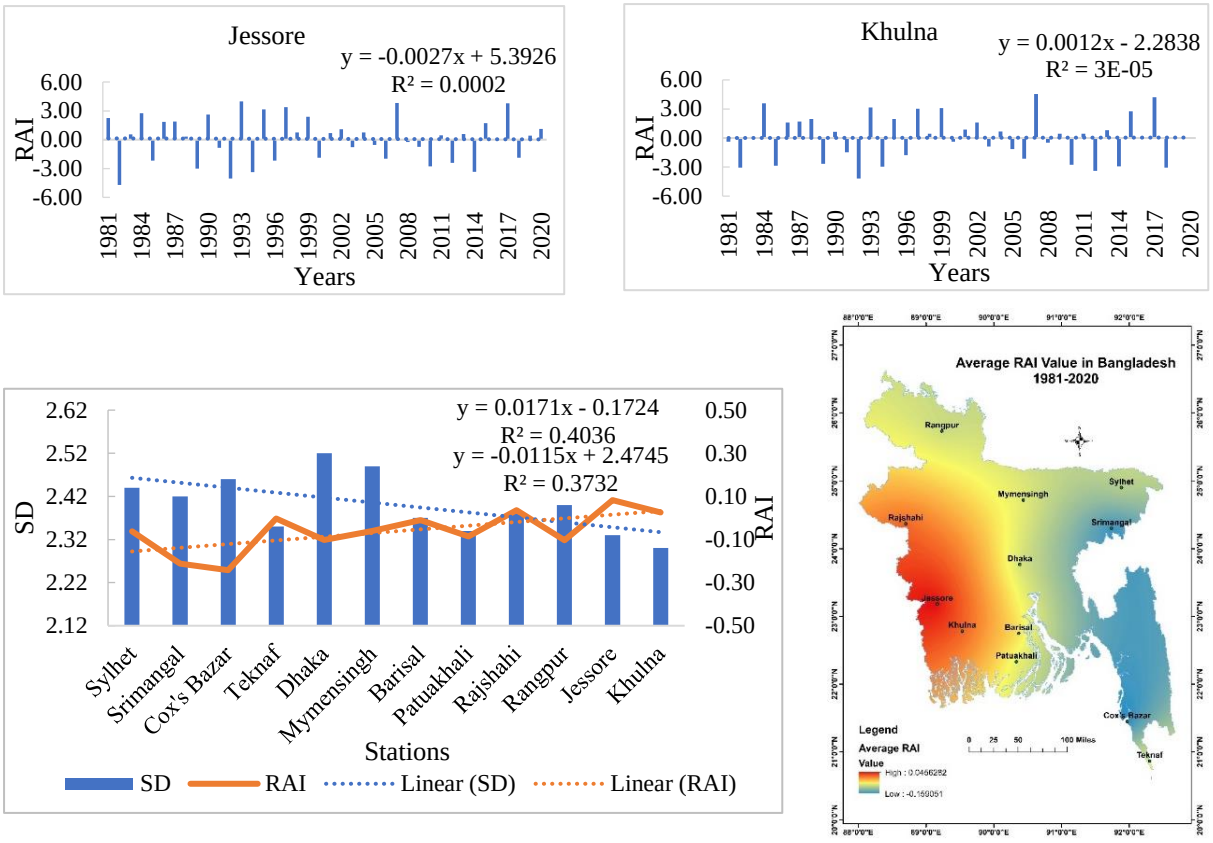


Fig. 3: Spatial and Temporal Distribution of RAI Value in Bangladesh Over 1981-2020

3.3 Spatial and temporal patterns of the Standardized Precipitation Index (SPI)

In this study time scale of 12 months, long term precipitation patterns of SPI were calculated. From Tab. 2 Sylhet (2.3% probability) and Teknaf (9.2% probability) showed that positive value and the wettest regions and the western region Rajshahi showed a negative value driest (9.2% probability) and most of the areas normal.

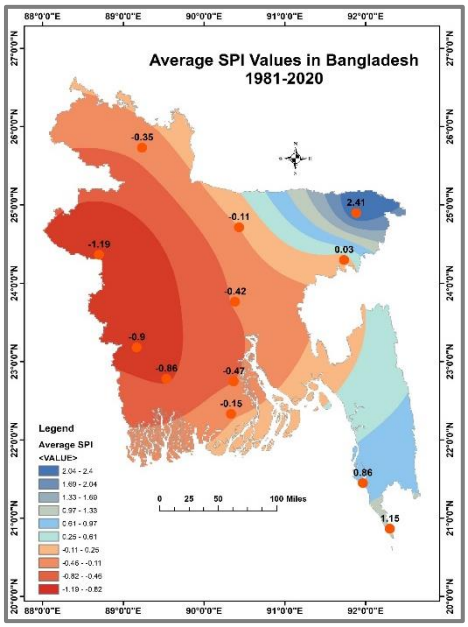


Fig. 4: Spatial and Temporal Distribution of SPI Value in Bangladesh Over 1981-2020

Stations	Alt	P (mm)	SPI	Category
Sylhet	35	5135.82	2.41	Extremely wet
Srimangal	23	2684.63	0.03	Normal precipitation
Cox's Bazar	4	3521.47	0.86	Normal precipitation
Teknaf	7	3810.99	1.15	Moderately wet
Dhaka	9	2205.56	-0.42	Normal precipitation
Mymensingh	19	2522.58	-0.11	Normal precipitation
Barisal	4	2151.61	-0.47	Normal precipitation
Patuakhali	6	2479.86	-0.15	Normal precipitation
Rajshahi	20	1421.15	-1.19	Moderately dry
Rangpur	34	2276.66	-0.35	Normal precipitation
Jessore	7	1713.09	-0.90	Normal precipitation
Khulna	4	1763.38	-0.86	Normal precipitation

Tab. 2: The Spatial Patterns of SPI Values in Bangladesh From 1981 to 2020

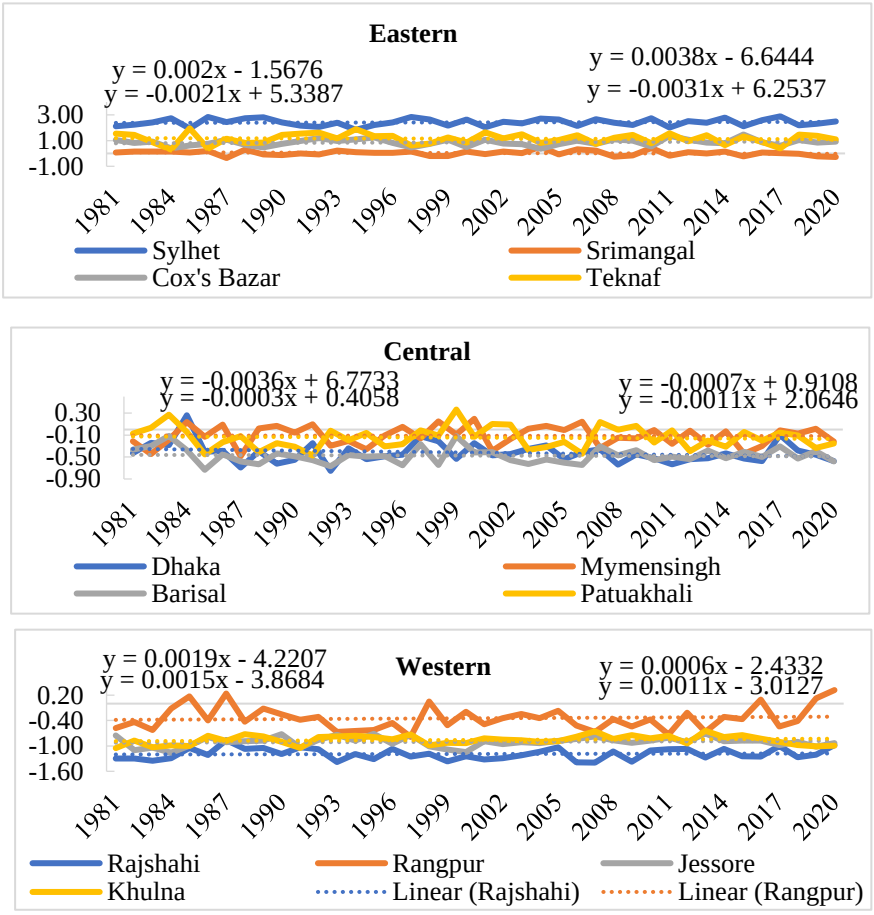


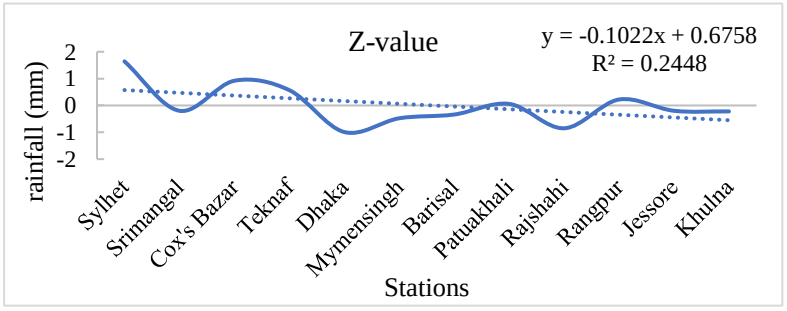
Fig. 5: Spatial and Temporal Distribution of SPI Value in Bangladesh Over 1981-2020

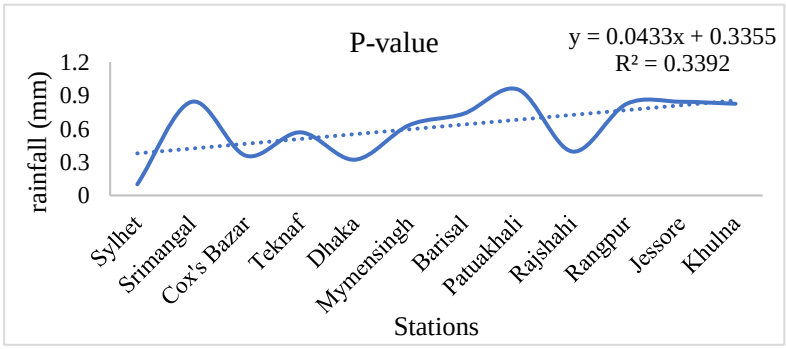
3.4 Trend analysis

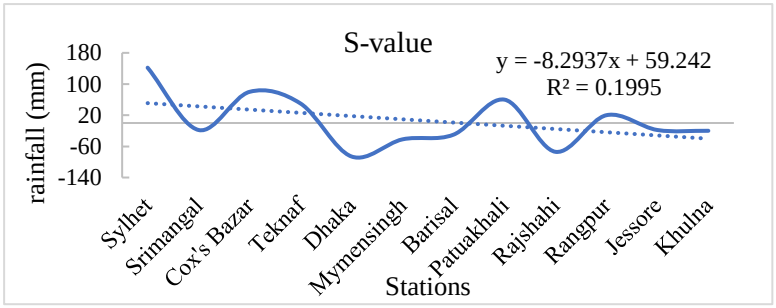
This study also found that the spatiotemporal significant monotonic annual rainfall trend both increasing and decreasing at present. Sylhet, Cox's Bazar, Teknaf, Patuakhali, and Rangpur showed an increasing trend and Srimangal, Dhaka, Mymensingh, Barisal, Rajshahi, Jessore, Khulna showed a decreasing trend.

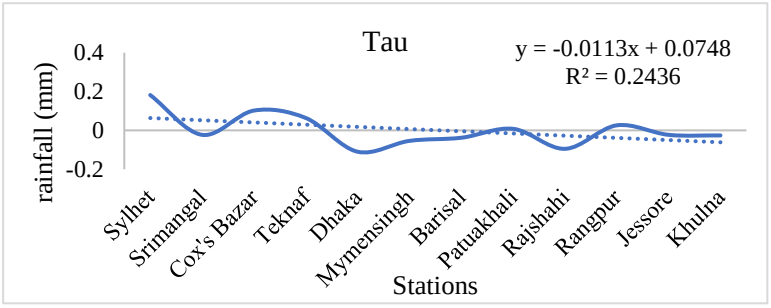
Stations	Z	p-value	Mann-Kendall Statistic (S)	Kendall's Tau	Alpha (α)	Monotonic trend
Sylhet	1.6428	0.1004	142	0.182	0.05	Increasing
Srimangal	-0.19807	0.843	-18	-0.023	0.05	Decreasing
Cox's Bazar	0.92043	0.3573	80	0.102	0.05	Increasing
Teknaf	0.5709	0.5681	50	0.064	0.05	Increasing
Dhaka	-0.99034	0.322	-86	-0.110	0.05	Decreasing
Mymensingh	-0.47769	0.6329	-42	-0.054	0.05	Decreasing
Barisal	-0.33788	0.7355	-30	-0.038	0.05	Decreasing
Patuakhali	0.058255	0.9535	60	0.008	0.05	Increasing
Rajshahi	-0.85053	0.395	-74	-0.095	0.05	Decreasing
Rangpur	0.22137	0.8248	20	0.026	0.05	Increasing
Jessore	-0.19807	0.843	-18	-0.023	0.05	Decreasing
Khulna	-0.22137	0.8248	-20	-0.026	0.05	Decreasing

Tab. 3: Results of the Mann-Kendall Trend Test for Rainfall Data in Bangladesh From 1981-to 2020









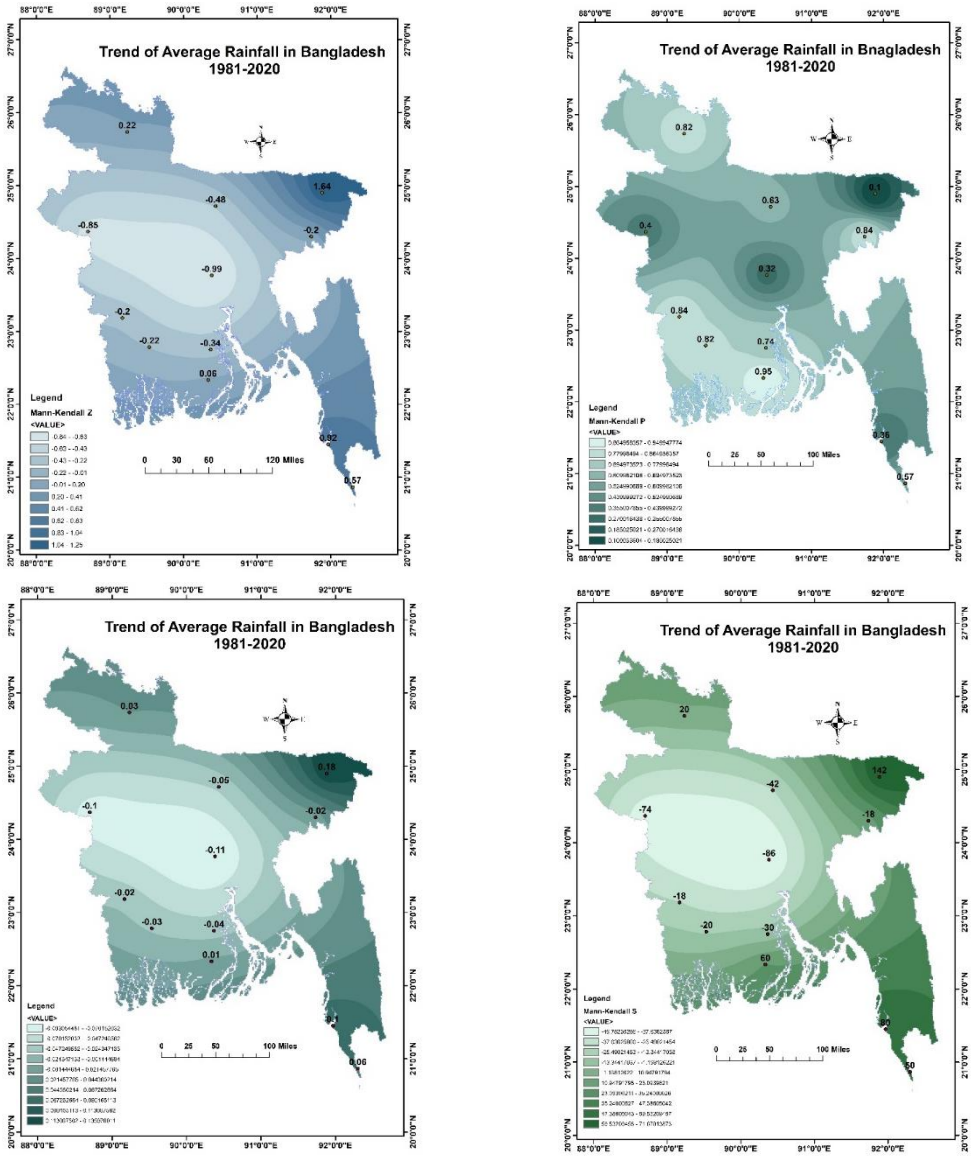


Fig. 6: Spatial Variation of Annual Rainfall Trend (Mann-Kendall test) in Bangladesh Over 1981-2020

4. Conclusions

Precipitation and drought conditions of Bangladesh were analyzed using Precipitation Concentration Index (PCI), Rainfall Anomaly Index (RAI), and Standardized Precipitation Index (SPI), and the trend was analyzed by the Mann-Kendall trend test then predicted the data by geostatistical interpolation method Kriging and IDW. This investigation showed that the coastal zones of Teknaf and Cox's Bazar are sensitive to disaster-prone zones. Drought index results showed that the frequency of drought is repeated in the western zones periodically. Trend analysis showed a decreasing rainfall trend found in Srimangal, Dhaka, Mymensingh, Barisal, Rajshahi, Jessore, and Khulna which are drought-sensitive zones. Based on the above results, if increasing rainfall trends continue in these states in the future it impacts the ecological, social, and economic environment. It is concerned especially third-world countries like Bangladesh because it changes and impacts the coastal areas, vulnerability to flood, drought, cyclones, tropical storms, and coastal storms arise. This spatial variability also impacts agriculture and food security.

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Suitability Assessment of Push-Pull Farming System to Combat Pest Infestation as a Nature Based Solution (NbS) of Climate Change Adaptation in Bangladesh

Afifa Tasnim[1] and Ahmmed Zulfiqar Rahaman[2]

Abstract

Bangladesh's economy is mostly centred on agriculture, which accounts for 18.6% of the country's GDP (gross domestic product) (BBS 2010). The adverse effects of climate change have a significant role to play in the rise in pest infestation that eventually obstructs agricultural yield. Diseases and pest incidences tend to rise in response to shifting temperatures and variable rainfall patterns (Rashid et al., 2014). According to estimates, 25% of vegetables, 20% of sugarcane, 16% of rice, 15% of jute, and 11% of wheat produced in Bangladesh are lost each year due to pest infestation (MoA 2010) (M. H. Kabir & Rainis, 2013). Despite the lack of a formal record, it is thought that this loss is greater than that resulting from natural disasters such as floods, droughts, and cyclones (M. H. Kabir & Rainis, 2013). Farmers rely heavily on chemical insecticides to compensate for this massive loss. In the long run, pesticides or insecticides, which are inorganic chemicals, may be harmful for agriculture and also the environment. On top of that, these chemicals can be too expensive for the poor farmers of this country. Pesticide use grew from 2200 metric tons in 1980–1982 to 6500 metric tons in 1992–1994, while modern rice agriculture increased from 20.3 percent of total rice land to 49.0 percent (S. Rahman & Thapa, 1999). As an alternative to using pesticides or insecticides, a nature-based solution (NbS), such as, the push-pull farming system may be applied. It is an environment-friendly and cost-effective approach to control pest attacks. This system has been made very popular in Kenya, Africa. In this system, Napier Grasses are used around the periphery of an agricultural field which release a chemical that attracts or pulls pests towards them. In addition to this, Desmodium crops are planted within the agricultural field that release a chemical which repels or pushes pests away from them. This push and pull system in combination work together to protect crops from harmful pests. It has also been reported that there is a rising pest infestation in the Rangpur district of Bangladesh. Moreover, Napier Grasses have reportedly been successfully grown in Rangpur since Napier grass has low water requirements and the Northwest region of Bangladesh is comparatively quite dry. This is why the push-pull farming system as an NbS may be attempted to be applied in Bangladesh as well. As a part of the National Adaptation Plan (NAP) project, Bangladesh is aiming to promote the concept of NbS. In this regard, this paper aims to popularize the push-pull farming system as an NbS initiative. In order to do this, a number of parameters, such as, soil characteristics, climate patterns, plant species characteristics etc. have been studied to ascertain if the push-pull farming system would be suitable in the context of Bangladesh. This paper has further provided recommendations for scaling up this NbS initiative and mainstream it among the general people.

Keywords: pest infestation, push-pull farming, climate change, nature-based solutions, adaptation

Background of the Study:

Bangladesh is one of the world's largely agro-based developing countries, with a land area of 147,570 square kilometers. Agriculture has been the backbone of Bangladesh's economy since

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its independence in 1971, producing roughly 17 percent of GDP and employing 45 percent of the country's workforce. Approximately 84 percent of the country's rural population relies on agriculture for their living, either directly or indirectly. Furthermore, it is the majority of rural people's principal source of employment, livelihood, and food security, as well as a source of raw materials for industry and a contributor to the country's exports. Agriculture is the lifeblood of many agricultural countries, such as Bangladesh's, despite the fact that the modern economy is mostly dependent on industrialization (M. T. Rahman, 2017). Because of the geophysical setting and fluctuation, as well as expected future climatic changes, Bangladesh is one of the most sensitive countries to climate threats ((Yu et al., 2010);(Ruane et al., 2013)). Among the extensive list of potential repercussions, climate change threats to agriculture stand out as the most critical production restrictions ((Yu et al., 2010);(Ruane et al., 2013)). According to the IPCC (2014), the negative effects of climate change on agriculture in Bangladesh are projected to be severe, unpredictable, and unprecedented. Drought is one of the extreme weather phenomena that has a negative impact on agriculture and rural lives in Bangladesh's western and northwestern regions ((Shahid & Behrawan, 2008);(Alamgir et al., 2015)). Infestations of crop insects or pests have been reported to have increased in reaction to the increased drought (Md. J. Kabir et al., 2017). Pest infestations are estimated to cause the loss of 25 percent of vegetables, 20 percent of sugarcane, 16 percent of rice, 15 percent of jute, and 11 percent of wheat produced in Bangladesh each year (MoA 2010) (M. H. Kabir & Rainis, 2013). To compensate for this significant loss, farmers mainly rely on chemical insecticides. Pesticides and insecticides, which are inorganic chemicals, may be hazardous to agriculture and the environment in the long run. Furthermore, these chemicals may be too expensive for the country's poor farmers. Pesticide use increased from 2200 metric tons in 1980–1982 to 6500 metric tons in 1992–1994, while modern rice farming climbed from 20.3 percent to 49.0 percent of total rice land (S. Rahman & Thapa, 1999). Fungicides are the most commonly used pesticides in Bangladesh (45.09%), followed by insecticides (38.85%), herbicides (15.55%), miticides (0.29%), and rodenticides (0.20%). Pesticides are imported from China in large quantities, with the remainder coming from India, Germany, and other nations, where they are made by 228 companies (Sarma, 2022). Pheromone traps are currently used as an alternative for pest management in the North-West region of Bangladesh. But the use of pheromone technology requires certain materials that are not sufficiently available and it is only limited to rice and a few other vegetables. Lack of synthesis of pheromones and the lack of knowledge regarding this technology are also some of the drawbacks of this pest control practice (Nahar et al., 2020). These are the reasons why a better and nature based pest management practice needs to be explored. Companion cropping tactics, which are utilized to reduce losses caused by insects or pests, such as stemborers and striga weed, result in higher crop production and improved nutrition (Z. R. Khan et al., 2014). In this regard, the 'push–pull' approach involves growing certain companion plants in between and around the primary crop. These companion plants produce compounds that (i) repel insect pests from the main crop when used as an intercrop, and (ii) lure insect pests away from the main crop when used as a trap crop ((Cook et al., 2007);(Z. R. Khan et al., 2010)). This is a nature-based solution (NbS) used mostly in Africa, for tackling the pest infestation issue threatening the agriculture sector. This study has been chosen to assess whether this type of nature-based solution would be suitable in the context of Bangladesh.

Study Area:

Droughts are common in the northwest region of Bangladesh due to climate unpredictability and scarcity of surface water, as well as rainfall variability and high temperatures. Droughts are exacerbated by a diversified environment, a semi-arid climate, and decreasing rainfall. Drought also increases insect infestation and reduces the production of certain agricultural

crops planted in the Rabi (mid-November to mid-March) and Pre-Kharif seasons, such as HYV Boro rice, Aus rice, wheat, sugarcane, and potatoes (mid-March to mid-May) (Mardy et al., 2018). The Rangpur district is situated in the northwest region of Bangladesh. A study was carried out to analyze the post-harvest losses of Maize in Rangpur, Kushtia and Bogura.

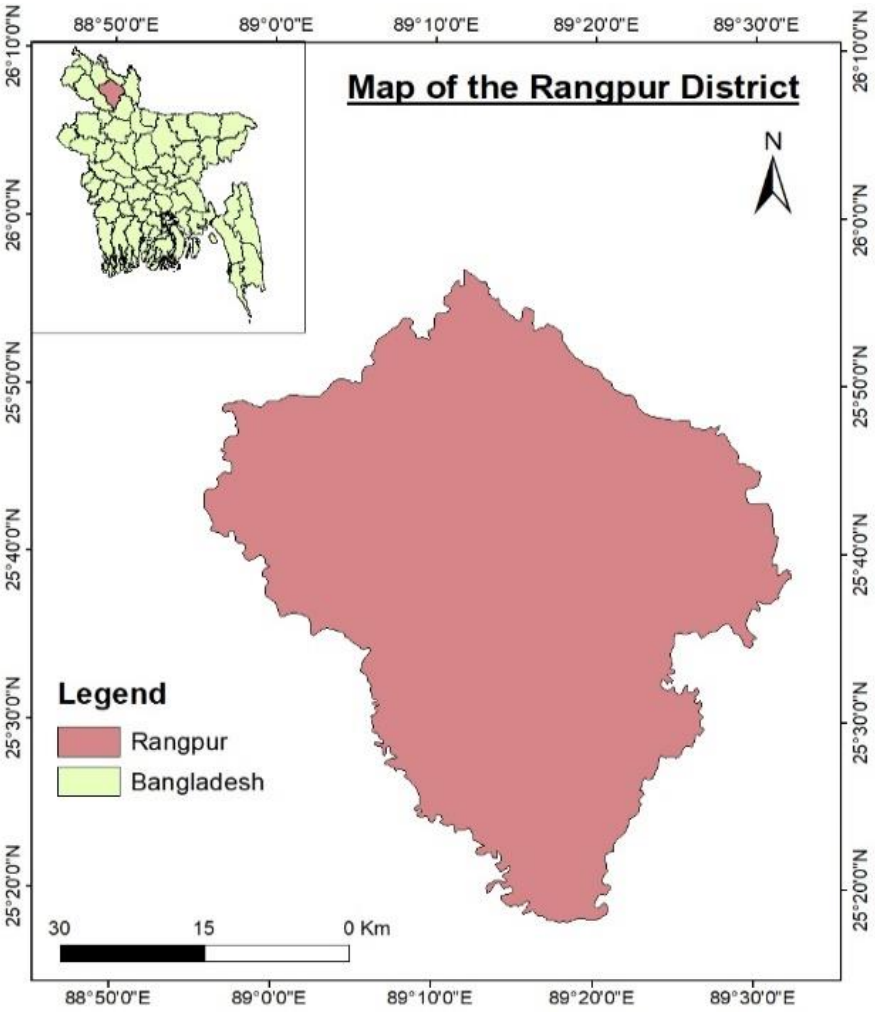


Fig. 1: Map of the Rangpur District (Study) Area)

districts. On the base of abundance of insect infestation, Rangpur district (41 percent) was the most heavily infested area in Bangladesh, followed by Kushtia (32 percent) and Bogura (27 percent) (Alam et al., 2018). So, the push-pull farming system may be applied in the Rangpur district of Bangladesh to control the pest infestation problem. Moreover, the Napier grass, which is used in the push-pull farming system as the trap crop around the main crop, grows in the Rangpur district. Napier grass is highly used as cattle fodder in the Rangpur district (Sarker et al., 2013). Thus, the Rangpur district (Figure 1) has been chosen as the study area for this paper.

Objective of the Study:

The specified objectives of the study are as follows:

(a) Analyze soil characteristics, climate patterns, plant species characteristics etc. parameters of the Rangpur district.
(b) Assess the suitability of applying the push-pull farming system in the Rangpur district.
(c) Recommend to scale-up and mainstream the push-pull farming system.

Methodology:

The working method can be

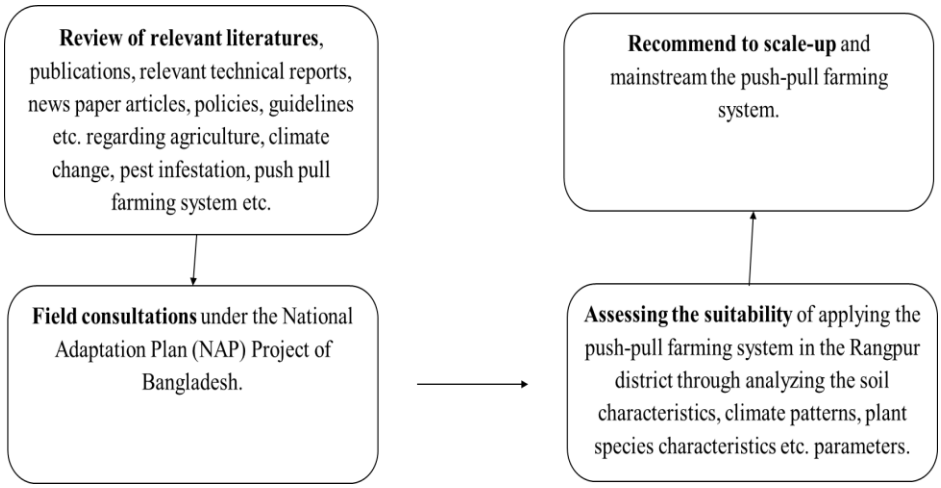


Fig. 2: Methodology Flowchart

Results and Discussions:

Literature Review Outcomes:

The literature review reveals the current situation in the crop sector of Bangladesh in terms of pest infestation. The agro-climate of Bangladesh is highly conducive to the proliferation of various kinds of pests and conservative estimates indicate 15–25% annual yield losses depending on weather and crop type (Mian et al., 2016). Hence, the climatic conditions of Bangladesh are a big driving force behind the rising pest infestations in this country. Different types of crops are lost every year for this reason posing a huge risk with regards to the national food security. Moreover, according to the IPCC (2007), the negative effects of climate change on agriculture in Bangladesh are projected to be severe, unpredictable, and unprecedented. Incidence of diseases and pests has lately become very severe due to the adverse effects of climate change, particularly rise in temperature (Mondal, 2010). High temperatures are often favourable for the spread of pests and insects. The rising temperature which eventually also lead to the occurrences of heat waves, droughts, evapotranspiration, sea surface temperature rise etc. are all very favourable climate situations for the rise in pest infestations. It is estimated that 4-14% of rice yield in Bangladesh is lost every year by different insect pests. Bacterial leaf blight (BLB) and nematode (ufra) are now the serious diseases in rice (Mondal, 2010).

NAP Consultation Outcomes:

The NAP consultations revealed vulnerabilities of the agriculture sector in the northwest region of Bangladesh, including the Rangpur district, as a result of climate change. There is an increase in pest infestation that has been observed in the Rabi and Kharif season. The use of pesticides has also increased excessively in this region. Increased pest infestation has been seen in Mango and Malta fruits during the summer and the winter seasons. Expansion of the geographic range of pests has occurred and there has been an increase in the overwintering survival of pests. At present, pests and insects have become more adaptive to low temperatures which makes them survive winter seasons more easily. Increased infestation of Yellow Stem Borer (RYSB) and Green Leaf Hopper in Boro rice and an increased infestation of Rice Brown Plant Hopper (BPH) and Rice Nek cutter pillar in Aman rice have occurred according to the local farmers. Rice blast and infertility (chita) has also increased in this region causing damage of about 15-

20% of yield. This is emerging as a big threat to the overall food security and livelihood security of this region. In this regard, the local farmers have expressed their dire need for a better solution to tackle this pest infestation issue.

Current Pest Management Practice:

The current pest management practice includes the pheromone technology. The use of pheromone requires a pheromone chemical, a trap, and a support to hang the trap in the field. The pheromone baited traps can capture male moths continuously, thus preventing mating and multiplication of the pest. But it is difficult to synthesize the pheromones in sufficient amount and all the items required to set the traps are not easily available. Given farmers' circumstances, two key implementation obstacles were observed: (i) farmers' ability to comprehend the pest's lifecycle and the trapping technique, and (ii) unavailability of pheromone lures, traps, and other tools at the village level (Nahar et al., 2020).

Push-Pull Farming System:

The discussion above is evident that the farmers in the Rangpur district are in need of an effective pest management system. This paper suggests the use of the Push-Pull farming system as an environmentally-friendly and cost-effective alternative to the current practices, such as, use of insecticides, pesticides, Pheromone traps etc. In Kenya, Africa, this approach has become extremely popular (Kassie et al., 2018). Napier Grasses, which emit a chemical that attracts or pulls pests towards them, are utilized in this technique around the edge of an agricultural field. They are called the Trap Crops as they trap the pests within them and away from the main crops of the agricultural land. Desmodium crops are also grown in agricultural fields, and they release a chemical that repels or pushes pests away from them (Figure 3 and Figure 4). They are called Intercrops as they are planted in between the main crops (Z. Khan et al., 2016). The combination of this push and pull technique protects crops from destructive pests (Push-Pull Cropping: Fool the Pests to Feed the People | Rothamsted Research, 2022).

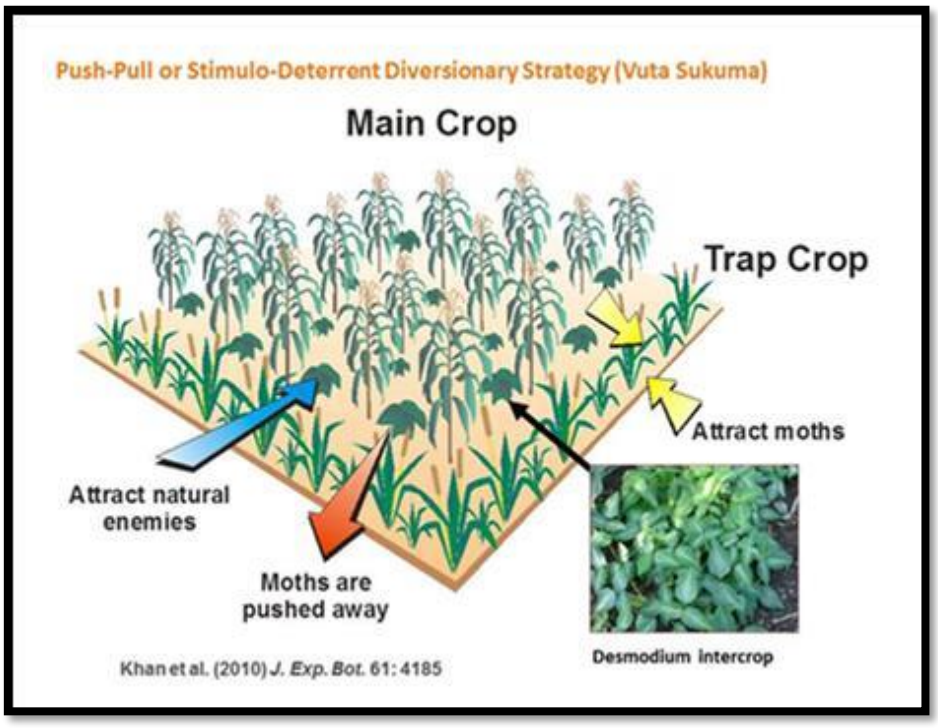


Fig. 3: Push Pull Technology Implemented in Kenya (Source: Rothamsted Research, 2022)

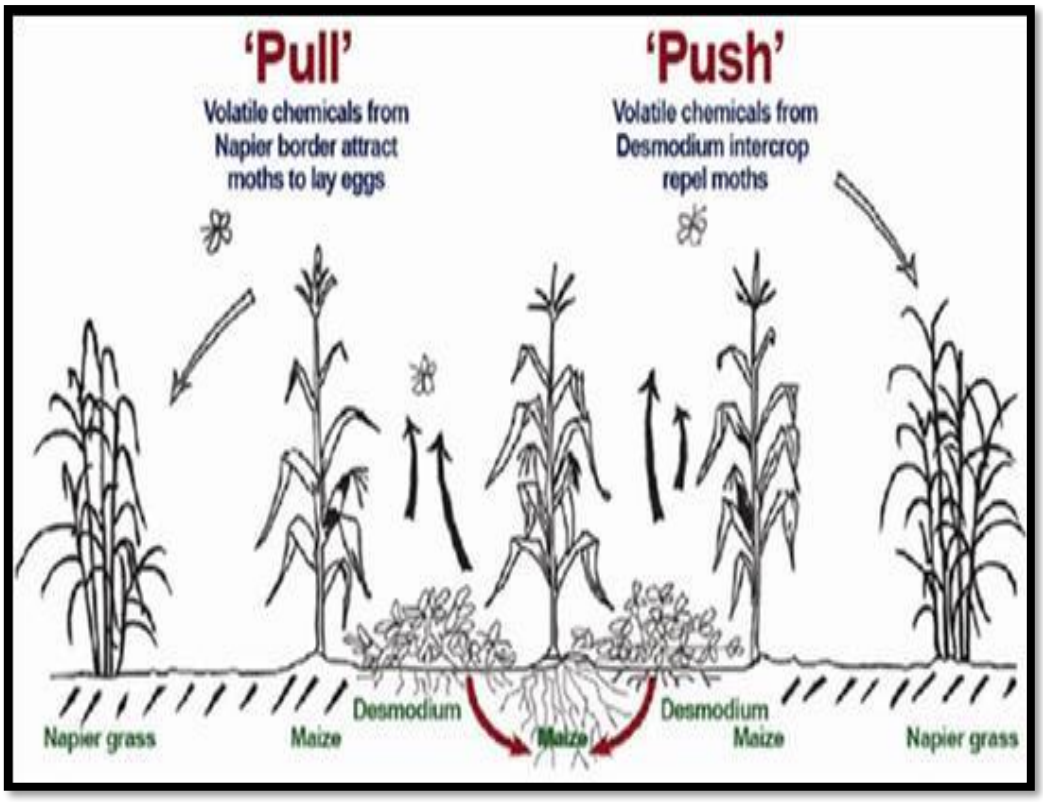


Fig. 4: Push Pull Technology (Source: Researchgate, 2018)

Benefits of the Push-Pull Farming System:

The literature review, also revealed many benefits of the Push-Pull farming system over other practices (Figure 5). For instance, this system efficiently controls the infestation of stemborers, striga and other pests. This also leads to the increase in crop yields and in turn improves the production of dairy and eventually improves human health. This system also increases the production of fodder that improves the health of cattle which eventually results in improved production of manure that also improves the soil health. Besides this, this system also fixes Nitrogen gas to the soil and raises the quality of the soil along with reduction in soil erosion. The production of forage seeds also increases due to this system that results in the increase in the overall household income of a family that eventually leads to the empowerment of women of the society. The biodiversity of a place is conserved which also leads to the improvement in soil health as a result of this push-pull system. Thus, this push-pull system has arrived as a tool to technologically empower the poor and vulnerable farmers of this country besides ensuring sustainable development and gender and social equity (Pickett et al., 2014).

Suitability Assessment of the Push-Pull Farming System:

The literature review culminated in the following suitability assessment of the Push-Pull farming system for the Rangpur District:

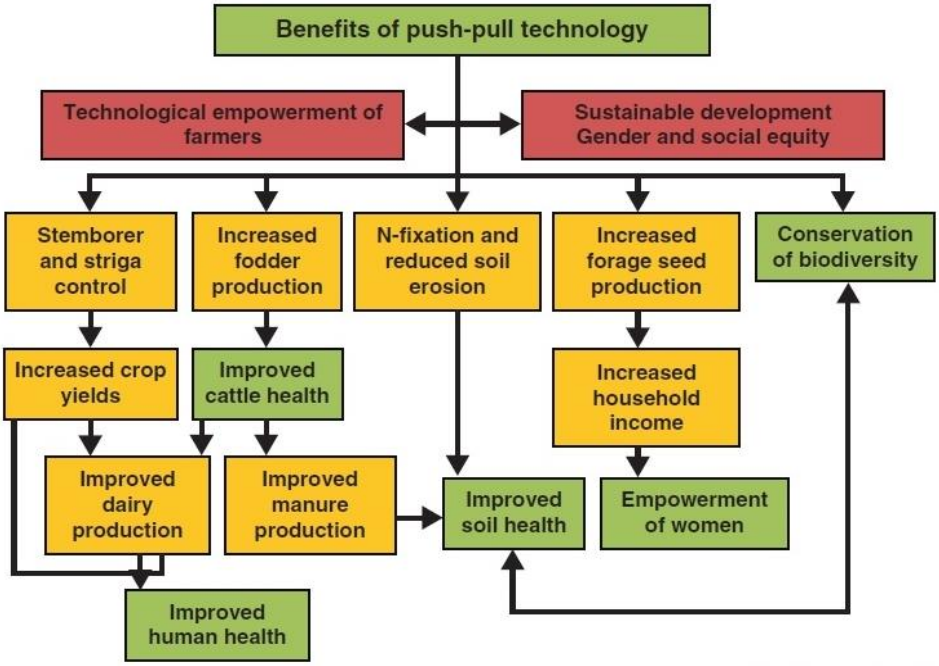


Fig. 5: Benefits of Push-Pull Technology (Source: Pickett et. al., 2014)

Suitability Criteria	Suitability for the Rangpur District
Soil Characteristics	• The soil of the Rangpur District is alluvial soil, which means it is mostly made up of sand, silt, clay etc. deposited by rivers. • Studies show that the Push-Pull farming system is favorable to be applied in alluvial soil. • One of the major reasons behind this is that Napier Grass grows well in sandy soils, which is used as the Trap Crop in Push-Pull farming (Islam et al., 2017).
Climate Pattern	• The climate of the Rangpur District is mostly warm and temperate. • The climate of the tropical African countries are also warm, where the Push-Pull farming system is widely practiced (Z. R. Khan et al., 2014).
Growth of Napier Grass	• Many farmers in Rangpur have achieved self-reliance and changed fortune through commercial basis cultivation of high yielding variety Napier grass across the district during the last 12 years (*Napier Grass Farming Brings Fortune to Many Rangpur Farmers*, 2021).
Growth of Desmodium	• Desmodium is a crop used as an intercrop within the main crop in the Push-Pull farming system. The *Desmodium gangeticum* grows well in the fallow lands, scrub jungles and woodlands of all the upazillas of the Rangpur district (S. A. Khan et al., 2021).
Nature based Solution (NbS)	• The Push-Pull technology is a Nature based Solution (NbS) in the agriculture sector that uses elements of the nature to tackle the negative impacts of climate change (Z. R. Khan et al., 2010)
Current Practice Location	• The Push-Pull technology has not been practiced in Bangladesh yet. It is currently being practiced largely in the African countries, such as, Kenya, Uganda etc. (Kassie et al., 2018).
Social Acceptability	• The Push-Pull farming system has reportedly been socially acceptable since it generates a source of income for the poor farmers and also empowers women along the way (Pickett et al., 2014).

Tab. 1: Suitability Assessment of the Push-Pull Farming System

Conclusion:

The crop sector of the Rangpur district suffers heavily due to the increasing pest infestation and the overuse of chemical pesticides. In this light, this study has attempted to find an alternative solution to this problem that is more nature based and hence, environment friendly.

The push-pull farming system has been introduced here in this regard. According to this study, both the soil and the climate of the Rangpur district of Bangladesh are suitable to apply the Push-Pull farming system, as a Nature-based Solution (NbS). This study also reveals that the Push-Pull technology has many benefits other than providing food security, such as, reducing soil erosion, fixing nitrogen to soil, providing an income source, conservation of biodiversity etc. So, this type of farming system may effectively solve the pest infestation issue of the Rangpur district.

Recommendations:

The following recommendations have been put forward from this study:

- The Push-Pull farming system needs to be scaled up at a national level all over Bangladesh to ensure food security, secure livelihood, conserve biodiversity, reduce soil erosion etc.
- The scaling up of this technology would require building awareness among the farmers regarding this push-pull farming system, providing training for the capacity building of the farmers and the local people, applying this technology to a limited area in order to test if it would work on a larger scale etc.
- The National Adaptation Plan (NAP) Project of Bangladesh is trying to popularize the concept of Nature based Solution (NbS) and this may be achieved by scaling up this Push-Pull technology.
- This research has been limited to the review of past literatures and field consultation outcomes only. There is scope for this to be updated further by more detailed research.
- Soil properties, rainfall variability, temperature pattern etc. data may be collected and analyzed in order to properly assess the suitability of the soil, climate, plants etc. of the study area to withstand the Push-Pull farming system.
- Consultation workshops may also be conducted at the study area to assess whether the new technology is acceptable to the people.

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An Artificial Intelligence-based Framework to Achieve the Sustainable Development Goals in the Context of Bangladesh

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Abstract

Sustainable development is a framework for achieving human development goals. It provides natural systems' ability to deliver natural resources and ecosystem services. Sustainable development is crucial for the economy and society. Artificial intelligence (AI) has attracted increasing attention in recent years, with the potential to influence many domains positively. AI is a commonly employed component in the quest for long-term sustainability. In this study, we explore the impact of AI on three pillars of sustainable development: society, environment, and economy, as well as numerous case studies from which we may deduce the impact of AI in a variety of areas, i.e., agriculture, classifying waste, smart water management, and Heating, Ventilation, and Air Conditioning (HVAC) systems. Furthermore, we present AI-based strategies for achieving Sustainable Development Goals (SDGs), which are effective for developing countries like Bangladesh. The framework that we propose may reduce the negative impact of AI and promote the proactiveness of this technology.

Keywords: artificial intelligence, sustainable development, SDGs, framework, environment, society, economy

1. Introduction

Sustainable development is defined as the growth of society, the environment, and the economy in such a way that it adds value to future generations. The term “sustainable development” refers to the development that fulfills current demands without jeopardizing the ability of future generations to satisfy their own needs [1]. To achieve sustainability, the viability of the economy, protectivity of the environment, and equitability of society need to be ensured. A developing country like Bangladesh needs a well-thought-out strategy to attain long-term development. We are currently extremely linked to smart technologies like Artificial Intelligence (AI), and we can make a difference by utilizing the beneficial consequences of these technologies.

AI can be used in every industry to open up new possibilities and increase efficiency. In the scenario of Bangladesh, AI has the potential to significantly cut human labor while ensuring task completion. We need to use technology as much as possible in diverse areas of our nation to accomplish the SDGs, but we must remember the three pillars of sustainable development. We cannot neglect any of the pillars in order to achieve sustainability, thus we should also analyze the negative impacts of AI. The use of AI technology can enrich the economic growth of a country as it ensures productivity.

Shamsuzzaman et al. [2] outline the several factors that have led to the inadequate fisheries regulatory framework of Bangladesh. The research looks into how the legal structure of the Bangladeshi fishing sector might be improved. According to their study, a reformed legal framework they propose in Bangladesh might help the country achieve SDG #14: Life Below Water. Islam et al. [3] develop a thorough conservation strategy for the coastal and marine ecosystem of Bangladesh. They also focus on SDG #14 and suggest a framework for playing

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an incremental role in boosting blue growth and achieving SDGs. Sourav et al. [4] propose a framework for developing a smart city for a densely populated country like Bangladesh to achieve sustainable development. The findings of their research provide a clear image of the key features of smart cities and the elements that determine their sustainability. Roy et. al [5] state that altering the framework around this nexus of sustainable development initiatives may boost the productive basis of the economy and provide the impetus for the people of Bangladesh to achieve equal human welfare. Although the previous studies are well-defined, employing AI for sustainable development helps us achieve our objective more quickly, which is an urgent need in our country.

After reviewing related articles, we have noticed that there is no suggested framework for acquiring SDG by executing AI in the case of Bangladesh. There are a few works available on the impact of AI on achieving sustainable development goals. So, AI-based frameworks will create a new extent in attaining sustainable development goals.

In this study, we analyze the influence of AI on three pillars of sustainable development: society, environment, and economics. Furthermore, we propose an AI-based framework to accomplish sustainable growth in four distinct sectors: agriculture, waste management, water management, and heating, ventilation, and air conditioning (HVAC) systems. In addition, we explore the negative effects of AI and possible solutions to mitigate these effects.

2. AI and sustainable development

The introduction of AI has ushered in a new era of computing where computers can do tasks that usually require human intelligence to complete. At the core, AI is a field that merges computer science, mathematics, and data science to enable problem-solving. Machine learning [13], and Deep Learning [14] are subfields of AI that are often discussed alongside AI. These fields have been shaping an increasing set of sectors. With its ever-increasing reach, AI can have a significant impact on sustainable development. From Google's use of AI to reduce the energy cost of cooling of its data center by 40% [15] to Xcel Energy's use of AI to predict power consumption patterns to burn coal more efficiently, AI has already started to show its usefulness in sustainable development.

Sustainable development encompasses the three pillars: social, environmental, and economic. In order to achieve sustainable development, we want to achieve a balance of economic growth, environmental sustainability, and social inclusiveness. In this section, we discuss how AI can impact these three pillars of sustainable development.

2.1 Social Pillar

AI can be used to distribute food, health, water, and energy resources more efficiently. More efficient smart cities based on AI can be low carbon-emitting because of their efficient use of their resources. Technologies like interconnected autonomous cars can reduce traffic loads and thus reduce pollution caused by traffic. AI can help us integrate renewable energy sources like wind and solar energy with our existing energy sources by predicting when to reduce burning fuel based on the weather. It creates new job opportunities and reduces overall labor-intensive work.

2.2 Environmental Pillar

AI enables us to fight climate change by enabling us to better utilize our resources. We can utilize AI to monitor and predict energy consumption to create more efficient power generation systems. AI may cause over-exploitation of natural resources which damages the environment greatly. As AI integration is not as prominent now, it is still too early to be sure that AI can have a net positive impact on our environment. It can help us improve and conserve biodiversity

by monitoring and predicting environmental changes. These systems help us with environmental planning, decision making, and environmental resource management.

2.3 Economic Pillar

The introduction of AI can have a massive impact on the economy of a nation. Automation using AI can reduce manual work and take over many dangerous tasks from humans. With the integration of AI, we can design and create more fast and sustainable infrastructures. This can lead to more responsible consumption and production. AI technologies can be very costly to develop. This creates more differences between the economies of low to mid-income countries and high-income countries. With AI replacing old manual jobs with jobs that require more technical knowledge, it has a heavy bias towards the educated.

3. Case Studies

For the above-mentioned four domains: agriculture, waste management, clean water, and climate change, we illustrate the relationship between AI and sustainable development; our case studies reflect similar fields. There are numerous additional sectors where AI has been effectively used for sustainable development, but for the sake of space, we confine our study to these four.

3.1 Agriculture and AI: a case of sustainable agriculture

The See & Spray system: The system from Blue River Technology allows farmers to spray herbicide exclusively to weeds, using less than a tenth of the herbicide used in traditional weed treatment. See and Spray has developed the first equipment in the world that allows farmers to improve every plant in their field using machine learning and robotics [6][2].

The Sowing Application: AI is being used in agriculture by Microsoft and ICRISAT to increase agricultural yields[3]. The results reveal a 30 percent greater average yield per hectare following the introduction of the pilot in June 2016, which tested a new Sowing Application for farmers paired with a Personalized Village Advisory Dashboard for the Indian state of Andhra Pradesh. The Sowing App was created to assist farmers in achieving optimal harvests by recommending the ideal time to plant-based on weather, soil, and other factors. The pilot was carried out in Kurnool's Devanakonda Mandal, and the advice solely applied to the groundnut crop.

3.2 AI and the Global Water Crisis: a case of smart water management

An Artificial Neural Network (ANN) based water need forecasting system was developed by the Spanish Ministry of Economy says [19]. The system connects ANN with the Bayesian framework and Genetic Algorithms (GA) to provide short-term day-to-day forecasting of water irrigation requirements. The method has enhanced the prediction exactness by 11% compared to non-AI-based techniques.

Water contamination issues can be detected by AI. By using trained models to identify dangerous particles and bacteria. Broadcasting devices that observe water for issues help municipalities to notice contamination as soon as possible.

3.3 An AI Approach for Waste Management and Recycling: a case of classifying waste

Clean Robotics - TrashBot™ has developed an automated system that detects and separates landfills from recyclables using robotics, computer vision, and AI. It performs this more accurately than humans, collects high-quality trash data, and alerts personnel when the bin is

[2] See & Spray - the world's first smart sprayer

[3] Microsoft and ICRISAT - Bringing Artificial Intelligence to agriculture to boost crop yield

full. Individual units can learn from the global TrashBot fleet and become more intelligent over time thanks to cloud connectivity. A monitor for business communications, education, and advertising are also included. According to CleanRobotics claim, with the help of AI TrashBot can separate landfills vs recyclables with more than 90% of accuracy where traditional mechanisms without AI are about 30% accurate.

A piece of trash is tossed into the TrashBot, which is subsequently covered by a little door. A camera is hidden behind that door, analyzing the sort of garbage. In addition, the object is weighed on a Teflon-coated plastic shelf that drains any moisture. CleanRobotics software assesses whether the item is going to a landfill or a recycling center, and then guides it to the proper container below. On technical terms, TrashBot does this by using image processing, computer vision, and AI. CleanRobotics additionally offers a monthly software subscription that allows more waste management facilities.

3.4 AI in making efficient HVAC systems

One of the largest sources of energy consumption is the heating, ventilation, and air conditioning system also known as HVAC systems. While there have been many advancements in the field of HVAC systems to make them more energy efficient, the field of HVAC systems have reached maturity and not much can be done to the hardware to make them more efficient. In recent years, the integration of AI in HVAC systems has shown promising improvement in energy consumption of the HVAC systems. DeepMind's machine learning model has proven to be highly efficient at reducing the energy consumption for google's data centers[15]. By integrating the ML-based cooling system into Google's data center, the energy consumption related to cooling is reduced by up to 40%. Given how advanced and complicated google's data centers are and how widely they are used, this is a very significant improvement. One of the primary sources of energy consumption in a data center comes from cooling. The computers in the data center generate a lot of heat. DeepMind took the historical data collected by thousands of sensors within Google's data center to train the Deep Neural Network model. These sensors monitored parameters like power consumption, temperature, pump speed, set points etc. The model was trained to reduce the average future Power Usage Effectiveness or PUE of the data center. The model can ensure that the data center won't go beyond operating constraints by predicting how much resources will be needed in the future based on the pressure and temperature of the data center. Major breakthroughs like this show us the huge potential ML has at reducing energy consumption and help us get one step closer to combating climate change.

4. AI-based Framework for Sustainable Development

In the context of Bangladesh, we propose a framework for the four major systems to accomplish the SDGs. We can achieve several SDGs by assuring the sustainability of agriculture, water management, waste management, and HVAC systems, which can lead to the sustainability of a developing country like Bangladesh.

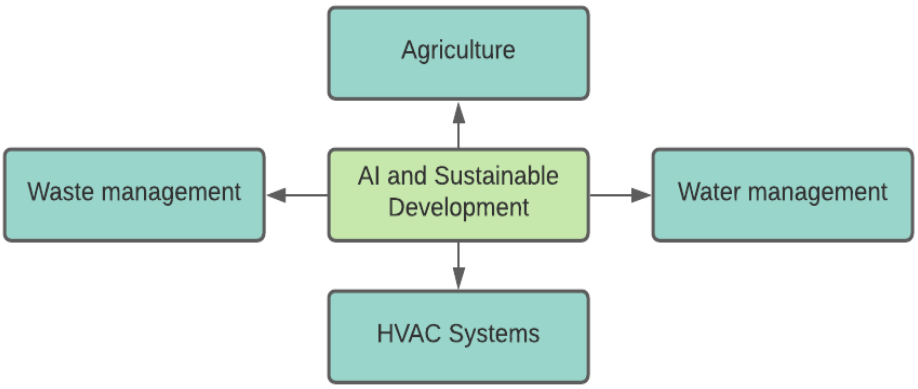


Fig. 1: Four major systems to achieve the SDGs in the context of Bangladesh

4.1 Decision-Making Support System for Agriculture

Agriculture must be prioritized in order to achieve SDG #2: Zero Hunger, and SDG #8: Decent Work and Economic Growth. Agriculture is an important component of economic development. The majority of the farmers of our country struggle to make informed

decisions based on crop, soil, and weather conditions. AI makes decision-making easier by making it quicker and smarter. Using the benefits of AI, we propose a decision-making support system for farmers that will assist them in taking appropriate actions depending on many parameters.

We can employ a drone to take the image of crops, which is usually applied for this sort of task. Following the capture of photographs, we can send the data to an AI system, which will determine the crop condition. YOLO, invented by Redmon et al. [7], is one of the most widely used algorithms for this purpose. Currently, the state-of-the-art for real-time object identification is YOLO V5[4]. For object detection, we can also use Region Based Convolutional Neural Networks (R-CNN) [8]. Crop condition is one of the criteria that goes into making a final decision. Soil condition and weather data are two more variables to consider as shown in Fig. 2.

For collecting meteorological data, we need to use meteorological sensors[5]. Climate and weather are monitored and assessed using meteorological sensors. For identifying the condition of the soil, we can employ an IoT soil condition monitoring sensor. Moreover, we can apply the IoT-Based Soil Condition Monitoring Framework proposed by [9]. We need to feed the data to the AI system for decision-making after acquiring the information utilizing various technologies.

Finally, depending on the criteria, the AI system will make task recommendations using proper machine learning algorithms. This decision-making mechanism will assist farmers in doing suitable farming activities.

[4] YOLOv5 | PyTorch
[5] Meteorological Sensors

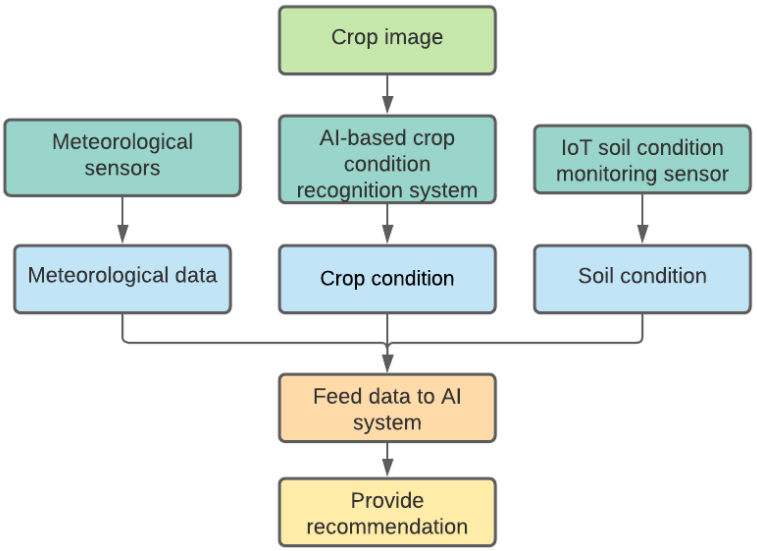


Fig. 2: Decision-Making Support System for Agriculture

4.2 Water Resource Management System with the help of AI

Water management is needed to achieve SDG #6: Clean Water and Sanitation, SDG #12: Responsible Consumption and Production, and SDG #14: Life under Water. With the help of AI, we propose a water resource management system that will monitor the water quality, forecast the water flow and help to manage according to the situation. A hypothetical framework for smart water management is shown in Fig. 3. The system is responsible for forecasting floods. For measuring water level, different types of sensors[6] can be used. The system can monitor water parameters through water quality sensors[7].

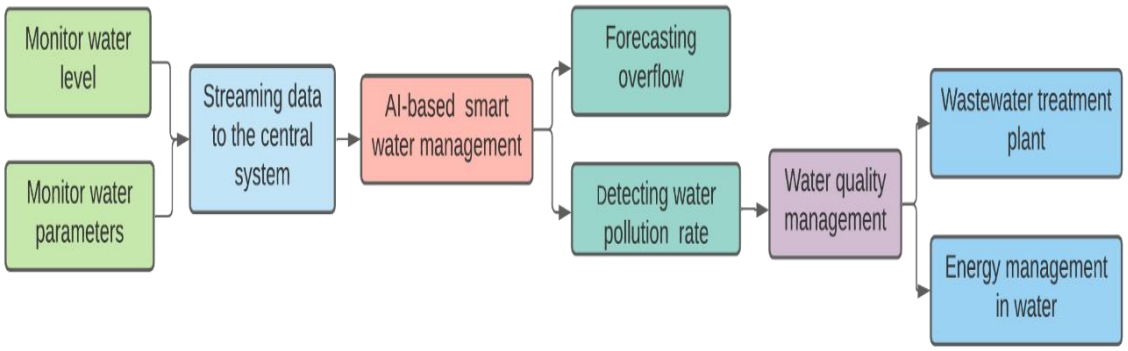


Fig. 3: Water Resource Management System

The six main parameters of water quality are bioindicators, dissolved oxygen, turbidity, nitrates, pH scale, and water temperature. Water pollution can be detected using the water quality monitoring framework proposed by [20]. For water quality management, we can utilize WQMCM framework proposed by [21]. Wastewater treatment can be done using the IoT based model proposed by [22]. [23] proposed a smart solution to improve water-energy. We can use the framework for energy management. Based on different indicators, the AI system will forecast and manage the water resource using necessary machine learning algorithms. This system will help predict overflow and measure pollution and manage smartly to achieve sustainability.

[6] Water Level Sensors
[7] Water Quality Sensors

4.3 Classifying and Managing Waste with AI

Waste management is the most important and largest field in environmental technology. In Bangladesh, waste management is a genuine issue. Most of our waste finds its way to landfills or ocean water. Recycling and reusing are less practiced and since almost all the wastes need to be collected and sorted via human labor, it's time-consuming and not cost-friendly to invest in waste management. Accordingly, an enormous amount of recyclables and reusable wastes are dumped into landfills. Non-biodegradable wastes are overlooked as it takes more human labor to classify and sort. We propose a waste management system that has an easy-to-build infrastructure and provides a cheaper solution than the traditional system.

The inputs of the system are wastes from several sources. For instance, we categorized the sources into three primary regions: household wastes, corporate wastes, and industrial waste. More sources of waste could be added to the system as input, the system function remains the same. After collecting all the wastes from various major sources, it would be gathered at a local waste treatment center. From the local waste treatment center, municipal solid wastes will go through a classification procedure where, with the help of deep learning and robotics, wastes would be classified and sent to a reserved section for a certain type of waste. All the liquid wastes from the local waste treatment center are sent to the liquid and water treatment center. The output of the local waste treatment center for liquid wastes could act as an input for the *Water Resource Management System*.

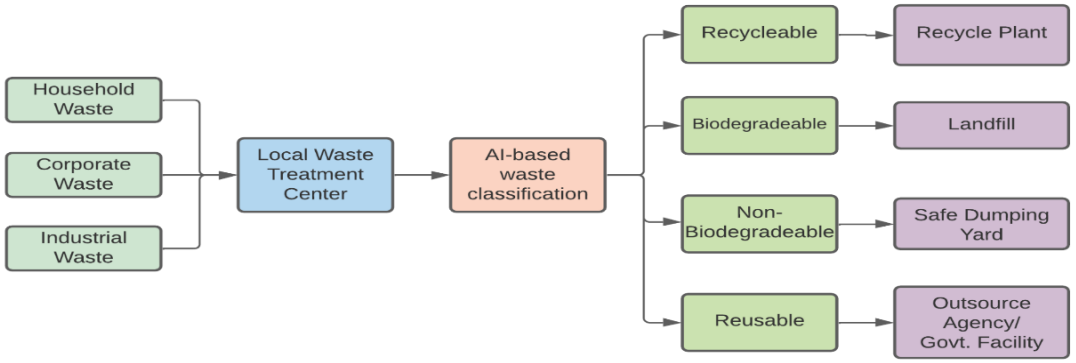


Fig. 4: Waste Collection, Treatment and Classification System

Once municipal wastes are classified and sent to a reserved section via a pipeline, a transportation or pipeline system would deliver those to the proper destination. Recyclable wastes will be delivered to recycle plants, biodegradable wastes into landfills, non-biodegradable wastes, or hazardous waste to a safe dumping place, outsource agency or government facilities would collect reusable wastes and treat those to be used again. Convolutional Neural Networks (CNN) or, as discussed in the previous system, YOLO, can be used to classify the wastes. After identifying wastes, mechanical arms or similar robotic mechanisms will sort the waste in a specific order per instruction.

4.4 An eco-friendly approach to HVAC systems with the help of AI

HVAC systems are responsible for a large amount of energy consumption and carbon emission. Making the HVAC systems more efficient will help us achieve SDG #11: Sustainable Cities and Communities as well as SDG #13: Climate Action. As the economy of Bangladesh grows and the temperature of cities rise, air conditioning which was once viewed as a luxury is becoming a necessity in order to live in cities like Dhaka. As the number of AC units used in the cities increase, the hot air released by the AC units is having a substantial impact on the temperature surrounding them. As a result, people are buying more AC units to cope with the rising temperature creating a loop of the ever-growing number of AC units in the cities. In order to make sure the cities of

Bangladesh doesn't reach an over air-conditioning situation like HongKong[8], we need to build centralized HVAC systems that take both efficiency and environmental effects into account. Here, we propose an eco-friendly approach to a centralized HVAC system with the use of AI.

In order to make an efficient HVAC system that also tries to minimize its effect on the surrounding environment, we will need to monitor both indoor and outdoor environmental parameters like temperature, humidity and air purity using air quality sensors. The monitored data will be sent to an AI model which will in turn predict future indoor and outdoor environmental parameters based on historical data. We will use an optimum demand response scheduling with the help of methods proposed by Kim et al. [16] & Wang et al. [17] We will then use another AI model to predict the effects of the HVAC system on the outside environment. Finally, we will feed the prediction data of the two models to another AI model that will suggest an optimal HVAC usage pattern that has the least amount of environmental impact.

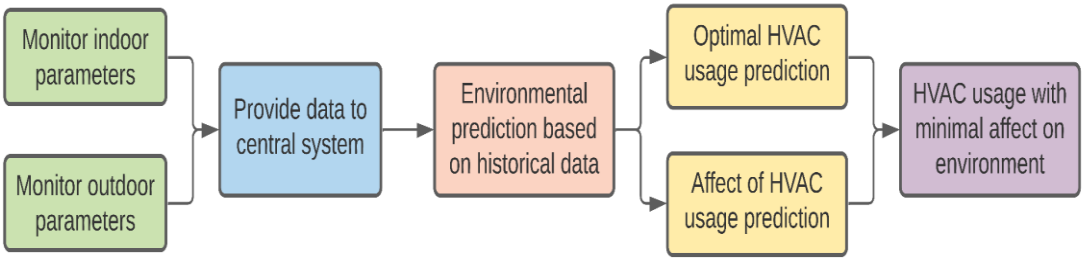


Fig. 5: Finding optimal HVAC usage pattern with minimal effect on the surrounding environment

5. Negative Impact of AI

AI is a vast computer science subject that focuses on developing intelligent machines that can do tasks that would otherwise need human intellect. As a result, AI is a frequently utilized tool for attaining long-term progress. However, this technique has several disadvantages. In this part, we'll discuss AI's detrimental influence on sustainable development.

AI has the potential to exacerbate environmental deterioration, according to the forum and experts on the subject [10]. The usage of high-power GPUs for machine learning training has previously been linked to an increase in CO2 emissions which is the major cause of global warming. Because the environment, economy, and society are all intertwined, global warming has the potential to harm not just the environment, but also the way of life of living creatures. To achieve sustainable development, any of the pillars of sustainable development is essential. Another big disadvantage of AI technology is that it generates a lot of e-waste, which is extremely difficult to control using IWM (Integrated Waste Management) techniques. AI training is an energy-intensive process. New estimates indicate that carbon dioxide emissions when training a single AI are up to 284 tonnes of carbon dioxide. This is five times the lifetime emissions of an average car [11].

The research and deployment of AI are in the control of huge corporations. This is due to the fact that AI requires cash, and society's tremendous wealth is typically concentrated in the hands of a few individuals. We are becoming sedentary as a result of the increased usage of AI-based technology, which is contributing to our health problems. The substitution effect of AI will not only increase unemployment but will also reduce wages, resulting in lower income for low-end workers, exacerbating the social divide between rich and poor.

[8] How did Hong Kong become addicted to air conditioning?

6. Discussion

This research focuses on achieving SDGs with the help of AI and modern automation technology. Our goal is to replace traditional inefficient systems with efficient and eco-friendly ones. Although AI and modern technologies are being used daily to make a traditional system more efficient in every sector, the use of AI in environmental development is overlooked even to date. We found that most of the research based on AI on sustainable development addresses the statistical problems we face to maintain sustainable development. While these papers proposed and presented smart solutions in terms of sustainable development, most of these researches are tunnel-visioned into a single category.

In this paper, we proposed a framework that includes agriculture, waste management, clean water, and power-efficient cooling solutions for households and industry. Our framework proposes to replace traditional systems that require a large amount of human labor, are inefficient, and create a negative impact on the environment. The proposed framework provides a replacement solution while being more efficient in carbon emission, energy usage, environmental pollution, and climate change.

While our solutions provide better and more efficient results in the paper, there are some challenges to be addressed in the context of Bangladesh or any other under-developed country. Primarily, it is difficult to take crop images using drones. It can increase the cost and drones are not permitted everywhere. Our Waste Management System and Water Resource Management System is relatively expensive to develop for a country like Bangladesh, but it is mandatory for us to take steps to manage waste properly to grow towards sustainable development. Finally, our HVAC (Heating Ventilation Air Conditioning) system is going to have a great impact on climate change considering it consumes less energy, less power and produces less heat output, and provides efficient cooling solutions both for residential and industrial scenarios. It will be costly to integrate with old hardware and it needs a centralized control center, to begin with. Besides, the machine learning models have to be area-specific, meaning we need to build a control center in each area to achieve the best results. This system might seem irrelevant at first, but with the rapid growth in urbanization and increasing amount of data centers, we must shift to an efficient system like the one we presupposed to maintain the sustainable development goals.

We hope to improve the framework in the future with more data and a wide range of integrated systems. To implement the systems in a real-world scenario, we need to make sure that all the stakeholders are informed about the use of AI and our systems co-operates with the rules and regulations of the area. We have to raise awareness and educate every stakeholder of our systems to achieve optimal output.

7. Conclusion

The coming era of AI will change many aspects of our day-to-day lives. From the assistant in our phones to the Self-Reliant Rovers [18] on mars, AI has already impacted our lives. It is high time we used AI in major aspects of our lives to extract the most from AI technologies to make our lives more efficient and sustainable. In this paper, we have explored the role of AI in sustainable development and how AI-based frameworks can be used for achieving sustainable development goals in developing countries like Bangladesh. Four case studies were made on some of the major sustainable development sectors. These studies take a look into the usage and research of AI in major fields of sustainable development, like agriculture, water management, waste management, and HVAC systems, to highlight the potential of AI in sustainable development. Based on these extensive case studies on major fields of sustainable

development, we proposed an AI-based framework for developing countries like Bangladesh that can be used to achieve major sustainable development goals.

To conclude, we discuss the challenges of implementing such frameworks and how the negative impact can be mitigated are discussed in detail. The research shows that if AI technologies are used with good intent and proper rules and regulations are followed, the positive impact of AI far surpasses the negative impact of AI. So, proper rules and regulations should be made to regulate AI usage while encouraging people to use AI in their day-to-day life to make our lives more sustainable.

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Exploring the options for best practices and possible incentive mechanism for valuing water in Bangladesh

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Abstract

Water is a unique resource unlike other natural resources in terms of availability and uses. Nature itself needs water to maintain a balance in biophysical and ecological system. Diversified and conflicting uses of water make its management very critical and complex. Human interventions and Climate Change put enormous pressure on the water system. Sustainable water governance needs informed policy and planning with regulatory interventions. Bangladesh aims at water secured development ensuring industrial and economic growth, needs to sensitize the value of water and mainstreaming the water security in the heart of the planning process. Still having troubled with the flood in the heavy monsoon season, the dry period puts pressures on water resources. On the other hand the coastal reason faces salinity and North-West region faces drought. Water demand is increasing with the economic advances. Still the sense of mass people is that water is priceless. Efficient allocation of resources is indicated by the absence of both overuse and misuse and for this, we need to know the value of such a resource. Since water is not priced through the market and is accessible for use by various users free either of charge or at a minimum nominal price (like water supplies in cities), it is likely that the resource is over-used and consequently over-exploited and so may face depletion which unless checked and regulated may be severe. As such, there is a need to understand such over-use and misuse and how actual prices paid for water differ from its values in such cases. In this study, detail policy review, Sectoral Consultation, Focus Group Discussion (FGD), Key Informant Interview are done extensively to explore the stakeholder perception and opinion on water uses, water security and mechanism for valuing water in different key sectors mainly Industry and agriculture. More detail study and mass sensitization on valuing water and raising awareness on best uses of water is prerequisite. In agriculture sector, water use efficiency can be improved using Alternate Wet and Dry (AWD) method. However it is not widely used due to the system of Irrigation which is based on Area Cultivated. Managed Aquifer Resurge System (MAR), Rainwater Harvesting, Circular use of Water, Integrated water resources management, Volumetric water allocation are the some of the best practices that have impact on water use efficiency and thus value water. In case of incentivize the sustainable approach, Payment for ecosystem services is an incentive-based instrument that seeks to monetize the external, non-market values of environmental services – such as removal of pollutants and regulation of precipitation events as well as green production – that can be used as financial incentives for local actors to provide such services. Rebate programs are commonly used to encourage customers to make investments in water conservation and efficiency improvements. Appropriate valuing water and thus adopting the best practices to ensure the judicious uses are fundamental to fulfil the future demand of the scarce water resources.

Keywords: Water security, valuing water.

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1. Introduction

Water is one of the most needed (and also misused) natural resource on the planet. Fresh water which is necessary for use by humans for sustaining life, is just about 2% of the total available water and of that 2%, only a negligible portion is available in liquid form as rainfall, in wet bodies and rivers, and water underground. This very small volume is distributed unevenly over space and time (between and within years) making it a scarce resource in most places and situations. Therefore, it is imperative that this scarce resource be allocated among its different uses and groups of users in an equitable and efficient way. This aspect of allocation of water is stated explicitly in SDG 6 on water and its sub-goals (United Nations 2015). One major guide for such efficient and equitable allocation is to do so based on how human society perceive the value of such a resource in alternative uses and contexts. Understanding the value of water in its various uses is, therefore, a requirement for its efficient and equitable distribution across different uses and users. One needs real life estimates of value of water for the purpose.

Efficient allocation of resources is indicated by the absence of both overuse and misuse and for this, we need to know the price of such a resource. Since water is not priced through the market and is accessible for use by various users free either of charge or at a minimum nominal price (like water supplies in cities), it is likely that the resource is over-used and consequently over-exploited and so may face depletion which unless checked and regulated may be severe. As such, there is a need to understand such over-use and misuse and how actual prices paid for water differ from its values in such cases.

Well-designed efforts to improve public understanding of household water use could pay large dividends for behavioral adaptation to temporary or long-term decreases in availability of fresh water. (Attrai, 2014). (Chowdhury, 2013) analysed irrigation water use and tried to estimate value of water by analyzing its marginal productivity. One study is by (Fouad & Mohammed Rachid, 2012) looks at water valuation in agriculture in the Souss-Massa Basin (Morocco). The study found that water valuation varies depending on water accessibility as this determines what crops to cultivate and how much water may actually be available. Finally, if users do not consider inter-temporal efficiency (they ignore future groundwater use), the shadow price can also be referred to as the current marginal value of water. Water valuation means assessing the value (or worth) of water to different stakeholders. Water, unlike other natural resources is used for many purposes and some of them are complementary while others are competing. In general, water resources have many uses and the existing literature has categorized them into four distinct types of use: a) provisioning use of water – where water is used directly or indirectly for production of various goods and services for us; b) regulatory use of water – where water is used to regulate various ecological functions like precipitation, drought, flooding, etc.; c) cultural use of water – where the ecosystems surrounding water bodies or water sources contribute towards developing non-consumptive use of water like tourism services, cultural heritages, etc.; and d) supporting use of water to continue life over time for both human and plants and animals. These different usages are not necessarily mutually exclusive and so it is hard to find values of water across individual uses.- Private sector tends to use the language of finance, while governments often employ concepts from economics using a range of environmental, rights-based, or social-goods for valuing water.

It has been emphasized that all of the stakeholders should have a legitimate claim on water and its use, and so a corporate perspective must both understand and negotiate these different ways of valuing water as a scarce resource (JA & Orr, 2015) . There are others who define value of water differently like (Rogers, et al., 1997) consider the value of water to be divided

into economic value (i.e Value of water in industrial and agricultural use) and intrinsic value (i.e pure existence value). Whereas, (Agudelo, 2001) consider the economic value of water resources and aquatic ecosystems in terms of four separate components (abstraction of water, fisheries, recreation and biodiversity).

2. Method

Valuing water is a priority action to achieve the water security targets. Valuing water is challenging issue as water has many dimensions and unique resources with competing user. The best way is to ask its user how it value in their lives and what they would like to pay for the services comes from water. In most of the case like Bangladesh people consider water as free resources. However farmers are paying charge for irrigation water use and in urban areas dwellers are paying water supply fees imposed by the City water supply authorities. In this case water is not valued as resources but people are paying for the services provided. On the other hand, the authorities are taking the charge mainly part of the development cost and O&M cost. Lacing the value of water as resources leads to misuse and unregulated use. In this study detail policy review, 7 Consultation workshop with key stakeholder from Industry, agriculture, Urban Water users and Ecosystem; 7 focus group discussions and 14 key Person interviews has been taken targeting water experts, water users and different level of stakeholders. After getting the best practices it is also prioritized based on opinions of the stakeholders (Figure 1). In the mean time during identification of best practices for valuing water, possible Incentives mechanisms for ensuring judicious uses of water also identified for policy recommendation.

3. Results and Discussion

The best practices that comes out from the Stakeholder Consultation, FGD and key Informant Interview has been found as:

Alternate Wet and Dry Method (AwD): Practicing AwD in Agricultural Water Management is one of the good examples of valuing water. It tries to ensure the demand driven water supply. Mass piloting and appropriate application of AwD may play significant role in judicious allocation of water for fulfilling the agricultural water demand. It also ensures the maximum rice production with minimum water use. Most of the academician and BADC officials gives preference in AwD than Ponding method of irrigation in rice paddy field. However the farmers are not interested in this method. The farmers perception is that they paid based on field size for irrigation.

Rain Water Harvesting:
Rainwater harvesting (RWH) is the collection and storage of rain, rather than allowing it to run off. Rainwater is collected from a roof-like surface and redirected to a tank, cistern, deep pit (well, shaft, or borehole), aquifer, or a reservoir with percolation, so that it seeps down and restores the ground water. Rain Water Harvesting is one of traditional water management practices for valuing water. Bangladesh faces immense rainfall during monsoon. Harvesting of these rain water and use it on non- rain period has ample benefit on ensuring IWRM. About 90 percent of the discussants put their opinion on rainwater harvesting method for water conservation for dry season use.

Circular Use of Water:
Optimise energy or resource extraction from the water system and maximise their reuse. Optimise value generated in the interfaces of water system with other systems. Maximise environmental flows by reducing consumptive and non-consumptive uses of water. The circular economy is “a regenerative system in which resource input and waste, emission, and

energy leakage are minimized by slowing, closing, and narrowing energy and material loops". Water management can contribute to the circular economy by closing water loops, recovering resources from water, and recovering energy from water. Water management covers the whole water cycle, namely: surface water management and groundwater management, drinking water production and transport, and sewerage and wastewater treatment and disposal. All of these elements offer opportunities to realize a circular economy.

Water smart urban development:
Water Smart development means the development of urban areas based on demand and sustainable supply of water resources with well-balanced integrated planning. The International Water Associations brought together 17 principles for water-wise urban developments, which are clustered mainly in four areas of policy focus: a) Regenerative water services ; b) Water-sensitive urban design; c) Basin connected cities and d) Water-wise communities. Water smart urban development will be best practice for sustainable water management for urban areas.

Integrated Water Resources Management (IWRM):
IWRM is the basis of all best practices in sustainable water management and thus valuing water. Since water is a scarce resource and need to fulfill the competing demands for all sectors so principal of IWRM and its implication is significantly important.

No Waste or Zero Waste:
There is a growing concern regarding sustainable waste management in developing economies such as Bangladesh due to the current growth of waste generation in these countries. Several company i.e Coca Cola Bangladesh flagship initiatives, World without Waste was launched in 2018 to resonate with the fundamental principles of circular economy; make-use-recycle. Adoption of a design-collect-partner framework and further developed specific working models that appreciate the closed-loop system so that the wastes like old bottles and cans can be recycled or up-cycled. To concretize this initiative, set the specific goals that give a clear vision of where we want to go in each sector to get No Waste or Zero Waste status.

Managed Aquifer Resurge (MAR):
Managed Aquifer Recharge (MAR) is a promising set of techniques to cope with a variety of water management-related issues. In recent years MAR implementations have witnessed an expansion and greater social acceptance in different countries of the globe. Innovative water management strategies such as the storage of reclaimed water or excess water from different sources in Managed Aquifer Recharge (MAR) schemes can greatly increase water availability and therefore improve water security. MAR seems as a sound, safe and sustainable strategy that can be applied with great confidence and therefore offering a key approach for tackling water scarcity.

Volumetric allocation of Water:
Volumetric allocations entitle each water license holder with an annual volume that can be extracted from the aquifer each water use year (1st July to 30th June). Therefore it is fundamental that water users such as industrialists or irrigators or others have a good understanding of volumetric measurement and the water requirements of their enterprise. If volumetric allocation could be ensure the user would be more conscious about uses and thus reduce the mis-use of waters.

Women Empowerment:
Women empowerment is one of good practices for valuing water as women's play key role in

water management. As per the Global Gender Gap Report 2020, Bangladesh has emerged as the best performer in the region of South Asia and ranked 50th on the global index. Historically, it is the only country in the world where women have had a longer tenure than men at the helm of the state over the past 50 years. The country's performance in closing 72.6% (2006-2020) of its overall gender gap demonstrates a promising future for women in the country. Women empowerment in Bangladesh that supports one of the key goals of the Government's Eighth Five Year Plan, which is focused on women empowerment and works along the lines of the women development objectives set by Bangladesh such as Ensuring full and equal participation of women in the mainstream socio-economic development and Bringing up women as educated and skilled human resources.

Every Drop Matters:
Every drop matters is a common slogan for now a day as one of the best practices in awareness rising. Consciously or unconsciously, we waste a lot of water in our daily life. The combined value of this water is huge. If we are aware about the value of every drops of water and make maters it in ourselves we can reduce the wastage of huge volume of water in total. So we have to consider the every drops of water and need to care about every drops of water. In water-stressed Barind tract, we have significantly invested since 2017 in a project titled 'Introducing Water-Efficient Irrigation Technologies" by engaging 10,000 smallholder farmers. The focus is on water conservation and enhanced agricultural outputs by introducing water efficient drip irrigation and alternate wetting and drying (AWD) technologies for ultra-high-density mango plantation and water-thirsty boro rice cultivation respectively.

Best Practices in In RMG:
Daily 410.9 crore litres of water used in readymade garments in Bangladesh. Every year 1,500 billion litres of water is used to dye and wash the cotton and clothes for the garment industry, according to a study of the International Finance Corporation.

More Water More Pollution:
As the inefficient plants draw more water to treat the same quantity of fabrics, they use more chemicals to do the job. More chemicals mean more pollution. If they could cut their water requirement by one fourth, which is very much possible with available technology, they could have substantially cut use of chemicals and thereby pollution too. Also, more water needs more gas to heat for the dyeing and finishing of fabrics. Gas is a scarce commodity. Bangladesh is already running short of gas. The inefficient plants are just adding to the crisis. It does not need to use all that water to wash every kg of apparel. Bangladesh uses 250 litres of water whereas the global standard is 60 to 70 litres . That is four times less than what we use. Experts say this use of water can be further reduced to 13.5 liters.

Adoption of Cleaner Production: Adoption of more cleaner production will reduces water use from 174 to 52 litres/kg, 70% less use of water in just 2 years. Fakir Apparels Limited of Narayanganj is one of them that adopt clean operation. Before this, it used 24.96 crore litres of water to wash and dye 1,200 tonnes of fabric a month. But after changing technology, it has reduced water use to 6.96 crore litres. This is a saving of 70 percent of water.

Fakir Apparels recovered its investment of $2.65 lakh only in six months. Mondol Fabrics of Gazipur has been able to save 27 percent of water by using new technologies. It needed 120 litres of water to process one kilogramme of fabric. Now it needs 80 litres only. It is working to cut down water use further by putting in more technologies. More industries is also under practices of water efficient uses for its production.

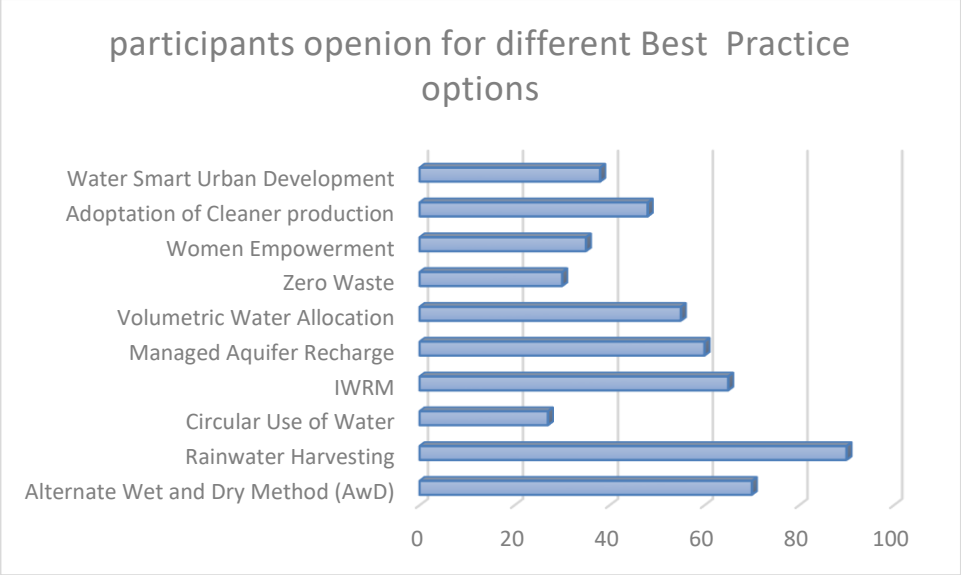


Figure 1: % of participants opinion for different practices

Incentive Mechanism:

To manage and better utilize our water resources, the focus can be on incentive-based solutions that harness the importance of ecosystems as an asset for smart development, economic and social progress, and long-term resilience. To reduce pressure on water resources while encourage and motivate relevant stakeholders/responsible parties and users in supporting water stewardship, an incentive-based instruments for instances found from the interviews –

- rebates against investment related water stewardship/ pollution management,
- technical support from the authority (if applicable),
- abstraction fees,
- grants for community initiatives,
- low-interest loans, and
- favorable tax treatment can be explored. Some more details incentives mechanism are also illustrated below:

Payment for ecosystem services:

Payment for ecosystem services is an incentive-based instrument that seeks to monetize the external, non-market values of environmental services – such as removal of pollutants and regulation of precipitation events – that can then be used as financial incentives for local actors to provide such services. In practical terms, they involve a series of payments to a land or resource manager in exchange for a guar-anteed flow of environmental services. Payments are made to the environmental service provider by the beneficiary of those services, e.g. an individual, a community, a company, or a government. Invest in clean-ups and restoration of water ecosystems to ensure sustainable water management.

Direct financial incentives:

Rebate programs are commonly used to encourage customers to make investments in water conservation and efficiency improvements. Residents and business owners' purchase new devices as the old devices wear out. While most new standard devices use less water than older models, there are many new high-efficiency devices available that use even less water. While efficient devices are often cheaper over their lifetimes due to lower water, energy, and

wastewater bills, users may be put off by the higher up-front costs. As a result, water utilities may provide their customers with a rebate to defray the additional cost of the more efficient device.

Education and outreach:
Education and outreach programs can also be effective for promoting water conservation and efficiency, for example, launching and adoption of Water Sense labeling program to promote water-conserving devices that are 20 percent more efficient than standard products on the market and meet rigorous performance criteria. Educating the people about the importance of water efficiency, including tying performance bonuses or operations-based incentives to efficient practices is also important.

Regulations:
In addition to financial incentives, acts and regulations are key demand management strategies. Regulations can take a variety of forms, ranging from a prescriptive approach focused on a particular appliance to a performance-based approach for sectoral water use.

Green Adjusted Tax:
Green adjusted taxation rates should be applied for promoting water efficient financing. Some industries have high GHG emissions but try to invest in green and water/ energy efficient projects to reduce their carbon surplus and achieve carbon neutrality. Tax therefore needs to be based on adjusted reduction of water use and pollution reduction.

Fiscal policy instruments:
FPI aimed at filling the water efficient investment gap and incentivising policies such as subsidies and tax exemptions can be highly appreciated. Voluntary agreements can also be efficient tools but need careful planning and monitoring, and their outcomes depend heavily on the stringency of the targets negotiated between governments and the private sector. In case of valuing water, subsidies in other resources uses like Removing energy price subsidies is also way of boosting private sector investments in green and water efficient projects.

Certification of Water Efficient Industries:
Promotion of prestigious awards for industries that used to value water and thus reduce, reuse and recycle of water in their own production system. Industries that transparent water auditing system, adequate rain water harvesting, adequate green spaces for nature conservation, adequate use of surface water and adequate treatment facilities may be awarded with certification for encouragement.

Tax subsidization:
Promotion of tax subsidization to support green and water efficient or energy efficient projects or industries to guarantee a higher rate of return of these projects. The after-tax rate of return on green and EE projects would then be much higher, and polluting industries would pay higher taxes

Promotion of green bond market:
Promotion or adoption of a well-developed green bond market, green labeling has helped as incentives but is not enough. We therefore need a clear greenness credit rating to identify a precise greenness ratio. Nowadays, since satellite photos show how much CO2 is emitted by companies or projects, it is possible to detect and measure emissions in order to accurately assess greenness. Globally speaking, having unified green rating agencies rather than different standards for each country is also necessary.

Promoting Energy and Water Efficient Financing:

Adoption or Improvements in energy efficiency (EE) can deliver a “double dividend” by reducing emissions and helping to protect the water & environment. Yet, constraints such as limited access to finance and inadequate policy tools and instruments have placed serious limitations on the promotion of Energy and water efficient financing. Removing energy and water price (if applicable) subsidies is one way of boosting private sector investments in green and EE industries with the consideration of valuing water.

Emission Trading Schemes (ETSs) and cooperative policies can also be used as incentives for water efficient industries. We have to understand that water and energy efficient finance schemes alone will not be sufficient to change markets. Robust policy frameworks with the right economic and regulatory drivers to incentivize and bring about change are required to strengthen the judicious uses of water.

4. Conclusion

Appropriate Valuing of water is a crucial demand of time because the world is facing serious imbalance in demand and supply in terms of fresh water. The situation will be more worsen in future. It is high time to pay due attention on appropriate valuing of water and its sustainable management. Policies should encourage adopting the best practices of water management and water saving technologies. Perception of different stakeholder and their involvement in water management is necessary for sustainable solution. Government should pay due attention in institutionalizing and promoting the best practices of valuing water and provide necessary incentives to encourage industries, farmers and users to adopt water saving technologies.

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Risk assessment of water consumption in Bangladeshi tanneries

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Abstract

The discharged wastewaters from various chemical operations of leather production need sophisticated treatment to reduce pollution threats before discharging them into the environment. The treatment cost of these wastewaters increases extra financial investment per annum. Therefore, proper water utilization is required to reduce financial and environmental risks. This research aims to find a better solution for the redemption of environmental and economic risks on the tanneries' residual treatment and water consumption. A standardized open-ended questionnaire was used for data collection, including water supply rate, amount of discharged effluents, wastewater treatment cost, and the possibility of further wastewater reuse. Besides, the characteristics of the tannery effluents were evaluated to focus their environmental hazard and a cost-benefit analysis showed the financial risk. According to analyses, few tannery wastewaters had reusable applications, but most were discharged after treatment, especially limewater, tanning, and dye liquor due to their hazardous environmental impact. It was also found that if discharged effluent were reused/recycled, the tanneries could save a significant amount of money per annum, maximizing their annual turnover up to 53% more than present turnover and mitigating environmental threats. Therefore, integrated water management attempts such as water recycling, optimization of chemical operations, proper monitoring of production factors, and adapt cleaner production technologies should be taken for eco-friendly and economic leather manufacturing.

Keywords: Water consumption, Tannery effluent, Tannery Industrial Estate Dhaka

1. Introduction

Water is essential for the survival and sustainability of human civilization on earth. In our daily life, water is used for drinking, household chores, and several industrial and agricultural activities. Several manufacturing industries such as textile, metal extraction, chemical, food and beverage, cosmetics, etc. use water as their principal raw material in different production stages. For this reason, water is mentioned as the earth's 'Lifeblood' [1]. Despite having extensive use, both groundwater and surface water are getting directly affected by industrial wastewaters and the adverse impact of climate change. As a result, the scarcity of freshwater is increasing day by day, which hampers performing our daily activities smoothly. Consequently, the situation is getting worse due to desertification in many parts of the world [2]. UNO assumes that 40% of the total world population will face the shortage of drinking water by the year 2050 [3]. Hence, proper monitoring and management are imperative for protecting surface water to save it for future generations.

Bangladesh is the 'land of rivers'. Approximately 700 rivers flow here constituting 24,140km waterway that covers 4% of the total hydrological resources of the Indian sub-continent [4]. In recent years, Bangladesh has had a noticeable economic growth compared to other Asian countries like Nepal, Cambodia, Vietnam, etc., initially driven by the industrial sector [5, 6]. Leather and its associated sectors (footwear and leather goods) are Bangladesh's second largest export-earning zone and an emerging sector of foreign investment and employment opportunity [7]. According to Paul et al. (2013) [8], 113 tanneries in Bangladesh produce 180 million ft2 finished and semi-finished leathers (crust) per annum.

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Moreover, around 55800 people are directly involved in this sector to earn their daily bread and butter. However, the leather industry is recognized as a potential pollutant generating industry despite having economic benefits. In the process of per ton wet salted hides/skins, 500kg chemicals, 15-50m3 water, and 2600-11700kWh energy are consumed that yield only 200-250kg finished leather remaining 72kg chemicals inside and release 600-750kg of various solid wastes (both tanned and non-tanned) and 30-35m3 wastewater [9, 10]. These wastewaters have no further possible application and need proper treatment before discharging them into the environment, as they contain a significant amount of toxic metals, colorants, and other organic and inorganic pollutants that create toxicological and aesthetical problems for both environment and living species [11]. Wastewater treatment requires sophisticated machinery, water purifying agents, and proper machine maintenance that increases extra financial investment per fiscal year. Moreover, excess water wastage in leather production might cause higher water consumption and a decreased groundwater level too if required water is lifter from underground [12].

Regarding the contribution of the leather sector to our national economy, this research was conducted to find out the possible risks of excess water consumption in tanneries from environmental and economic perspectives. The specific objectives of this research included-

To measure the actual water demand and residual float rate
To evaluate the quality of the discharged wastewater to understand their environmental impact
To observe the operational procedures in leather production to find out any possible reuse of wastewaters

2. Materials and methods

2.1. Study site and sampling

This research was designed as a cross-sectional study. It was conducted at Tannery Industrial Estate Dhaka (TIED) which is located at Harindhara village under Hemayetpur Thana in Savar, Dhaka. The duration of this research was from August 2019 to October 2019. Around 220 tanneries are situated here. The following equation was used to determine the sample size of this research [13]:

$$\text{Sample size}=\frac{Z_{1-\propto/2}^{2} P\ (1-P)^{2}}{d^{2}} \qquad (1)$$

Here, $Z_{1-\propto/2}$= Standard normal variant, P= Expected proportion in population (95%), and d= Absolute error/precision (5%). Based on the population, the estimated sample size was found 141 and the tanneries were selected by random selection method.

2.2.Data collection

A standardized open-ended questionnaire was used to collect data from the selected tanneries by face-to-face interviews. Permission from the respective tannery authorities was taken and before data collection. The correspondence gave verbal consent to participate in the interview sessions and had the liberty to not respond in a particular question/leave the sessions. The questionnaire was prepared based on the information of a pilot survey that included parameters like-

a) Source and amount of water supply in tanneries
b) Duration and interval of water supply
c) Amount of discharged effluent and its treatment cost
d) The possibility of further reuse of tannery wastewaters

2.3.Wastewater collection and characterization

The tannery wastewaters discharged from different chemical operations from beam house (wet processing) to finishing were collected in labeled plastic bottles. Wastewater samples were collected according to Pearson et al. method [14]. The bottles were disinfected before sample collection using 5% HNO3 solution to avoid any type of contamination. The collected wastewater samples were preserved at 4˚C temperature to prevent possible oxidation/hydrolysis. Different physicochemical parameters viz. pH, BOD5, COD, TDS, Cl- concentration, etc. were measured by using calibrated apparatuses according to standard testing methods upon filtration of the effluent samples [15, 16].

2.4.Data analysis

The collected data and test results were analyzed by using SPSS version 12. The overall scenario of water consumption and residual were represented by descriptive analysis. The water consumption rate in each chemical operation was calculated by the following equation [17]:

$$SWC=\frac{C\times 1000}{D} \qquad (2)$$

Here, SWC= Specific water consumption (L/kg), C=Water consumption (m^3/day), 1000 is the conversion factor to convert m^3 in Litre and D= daily production (kg/day).

The experimental results were described by comparative analysis with respect to the threshold limit of the physicochemical parameters in industrial effluent. Finally, the possible financial loss was represented by a cost-benefit analysis.

3. Results and Discussion

3.1. Bangladeshi leather industries-An overview

From the assessed tanneries, 120 were run as sole proprietorship; 15 were partnership farms and 6 were limited company in ownership with the involvement of 16,500 workers. 96 tanneries carried out beam house to finishing process; 35 performed beam house and wet end step and only 10 tannery conducted wet end operation. Tanneries producing wet-blue leather used all tanning methods (chrome, vegetable, combination). Most of their export-oriented productions and rejected lots were sold in the local markets. The average annual turnover of these tanneries was estimated at BDT 32.8 million/ton hide processing.

3.2. Water consumption rate in operational stages

To evaluate the water consumption rate during leather production from raw hides/skins, each phase of shoe upper leather production from 1000 kg wet salted cowhide was observed because almost 90-95% of leathers are made for shoemaking, and 56% of them are from cowhides [18, 8]. It was observed that the tanneries mainly use groundwater. As the leather industrial estate is situated in a village area, there is a scarcity of municipal water supply, which was available when the tanneries were located at Hazaribagh. Generally, the tanneries use hydraulic pumps to lift groundwater used for leather making, cleaning, and personal hygiene. The amount of water consumption in leather production and miscellaneous works were showed in Table 1.

Water supply process	Amount	Application	Amount
Lifted groundwater by hydraulic pumps	100,00,000	Leather production	48,00,000
		Cleaning	32,50,000
		Personal hygiene	14,50,000

		Miscellaneous	5,00,000

Tab. 1: Amount of total water consumption rate in tanneries per day (in m^3)

Tanneries that carried out bean house to finishing operation used the highest amount of water followed by the tanneries perform beam house and wet end process and only wet end step used comparatively moderate and less water respectively. The quantity of water consumption by the tanneries was listed in Table 2. The amount of water was considered on the weight basis of treated hides and their histological nature.

Sl. No.	Operational procedures	Volume
1	Soaking	9
2	Liming	4.3
3	Fleshing	2
4	De-liming and Bating	5
5	Picking	3
6	Chrome-tanning	0.8
7	Sammying	0.5
8	Wet back	0.6
9	Dyeing and fat-liquoring	1.5
10	Setting out and drying	4
11	Finishing	0.3
12	Washing	20

Tab. 2: Water consumption rate in per ton hide processing (in m^3)

From the table, it was found the highest quantity of water was used in soaking among all chemical operations because the hides/skins were rehydrated in this operation so that they can maximum chemical uptake from other chemical operations [19]. However, an excess amount of water was consumed in washing of treated hides to remove surplus chemicals from the hide surface. Therefore, each chemical operation's water consumption was similar to the previous research works [20, 21].

3.3. Effluent generation and characterization

The generation of effluents from various chemical operations of per ton hide processing was presented in tabular form (Table 3). It was found that the amount of effluent was discharged from soaking operation and the amount of discharged water from washing was the same as described in Table 2. However, the effluent generation rate was higher than the water consumption in fleshing, sammying, and drying because surplus water was removed from inside of the leathers in these operations to keep optimum moisture in the finished leather.

Sl. No.	Operational procedures	Volume
1	Soaking	7
2	Liming	4
3	Fleshing	5

4	De-liming and Bating	3.7
5	Picking	2.5
6	Chrome-tanning	0.6
7	Sammying	0.9
8	Wet back	0.4
9	Dyeing and fat-liquoring	1.5
10	Setting out and drying	6
11	Finishing	0.2
12	Washing	20

Tab. 3: Effluent generation in per ton hide processing (in m^3)

The results of experimental analyses showed that the physicochemical parameters of the collected tannery effluent samples viz. pH, BOD5, COD, TDS, etc. were beyond the threshold limit to discharge industrial effluents into the environment (Table 4). The pH values of most effluent samples were found permissible except liming and pickling; these effluents are very harmful to the aquatic environment and living organisms. Moreover, the values of other parameters were higher than the marginal level, requiring a higher amount of oxygen and microbial leaching to decompose. As a result, the amount of dissolved oxygen (DO) will decrease, posing a threat to aquatic photosynthesis and the ecosystem [22-24]. From the interview sessions, it was depicted that the limewater, tanning, and dye liquors demand a high treatment cost and machinery as these effluents create both toxic and aesthetic problems. The correspondence opined that if the application of effective and low-cost treatment agents in the wastewater treatment or reuse of spent liquors were possible, it would have reduced the wastage rate of water.

Parameters	Soaking	Liming	De-liming and bating	Pickling	Tanning	Re-tanning	Permissible limit [17]
pH	7.50	12.5	8.9	2.8	3.5	4.5	6.5-9
BOD_5	2000	7500	2500	600	650	1450	50
COD	4500	19000	6000	1500	1750	3650	200
TS	45000	36000	9000	52000	46000	12000	2250
TDS	36500	25000	5800	50000	44000	10500	2100
TSS	8100	9000	3200	2500	2000	1500	150
Cl^-	20000	-	-	23500	-	-	600
S^{2-}	-	390	-	-	-	-	1

Tab. 4: Characteristics of tannery wastewaters

*All parameters were measured in mg/L except pH values

3.4. Possible reuse of wastewater

The discharged tannery effluents cannot be reused in other fields or possibly used in leather production. However, some integrated approaches can be taken to reduce the excess wastage of water (Table 5).

Process	Applicable technology [25]
Pre-soaking	Mechanical/manual desalting
Soaking	Counter soaking, application of soaking enzymes
Liming	Enzymatic unhairing, hair saving unharing, reuse of lime liquor
De-liming	Application of organic acid/CO_2 based and NH_3 free de-liming agents
Picking	Removal of salt swelling
Chrome-tanning	Chromium recovery and reuse, use of pickle-tan loop

Tab. 5: Possible options to reduce excess water consumption in tanneries

The cost-benefit analysis (CBA) was carried out based on the recent treatment cost of each tannery effluent and the market price of treated water. From the analysis (Table 6), it was observed that the net cost of discharged effluent from per ton hide processing was BDT 39,150/day. If these effluents were reusable, the tanneries could save BDT 97,850/day. As a result, the tanneries may save yearly BDT 17million from per ton hide processing and may increase the profit up to 53% extra than the recent turnover (BDT32.8million/ton hide processing) for the tanneries.

Effluent	Treatment cost/day (A)	Market price of treated water (B)	Daily discharge cost (C)	Comments
Soaking	2100	40000	3000	BDT 450 is required for per aerobic wastewater treatment (total 3 times per day) BDT 750 is required for per chemical treatment (total 3 times per day) Applicable for all type effluent treatment
Liming	3150	25000		
Picking	4500	25000		
Chrome-tanning	18300	5000		
Re-tanning	1200	13000		
Dyeing and fat-liquoring	6000	16000		
Finishing	600	6000		
Washing	300	7000		
Total	**36150**	**137000**		

Tab. 6: Cost benefit analysis (in BDT) of reusing effluent/ton hide processing

4. Conclusion

Leather export is an emerging sector foreign earning in Bangladesh. However, the industrial revolution in this sector had occurred haphazardly that result generation of higher quantity solid wastes and wastewater. The significant discharge of wastewater can be by minimized the adaptation of cleaner processing technology by the optimization/recycle of wastewater in the production phase. The study of Rao et al. (2003) [25] showed that the reused water/optimized chemical process can reduce 55-58% of the total water consumption in leather processing and can save 67% of the required water in beam house operation. Hence, integrated water management approaches should be prioritized in the industrial application for water conservation. Additionally, the application of eco-friendly processing chemicals, optimization of process recipes for maximum chemical uptake, and in-house monitoring will

positively impact environmental pollution caused by harmful tannery wastewaters and make leather production economy friendly too.

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CO2 Management and Clean Transport Policies for Bangladesh

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Abstract

This paper introduces DTReMB (Dynamic Transport emission Model for Bangladesh) which is imitative from the DTReM-LV (Dynamic Transport emission Model for Latvia) to calculate the amount of CO2 emitted from the transport sector of Bangladesh. The general structure of the model brought the scenarios of passenger and freight transport systems based on the population GDP and fuel economy in producing CO2 and contributing to environmental degradation. After that, this model calculated the energy demand and quantity of CO2 by considering the types of vehicles, fuels, and emission factors in four categories of vehicles: cars, trucks, trailers, and buses. The findings of the research state that conventional vehicles in the road transport sector that operating currently are the major source of CO2 emissions and take up the maximum spaces against the capacity of said vehicle. The road transport sector is the main source of CO2 and contributor to environmental degradation where a modal split is essential. It is highly required to divert the carrying load from road to river mode that is underutilized also to rail mode by increasing its capacity and modernizing the rail transportation system. Overall, the DTReMB model will give a summary for a better understanding of the source of CO2 that is produced in the transport sector and quantification of CO2 will help to design clean transport policies for Bangladesh.

Keywords: CO2 Management, Dynamic Transport Emission, Population GDP, Fuel Economy, Road Transport Sector, Environmental Degradation.

Introduction

Transportation is the lifeblood of a country and is essential to its careful economic development. Without efficient transportation facilities, no one can think about the development of a country and also the sectoral development connected with this. This sector also controls the mobility of the population and ensures economic growth. But nowadays, beginning from the twenty-first-century climate change has become an important concern over the world as well as for every country. So, transportation become one of the responsible sectors because it's consumed a large amount of fossil fuel and emits a large amount of CO2 into the environment. This CO2 is the major source of GHG gas. GHG is the combination of different gases Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) all are the examples of greenhouse gases (Sarkar et al., 2018). As CO2 emission harms the climate change of the environment, concentration should be given to this sector to reduce the emission rate. Surprisingly, in 2020 the CO2 emission rate was lower than in 2019. Due to COVID 19, it was seen that not only the annual emissions in 2020 are set to decline at an unprecedented rate, moreover, but the decline is also expected to be twice as large as all previous declines since World War II combined. Global CO2 emissions were much more than 5% lower in 2020 than in 2019, potentially arising in an 8% decline in coal emissions, a 4.5% decline in oil emissions, and a 2.3% decline in natural gas emissions (Hossain, Chen, and Khan, 2021). CO2 emissions fell quicker than energy demand, as demand for most carbon-intensive fuels fell the most during 2020.

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Transportation consists of different modes of transport like road, rail, air, inland waterways, and pipelines. The study found that different mode of transport mode emits different amounts of emission. This study gives the scenario of CO2 emission from the different transport modes. Finally, it will suggest some alternative ways to reduce the CO2 emission rate as well as some strategies to reduce this emission rate and also to formulate a clean transport policy for Bangladesh. The road transport sector is the main source of CO2 and contributor to environmental degradation where a modal split is essential.

It is highly required to divert the carrying load from road to river mode that is underutilized also to rail mode by increasing its capacity and modernizing the rail transportation system. This paper introduces a new methodology DTReMB model derived from the model DTRe-MV model (Barisa and Rosa, 2018) for carbon emissions intensity measurement, at a strategic level, this paper will also provide suggestions for aligning study findings with and inclusion of carbon emissions monitoring into the standard reporting process for the future.

Although this paper aims to reduce transport-related carbon emissions, enhance mobility and affordable access, and also recommend a clean transport policy. The inclusion of carbon emissions monitoring and mitigation measures is envisaged to make transport more environmentally sustainable. The methodology has used in this paper DTReMB method will help to formulate a clean transport policy for Bangladesh. This model has six-module processed steps transport activity modeling, Mode split, vehicle demand forecast, technology distribution, energy demand modeling, and CO2 emission modeling for mitigating CO2 from the transport sector but this paper use only CO2 emission modeling for calculating CO2 emission from different transport mode based on findings the paper suggested some strategies which can be used as clean transport policy. CO2 Management in Bangladesh can be made efficient with the use of the right type of fuel for specific vehicles. Like, if using gas, petrol, diesel is feasible in the road transport in Bangladesh. Among those, the use of gas in most of the vehicles instead of diesel or petrol, need to get less CO2 emission. Greatly, to provide the best policy where people should use the efficient fuel or have to increase the price for those fuels where emission is more. Also, if Bangladeshi roads are made properly to increase electric vehicles, then Bangladesh's CO2 Management become more efficient.

Problem Statement

Global CO2 emission is increasing day by day but this needs to befall rapidly. To reduce this rate, first of all, it is needed to know from where the emissions are coming from and which sector is contributing most. This understanding will help to reduce this pollution by formulating clean transport policies for Bangladesh's carbon dioxide concentrations.

Globally, human activities are responsible for carbon dioxide concentration or GHG emissions in the environment, which include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). Among different GHG gas Carbon dioxide is the most prevalent GHG (greenhouse gas), accounting for 77% of total world GHG emissions, with CH4 for 14%, N2O for 1%, and other gases contributing only 1% (Sarkar et al., 2018).

This paper has tried to draw the relation GDP growth rate with CO2 emission and also to calculate the CO2 emission rate from different transport modes by DTReMB model. Although this model has six sequential steps CO2 emission modeling has been used for this study. Based on this analysis author has given ways that can be used in formulating a clean transport policy for Bangladesh. The calculation provides the alternative ways or strategies to reduce CO2 and it will help to make a clean transport policy for Bangladesh.

Scope of the Work

Global climate change is now mostly caused by carbon dioxide emissions. It is widely believed that, in order to avoid possibly the worst effects of climate change, the world need reduce emissions as soon as possible. However, how this accountability is shared across regions, countries, and individuals has long been a matter of discussion in international forums. Bangladesh's large portion of CO2 emissions comes from transportation. Therefore, having a clear policy is important to make things stable as soon as possible. Therefore, the Government of Bangladesh has taken a few clear transport policies which will be mentioned below.

The scope of this research has been confined to the transport sector of Bangladesh to reduce the CO2 emission from various transports and how can reduce the CO2 emission to formulate a clean transport policy. This paper also suggests an alternative transport mode for a clean CO2 management policy. This paper introduces the DTReMB model in our country to calculate the CO2 emission from different transport modes. The result of this modeling DTReMB CO2 emission modeling will help to formulate a clean transport policy for Bangladesh.

Research Methodology

This study introduces DTReMB (Dynamic Transport Emission Model for Bangladesh), a model for calculating CO2 emissions in Bangladesh's transportation sector that is based on DTReM-LV (Dynamic Transport Emission Model for Latvia) developed by (Barisa and Rosa, 2018). The study looked at Bangladesh's energy consumption and CO2 emissions trends. The analysis relied on secondary data sources, with the majority of the information coming from the World Bank's World Development Indicators database (World Bank, 2020). The time series trend was created using data from 2010 to 2020 to investigate trends in energy usage and CO2 emissions. The study calculated Bangladesh's annual CO2 emission growth using the equation (percentage) Using the equation, the study computed Bangladesh's annual CO2 emission growth (percentage). CO2 emissions have been related to the country's annual GDP and energy consumption growth. As a result, the study looks at the trend of energy consumption and CO2 emissions over time. Finally, this study synthesized the country's continuous efforts to reduce CO2 emissions and sustainably consume energy, as well as providing policy recommendations for the design of clean transportation policies.

Literature Review

There are various numbers of modeling/tools that have been used for calculating CO2 emission, to evaluate the impact of the mission of traffic management (Zhou et al., 2015) by different researchers who have used different aspects, assumptions, approaches, and s, the scope for their study. The study found that Sarkar et al. in the study of energy consumption and CO2 emission in Bangladesh trend and policy implications paper given emphasize on the concentration of all types of GHGs has increased in the atmosphere, the focus is always on the CO2 emission, as it constitutes a large share of GHG emission (Hossain, Chen and Khan, 2021).Energy Consumption and CO2 Emission Growth there is an obvious relationship between GDP growth, energy consumption, and CO2 emission (Sarkar et al., 2018). Bangladesh found that energy consumption has a positive and significant impact on economic growth while carbon emission has a negative and insignificant effect on economic growth (Sarkar et al., 2018). The CO2 emissions from electricity, manufacturing, construction, residential and commercial, and public services. CO2 emissions from other sectors. The trend among the growth of GDP, energy consumption, and CO2 emission in Bangladesh is the results indicate that the growth of

CO2 emission trend has crossed over the growth of GDP and energy consumption in Bangladesh with a larger fluctuation. The role of biofuels in China's transport sector in carbon mitigation scenarios. Biofuels will be indispensable in China's transport decarbonization, and pertinent and coherent policies will be needed to propel the sustainable development of biofuels (Zhang and Chen, 2015). According to the findings of this study, energy consumption has a positive and significant impact on economic growth, whereas carbon emissions have a negative and insignificant impact, ensuring that economic growth in Bangladesh can be achieved without degrading the quality of the environment. Considering that the majority of artificial carbon emissions are actually caused by the energy consumption sector and that energy is also a vital resource for economic development, this study examines the relationship between economic growth, CO2 emissions, and energy consumption in Bangladesh using cointegration test(Ghosh,et al., 2014). Bangladesh cannot fulfill its own energy demand, so it must import energy in the form of crude oil, coal, distillate fuel, motor gasoline, and so on every year. The most observable alternative strategy is to increase all use of coal in combination with renewable sources such as solar energy, biogas, wind power, and nuclear energy (Malek, Hoss, ain, and Sarkar, 2015).

For passenger cars that are not type-approved by Regulation No 715/2007, 'specific emissions of CO2' means the CO2 emissions measured by the same measurement procedure as specified for passenger cars in Regulation No 692/2008, or by procedures adopted by the Commission to establish the CO2 emissions for such passenger cars specific emissions target' means, in relation to a manufacturer, the average of the specific emissions of CO2 permitted in accordance with in respect of each new passenger car of which it is the manufacturer or, where the manufacturer is granted a derogation under Article 11, the specific emissions target determined in accordance with that derogation (European Parliament and Council of the European Union, 2009). In many countries it has emphasized a modal shift from road transport to waterways or rail transport sector as day by day in most of the countries this sector emits a bigger portion of CO2 (Kaack et al., 2018). In Bangladesh few authors have worked on this like decomposition of CO2 emission (Hossain, Chen and Khan, 2021) and energy consumption and trend and policy (Sarkar et al., 2018)but they did not use any model in Bangladesh for this study. This paper will introduce a modeling for calculating CO2 and based on this it will suggest some policies that can be used as clean transport policy.

Data Collection

CO2 emissions from electricity, manufacturing, construction, residential and commercial and public services. In Bangladesh by sectors Trend of GDP, Energy Consumption and CO2 Emission Growth There is an obvious relationship between GDP growth, energy consumption, and CO2 emission. Bangladesh and found that energy consumption has a positive and significant impact on economic growth while carbon emission has a negative and insignificant effect on economic growth (Sarkar et al., 2018). The trend among the growth of GDP, energy consumption and CO2 emission in Bangladesh is the results indicate that growth of CO2 emission trend has crossed over the growth of GDP and energy consumption in Bangladesh with a larger fluctuation.

This below Figure 1 is clearly showing that, as the world reduced its per capita CO2 emission, on the other hand, Bangladesh has increased its per capita CO2 emission which shows a negative sign for the whole country and community because the government might not take the perfect step which might decrease the level to make our environment sustainable.

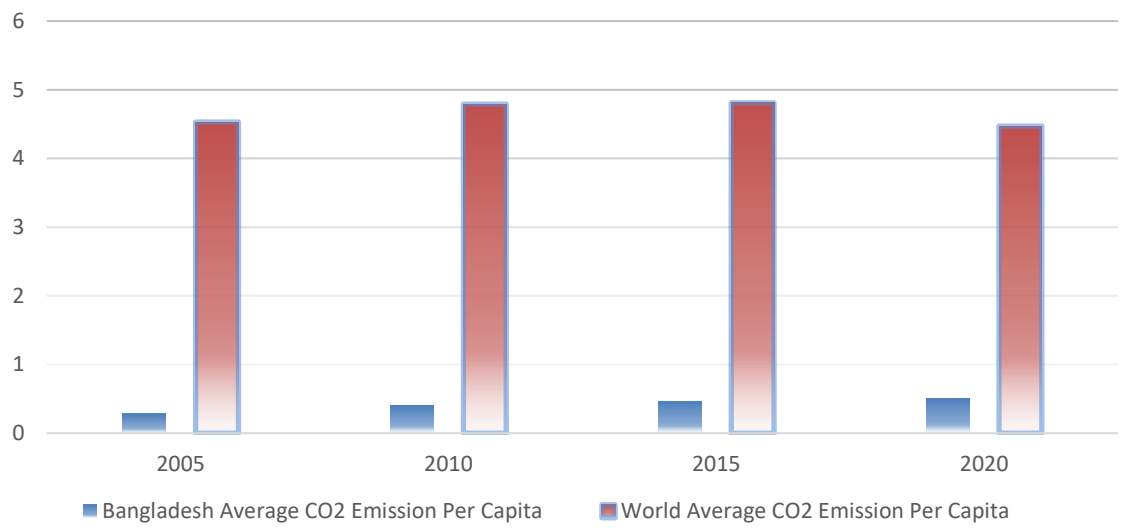


Fig. 1: Bangladesh's per capita CO2 emission in World Wide Comparison (Author)

Transport sector is one of the major sources of CO2 and here Figure 2: showed that here CO2 is coming from many sources like buses, pick up, microbuses, trucks, carmotorcyclele. Among the sources the large portion is coming from bus 31%, from pick up 23%, microbus also 23%, from truck 14% from car and motorcycle 8% and 1% respectively.

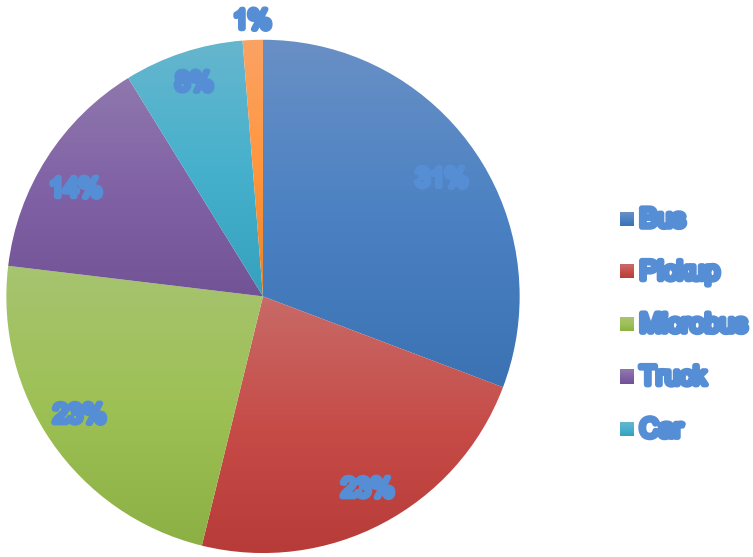


Fig. 2: Road Transport CO2 Emission Ratio Based on (gm/km) (Developed by Author)

CO2 emits from different sources like buildings, power industry, transport, non-combustion, other industry, and so on. Here Fig 2 shows that a large portion of CO2 is coming from the power industry, then a large portion is coming from other industries, transport, building, and non-combustion respectively as per CO2 emissions - Our World in Data(Ritchie, et al., 2020).

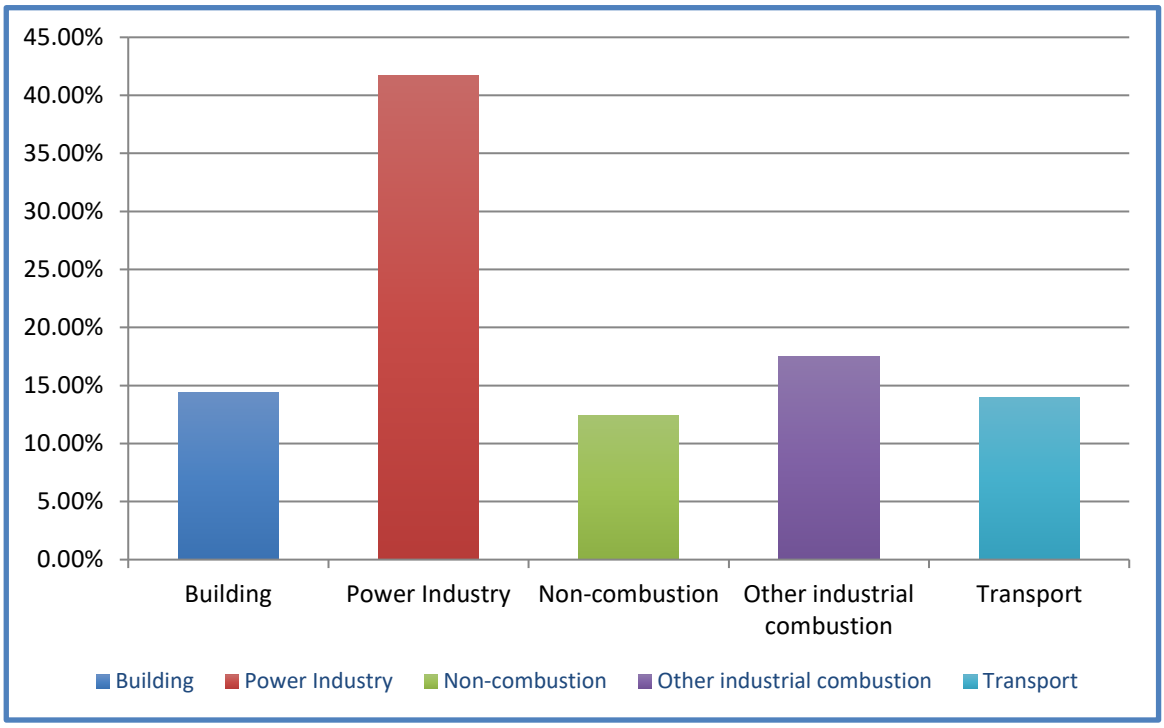


Fig. 3: CO2 Emission by Sector Based on (Based on (gm/km) (Developed by Author)

Power industry, construction, industrial and public services, transport, and other sectors each produced 20.87 %, 11.13 %, 14.49 %, and 5.79 % CO2 emissions in Bangladesh, respectively.

Data Analysis

The paper analyses the opportunities and barriers to decarbonizing freight using many strategies, such as reducing freight demand, optimizing vehicle use and loading, increasing vehicle efficiency, minimizing the carbon content of freight-transporting fuel, and shifting freight to low-carbon modes of transportation (rail or waterways). This method is also referred to as a modal shift (Kaack et al., 2018) by the authors, and it is the main subject of their work. The deep decarbonization of the freight sector can only be achieved by combining modal shifts with various solutions, such as energy efficiency, switching to low or net-zero carbon fuels, and enhancing operational efficiency. Not only is it difficult to control freight transportation demand, but also that it is uncertain whether doing so is desirable, considering that freight transportation is linked to economic growth. By more efficient routing and packing of trucks and training drivers' inefficient driving procedures, the transportation sector can reduce emissions. According to the article, rail and inland waterways emit less carbon than roads, although inland water transport may emit more carbon than rail and ocean shipping in some areas. The study proposes that need to cut emissions further by electrifying our transport systems, although this will be incredibly expensive. Similarly, electric vehicles and electrified highways could improve to decarbonize road freight, however, this is both costly and difficult to implement technologically (Hossain, Chen, and Khan, 2021).

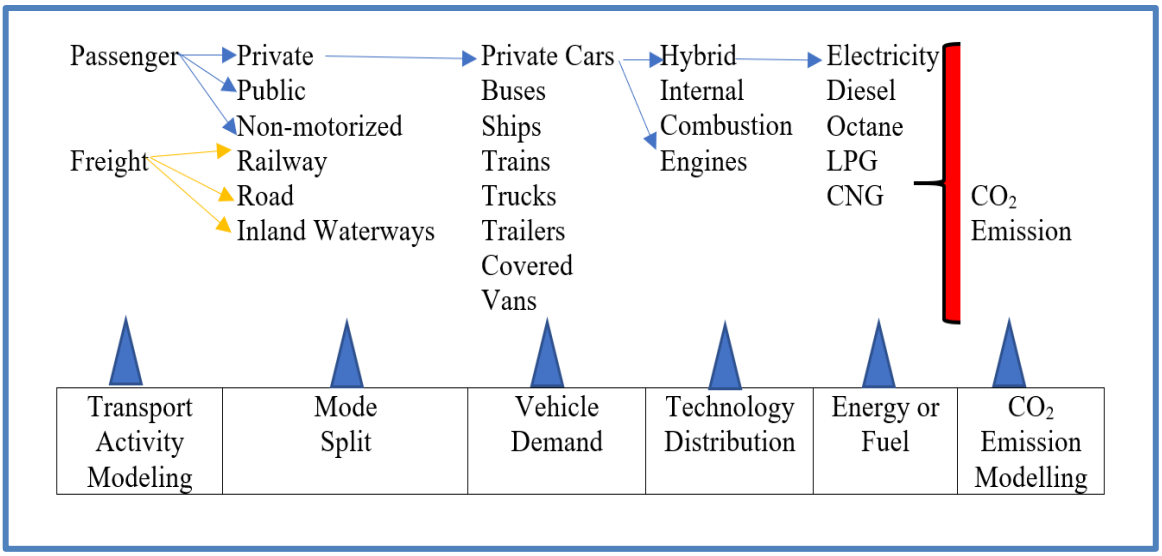


Fig. 4: General Structure of the DTReMB Model followed by the DTReM-LV Model

Figure 4 shows two types of transport activities passenger and freight in Bangladesh as per transport activity modeling to operate the whole transportation system. The modal split in both activities is performed by private and public management. In addition to private owners, buses and trucks are also managed by the government-owned Bangladesh Road Transport Corporation-BRTC. For freight and passenger, all types of vehicles are rented out in the private business and able to take rent daily, occasionally, and long-term basis. In terms of combustion technology and fuel, diesel fuel is commonly used in internal combustion engines that are the main reason for producing CO2 and contributor to air pollution in the country.

SL# Mode	**Mode-Vehicles**	**CO_2 emission**	**Remarks**
01-Air	Aeroplan	92 Kg/ hour	
02-Rail	Train (Public)	35.1(gm/km)	
03-Rail	Train (Electric)	18-80 gm/ton	
04-River	Lunch	25-70 gm/ton	Underutilized in Bangladesh
05-River	Ferry	25-70 gm/ton	
06-River	Boats	25-70 gm/ton	
07-River	Speed Boats	25-70 gm/ton	

Tab.1: CO2 emission rate other than road mode (McKinnon, 2012)

Table 1 is indicating the CO_2 emission rate other than road mode where rail has the minimum emission (McKinnon, 2012). Explored rail is giving the maximum output in transportation system irrespective of passenger and freight (Qu, Bektaş, and Bennell, 2016) advised to use of the intermodal system in freight management.

The globalized world is now revolving around transportation and communication systems and the basis of economic development and progress of any country is the planned and sustainable development of the systems. The country needs economic growth without harming or destroying the 'green' environment. At the same time, it is indispensable to improve the environment. But that is not without innovation and economic growth. Both the environment and the economy must be saved, so, need to formulate a long-term policy. Transportation emits the most important greenhouse gas (GHG). High energy consumption increases emissions and increases global warming, both of which have significant consequences for all countries and regions. Bangladesh is one of the most vulnerable countries to climate change due to global warming. CO2 emissions are reported to be growing faster than Bangladesh's energy and GDP growth. Since most countries agreed in 2009 at the United Nations Climate Change Conference (Robinson, 2010) in Copenhagen to reduce GHG emissions to keep global temperatures below 20 degrees Celsius by 2100, immediate action is needed to reduce CO2 emissions. Effective pollution mitigation measures are needed to reduce pollution. In a recent study, Decarbonizing Intraregional Freight Systems with a Focus on Modal Change, led by EPP Ph.D. student Lynn Kaack, a group of Carnegie Mellon Engineering and Public Policy experts explore options for decarbonizing freight transportation and policies to facilitate the shift (Kaack et al., 2018).

Findings And Contrast

The conventional vehicles in the road transport sector that operating currently are the major source of CO2 emission. The introduction of CNG as a cheap source of fuel brought attention to the vehicle owners and they converted diesel engines to CNG engines by using cylinders. Latterly, when CNG prices increased and converted engines lost their capacity, again diesel engines became popular. So, no change in fuel management as CNG prices hiked and it was a crisis to get fuel from fuel filling stations all over the country. Qu et al. (2016) explored an intermodal transportation problem with explicit consideration of greenhouse gas emissions and intermodal transfers that will reduce CO2 compared to other freight transportation systems especially carrying goods by open trucks and covered vans. In Bangladesh, the maximum number of trucks and covered vans operating on the road are consumed diesel fuel. An intermodal transportation system is absent that resulting in unhealthy transport vehicles such as trucks and covered vans dominating the freight transport sector.

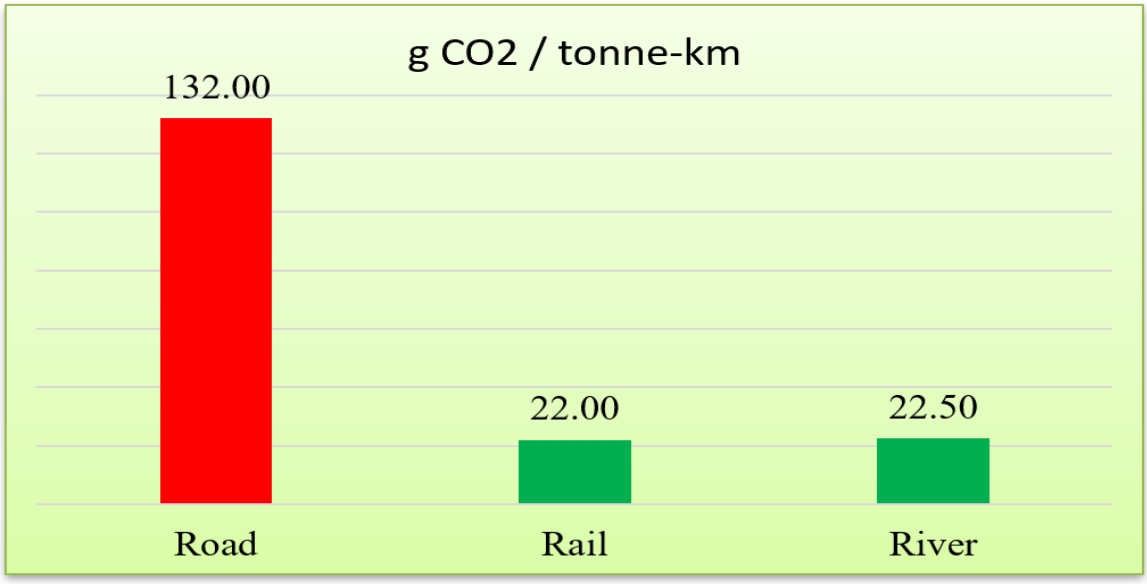


Fig. 5: CO2 emission rate in the road, rail, and river (McKinnon, 2012).

In the quantitative analysis, it is found that CO2 emissions of diesel fuel that is 132 g/Tone-Km. One-liter diesel weights 835g that consists of 86.2% of Carbon equal to 720g. During combustion, it has required 1920g O2. Therefore, the sum is 2640 CO2 per liter of diesel. Figure 5 is indicating the dangerous amount of CO2 but rail gas is the minimum 22 g/Tone-Km. But rail infrastructures and several trains are not good enough to serve adequately against the demand for rail services in Bangladesh.

This model will assist to calculate the carbon emissions from the local transport vehicle. Maximum vehicles are using Diesel fuel that is responsible for maximum emission. Alternative fuel such as CNG, LPG, and Biogas was tried to replace but with no success yet. From the empirical view, transport vehicles such as trucks and busses were made with old model's diesel engines. A new model was introduced but the types of fuel have not changed and diesel is a common fuel for passenger and freight transport vehicles. This traditional approach is not diversified and changed as the government is not playing any role to make a revolutionary change to stop vast emissions from the transport sector. Now, it is the time to change diesel fuel and search for an alternative that will assist to produce less carbon but the price of fuel will not be increased.

Clean Transport Policies And Sdgs

For achieving Sustainable development goals through social, economic, and environmental development it is very much urgent to develop proper clean transport policies by making time-worthy plans and strategies and just need to implement them for social, economic, and environmental advantages. Bangladesh’s large portion of CO2 emissions comes from transportation. Therefore, having a clear policy is important to make things stable as soon as possible. Therefore, the Government of Bangladesh has taken a few clear transport policies along with SDG which will be mentioned below.

Sustainable transportation is the enabler that elevates poverty alleviation and long-term development. SDG 3 on health (increasing road safety), SDG 7 on energy, SDG 8 on decent work and economic growth, SDG 9 on resilient infrastructure, SDG 11 on sustainable cities (access), and transportation are all closely associated with transportation. SDG 12 on sustainable use and production (dissolution of fossil fuel subsidies), and SDG 14 on oceans, seas, and marine resources (UN-Habitat, UNEP, and SLoCaT, 2015). Furthermore, through interconnection effects, the transportation system will enable the implementation of now almost all SDGs. Access to sustainable transportation should be given preference for everyone, including women, children, people with disabilities, and vulnerable groups like the elderly.

CO2 Management in Bangladesh can be made efficient with the use of the right type of fuel for the specific vehicle. Like, if using gas, petrol, diesel is feasible for the road transport in Bangladesh. Among those, gas is viable in most of the vehicles instead of diesel or petrol, to generate less CO2 emission. In this context, dynamic steps are to be taken to provide the best policy where people should use the efficient fuel or have to increase the price for those fuels where emission is more. Also, if Bangladeshi roads are made properly to increase electric vehicles, then Bangladesh's CO2 Management become more efficient.

Future directions

As environmental sustainability has taken concern all over the world for this reason every country took it seriously and Bangladesh Government has also taken many initiatives for the sustainability of the environment. Bangladesh government has taken many strategies to reduce the CO2 emission rate from the transport sector like the use of LNG, LPG instead

the use of diesel fuel and taken initiative for low Sulphur fuel cap 2020 for Ships. Through the study author also suggested the alternative transport mode waters ways or rail transport which emits less CO2 compared to other transport modes. This study also suggests below recommendations to reduce CO2 emissions and include them in the clean transport policy for Bangladesh:

1. Need to make strong transport policies, strategies, and plans to ensure a safe and sound environment with low carbon emissions from various transport modes.
2. Emphasize the modification of existing transport policies, strategies, and plans for sustainable energy use.
3. Need to use efficient transport mode from the existing transport mode which emits a large amount of CO_2. Road mode to be discouraged and divert passenger and freight to rail and river mode. Rail has minimal capacity and needs to increase by introducing double lines on all routes and increasing the number of trains.
4. Concentrate on the use of cleaner fuel, an alternative source of fuel, wind energy, and biomass energy.
5. To ensure the proper implementation of policies, plans, and strategies to ensure a pollution-free environment.
6. Promote research and development related to this transport sector to ensure a clean and healthy environment.
7. Regular monitoring of the energy-consuming industry to ensure sustainable energy use and provide subsidies in using clean fuel.
8. Arrange seminars, symposium, conferences to reduce emissions and about their bad effects.
9. Develop a diversified river transportation system and increase its capacity by constructing standard inland terminals and vessels to make it popular with other mode users.
10. Increase in the gas-based vehicle instead of Petroleum oil based on what initiates less gas emission.

Conclusion

Considering the current requirements of energy, it is vital to use a minimum quantity of fuel and select environmentally friendly fuel to save the environment from the negative impacts of transport in terms of fuel use and combustion. Importantly, energy is necessary for economic development and progress, but the government must have a long-term energy policy to sustain bringing fuel from abroad which is a costly and time factor. Moreover, higher energy use results in increased emissions and global warming, both of which have significant consequences for all countries and regions.

The paper examines the opportunities and challenges of decarbonizing freight using a variety of strategies, including reducing freight demand, optimizing vehicle usage and loading, increasing vehicle efficiency, reducing the carbon content of freight-carrying fuels, and moving freight into low-carbon modes. Although many railroads around the world are electrified, freight trains and others road-based are still run-on diesel. Transitions to these lower levels should be encouraged. Policymakers should use tolls and taxes to discourage road freight and support the construction of intermodal terminals that allow for efficient rail and river as much as possible before moving efficiently and reliably for last-mile delivery and ensure an efficient sustainable transportation system for Bangladesh. So for ensuring a better future and environmental sustainability must need to give concentrate in viable sectors of transportation by using low carbon emission fuel, biomass energy, wind energy, and also transport system like waterways or rail-based transportation.

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A Comprehensive Overview of the Impacts of Natural and Anthropogenic Activities on Biodiversity and Ecosystem Restoration of Sundarbans

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Abstract

The environmental condition of Sundarbans is deteriorating as a result of both natural and anthropogenic influences. Currently, it is having a significant impact on the biodiversity of the Sundarbans, which is the world's biggest mangrove forest. This research is concerned with the variability of this biodiversity and ecological state of Sundarbans because of the immense change in Bangladesh's climatic pattern. The Sundarbans is facing a number of difficulties as a consequence of climate change. Islands are dwindling due to rising sea levels, and the growing salinity of the water and soil has posed a serious threat to the health of mangrove forests, as well as the quality of soil and crops in the region. The suggested holistic strategy takes into account the present practices while also incorporating up-to-date knowledge obtained from further scientific research and excursions to mangrove forests. Adequate design of adaptable schemes, such as embedding all parties involved to safeguard the forest, creating capacity building, mitigating ambient habitant dependability on the forest, reinforcing surveillance, wildlife conservation, adopting statutory duty, emergency response, and undertaking equitable planning and research, could be beneficial for the protection and restoration of the Sundarbans.

Keywords: Biodiversity, ecological restoration, integrated forest management, ecosystems.

1. Introduction

Sundarbans, located on the Bay of Bengal's eastern shore, has the most diversified ecosystem. It is one of the consecutive mangrove forests and UNESCO World Heritage Site. It is distinguished of species abundance, also for its adaptability features surges, saltiness, water runoff, and deposition, among other phenomena. Mangroves play a vital role in the domestic economic growth of the country amidst their intrinsic efficiency and extensive variety of services they go through in the guise of sustainable resources. In harnessing the full commercial viability of mangrove forests, three essential components must be considered: forestry commodities, aquaculture, and nature tourism (Islam and Bhuiyan 2018). Besides, mangroves serve a significant function in coastal habitats as well as the safeguarding of ecosystems for vulnerable species and their descendants. Over the past few decades, the natural and human influences on Sundarbans have increased drastically. Mangrove ecosystems are frequently demolished to make way for aquaculture, coastal city establishment, and the construction of beaches. Overharvesting, licit and illicit carried out cutting down trees, and pollution are all being held responsible for the fast decline. The advent of two main shipping ports in Bangladesh, Khulna, and Chittagong, which deal the majority of the country's international trade, has also had negative consequences for the environment. The purpose of this research is to investigate core reasons of the deterioration of the Sundarbans and to make appropriate suggestions for optimal protection and utilization of this distinctive World Heritage Site by UNESCO for the protection of both community and wildlife. The biodiversity of the Sundarbans and its surrounding ecosystem is severely threatened as a result of all natural and anthropogenic activity. It is beyond time to adopt a more comprehensive approach to solving these issues.

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2. Materials and Methods

2.1 Study area

Sundarbans, the tidal halophytic mangrove forest, is located in southwestern regions of Bangladesh which lies on the Brahmaputra-Ganges-Meghna Delta at the Bay of Bengal. It is the world's largest mangrove forest and undoubtedly a unique ecosystem. The forest lies between latitude 21° 27′ 30″N and 22° 30′ 00″ N and longitude 89° 02′ 00″ E and 90° 00′ 00″ E. Approximately 60% of mangrove forests are located in Bangladesh, with the remaining 40% being in India. The entire extent of the Sundarbans in the two nations is frequently estimated to be vastly different.

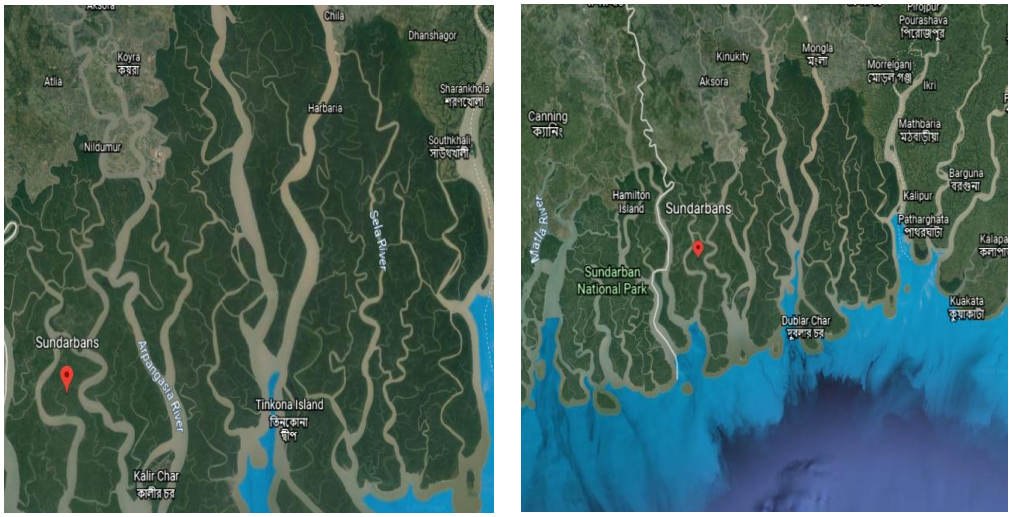


Fig. 1: Study area of Sundarbans

2.2 Research Methods

The overall strategy used in this study is to emphasize the findings that have been published in the studies of the effects, adaptability, and susceptibility of the Sundarbans to climate change and anthropogenic influenced in Bangladesh. Interviews with representatives from important government entities, non-governmental organizations, and stakeholders were used to perform the analysis.

3. Results and Discussions

Bangladesh is among the highly vulnerable countries to catastrophic events. At various seasons of the year, several types of cyclones sweep throughout Bangladesh. Due to the sheer low air pressure in the Bay of Bengal, these events evolved in and around the Bay of Bengal. In addition, moderate and low pressure are formed in the coastal areas on a daily basis that creates extreme conditions resulting in waves in the sea. Studies conducted over the last few decades have revealed that these natural severe phenomena occurred more frequently at specific periods of the year, particularly during the early summer (April-May) and post monsoon seasons (October-November). It has also been noticed that anthropogenic activities contribute to the deterioration of the biodiversity and the ecology of this mangrove wetland. The primary contributing factors to the decline of the Sundarbans ecosystems are discussed in further detail in the following sections.

3.1 Climate Change

Climate change threatens coastal ecosystems and livelihoods, including mangroves. The weather patterns are significantly altering because of several external factors such as variability of rainfall patterns, brine water pH, and mean temperature. The impacts of climate change in Sundarbans are discussed below.

3.1.1 Natural disasters

The most recent cyclone to impact the Sundarbans was Amphan in 2020. Residents report an increase in storm frequency and intensity over time. The months of July through October have always been stormy, but today they are more frequent and do more damage. The Sundarbans residents are particularly exposed, and they have no protection when storms come. Pre- and post-monsoon storms are more violent. A strong cyclonic storm in the Indian Ocean lasts around four days from formation to landfall. Since the turn of the twentieth century, the frequency of extreme natural disasters in Bangladesh has increased dramatically.

3.1.2 Rising sea levels

We can see the Sundarbans' relative mean sea level rise from 2000 to 2008. The Sagar Island observatory found a 12 mm/year rise in sea level (Bakshi and Panigrahi 2015). Except in 2004 and 2006, the overall trend was upward. From 2003 to 2006, the mean tide level decreased by 9.73 mm per year, from 2006 to 2009, it increased by 4.71 cm per year. From 2001 to 2009, the pace of coastal erosion in the Indian Sundarbans was estimated at 5.50 square kilometers per year. The Indian Sundarbans' land area decreased from 6402.09 square kilometers in 2001 to 6358.05 square kilometers in 2009 (Bakshi and Panigrahi 2015). This equates to 44.04 square kilometers of net land loss due to erosion and 20.12 square kilometers of accretion. Maximum erosion was reported in the Sundarbans' south-west. Even mangrove-covered islands have been observed to be eroding. In this study, the most susceptible islands are Dakshin Surendranagar, Sagar, Namkhana, Moushuni, Ghoramara. The local observatory links coastal erosion to variations in precipitation patterns. Changes in precipitation patterns may have a significant impact on mangrove development and area. Invertebrate populations on coastal region will be impacted, affecting bird energy needs. Tidal flooding destroys natural aquatic bird nesting places.

3.1.3 Saline invasion

The salinity of the water system of the whole delta has changed due to global warming and glacier melting. Salinity falls in the western delta region but increases in the eastern delta zone. Metropolitan wastes also raise salinity. Salinity changes impact the delta's overall ecology, notably the aquatic biota.

3.1.4 Fluctuation of temperature

The fundamental issue with the Sundarbans appears to be that when the ambient temperature rises, the sea erodes and degrades more land. The 1990 to 2000 research analyzed the temperature in the Sundarbans from 1965 to 2000. It detects a noticeable rise in air temperature both on land and at sea. The rise in the Bay of Bengal is 0.019 degrees Centigrade every year, and the Sundarbans are increasing at a similar rate (Bakshi and Panigrahi 2015). The analysis predicts that if this tendency continues, the temperature will climb by a degree Celsius by 2050 (Bakshi and Panigrahi 2015). Thus, rising temperatures are linked to rising sea levels in the region. Decreased freshwater supply, sediment and nutrient inputs, and salinity regimes are all variables impacting mangrove adaptation to sea level. A change in atmospheric CO2 would immediately alter the carbonate system of the ocean, affecting rich fisheries supplies.

3.1.5 Variation of rainfall pattern

There is evidence that rainfall has reduced, and the pattern of rainfall has altered, making conventional crop farming harder for farmers, the overall rainfall has grown over the previous two decades (Bakshi and Panigrahi 2015). As a result of the survey, farmers in the Sundarbans no longer know what to plant when. Farmers in the Sundarbans reported less rain. They also complained about long summers and unpredictable monsoons. They claim this has reduced crop yields and rendered crops more susceptible to disease, necessitating

additional pesticides and fertilizer. The most confusing aspect of the rainfall variations stated is that most rains do not occur during the monsoons. Post-monsoon rains have arrived. This negatively impacts agricultural output. The Sundarbans rely on rain-fed paddy to feed its population. Weather patterns fluctuate and the rains do not come when seeds are sowed. They arrive to reap the harvest. As a result, the standing crop is gone. Because most Sundarbans farmers only grow one crop, a loss of livelihood threatens food security. In terms of rainfall, both studies from 1990 to 2000 and 2001 to 2008 show an increase over the Sundarbans. The preceding study found a slight rise in monsoon and post monsoon rainfalls between 1990 and 2000. The Sundarbans receive 1625mm of rain annually. It may reach 2000mm in good rainfall years and 1300mm in low rainfall years. The pattern from 2001 to 2008 is similar. Overall and monsoon rainfall rose across the Bay of Bengal over the research period (2003-2009) (Bakshi and Panigrahi 2015). So, at first appearance, the reports of decreasing rainfall over the Sundarbans appear to be unfounded. Because cultivators have yet to acclimate to the temporal shift in precipitation, the slight increase in monsoon and post monsoon rainfall may be hindering agricultural production.

3.2 Anthropogenic influence

3.2.1 Habitat fragmentation of natural resources and forest degradation

One of the most serious issues confronting the Sundarbans is the overexploitation of trees in order to fulfill the increasing demands of the population. The illegal cutting down of the trees, as well as the lack of long-term wildlife management practices, are the most serious woodland preservation issues, according to experts. It is believed that the following factors contribute to illegal timber removal: a substantial disparity between demand and availability of wood; widespread and unemployment in rural regions; organized parties of mongers who participate in the unlawful chopping and removing of precious trees on a regular basis. Mangroves may be found in part of the district of Khulna, which also happens to be the location of a government paper factory. The plant is reliant on legal timber supplies from the surrounding area, but because the Sundarbans is so close, illicit loggers have begun making expeditions into the forest's interior sections.

3.2.2 Changes in farming practices and land use along the coast

Current agricultural output cannot keep up with the demand in the adjoining environment of Sundarbans, owing to demographic increase that is outpacing it. Cultivating salinity-tolerant rice varieties is the most important source of income for the locals. Furthermore, the fast expansion of shrimp aquaculture and salt manufacturing contributes to the degrading of Bangladesh's mangrove ecosystems (Abdullah, Myers, Stacey, Zander and Garnett 2017). Anglers in the Sundarbans employ a variety of fishing methods, as well as shrimp aquaculture ponds, to get their catch. In order to construct shrimp culture ponds, extensive clearing of mangroves is being carried out. This leads to a loss in the natural habitat for mangrove species. Southwestern coastal Bangladesh has seen a significant increase in the number of shrimp farms. To manage disease and pests in shrimp farms (Islam and Bhuiyan 2018), large quantities of herbicides and pesticides and hormones are used, resulting in the degradation of coastal habitats.

3.2.3 Coastal pollution

Large volumes of discarded substances are released into these unique ecosystems as a result of industrial expansion, farming, and fishing in river basins, population growth, and attempts to enhance or modernize living conditions in coastal communities (Rahman, Chongling, Islam and Haoliang 2009). The Sundarbans mangrove forest ecology has also grown sensitive to pollutants, toxic substances and agrochemicals–particularly pesticides and nutrient enrichment–all of which have the potential to alter the biogeochemistry of the mangrove ecosystem (Rahman, Chongling, Islam and Haoliang 2009). Increased traffic

contributes to greater air and noise pollution, as well as the risk of oil spills and industrial effluents degrading mangrove habitat.

3.2.4 Spillage of oil

Oil spills create substantial harm to mangrove and are damaging to marine organisms and birds. Oil contamination could be a consequence of the Mongla sea port, which is only 3 kilometers from the Sundarbans. Estimated 1500–1600 boats and 12,000–13,000 container ships pass through this harbor each year (Rahman, Chongling, Islam and Haoliang 2009). These ships emit crude oil, causing oil spills, as well as other pollutants. During conveyance via the Sundarbans streams, oil production and its derivatives also cause major pollution (Rahman, Rahman and Islam 2010). There are several examples of this type of unintentional leakage. In 1990, a massive oil spillage from an unknown source was seen in the Chandpai Range in the Sundarbans (Rahman, Chongling, Islam and Haoliang 2009). Vegetation, phytoplankton, small fish, mammals, and seabirds were all affected by such accidents. Furthermore, oil on the leaf surface can obstruct stomata, affecting mangrove plants' photosynthesis, respiration, and metabolism (Rahman, Rahman and Islam 2010).

3.2.5 Lack of enforcement

The mangrove ecosystems are diminishing for a range of factors, including a lack of qualified representatives and organizations to properly regulate coastal wetlands assets and wildly divergent operations, improper planning and understanding of coastal resource use, and the development of integrated strategies which do not include protection of the environment values.

3.2.6 Insufficient knowledge and a significant reliance on locals

The living standards of the local inhabitants are heavily reliant on the Sundarbans for their survival. These residents are not well knowledgeable and have little awareness of the importance of mangrove conservation to the environment. They lack information about forest conservation, and as a result, they deplete the forest's assets (Rahman, Rahman and Islam 2010), even though several laws, rules, and regulations exist to safeguard the mangrove ecosystem.

3.2.7 Uncontrolled tourism

The tourism industry in the Sundarbans has flourished, with the number of tourists growing by 30,000 per year. In the fiscal year 2018-19, over 250,000 domestic and foreign visitors visited the Sundarbans (Sachin 2020). The Royal Bengal Tiger and spotted deer are the major attractions for Sundarbans visitors. Although tourism contributes significantly to Bangladesh's economies, it has a negative impact on the Sundarbans due to habitat degradation, excessive sound, inadequate sanitation, garbage discharge, and residues. The Sundarbans ecology is deteriorating day by day due to improper management and ineffective implementation of ecotourism practices.

3.2.8 Arising hostility between humans and animals

Wildlife habitat is being harmed as a consequence of global changing climate, recent catastrophic storms, and growing habitat loss. Furthermore, enormous swaths of forest area are being submerged in water, increasing the risk of animals in the wild seeking shelter and food in human settlements. Man-wild beast conflict is becoming more frequent now than ever, which is detrimental to both. This seems to be extremely harmful for the severely threatened Royal Bengal Tigers in the Sundarbans delta.

3.3 Biodiversity and Ecosystem Restoration of Sundarbans

The Sundarbans are habitat to an exceptionally diverse range of marine and terrestrial vegetation and wildlife. The Sundarbans' biodiversity and habitat need to be conserved, and to do so, several comprehensive measures need to be implemented.

i. Ecosystem restoration and landcover expansion

Ecosystem resilience is critical for saving endangered wildlife. It may be improved by conserving vulnerable species, ensuring hydrological inflow, developing environment friendly tourism, and enhancing woodland space. Controlling stream and ocean surface reliability is vital to a balanced habitat. The disposal of petroleum pollutants expelled from the seaport of Mongla and Khulna territory must be governed.

ii. Modifying the existing policy

Forest management requires effective rules and regulations, institutional and personal education, efforts to mitigate risks to natural vegetation, mechanisms for preservation, maintenance, and utilization among participants, governance, and financial reporting. Despite numerous rules and regulations, forest industries are particularly susceptible owing to improper implementation. Thus, the involved authorities' directions must be quickly implemented. It is also necessary to alter regulations and legislation to properly handle the demands.

iii. Campaigns to promote awareness

Public awareness raising activities such as conferences, forums, programs, meetings, documentaries, and slide shows may all contribute to promote public understanding of the significance of wildlife and natural preservation. It may also be good to read publications that emphasize the importance of mangrove forests.

iv. Proper involvement of indigenous community

Attendees include native inhabitants, forest authorities, federal and state government entities, research scholars, regional and global specialists and organizations, financial institutions, legislators, and women's rights activists. Among the most essential and powerful stakeholders are the local people.

v. Adequate planning and Scientific research

In order to secure the protracted profitability of the Sundarbans mangrove ecosystem, it is absolutely essential to conduct competent detailed analysis. This will be hard to accomplish the restoration of damaged portions of the forest without a thorough scientific grasp of the situation.

vi. Supervision, assessment, review, and simulation

Monitoring of woods, especially fuel timbers, emission reduction, and forestry resurrection should be handled in the Sundarbans. Poorly regulated insecticide portability and uncontrolled manufacturing and drainage runoff outflow should also be severely restricted.

4. Conclusion

The degradation of mangroves can have major repercussions, such as a drop in diversification of ecosystem, an increment in taxonomic complexity, hereditary attrition, endangerment, heightened floods, and a diminishing in aquatic substances. The formulation and strategic policy of a prolonged action plan to maintain as well as conserve this diversified ecosystem in Bangladesh is critical to the long-term survival of this significant resource. The government has attempted to implement certain steps to safeguard these critically prominent habitats, yet this resources' long-term viability is a concern as a result of a lack of appropriate resource management practices. The development of a sustainable management plan should include participation of all beneficiaries and stakeholders, and the

plan should be properly executed in order to protect the world's biggest mangrove ecosystem for the benefit of present and future generations.

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Socioeconomic Vulnerability of City Dwellers during COVID-19 Shock: A Study in Southwestern Coastal Bangladesh

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Abstract

Life is full of challenges. A shocking pandemic in the name of COVID-19 pushed the universe to face different challenges at a time. Bangladesh is well known for dealing with natural disasters every year with its coastal region. A shock like COVID-19, which is entirely new, seems to pour water on a drowned mouse. This paper has considered such an ongoing problem to study and has aimed to assess the socioeconomic vulnerability of the southwestern coastal cities of Bangladesh as the urban area is the main victim of this virus. With a structured questionnaire, 160 household data, 80 from each city, Khulna and Satkhira cities, have been collected using multi-stage sampling. Several methods like the logit regression model, Gini coefficient, t-test, and vulnerability index have assisted in attaining the objective. Income is affected mainly during the COVID-19 lockdown, and the occupation and education level of the household head is the main reason behind it. Households with per day income and lower education significantly pulled down the incomes. Despite that fall, income inequality is relatively low as most households face a negative impact. The socioeconomic vulnerability index shows that both Khulna and Satkhira cities are moderately vulnerable, but Khulna is more vulnerable than the latter, proven significant through the t-test. Among the seven dimensions, excluding cross-cutting, the vulnerability index of Khulna city is higher than Satkhira city. Both cities are almost equally vulnerable; the rest two determinants- sensitivity and adaptive capacity have played the deciding role in deriving different vulnerability index scores.

Keywords: Vulnerability, Determinants, Households, COVID-19, Socioeconomic

1. Introduction

The world is suffering from an unprecedented catastrophe, COVID-19, a pandemic caused by the SARS-CoV-2 virus (Sannigrahi et al. 2020, p. 102418; Shammi et al. 2020, p. e04063). The death toll it has made is numerous, even though it is very few compared to the number of infected people. The globe has witnessed more than five million death all across, while the confirmed cases are above 260 million till now (Weekly Operational Update on COVID-19 Situation Report 2021). World Health Organization (WHO) has declared COVID-19 as the pandemic when confirmed affected cases exceed 1,18,000 and 4291 deaths among 114 countries (Williamson 2020, pp.430-436; Spinelli & Pellino 2020, pp. 785-787). In the name of lockdown, health priority has imposed an uncertain cost on the economy and overall society. People who faced Covid-19, both directly and indirectly, have undergone the adverse impact. Ultimately, it has affected their normal socioeconomic condition. Many have lost their jobs, day laborers have spent days with no earnings, business owners have gone bankrupt, migrated people have returned after losing their job (Mikolai, Keenan, & Kulu 2020, p.100628; Shammi et al. 2020, p. e04063). Initially, China was the victim of this virus's extremism as its origin. However, later, the USA exceeds the death toll across the world (Chakraborty & Maity 2020, p. 138882). The number of people living with extreme food insecurity was projected to exceed 265 million at the starting of 2021. COVID-19 has made poor people poorer. They can hardly enjoy food supply, health care, education,

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social security, and the overall socioeconomic safety nets. (Lambert et al. 2020, pp.4783-4791). This global pandemic hits the economy most with the direct attack in the tourism sector of about 50 to 70 percent output fall. Lockdown in the world confined people in a specific region. Excessive fall in production and the cost in the health sector raised inflation and unemployment immensely (Chakraborty & Maity 2020, p. 138882).

Furthermore, on the eve of April 2020, COVID-19 had already influenced 1.58 billion students from 200 countries (Toquero 2020; Policy Brief: Education during COVID-19 and beyond 2020). Moreover, 40 million kids have lost their early childhood education (Guthrie et al. 2020). As a proxy, an online education system is introduced to conduct the regular session (Chen et al. 2020, p. 200; Adnan & Anwar 2020, pp. 45-51). Unfortunately, this new method could not grab vast amount of learners as it requires technical support at a higher cost. Poor people failed to grab the modern method's fruit (Adnan & Anwar 2020, pp. 45-51). From a research in Canada, the skill gap in the socioeconomic sector may increase by 30 percent. The previous outbreaks also ignored the education sector (Policy Brief: Education during COVID-19 and beyond 2020).

Even though China was the first to suffer the adversity of COVID-19, it successfully took a U-turn in strengthening its economy with the virus's global spread. In contrast, the USA had to face a more significant catastrophe. Unemployment rose from 3.6 percent to 10.1 percent, corresponding to the 9 percent fall in industrial production until July 2020 (Thorbecke 2020, p. 233; del Rio-Chanona et al. 2020, pp. S94-S137). To support the economy, the US government offered relief (7.73%), aid (7.30%), and economic security (7.33%). The Fed minimized the interest rate by 0.5% and prompted loans and guarantees of about 500 billion US dollars and 10 billion emergency grants to the business sector at the beginning of the attack (both small and large). Chancellor Rishi Sunak guaranteed £330 billion in emergency loan packages to financially vulnerable UK citizens. China and Japan also followed this path, spending 240 billion and 43 billion US dollars sequentially (Nicola et al. 2020, pp.185-193).

This pandemic has stuck city life in a whirlwind compared to rural life, covering about 95 percent of its total cases (Chakraborty & Maity 2020, p. 138882). The United Nations Habitat confirmed it through its 'World Cities Report 2020'. Bangladesh prominently held the example of 78 percent confirmed infected cases were constituting its capital, Dhaka, and the other four cities (Khatun 2020). The first COVID-19 confirmation case on March 8, 2020, led the whole country to be in official lockdown from March 26, 2020. The city is the center of the industrial and service market, which was collapsed. This resulted in an 8.36 percent loss within a single year (Salim 2020). This lockdown pulled the economy to a standstill. The overall market failure, mainly due to transportation complications, caused the misutilization of the produced distribution. So, the whole country faced a shortage of food, which raised the price. Again, the reduction in export and imports caused a significant loss to the GDP of our economy (Khatun et al. 2020). COVID-19 combined all the crises like poverty, unemployment, and investment degradation and caused doldrums in the economy (Khatun et al. 2020 ; Salim 2020). In FY 2019-20 July-May, export earnings drastically fell to USD 30.95 billion, 18 percent lower than the previous year. SME accounts for employment opportunities for 7.8 million, which are the source of livelihood for around 32.1 million people. This sector remained volatile due to capital shortage, poor supply chain management, and sales reductions. COVID-19 has made this general problem serious, making SME-dependent people vulnerable. The private sector exceeded 10,00,000 crore loan, and the government was also occupied by borrowing 79 percent in April. Exports and imports fell by 83 percent and 62 percent, respectively (MTBiz 2020). Mostly 13 percent of people lost their job during the pandemic, and around 16 million people were doomed under the poverty line. Bangladesh Institute of Development Studies has confirmed this through a survey (Salim 2020). The current economic loss of Bangladesh due to COVID-19 could be

a threat to the entire society. The intensity of unemployment might double the poverty rate by 40.9 percent (Sharmin 2021, p. 2).

Based on The Congressional Research Service (2020) prediction, the global Gross Domestic Product (GDP) would reduce by 24% annually, accompanied by a 13% to 32% fall in world trade (Sannigrahi et al. 2020, p. 102418). The removal of disturbance every human being faces in their life is the prime concern of every nation. Unfortunately, no one can control COVID-19 directly. So, it is wise to deal with its effect to minimize the associated cost. Assessment of the level of vulnerability of these people can provide potential information to the sector of concern. That is why is this study aims to assess the socioeconomic vulnerability of the southwestern coastal city dwellers during COVID-19 shock.

It is not a local or regional problem rather a global crisis. Single research can be a support system for the new ones. Again, the strategic policies of one nation can assist others, like the 'Flying Geese Model.'

2. Methodology

COVID-19 has become a buzzing topic for research as necessary actions are required to lessen its adversity. This study has chosen to assess the socioeconomic vulnerability of coastal city dwellers, which others have not yet accomplished. Previously, this area generally attracted researchers for environment-related issues. Most articles addressed coastal rural areas as natural hazards affect. However, this time, the concern is COVID-19. The pandemic has attacked city areas more than rural. So, this study has made itself unique by focusing on such a region. Over and above, the assessment explained the socioeconomic status briefly and then compared the level of vulnerability between the two selected region- Khulna city and Satkhira city, covering several tools of central tendency. Khulna and Satkhira are two border areas, and so these areas have an outstanding possibility to face the amplitude of COVID-19 cases through migration. They are also the southwestern coastal zone where every year natural disaster attacks. So, this study fruitfully justifies selecting these two cities as its study area. The overall sample selection had multiple stages. Initially, Khulna Division was chosen from the prevailing coastal divisions, then from Khulna Division, two cities- Khulna and Satkhira, which hold the potentiality of this objective, were considered. Finally, 80 households from each region are used as the study data, indicating households as its sampling unit.
Lorenz curve, Gini coefficient, hypotheses testing, and regression model captured the socioeconomic status of the households, and socioeconomic vulnerability index depicted the level of vulnerability of the two regions.

2.1 Lorenz Curve and Gini Coefficient

Lorenz curve shows income or wealth distribution of population. With percentile, it explains what percentage of the population consumes what percentage of income. The straight line with slope 1 depicts the line of equality. Inequality is measured from that straight line with the curved line data. The curved line is the ultimate Lorenz curve. The area between the two lines is called the Gini coefficient. It shows the existing inequality of the observed population (Syndar & Parks 2020, p. 102471). The value of the Gini coefficient lies between 0 to 1; 0 represents the line of equality where all earn equally, and 1 depicts only one person holding all the earnings.

Gini coefficient = $\frac{A}{A+B}$ [A=the area above the Lorenz curve; B=the area under the Lorenz curve]

If the value of the Gini coefficient tends to 1, there is high intensity of inequality, and if it tends to 0, then the result is opposite.

2.2 Hypotheses Testing

This study has considered three hypotheses to highlight the variation of two areas and two situations. Khulna and Satkhira are two cities in the same division. However, the people living in the two cities are different. COVID-19 affected people differently, and this deviation has variation regionally. This hypothesis focuses on whether the two cities' residents are equally vulnerable or not.

H_{01}: Khulna and Satkhira cities have no significant difference in socioeconomic vulnerability.

During COVID-19, the lockdown has made the whole economy stagnant to a certain extent. After the lockdown, the wheel of the economy has started to run again. This hypothesis shows how the income of households differs during and after lockdown.

H_{02}: Income has no significant variation during lockdown and post lockdown.

H_{A2}: Income has a significant difference during lockdown and post lockdown.

The life of people during lockdown was completely different from regular life. When lifestyle changes, it can affect the living cost. That is why a hypothesis test can assist in exploring the change in living costs during and after lockdown.

H_{03}: Living cost has no significant variation during lockdown and post lockdown.

H_{A3}: Living cost has a significant difference during lockdown and post lockdown.

2.3 Logit Regression Model

This model showed the influence of factors over the change in income during the lockdown.

The equation used for the logit regression model is:

$$Y = \beta_0 + \sum \beta_i X_i + u_i \quad \text{..... (i)}$$

Y denotes the dummy dependent variable; Xi refers to the explanatory variables for the respective model; β_0 is the model's intercept; β_i denotes the coefficients of the respective explanatory variables; u_i is the error term or the unobserved values.

This model helped to run a regression for a dummy dependent variable. When the dependent variable is a dummy and the data distribution pattern is logistic, the logit regression model is a must. The dependent variable for this model is the income effect during lockdown divided into two categories – fall in income and stable income.

For this logit model, the respective explanatory variables are the age of household head (HH), education of household head, sex of household head, occupation of household head, household size, house ownership, earning members, and sources of income. That means,

Y_d = Lockdown income effect

X_{1i} defines explanatory variables, the factors that are being taken under consideration for the model.

2.4 Socioeconomic Vulnerability Index

Any undesirable event can affect negatively. When such events expose a threat to a community and make them susceptible, the level of their ability to defend and protect them defines their vulnerability (De León & Carlos 2006,). According to IPCC (2007), Vulnerability is a function of three determinants (Sharma & Ravindranath 2019, p. 051004).

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

Here, exposure defines the propensity to get affected, while sensitivity outlines the degree to get affected. Adaptive capacity is the opposite of exposure and sensitivity as it shows the strength to overshadow adversity. Exposure and sensitivity positively influence vulnerability, whereas adaptive capacity has an inverse relationship with vulnerability (Ahsan & Warner 2014, pp. 32-49). Relying on the relationship, this study has chosen to accomplish the following to derive the socioeconomic vulnerability score:

Vulnerability = Exposure + Sensitivity – Adaptive Capacity

These determinants are explained in terms of seven socioeconomic dimensions. The distribution of the dimensions clarifies vulnerability. The dimensions are the combination of several variables. The variables are different. To get a suitable value for further calculation, all the variables are taken into the standardization process (Ahsan and Warner, 2014).

Standardization = $\frac{x_i - x_{min}}{x_{max} - x_{min}}$

While accumulating the individual vulnerability scores of the respondents, the author compared three ways of average score. Arithmetic mean is the value obtained by summing all the scores and dividing it by the total number of respondents. It is the simplest way of getting the average score. Weighted Mean Index (WMI) is another way of getting the score where the observed values are given weights. Here, the summation of the product of observed values and weights is divided by the sum of the weights. In this way, it is possible to ignore the impact of extreme values or outliers among the observations. Nowadays, Geometric Mean (GM) is widely used in Human Development Index (HDI) and different vulnerability indexes. It ensures the equal influence of all the observations. So, GM has supremacy over other methods for deriving the average value (Cogswell, Greenan & Greyson 2018, pp. 46-51). The formulas of the three means – AM, GM and WMI are here-

AM = $\frac{\sum Xi}{n}$; GM = $\sqrt[n]{x_1\, x_{2\ldots\ldots} x_n}$; WMI = $\frac{\sum x_i w_i}{\sum w_i}$

To explain the level of vulnerability, this study has converted the maximum and minimum scores into four parts. For the individual dimension, the values oscillate between 0 and 1, and for the final socioeconomic vulnerability score, the values fluctuate between -1 to +2.

Levels	**Score (0 to 1)**	**Score (-1 to +2)**
Negligibly Vulnerable	0 to 0.25	-1.00 to -0.25
Slightly Vulnerable	0.25 to .0.50	-0.25 to 0.50
Moderately Vulnerable	0.50 to 0.75	0.50 to 1.25
Extremely Vulnerable	0.75 to 1.00	1.25 to 2.00

Tab 1. Levels of Vulnerability
Source: Author's compilation based on Shammi et al. 2020, p. e04063

3. Results and Discussion

This chapter discusses the results obtained from the collected data using the mentioned methods in the previous chapter. The discussion is divided into two sections where the first section contains socioeconomic status and the second one holds socioeconomic vulnerability index. It eventually assisted in highlighting the existing problems and finding solutions.

3.1 Socioeconomic Status of Households

3.1.1 Lorenz Curve, Gini Coefficient and Income Inequality

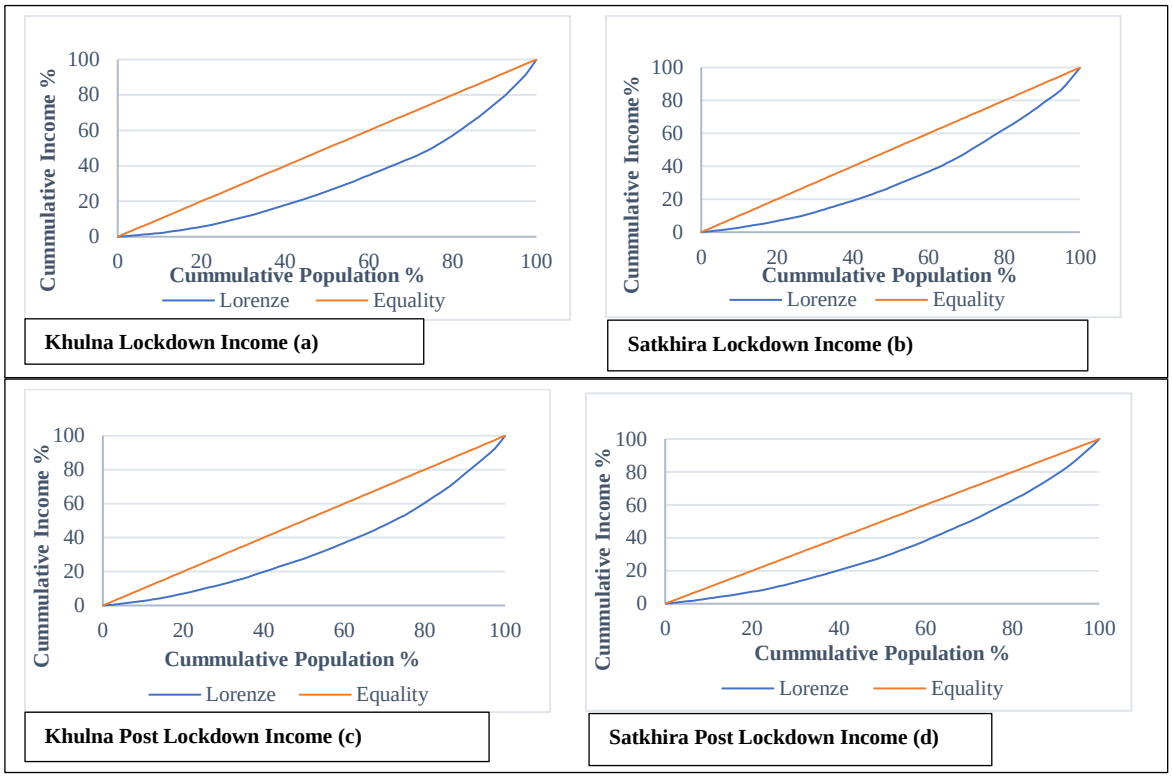


Fig 1: Income Inequality
Source: Author's compilation based on field survey, 2021

Periods	Gini Coefficient	
	Khulna	Satkhira
Lockdown	0.36	0.32
Post Lockdown	0.32	0.30

Tab 2: Gini Coefficients
Source: Author's compilation based on field survey, 2021

In Figure 1, a glimpse of inequality in Khulna and Satkhira City is noticeable. During lockdown in Khulna city, around 40 percent of households have less than 20 percent of total income, 60 percent of them have around 30 percent of income, and 80 percent of households hold about 50 percent of income. That means the top 20 percent of households account for half of the total income. The scenario is almost the same for the other city. For Satkhira, the bottom 80 percent of households consume 60 percent of the total income, the rest top 20 percent have 40 percent, which is 10 percent lower than Khulna city. Post lockdown, the distribution is almost the same for Satkhira, but for Khulna, there is a positive change as the top 20 percent has 10 percent less than lockdown period.

Overall, Inequality is not severe in either of the areas, irrespective of the situation. It is prevailing to a small degree. That is why all these four figures look almost the same. Still, it is not wise to ignore the difference.

The values of the Gini coefficient in Table 2 state that whether there is lockdown or not, Khulna city has higher income inequality than Satkhira city. The level of inequality is slightly higher during the very obvious lockdown.

3.1.2 Hypotheses Testing through T-test

In Table 3, the vulnerability of Khulna city is surpassing Satkhira city's, which is significant at a 1% level. It is also evident that income and living costs during lockdown are relatively lower than post lockdown. In this comparison between post lockdown and lockdown cases,

income variation is significant at 1% level of significance, and living cost is so at 5% level of significance.

Null Hyp.	Variables	Obs	DF	Mean	Mean Diff	Std. Err	t Value	Decision
H_{01}	Khulna's Vulnerability	80	158	0.98	0.09***	0.019	3.25	Rejected
	Satkhira's Vulnerability	80		0.89		0.016		
H_{02}	Post lockdown Income	160	318	25.86	4.81***	1.18	3.02	Rejected
	Lockdown Income	160		21.04		1.07		
H_{03}	Post lockdown Living Cost	160	318	23.29	2.95**	0.98	2.14	Rejected
	Lockdown Living Cost	160		20.34		0.97		

Tab 3: Hypotheses testing through T-test
Source: Author's compilation based on field survey, 2021

N.B.: ***p<0.01, **p<0.05, *p<0.10

3.1.3 Logit Regression Model on Lockdown Income Effect

Dependent Variable
Lockdown Income Effect (Fall in income = 0, Stable income = 1)

Explanatory Variable	Unit of Measurement	Coefficient	Marginal Effect
Age of HH	Years	-0.007	-0.0009
Gender of HH	Male = 0, Female =1	0.097	0.0117
Occupational Return of HH	Monthly payment = 0, Daily payment = 1	-1.542***	-0.1966
Education of HH	Years	0.112**	0.0133
Ownership of house	Owner = 0, Rented = 1	-0.260	-0.0305
Household size	Numbers	0.038	0.0045
Sources of income	Numbers	0.118	0.0140
Earning members	Numbers	0.077	0.0092
Constant			-2.040
Observations			160

Tab 4.: Logit Regression Model on Lockdown Income Effect
Source: Author's estimation based on field survey, 2021

N.B: *** p<0.01, ** p<0.05, * p<0.1

During the lockdown, some households faced fluctuation in their income. Among several factors, the occupation of the household head has a substantial probability of influencing the income status at a 1% level of significance. The household head who earns per day instead of monthly payment has less probability of having stable income by 0.1966 percentage point; ceteris paribus. At 5% level of significance, an increase in 1 year of education of household head holds 0.0133 percentage point more probability of getting stable income during lockdown if other things are constant.

3.2 Socioeconomic Vulnerability Index

Dimensions	Indicators	Khulna	Satkhira
Demographic	Dependency ratio	0.31	0.21
	Household head age	0.55	0.45
	Household head education	0.60	0.50
	Rooms	0.66	0.69
	House ownership	0.25	0.19
	House pattern	0.35	0.19
	Average	0.46	0.37
	Weighted Mean Average	0.50	0.45
	GM	0.43	0.32

Dimensions	Indicators	Khulna	Satkhira
	Std	0.31	0.30
Health	Public transport uses	0.74	0.73
	Failure to maintain social distance	0.93	0.91
	Musk dumping	0.89	0.87
	Number of times households go out	0.39	0.27
	Smoking	0.48	0.55
	COVID affected members	0.27	0.16
	Chronic diseased members	0.05	0.05
	Sanitizer uses	0.60	0.67
	Musk uses	0.44	0.41
	Jogging	0.75	0.76
	Other exercises	0.93	0.98
	Visiting doctor	0.60	0.58
	PPE uses	0.93	0.96
	Washing food	0.24	0.26
	Average	0.59	0.58
	Weighted Mean Average	0.69	0.69
	GM	0.48	0.46
	Std	0.37	0.38
Cross-cutting	Expected rise in financial problem	0.89	0.87
	Expected costly vaccine	0.54	0.61
	Expected unavailability of vaccine	0.73	0.81
	Excessive use of the internet	0.73	0.71
	Poor hospital facility	0.92	0.92
	Expected inefficacy of vaccine	0.61	0.61
	Scope of working from home suitability	0.75	0.87
	Shock advantage taking	0.92	0.92
	Education Affected ratio	0.93	0.95
	Average	0.78	0.81
	Weighted Mean Average	0.79	0.82
	GM	0.76	0.80
	Std	0.27	0.24
Financial	Number of times earning members changed their occupation	0.17	0.08
	Change in living cost during lockdown	0.78	0.70
	Number of months facing financial problem	0.58	0.36
	Unemployment problem	0.98	0.98
	Number of sources of income	0.66	0.82
	Post lockdown living cost	0.67	0.66
	Number of earning member	0.78	0.86
	Expensive online class	0.65	0.65
	Average	0.66	0.64
	Weighted Mean Average	0.72	0.73
	GM	0.60	0.52
	Std	0.33	0.35
Social	Social interaction level	0.55	0.53
	Enjoying refreshment	0.78	0.79
	Family violence	0.59	0.44
	Social violence	0.92	0.83
	Financial help coverage	0.56	0.53
	Non-financial help coverage	0.36	0.23
	Average	0.63	0.56
	Weighted Mean Average	0.66	0.63
	GM	0.60	0.52
	Std	0.35	0.37
Psychological	Confining in home	0.68	0.69
	Insomnia	0.78	0.68
	Depressed	0.84	0.83

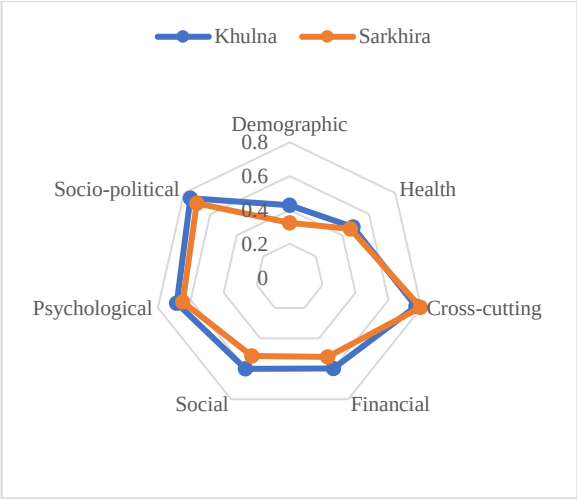
Dimensions	Indicators	Khulna	Satkhira
	Traumatized	0.63	0.53
	Angriness	0.53	0.52
	Sadness	0.83	0.86
	Anxiety relief medicine	0.52	0.41
	COVID protection-based medicine	0.75	0.77
	Average	0.70	0.67
	Weighted Mean Average	0.71	0.69
	GM	0.69	0.65
	Std	0.30	0.27
Socio-political	Government regulation satisfaction	0.87	0.78
	Public awareness	0.69	0.64
	Smooth government activity	0.88	0.85
	Corruption free	0.73	0.69
	Crime free	0.94	0.94
	Sound lockdown decision	0.63	0.58
	Sound lockdown release decision	0.58	0.62
	Education institution shutdown preference	0.47	0.42
	Sufficient government incentive	0.84	0.77
	Sufficient community support	0.89	0.73
	Aid management strength	0.91	0.91
	Average	0.77	0.72
	Weighted Mean Average	0.79	0.75
	GM	0.75	0.70
	Std	0.28	0.27
All these scores lie between 0 and 1.			
Overall Vulnerability Score	**Average**	**0.98**	**0.89**
	Weighted Mean Average	**1.02**	**0.94**
	GM	**0.94**	**0.82**
The overall scores lie between -1 to +2 as Vulnerability = Exposure (1) + Sensitivity (1) – Adaptive Capacity (1)			

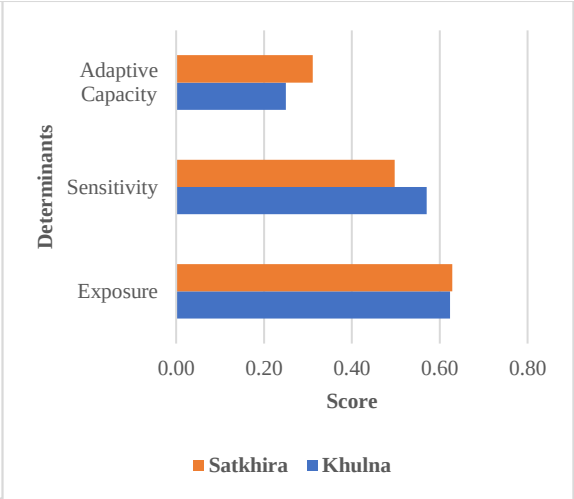
Tab 5: Vulnerability Scores
Source: Author's compilation based on field survey, 2021

NB: Exposure=health, cross-cutting; Sensitivity=demographic, financial, psychological; Adaptive Capacity=social, socio-political

To get the overall score, the vulnerability equation has been considered. While considering the determinants of vulnerability, exposure, sensitivity, and adaptive capacity, the scores standardized between 0 to 1 have been converted into -1 to +2. The closer the value is to +2, the more vulnerability the households comprise.

Among the three methods – average, weighted mean average, and geometric mean, this paper has focused on geometric mean value as it is widely used in human development index or vulnerability index. So, based on Geometric Mean (GM), the vulnerability scores of Khulna and Satkhira cities are 0.94 and 0.82, respectively. If the score lies between 0.5 to 1.25, it is called moderately vulnerable. That means they have a noticeable level of socioeconomic vulnerability, but it is not extreme. Even though both areas are at the same level of vulnerability, Khulna city is 0.12 points more vulnerable than Satkhira city. T-test has already shown that Khulna is significantly more vulnerable than Satkhira. The score of GM proves it with justification and detects how much vulnerable they are and how to differ they are.





Source: Author's compilation based on field survey, 2021

Fig 2: Region Specific Dimensional

Fig 3: Determinants on Vulnerability

In Figure 2, all the dimensions under vulnerability determinants have individual contributions to vulnerability. Their influence has a maximum limit of 1 and a minimum limit of 0; if a dimension has a score closer to 1, that dimension has more strength to make the household vulnerable. If it is near 0, the scenario will be the opposite. The values here are taken from the geometric mean, which provides more reliable results. The dimensions that have slightly imposed vulnerability on the households are demographic and health. Among them, the demographic dimension is the weakest to influence vulnerability, especially for Satkhira city. Health influences vulnerability lightly. It is not that people are strong in these aspects. They are vulnerable in these dimensions, but not to a large extent. So, both cities are slightly vulnerable in demographic and health dimensions. However, Khulna is a little ahead of Satkhira in vulnerability. Economic, social, and psychological dimensions moderately affected vulnerability among the other dimensions. The socio-political dimension lay at the end of moderate level. COVID-19 shock has quaked the whole world. It was not possible to escape from the negative influence of this virus.

Financial problems became a common problem for many households during those days. It would eventually affect them psychologically. Apart from it, the continuous death toll could make people mentally unstable. If all these issues affected people greatly, it would make them vulnerable, which was evident in Khulna and Satkhira city. The most influential dimensions were socio-political and cross-cutting dimensions; of them, the influence of the latter one on vulnerability was highly noticeable. People built a negative thought that they would have to suffer more. They did not have hope to live a sound future. The environment of the country forced them to become more vulnerable. Overall, except for cross-cutting dimensions, Khulna city ruled over Satkhira city in terms of dimensional vulnerability, which was not something to boast. Both cities were almost the same level of vulnerability which was a matter of concern as the level entirely among the levels of vulnerability.

Determinants helped to figure out the final socioeconomic vulnerability score. The determinants themselves had individual scores (Figure 3). Comparing the values between two cities could help to understand the similarities and dissimilarities between two cities' socioeconomic vulnerabilities. Both regions were almost equally exposed to socioeconomic vulnerabilities. While considering sensitivity, Khulna city was way more vulnerable than Satkhira city. On the contrary, Satkhira city contained more adaptive capacity to fight against the shock than Khulna city. Ultimately, due to excess sensitivity and lack of adaptive

capacity compared to Satkhira city, in terms of socioeconomic vulnerability, residents of Khulna city were more vulnerable than Satkhira city.

According to the analysis, income inequality was slightly prevalent in the different coastal cities. Inequality during lockdown was a little higher compared to the days after lockdown. In Khulna city, the distribution income was more dispersed than in Satkhira. During the lockdown, many households had faced a fall in their income. However, for some people, COVID-19 did not affect their regular income. The most significant factor for such change was their household head occupation. Households who lived their lives on daily income suffered from income loss during the lockdown. Whereas education proved itself significant as household heads with a higher level of education had a propensity to get stable income. In general, income and living costs were relatively low during the lockdown period. Post lockdown, the situation became a little better. Among the seven dimensions, the impact of the cross-cutting dimension was extreme, while financial, social, socio-political, and psychological dimensions had a moderate effect on vulnerability. Individually, only for cross-cutting dimension, the conditions of Satkhira city's households were more vulnerable than the other city. Khulna was superior to Satkhira city for the rest of the dimension, even though the deviation was slight. The determinants of vulnerability show that both cities were exposed to the adversity of COVID-19 to an almost similar extent. The significant difference was between sensitivity and adaptive capacity. Khulna was the city of greater sensitivity and poor adaptive capacity.

On the contrary, Satkhira was less sensitive and held a level of adaptive capacity superior to Khulna city. This difference made Khulna more vulnerable than Satkhira. The level of vulnerability is similar for the two regions – Khulna and Satkhira city, which was moderately vulnerable. Despite being at the same level, Khulna city was significantly more vulnerable than Satkhira.

4. Conclusion

COVID-19, a contagious disease, messed the world within a very short time. It is contagious at a severe level which has made it become a pandemic. The pandemic has forced the universe to bear the toil. It has affected different sectors and the affect varies from region to region. Not all sectors are affected equally in an analogous region. Those adversity could make the residents vulnerable. This study pinpointed all the noticeable sectors and organized them to derive the socioeconomic vulnerability of a particular region. COVID-19 impact is drastic on urban area. When the area is coastal, it is already in a hostile state. Another shock like COVID-19 made its residents more vulnerable. This study assessed the socioeconomic vulnerability of this region so that necessary steps could be taken according to the needs. Following a fettered methodology, the author used data from southwestern coastal city households to assess their socioeconomic status and the level of vulnerability. During COVID-19, households had to bear the toll of this unexpected event and their level of income along with living cost declined. Between the two decided region, Khulna and Satkhira city, Khulna was superior to Satkhira city in terms of overall socioeconomic vulnerability which was evidently significant. But both regions were remaining in the identical level of vulnerability which was moderate.

The situation has apparently changed from the period of data collection. At that time, there was no room for vaccine. But now, we do have the access of vaccine. So, we must need to include all the suitable citizens under vaccination which is a challenging task. Even though we have vaccine, it still can not ensure certain safety and education is continuously getting hampered. Online education can ensure safety but without concrete strategy this system may not work. So, proper strategy and monitorization is a must not only in education section but

also in all other sectiors, especially health. If medical facility does not develop steadily, it will bring down all the regulation growth process. Financial loss incurred during lockdown is being mitigated in macro level. Individual financial crisis can appear anytime as the virus is still threatening. So, backup plan for avoiding can be effective considering this immediate response and working from home. Once, the dimensional influence and regional vulnerability is identifiable, it becomes quite easy to provide immediate support. Overall, policies need to be modified based on the requirement along with proper monitorization. All these could help lessen the level of vulnerability.

It has opened an arena of further study that is relevant to this study. This study is based on primary data with no inclusion of rural area. For future study, both primary and secondary data considering urban and rural region can be used to derive the influence of regional attributes on vulnerability and factors behind the influence on a broader aspect.

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An Evaluation of the Impact of Body Mass Index on Academic Performance and Living in a Residential Facility among Undergraduate University Students.

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Abstract

Many previous studies of undergraduate students have linked corpulence to academic performance. The objective of the study was to justify the actual change of nutritional status of undergraduate student's by calculating BMI after living in a hostel. The stratified sampling of KUET students aged between 18 to 20 was done and their weights and heights were collected for calculating BMI. Variables associated with physical exercise, eating behavior, health status, lifestyle were selected for the analysis. Our findings showed that students have a different body mass currently in comparison to the time when they were admitted to this university. Again, BMI was negatively correlated with the student's final grades and had also a negative relationship between the academic result and lifestyle was observed. Female students showed higher obesity rates than male students because of their unhealthy eating behavior and lower levels of physical activity. The outcomes of this study highlighted the importance of university's microenvironments on eating behavior and lifestyle of the students and also constructed a linear regression model between health, eating behavior, lifestyle and final grades of the students.

Keyword: Health status, Nutrition, Undergraduate students, Academic performance, Lifestyle.

1. Introduction

The apprehension with the physical form and body image certainly has a great impact on both developing and developed countries; growing investment in nutrition and the adoption with nutrients can convey a positive change in behaviors (Carvalho, Miranda, Priore, & Oliveira, 2015). About one-third of the total population of Bangladesh is youth and young people. Thus, the wheel of economic and social development depends on the future growth of the youth of Bangladesh. According to our national youth policy, "youth" age is bracketed between 18 and 35 and nearly 45 million people fall within that age range here (Biswas, 2017). So, Bangladesh has come to a condition where a healthy and strong youth need to be built to ensure future development.

Good nutrition is the foundation for survival, health, growth for present and developing generations (Kana Sop, Gouado, E. Tetanye, & Amvam Zollo, 2010). It is claimed that the performance of a person always correlated with their health; maximum studies stated that health and academic appearance associated with one another's (Dr. Mary Larson, 2016). Some relationship has been revealed where it has been investigated that healthy body weight can improve academic performance. (Angela S. Anderson, 2016). So, there is a significant impact of academic microenvironments on eating behaviors of students because living on campus increases their irregular eating behavior patterns (Jina Tanton, 2015). Simultaneously, there is a difference between the need and demand of intake based on the gender and age of people. (Takashi Izutsu, 2006). BMI increases with age for male students but decreases with age for female students which indicated a dependency of age-growth and body weight (Bai Jingya, 2013).

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High consumption of vegetables and olive oil and moderate consumption of protein and physical activities can ensure healthy body composition in young adults (Lovro Štefan, 2017). On the other hand, overweight, obesity and underweight conditions are the most dominant nutritional problems of young adults in developed and developing countries (Kana Sop, Gouado, E. Tetanye, & Amvam Zollo, 2010). Considering the seriousness, it is important to assess the different dimensions of health conditions and lifestyle to find the initial threat (Boscatt, Silva Duarte, & Silva C, 2012). So, in the framework of universities or colleges; promoting the health and well-being for all the fellows can bring stimulating effective learning and ensuring emerging interruptions (Ansari & Stock, 2010). In Bangladesh at KUET, Dhaka University and Jahangirnagar University there are respectively 4500 (KUET, 2018) ,2500 (du, 2019) and 10000 (juniv, 2018) undergraduate students; whose nutritional supplies generally are not being monitored. As it is noticed that, undergraduate university students tend to have poor eating habits or have unlimited fast food consumption as well as a very poor dietary habit (Hakim, Muniandy, & Danish , 2012). Because most of them do not abide by the suggested intakes for most of the micro and macro intakes (Sanlier N, 2007). Thus, there is a thought that they face significant change in nutritional status during this period of life which can affect their future development. As there are few studies that address the nutritional status of the young generation however there are several factors affecting their health. (Kana Sop, Gouado, E. Tetanye, & Amvam Zollo, 2010), (Angela S. Anderson, 2016), (World Health Organization, 2011) As a result, this study has been carried out to obtain the initial assessment on the nutritional state of an undergraduate university student's so that a future intervention can improve the nutritional status of the young generation. The objective of the study is to justify the actual change of nutritional status of undergraduate student's by calculating BMI after living in a hostel.

So, this study contains an anthropometric measurement (BMI) of a group of undergraduate students to identify their change in nutritional status due to the food habit or lifestyle that they are adapted to. In the assessment of the nutritional status of individuals or a group, anthropometric measurements play a very important role because deviations from normal status can easily be detected earlier by anthropometry than by clinical examination and anthropometric figures are more objective than clinical assessments (Bailey A. & Luzzi, 1995). For this purpose, the students of Khulna University of Engineering and Technology (KUET), Khulna, Bangladesh were examined to find answers to the following key questions that shaped this research:

1. Is there any change in BMI of under-graduate students after starting to live in ahostel?
2. If there is any change in BMI, does it depend on how many years the students have spent in a hostel?
3. If there is any change in BMI, is it more significant is either of the two genders of students, male and female?
4. Is there any dependency in academic result with health, eating and lifestyle pattern of Under-graduate students?

2. Methods

2.1 Study Design:

To justify the research a cross-sectional study has been designed where the investigation involved student's current data regarding their health and lifestyle. As for the study area Khulna University of Engineering and Technology (KUET) which is one of the leading public universities of Bangladesh ranked as 8th has been considered (webometrics, 2018). KUET offers engineering education in both undergraduate and post-graduate levels where around 4635 undergraduate & 967 postgraduate students are studying in 18 Academic

Department under 3 Faculties. Most of the students at KUET accommodated in hostels as there are 6 residential hostels for male & 1 for female. (KUET, 2018)

2.2 Study Population:

After, determining the sample size with Cochran's formula this study has conducted the "stratified sample" method to collect the data from students who live at the hostels in KUET. Collection of data has been divided based on the characteristics of the respondent (gender, living years in the hostel) so that it can give a consecutive view about the nutritional status of the students.

$$\text{Sample size}, n = (n\circ)/(1 + \left(\frac{n\circ - 1}{N}\right))$$

Source: (Cochran, 1977)

Total 342 students with 193 male and 149 females from three consecutive academic years joined in this study; where 43.9% participant is in the 1st year and remaining both 28.1% participant is in the 2nd & 3rd year. Each of the participants has an average age of 20.92 ± 1.08.

2.3 Body Mass Index (BMI) calculation:

BMI is a simple measure of total body components which will be compared with standard values. This method is used to evaluate the under and overnutrition in people. BMI can be calculated by a simple method where weight in kilograms divided by height in meters squared. (N. Jeejeebhoy, 2000) By calculating the BMI of each student it has been compared with the standard of BMI chart (Table-1.1) to find the actual state of nutrition

$$BMI = \frac{\text{Weight in Kg}}{\text{Height in meter}^2}$$

Classification BMI	Underweight	Normal weight	Overweight	Class-1 obesity	Class-2 obesity	Class-3 obesity
Range	≤19.9	20-24.9	25-29.9	30-34.9	35-39.9	≥40

Table 1: BMI Chart

Source: (Q.Nuttall, 2015)

2.4 The pattern of Questionnaire and Data Collection:

The questionnaire has been developed with the information of the student's present weight-height across the academic year of 2017-2018 and collected their dietary habits and lifestyle to establish a relationship between BMI scenario at present after living in a hostel and at the time of admission. The eating pattern like intense of consuming rice, vegetable, water, fast food, beverage has been included in the questionnaire with the pattern of lifestyle and physical activity like when did they sleep/how long do they exercise/do they smoke/do they face physical problem, etc. and rated them based on an individual's experience.

Past data of participants have been collected based on their student ID from the administration of KUET where the weight-height of each individual has been recorded at the time of admission. So, the change in the nutritional status of hostel living students can be spotted easily.

2.5 Statistical Analysis:

For further analysis EXCEL and SPSS has been used where the data has been investigated based on gender and year spent at the hostel with the mean-standard deviations. Also, Chi-square and ANOVA test have been conducted to compare values of BMI and eating-lifestyle pattern of male & female students. Regression model has been developed to justify the academic performance of students based on their health and living patterns.

3. Results

The analysis has been conducted based on the hypothesis taken in this study. The study results have been provided-

3.1 There is a significant change in BMI situation of Undergraduate students after they started to live in a hostel

To know the change in BMI condition, paired sample t-test has been performed with 99% confidence level for a total 342 students and it has been increased in present days from the time they have been admitted to the university. The average BMI significantly changes from 22.28±4.2 to 23.41±5.4 which indicates there is a change in the nutritional status of students after living in a hostel.

Category	**Past BMI condition** (at the time of admission)	**Present BMI condition** (after passing1-3years in the hostel)
Underweight	17.8%	12.6%
Normal	61.7%	56.7%
Overweight	20.5%	30.7%

Table 2: Overall BMI change of the students

Source :(Field Survey, 2018)

Around 30.7% of students are estimated overweight in present days where 20.5% are estimated at the time of their admission. The percentage of students admitted as normal weight is 61.7% but it decreases over the years. But one exception has been identified that students gain more weight on their first and second year in hostel life rather than the third year since they become more health conscious in age of 22.09±0.58; according to questionnaire survey around 89.7% are aware about the knowledge of nutrition where only 76% have consciousness of nutrition on their first year of living in hostel.

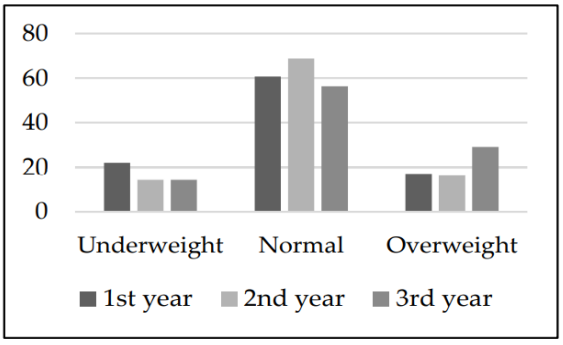


Figure 1: Health Status (at the time of admission)

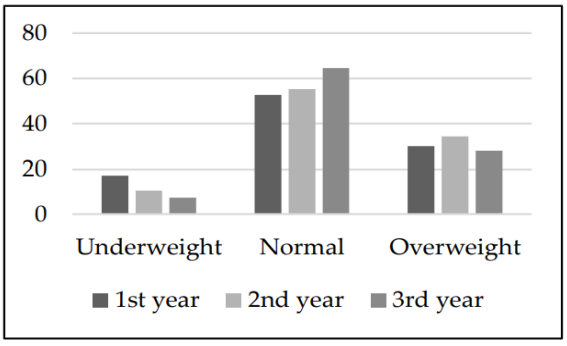


Figure 2: Present Health Status

3.2 Year differences regarding living in a hostel do not affect BMI levels significantly but Gender differences do affect the BMI level

With the one-way ANOVA test, it has been perceived that BMI differs based on the gender of a student and their new lifestyle or overall microenvironment. With Welch and Brown-Forsythe's 0.004 significance level the assumption has taken; where the gender of students affecting their BMI change. In this test, the mean of male's BMI change has been identified as 0.425 and female's BMI change 2.021 which was more than double from a male student. So, the female students have been gaining more weight compared to a male student.

	Statistic [a]	df 1	df 2	Sig.
Welch	8.226	1	252.775	.004
Brown-Forsythe	8.226	1	252.775	.004

Table 3: Robust Tests of Equality of Mean Change in BMI

**a=Asymptotically*

Consequently, after assessing the past BMI at the time of admission and present BMI according to genders, 21.7% boys were overweight which turned to 27.4% at present 2018; whereas only 18.8% of girls were overweight before living in a hostel at the time of admission; which turned to 34.9% in 2018 after living maximum 3 years in hostel which has been denotation that the number of overweight girls doubled over the years.

Variable	Total(n=342)			Female (n=149; 43.6%)			Male (n=193; 56.4%)		
Age, years Mean±SD	*1st year*	*2nd year*	*3rd year*	*1st year*	*2nd year*	*3rd year*	*1st Year*	*2nd year*	*3rd year*
	20.01 ±0.63	21.18 ±0.72	22.09± 0.58	19.88± 0.62	21.08± 0.4	22±0.5 4	20.12± 0.62	21.23± 0.8	22.23 ±0.62
Academic Result, CGPA (%)	*<3.00*	*3-3.50*	*>3.5*	*<3.00*	*3-3.50*	*>3.5*	*<3.00*	*3-3.50*	*>3.5*
	27.5 %	52.3 %	20.2%	12.1%	59.7%	28.2%	39.4%	46.6%	14%
Anthropometry, BMI (kg/m²)									
At the time of admission	22.28±4.52			22.02±4.15			22.48±4.33		
After livingin a hostel	23.41±5.28			24.03±6.32			22.93±4.23		
Present Health Status									
Underweight	12.6			11.4			13.5		

Normalweight	56.7	53.7	59.1
Over weight	22.5	24.8	20.7
Obese-1	5.6	5.4	5.7
Obese-2	2.0	3.4	1.0
Obese-3	0.6	1.3	0
Eating and Lifestyle Pattern (%)			
Amount of vegetable consumption			
Never	4.4	6.7	2.6
Occasionally	9.9	10.7	9.3
In a week	10.5	15.4	6.7
More than a day	33.6	31.5	35.2
Once in a day	40.5	35.6	46.1
Amount of water consumption (liter)			
<=1	14.6	22.1	8.8
1-2	50.9	53.7	48.7
2-3	26.6	16.8	34.2
>3	7.9	7.4	8.3
Amount of fast-food/ rich food consumption			
Never	1.8	0	3.1
Occasionally	31.6	26.2	35.8
In a week	30.1	34.9	26.4
More than a day	10.5	5.4	14.5
Once in a day	26.0	33.6	20.2
Amount of fast-food/ rich food consumption			
Never	1.8	0	3.1
Occasionally	31.6	26.2	35.8
In a week	30.1	34.9	26.4

More than a day	10.5	5.4	14.5
Once in a day	26.0	33.6	20.2
Amount of beverage consumption			
Never	2.3	2.0	2.6
Occasionally	24.0	22.1	25.4
In a week	23.7	25.5	22.3
More than a day	15.2	8.7	20.2
Once in a day	34.8	41.6	29.5
Amount of smoking			
Never	69.3	99.3	46.1
Occasionally	2.3	0	4.1
In a week	2.9	0.7	4.7
More than a day	18.4	0	32.6
Once in a day	7.0	0	12.4
Bedtime			
Before 10 pm	0.9	0.7	1.0
10pm-12am	7.9	9.4	6.7
12am-2am	45.6	55.7	37.8
After 2am	45.6	34.1	54.4
Physical activities			
Yes	26.3	11.4	37.8
No	73.7	88.6	62.2

***SD=Standard Deviation *BMI=Body Mass Index (Source: Field Survey, 2018)*

Table 4: Overall condition of BMI change and eating-lifestyle pattern of student's

3.3 There is a significant connection between academic result with the health condition of students which ultimately have a dependency on their eating behavior and lifestyle pattern.

From the analysis of the results of the respondents, it has been indicated that 72.5% of students has preferably held CGPA within 3 to 3.50 and above them, only 42.7% of students are in normal weight or in balanced health condition. That means out of 342 students there are 248

who are having a reasonable result in the academic curriculum and out of 248 students, almost 148 are having a satisfactory body composition. At the same time, 48 students out of 96 that was 50% of total below-3 CGPA who are not doing well in their academic activities were in underweight or overweight condition. Thus, representing that there has been a significant connection between their academic performance and health status.

CGPA / Health Status	Bellow 3(%)	3-3.50 (%)	Above 3.50(%)	**Total(%)**
Under Weight	5	6.1	1.5	**12.6**
Normal Weight	14	31	11.7	**56.7**
Over Weight	9	15.2	7	**30.7**
Total (%)	**28**	**52.3**	**20.2**	**100**

**CGPA=Cumulative Grade Point Average*

Table 5: Relation between CGPA and health status

For the variation of CGPA, change in health status may be described by their lifestyle changes. Therefore, some riskier lifestyle factor like the amount of having fast foods or rich food in a regular basis and having rice-bread/carbohydrate, water consumption in a day as well as the habit of physical exercise or amount of smoking has been taken under consideration which has significantly associated with the educational performance of the students.

Variable	**Standardized Coefficients, Beta**	**Sig.**
Physical Exercise	.039	.473
Fast-food/ rich food consumption	.040	.470
Beverage consumption	.042	.456
Amount of smoking	.230	.000
Amount of taking carbohydrate	.101	.057
Water consumption	-.010	.852
Health status	.097	.067

Table 6: Correlation of academic result and lifestyle

In further analysis of 'Stepwise Linear Regression' model, it has been perceived that smoking and amount of having carbohydrate has been most significantly affecting their academic performance. In this model, the adjusted R-square value has been 0.055 and 0.063 that means these factors has been the probabilities for influencing the academic performance. In the total result, the amount of student having smoking has 5.5% and consuming carbohydrate in a day has a 6.3% impact.

Model	Variable Entered	Method	Adjusted R-square
1	Amount of smoking	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).	.055
2	Amount of taking carbohydrate	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).	.063

Table 7: Linear regression model of affecting variable with academic performance

Overall, the irregular lifestyle and riskier eating pattern have an adverse impact on their present health status which connectively influences their overall academic performances. Between many dangerous patterns of lifestyle, smoking and irregular consumption of carbohydrates are mostly affecting their body.

4. Conclusion:

This study attended a preliminary opinion which investigated the BMI, food habit, health status change of the students at a variety of times as well as connected them with their academic activities. In the study, the students of KUET demonstrated different BMI in current time regarding their entrance time which indicated the degradation of health status. Furthermore, female students exposed higher obesity rates than male students because of their unhealthy eating behavior and lower levels of physical activity. It also showed that a student with good health status obtained a good grade in his/her undergraduate education. Similar kind of studies also showed BMI was negatively correlated with students' final grades (Angela S. Anderson, 2016). High consumption of fast food, beverage and lower levels of exercise, water consumption and irregular sleeping behavior had been associated with their change in health status. The linear regression model exposed that the amount of consuming a large number of carbohydrate and smoking on a daily basis was highly affecting their health and final grades. Outcomes of the studies recommended that improved BMI could upgrade their academic performance. Riskier patterns of eating more greasy components were detected in the student's behavior who was living in a hostel (Jina Tanton, 2015). Therefore, increasing a balanced nutritional diet in a hostel with a healthy lifestyle can bring a positive change in the health status of students.

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Covid-19 Effect on Tobacco Smokers & Its Determinants: University Edition

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Abstract

The major goal of this study was to look into the smoking habits of university students and assess the elements that influence them. This research also contributes to determining the level of smoking awareness and consciousness among university students in the current Covid-19 situation. A self-directed survey was used to collect data from 229 students in order to investigate the determinants of tobacco smoking and their relationships with it. Our data revealed that about 21.4% of students smoked, with the male ratio being the highest, most likely due to cultural and social barriers preventing females from smoking. Stress and the influence of friends were the key drivers of tobacco smoking initiation, with family members of tobacco smokers playing a significant but indirect role in it. Anti-smoking commercials, such as LED TV billboards and adverts or pop-ups on social media networks, should be promoted to alleviate this global concern.

Keywords: Tobacco Consumption, Student Health, Covid-19 & Smoking, Tobacco Control, Policy and Regulations.

Introduction

Tobacco continues to be one of the world's most serious public health issues, killing more than 8 million people each year. Tobacco usage is directly responsible for about 7 million of these fatalities, while approximately 1.2 million are due to non-smokers being subjected to passive smoking. All categories of tobacco are toxic and there is no acceptable amount of tobacco consumption. Some tobacco products include water pipe tobacco, assorted smokeless tobacco products, roll-your-own tobacco, cigars, chewing tobacco, cigarillos, kreteks and bidis [World Health Organization, 2020a]. Cigarettes are deemed to be demerit goods, often referred to as “merit bad”. This indicates that the use of these goods influences the consumer and the third party [Para and Nawrot, 2014]. Bangladesh is one of the high-achieving countries recognized for various tobacco control measures, namely taxes on tobacco products, anti-tobacco mass media promotions and healthcare warning labels. The benchmark considered to be a best practice by WHO is at least an increment of 75% tax on tobacco market value. Bangladesh's high level of tobacco taxation achievement is offset by a rise in per capita tobacco consumption. As tobacco prices rise, overall cigarette intake is anticipated to decline. Contrarily, an increase in consumers’ income could significantly raise their potential to afford more cigarettes and increase the demand for cigarettes [Nargis et al., 2019].

When it was revealed that smokers were more likely than non-smokers to acquire the serious disease from COVID-19, it prompted millions of smokers to quit smoking. However, quitting can be extremely difficult without proper assistance. As a result, WHO established a year-long campaign with the theme “Commit to Quit” for World No Tobacco Day. The program focuses on empowering 100 million tobacco users to quit by building support networks and improving access to services that have been shown to aid tobacco users to quit efficiently [Krech, 2021]. The motive behind choosing this particular topic is that university students are

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quite a high-risk group for engaging in unhealthy activities, such as smoking and illegal drug use.

Methods

The research involves both the qualitative and the quantitative aspects with primary data. A cross-sectional analysis was conducted at East Delta University. Respondents were notified that the information gathered would be kept confidential and that their involvement was entirely voluntary. We prepared our questionnaire using google forms and distributed it to all the enrolled students via email. The self-assessment survey questionnaire consisted of the demographic data, smoking status, smoking patterns, factors leading to initiation and continuation of tobacco consumption, the average number of cigarettes/self-rolled cigarettes consumed per day. We thought to follow a different route and tried to relate this issue with our now alarming concern, Covid-19. Cross-tabulation was performed to look for any relationship between two variables using Chi-square [Tarafdar et al., 2009]. We used SPSS software version 20 to analyze all the predictors. Data was obtained, verified and inserted into Microsoft Excel before being moved to the SPSS software version 20 for analysis. $P<0.05$ was the level of significance.

Results

Out of 229 respondents, there were 88(38.4%) female respondents and 141(61.6%) male respondents and they were found to be statistically significant ($P<0.05$). Among 229 respondents, 21.4% were smokers where 0.9% were female and 20.5% were male. The female smokers' age was less than 21 years old whereas 10.5% of the male smokers' age was between 21-23 years old and the rest were of age 24 years or above. Out of 21.4% smokers, 17.9% were enrolled in an undergraduate degree program and 3.5% in a Master's degree program. Among them, 5.2% were from 1st year (including the ones of Masters), 3.1%, 5.2% and 7.9% were from 2nd, 3rd and 4th years respectively. From the p-value ($P<0.05$) provided in Table-1, we can understand that the statistically significant demographics are gender and age as these are less than 0.05. This means that gender and age are respectively associated with smoking status. In other words, smoking status is dependent on gender and age respectively.

Demographics of Respondents	**Attributes**	**Smoker (a person who smokes cigarettes) N= 49(21.4%)**	**Non-smoker (a person who doesn't smoke cigarettes) N= 180(78.6%)**	**P-value(P<0.05)**
Gender	Female	2(0.9%)	86(37.6%)	0.000
	Male	47(20.5%)	94(41.0%)	
Age	<21	2(0.9%)	29(12.7%)	0.001
	21-23	24(10.5%)	110(48.0%)	
	24 or above	23(10.0%)	41(17.9%)	
Academic Degree	Under-graduate	41(17.9%)	159(69.4%)	0.240
	Graduate	0(0.0%)	4(1.7%)	
	Master's	8(3.5%)	17(7.4%)	
Academic Year	1st	12(5.2%)	33(14.4%)	0.637
	2nd	7(3.1%)	35(15.3%)	
	3rd	12(5.2%)	52(22.7%)	
	4th	18(7.9%)	60(26.2%)	

Table- 1: Demographic attributes and smoking proportions of the respondents

21.4% of the students indicated that at least one of their family members smoked. Out of these 49 respondents, 11.4% of students revealed that their grandfather smoked tobacco and 11.2% revealed that their father/brother smoked tobacco. These two factors are not statistically significant since their P>0.05. So, we can conclude that father's/brother's and grandfather's tobacco usage are not at all associated with smoking status. Students were questioned to identify the factors that affected their decision to continue smoking. A large proportion of the respondents responded with bad family relations as the reason to continue smoking. Another influencing factor was mental depression. Other factors were curiosity and others.

Factors Influencing Smoking Initiation	**N= 49**	**Percent**	**P-value(<0.05)**
1. Peer pressure	47	11.2%	0.465
2. Friend's influence	36	8.6%	0.033
3. Father's/Brother's use	47	11.2%	0.465
4. Grandfather's use	48	11.4%	0.609
5. Looking smart & modern	48	11.4%	0.609
6. Desire to imitate	43	10.2%	0.185
7. To rebel against loved ones	46	11.0%	0.365
8. Stress	28	6.7%	0.002
9. Curiosity	34	8.1%	0.19
10. Other	43	10.2%	0.185

Factors Influencing Smoking Continuation	**N**	**Percent**
11. Mental depression	13	20.0%
12. Bad family relation	30	46.2%
13. Educational problems	01	1.5%
14. Difficulties in relationship with a girlfriend	05	7.7%
15. Habit	02	3.1%
16. Curiosity	08	12.3%
17. Other	06	9.2%

Table- 2: Smoking Initiation & Continuation of the Respondent

Several questions were asked to the respondents to assess their knowledge regarding tobacco smoking. A large proportion of respondents (65.9%) were exposed to environmental tobacco smoke commonly known as second-hand smoke. By definition, it means smoke generated by the combustion of a tobacco product as well as the smoke exhaled by smokers [NCI Dictionary of Cancer Terms, no date.]. We took a different approach and tried interlinking this with the Covid-19 scenario. Tobacco consumption is considered to suppress the immune function and serve as a mediator in the adherence of COVID-19. Almost all COVID-19 research has discovered that individuals with such chronic diseases have the highest mortality, indicating that tobacco use is a proven risk determinant for COVID-19 [Grover et al., 2020]. Thus, we asked the student smokers if they continued smoking, despite being aware of the consequences of Covid-19 and the majority of them admitted that they are still consuming tobacco.

Smoking-Related Factors	Forms	Frequency, N	Percent
Despite knowing the consequences of Covid-19, do you still smoke?	Yes	43	18.8%
	No	6	2.6%
Will you continue to smoke if the pandemic situation gets better?	Yes	43	18.8%
	No	6	2.6%
Death of family from CHD (Coronary Heart Disease) and Cancer	Yes	63	27.5%
	No	165	72.1%
Exposed to environmental tobacco smoke	Yes	151	65.9%
	No	77	33.6%
Aware of the hazardous effects of smoking on health	Yes	213	93.0%
	No	15	6.6%

Table- 3: Respondent's Knowledge on Smoking-Related Factors

Student smokers were questioned how frequently they smoked tobacco and the majority of them revealed that they smoked regularly, 4.4% of them smoked irregularly and 1.7% smoked occasionally. A majority of smokers had three or more peers as smokers and the rest had either two smoker friends or no smoker friends. The majority of the smokers, in this study, invested their self-earned money to buy cigarettes. 7.4% of the smokers used their allowance to purchase cigarettes whereas the rest used other means to afford cigarettes. As for the perception towards smoking, 75.4% of non-smokers and 14.0% of smokers believe that a student should not smoke. When asked if tobacco brings mental tranquility, 12.3% of smokers agreed with this statement whereas a major proportion of non-smokers did not agree with this statement.

Smoking Perspectives	Smoker		Non-smoker		P-value(< 0.05)
	Agree	Disagree	Agree	Disagree	
Do you think a student should smoke?	17 (7.5%)	32 (14.0%)	7 (3.1%)	172 (75.4%)	0.000
Tobacco brings mental tranquillity. Do you agree?	28 (12.3%)	21 (9.2%)	63 (27.6%)	116 (50.9%)	0.005
The use of tobacco is a cause of economic loss. Do you agree?	26 (11.4%)	23 (10.1%)	142 (62.3%)	37 (16.2%)	0.000
Do you think one should smoke even after knowing the consequences of Covid-19?	5 (2.2%)	44 (19.3%)	16 (7.0%)	163 (71.5%)	0.786

Table- 4: Perception of Smoking

Smoker respondents were questioned if they faced any sort of health problems while consuming/smoking tobacco. Respondents were asked if the warning labels on cigarette packs ever discouraged them to smoke tobacco. This indicates that such policies are not effective in reducing the level of tobacco consumption. As per studies, visual warnings dramatically raise everyone's awareness of the dangers of tobacco usage. Since the warning labels are not effective enough to reduce the rate of tobacco consumption, we can take a different approach instead [World Health Organization, 2020a].

	Loss of appetite	Chest Pain	Breathing Problem	Cough
Frequency	1	2	1	11
Percent	0.4%	0.9%	0.4%	4.8%

Table- 5: Health Problems

Discussions

The observations of our study demonstrate that students initiated smoking tobacco around their adolescent years and throughout their university years. Our findings imply that age and gender are the significant determinants associated with smoking tobacco. As per WHO, most students begin using tobacco at a young age, commonly in high school [Hossain et al., 2017]. This could be due to the ease of availability and affordability of tobacco products in various areas of Chattogram. Furthermore, kids can purchase cigarettes or any tobacco products whenever they desire because there are no age limitations. We discovered in our study that tobacco consumption was prevalent among about 21.4% of students, with males accounting for the majority of smokers, probably because females had limited opportunity to smoke because of cultural and social constraints. Our data revealed that there were fewer female smokers than male smokers, supporting our hypothesis that, due to patriarchal domination in our country, the female population does not have the opportunity to participate in such activities. Stress and friend's influence were the primary drivers of tobacco smoking initiation, with family members of tobacco smokers playing an important indirect influence in initiation.

The majority of the students in this study reported that the main reasons for initiating smoking are father's/brother's and grandfather's tobacco usage. Tobacco consumption has been linked to a higher risk of serious sickness and mortality from a variety of respiratory illnesses. In the COVID-19 pandemic, there has been speculation concerning the clinical effects for smokers and if they are equally prone to contamination [World Health Organization, 2020b]. Tobacco smokers may be more sensitive to COVID-19 because smoking requires a finger to lip interaction, which enhances the likelihood of virus transmission from hand to mouth. Tobacco use decreases lung function, making it more difficult for the immune system to withstand this virus and other respiratory illnesses. According to available studies, smokers are at a higher risk of experiencing catastrophic COVID-19 results and death [World Health Organization, 2020c].

Limitations

We collected cross-sectional data within a small area and with a relatively small sample size. The data collected in this study were all self-reported. This may be prone to bias. Since our sample area and sample size are relatively small, our findings may not reflect that of other areas of the country. This study was limited to one out of all the universities in Chattogram, Bangladesh. The study was solely based on tobacco smoking. No data were obtained or mentioned concerning illegal drug use or any non-tobacco products. This study focused only on university students. It did not involve any school going students or non-students. This needs to be explored further in the future.

Conclusions

Given the health dangers associated with tobacco smoking, WHO urges quitting [World Health Organization]. Mass awareness programs should be launched so that smokers and non-smokers and passive smokers are aware of the hazardous implications of smoking and

how this impacts not only the smoker but everyone around him/her. Because social campaigns cannot be carried out at this critical period, online anti-smoking campaigns should be carried out. In addition to initiatives, anti-smoking commercials should be implemented. Each university should provide academic counselling on tobacco smoking or offer a Smoking Prevention Clinic Program so that smokers who want to quit or need assistance can get the aid they need. To reduce cigarette consumption, the government should impose age restrictions and levy a higher charge on cigarette goods. Even if such legislative safeguards are in place, NID verification should be enforced if smokers want to purchase tobacco products. No one would be able to buy cigarettes or tobacco goods if their NID cards were not presented. The government should establish and improve tobacco control legislation and initiatives. Bangladesh intends to raise cigarette prices to minimize smoking and enhance tax revenue [The Financial Express, 2021].

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Factor affecting workers' migration from the Loom industries to the other profession: A case study on Sirajganj District in Bangladesh

Md. Sabuj Sarker[1], Md. Al amin[2], Md. Shawrat Hayat Sajib[3], Md. Mostafizur Rahman[4], and Most. Arifa Khatun[5]

Abstract

As we know that Sirajganj District has 8.42 percent handloom units and ranks fifth position in Bangladesh according to the Handloom census 2018. In Sirajganj District, there are two categories of weavers: family workers and contracted workers. However, the workers are trying to migrate their profession to other job and that is why the researchers are willing to identify the influencing factors of switching work from handloom weaving and related industry to other profession. This empirical research shows the overall factors of the topic. Stratified sampling are used to collect data and descriptive statistics are used to show demographic information. From the research major factors of migration Senior of handloom workers are to be identified from statistical analysis for further implementation of the business planners.

Keywords: Handloom Industries, Workers, Migration, Sirajganj, Census.

Introduction:

The handloom industry is Bangladesh's largest commercial activity, and it has consistently also been country's largest rural industry(Islam and Hossain, n.d.). In Bangladesh, there are more than 0.183 million handloom units, 0.505million handlooms, and around 1 million handloom weavers, with about half of them being women(Banarjee et al., 2014).In Bangladesh, tiny and cottage enterprises play an important role in reducing poverty by raising household income and generating employment (Islam et al., 2013). The handloom industry accounts for 48.04 percent of total cottage industry employment and 49.46 percent of total cottage industry production in the country (Islam and Hossain, n.d.) Cloth is one of humanity's most fundamental requirements. Mills, handlooms, and powerlooms are the three autonomous sectors of the textile industry, which compete with each other to a substantial extent and jointly supply the country's clothing needs, generate excess for export, and employ a huge number of people (Tania Parvin et al., 2020) The competence of Bangladeshi weavers, according to an international specialist, is second to none in the world(Rahman, 2013). Due to a number of internal and external variables operating behind the scenes, Bangladesh's handloom industry has a brilliant past, an insecure present, and an uncertain future(Rabiul Islam Liton, 2016). The current state of handloom weaving is debatable, and the number of weavers in the business is rapidly dwindling as a result of a variety of internal and external issues that have a direct impact on our sector(Sharmin and Tousif Hossain, 2020). The Bangladesh Bureau of Statistics (BBS) conducted the 3rd Handloom Census 2018 from 10 to 14 May 2018 to assess the current number of handloom employees and the overall state of the industry, and the results indicated an alarming picture(Aziz et al., n.d.). In the current situation, the handloom sector has lost its capacity for competition when compared to other industries, particularly in terms of market share, and in most countries, it has become almost

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fictitious(C-169, HAL Colony, HAL Post, Balanagar, Hyderabad, India. et al., 2017). Due to a lack of working capital, about 0.2 million looms have been closed. The fixed capital and demand for loan per loom, according to the handloom census of 1990, are Tk.10,008 and Tk.8,904, respectively(Raihan, 2010). The electric power handloom is an alternative to the handloom. In the same way, the weaving business is being updated in stages. Weavers are switching careers due to a lack of training in how to operate modern machinery(Roy, 2017). Between 1990 and 2003, the rate of loss in businesses and employment was predicted to be 3.8 percent and 1.31 percent, respectively. For the years 2003–2013, the comparable rates are expected to be 5.0 percent and 6.80 percent, respectively. Using the aforesaid drop rates, the number of surviving handloom establishments in 2017 would be around 45 thousand, down from 100 thousand in 2003 and 165 thousand in 1990. The handloom sector, on the other hand, has pursued its own path toward powerlooms. Nonetheless, this industry is projected to remain to the extent that it is required for the production of specialist textiles for which demand will prevail and weavers will be compensated in a manner that is compatible with powerlooms.

Objective of the research:

The study's main goals are to call attention to existing improvements in the Handloom industry. In light of this overarching goal, the study's specific aims are as follows:

- To determine the current state of the handloom business.
- To investigate the handloom industry's critical aspects.
- Causes of workers migration from the Loom industries.

Literature:

Psychological Factors:
Workers in developing countries must frequently transition from rural life, with its quiet and close relationships, to the factory environment; from traditional dependence on natural processes in agriculture and physical work to standardized production, precise timing, rapid output, and energy dependence; and from a context of identify cation with the land and crops to the impersonal environment of the machine (Kalimo et al., 1987). Psychological elements are those that affect an individual's psychology and motivate them to lead a good life. Work satisfaction increases both employee engagement and the amount of discretionary effort team members are happy to devote in.When people are unsatisfied with their work, their performance at work, as well as their overall quality of life, decreases. Work migration of handloom workers is heavily affected by multiple psychosocial processes such as co-worker collaboration, doing the same monotonous work, having no choice to take a break all through the shift, and weaving being an extremely important job.

Health Hazard (Repetitive Stress Injury):
Intensifying, loudness, radiation, and pressure are all physical hazards that can injure an employee without requiring them to contact them. Working people's opinions of stress are associated with a multitude of conditions in the profession and in respective lifestyles (Kalimo et al., 1987). In relation to public, political, technological, and economic changes, the scope of health and safety at work has gradually and steadily increased. Globalization of the world's economies and its connotations have been viewed as the most powerful factor for change in the workplace, and therefore in the scope of occupational safety and health, in both

positive and negative aspects, in recent years (“Fundamental principles of occupational health and safety,” 2002).

Financial factor:

When employees are in financial trouble, their productivity may suffer as well. To attract and retain capable workers, handloom owners must pay higher wages to workers in areas with a high cost of living. However, under the current scenario, the owner provides minimal salaries to the handloom workers in order to cover their living expenses. In this concern there are some financial factors are identified which are advance payment facilities, limited income opportunity, limited wages, responsibility of accidental faulty production, no way to other financial opportunity.

Nonfinancial factor:

Non-financial variables including quality of service, a company's flexibility, resource utilization, and market orientation were shown to be important predictors of a service company's profitability (Kien Phan et al., 2021). Non-financial factors have long been recognized as impacting important indicators of willingness to achieve targets. For the handloom workers migration some nonfinancial factors are identified such as: uncertainty of getting work, underestimating of the work, work demands depends upon the willing ness of owner of handloom, lake of the availability of work.

Handloom worker migration:

Hand loom productions are converted to the power loom industry, surplus of worker, demand of other work opportunities, availability of other work against handloom work, humiliation of the handloom work, hardworking in nature are the main dependent variables of Hand loom worker migration.

Hypothesis development:

H1: psychological factors have direct impact on Handloom worker migration.
H2: Physical Factors have direct impact on Handloom worker migration.
H3: Financial factor have direct impact on Handloom worker migration.
H4: Nonfinancial factors have direct impact on Handloom worker migration.

Research Methodology:

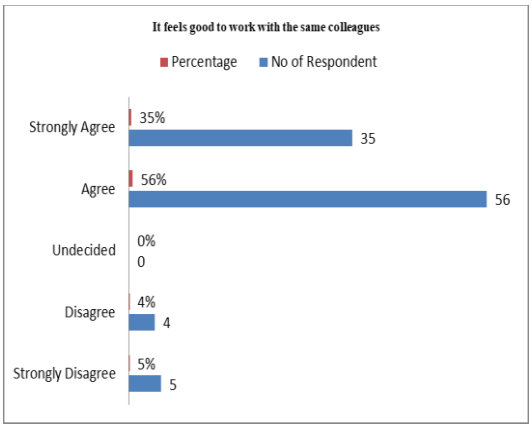
Through interviews, we acquired information from 100 handloom workers in Sirajganj. This information was gathered through a standardized 30-question survey. The appropriate sampling respondents who were gathered using the preference survey approach must be identified. The factors determining Bangladesh's prosperity were discovered using a proposed technique. The Likert scale was used, which is a 5-point scale with 1 indicating strong disagreement and 5 indicating strong agreement.

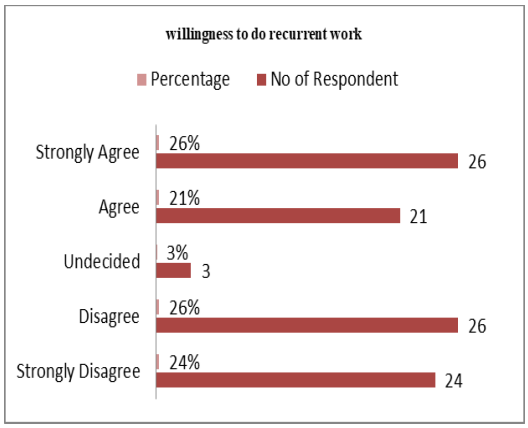
Data Presentations & Findings:

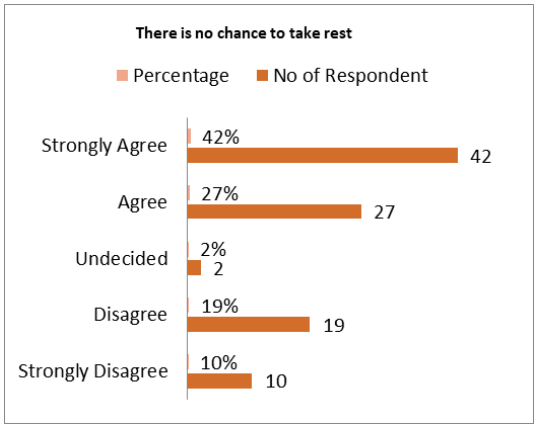
Demographic Information			
Description	**Items**	**Number**	**Percentage**
Education	Illiterates	39	39%
	Below PSC	16	16%
	JSC	19	19%
	SSC	18	18%
	Below PSC	4	4%
	Degree /Honours	2	2%
Age	10-20	7	7%
	21-30	30	30%
	31-40	21	21%
	41-50	18	18%
	51-60	14	14%
	61-70	7	7%
	71-80	3	3%
Experiences (as a handloom worker)	00-10	55	55%
	11-20	25	25%
	21-30	12	12%
	31-40	5	5%
	41-50	3	3%
Experiences (as other profession)	00-10	91	91%
	11-20	7	7%
	21-30	2	2%
	31-40	0	0%
	41-50	0	0%

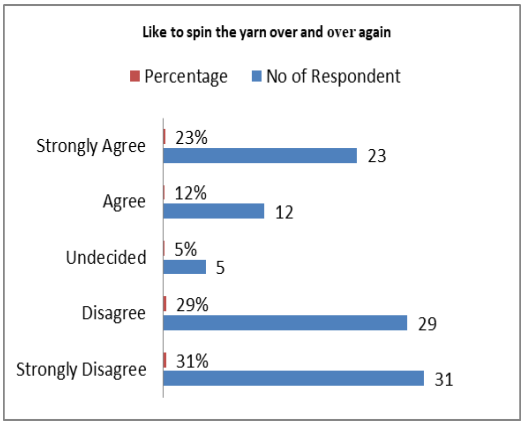
This table is commonly used in data analysis and research. It can be seen that the majority of handloom employees, 39 percent, are illiterates. The majority of weavers are between the ages of 21 and 30, representing for 30% of the total. As a handloom worker, 55 percent of the workers have extensive experience. Because of the severe issues in the handloom sector, 91 percent of people have discontinued weaving.

Psychological factor:



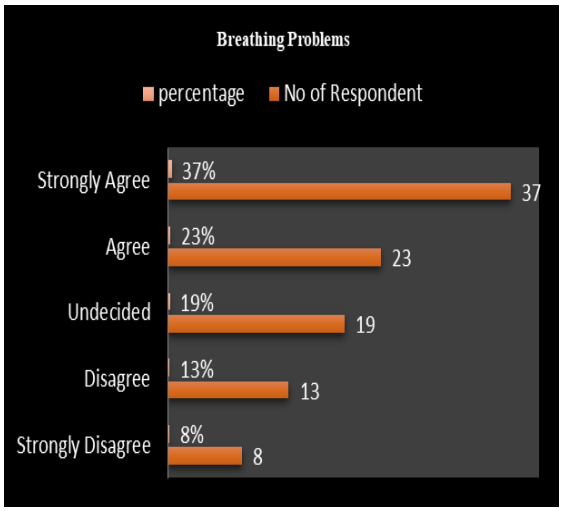


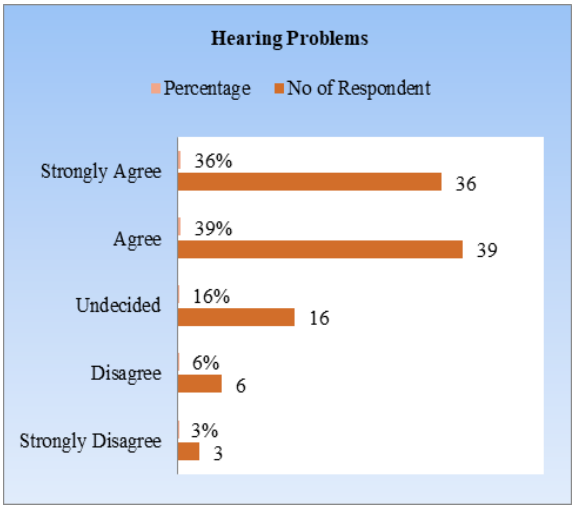


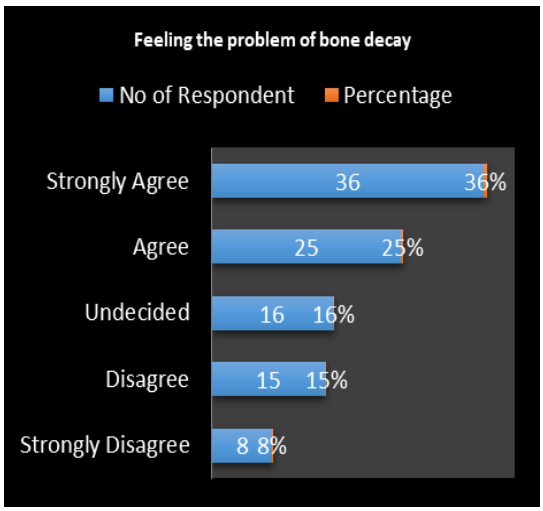


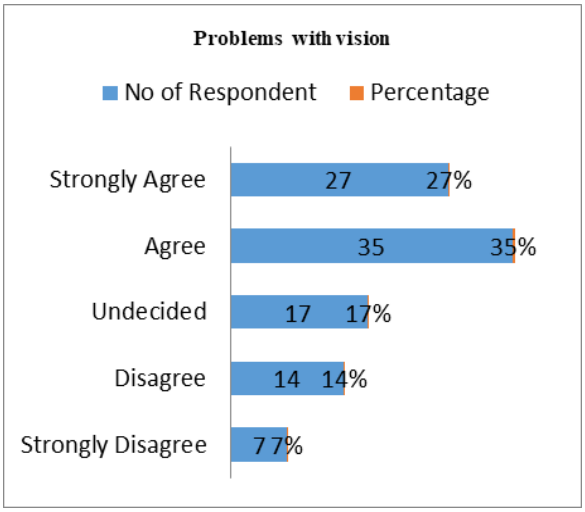
The chart shows in the variable of psychological factor of handloom workers that In figure 1.a It is shown that 56% respondent agree that they feels good to work with the same colleagues. Now In Figure 1.b we observe that Disagree and agree Likert Item are almost equal .And last of all it is noticed that In Figure 1.c strongly agree is 42% and In Figure 1.d strongly Disagree is 31% which is almost contrary.

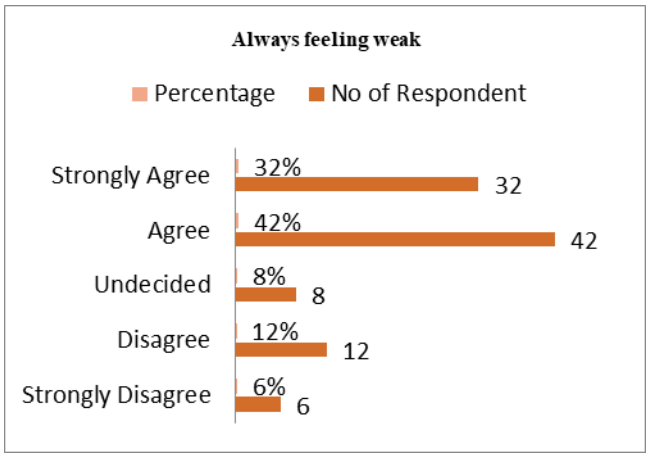
Health hazard (repetitive stress injury):





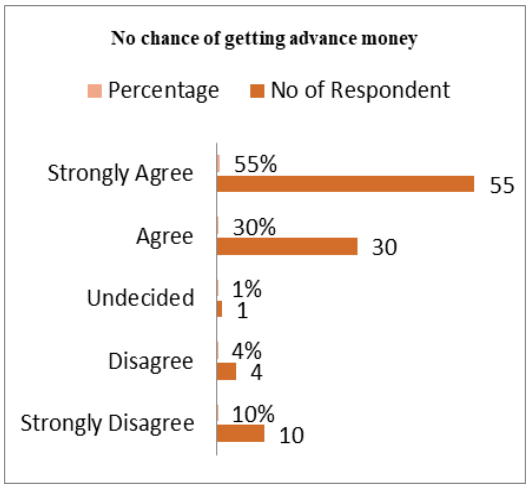


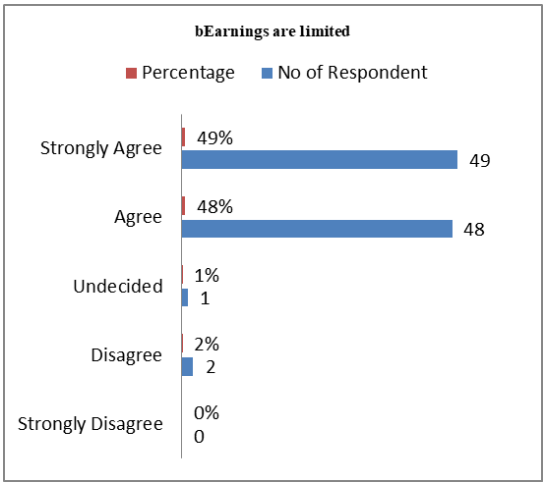


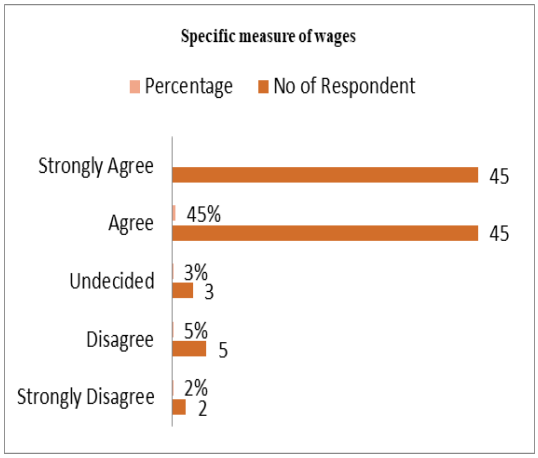


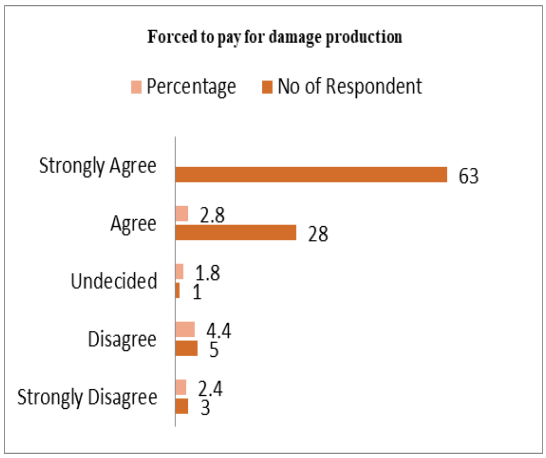
In those charts, the health risk of repetitive stress injury is shown as an independent variable. Figure 2.a shows that 37% of respondents believe breathing is a problem, whereas Figure 2.b shows that 39% believe hearing is an issue. It also demonstrates that 36% of respondents agree with the bone degeneration concern In Figure 2.c. 35% agree with the vision problem in Figure 2.d. Finally, it reveals that 42% of respondents believe they are constantly fatigued.

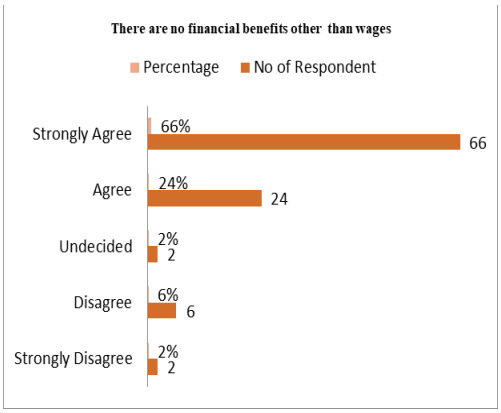
Financial Factor:





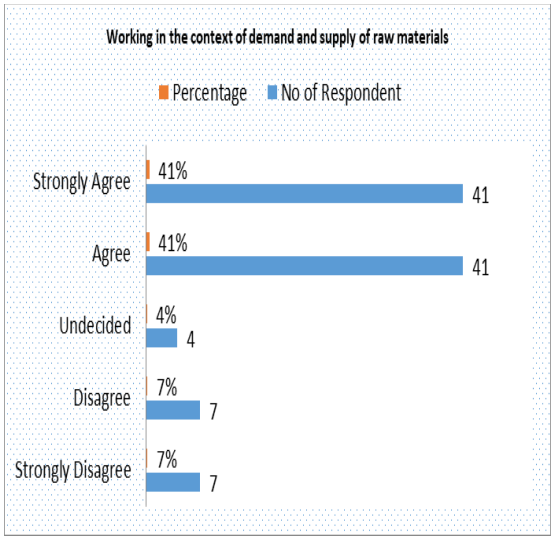


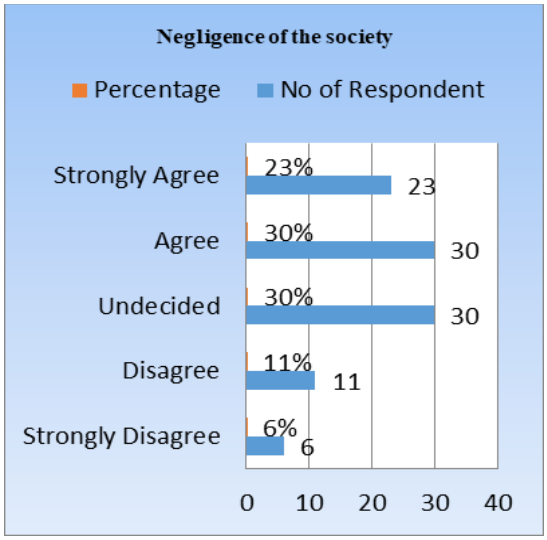


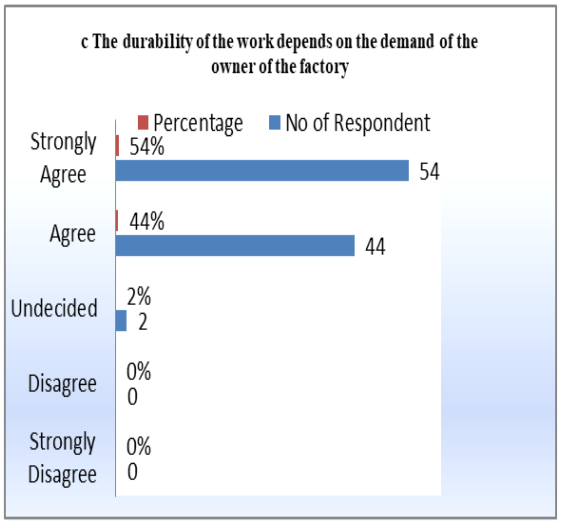


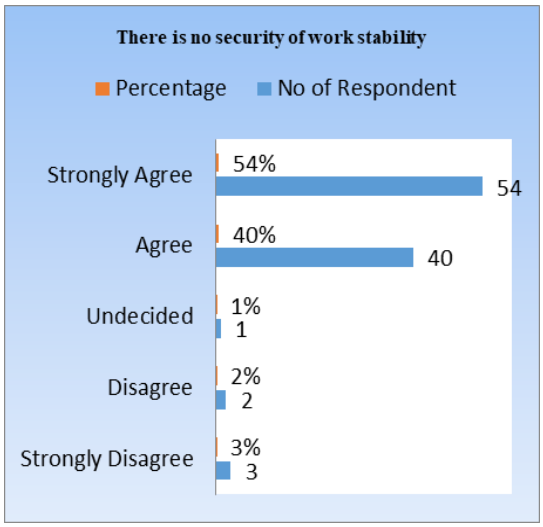
Those bar graphs provide information on the financial factors affecting handloom workers. Figure 3.a shows that 55% of respondents strongly agree that there is no possibility of collecting advance money. Figure 3.b reveals that 49% of people strongly agree that wages are restricted. Figure 3.c similarly exposes that 45 percent of people agree or strongly agree with certain wage procedures. To close, 63 percent of respondents strongly believe that concerns should be requisite to pay for damaged production, and 66 percent strongly agree that there are no financial gains other than wages.

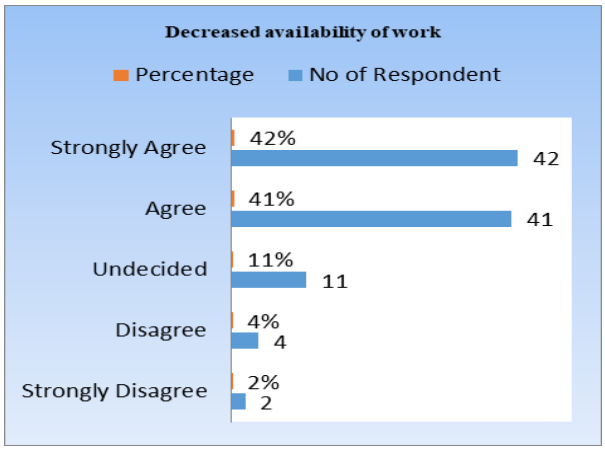
Non Financial Factor:





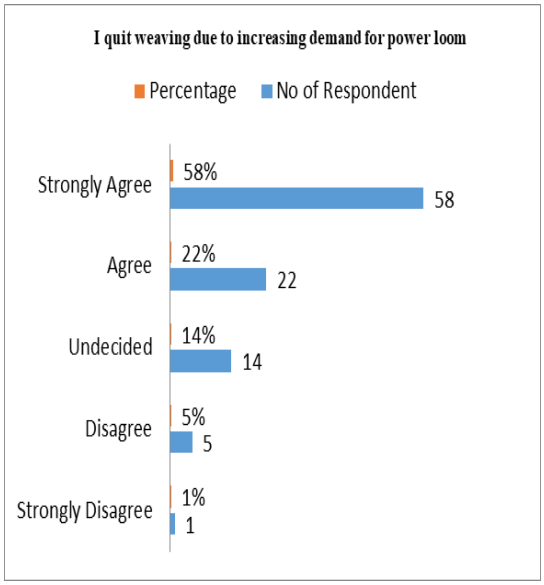


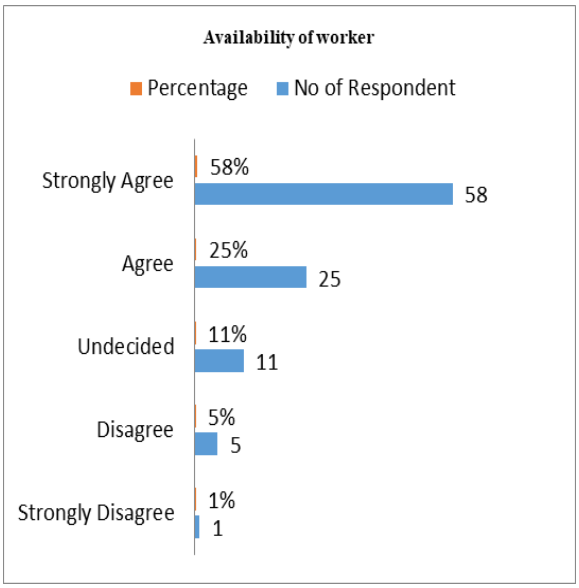


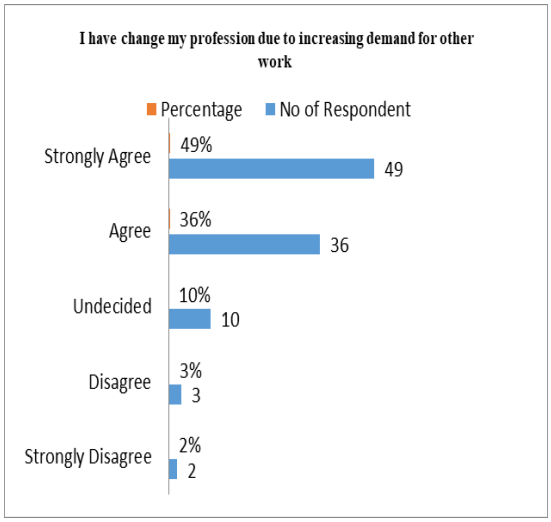


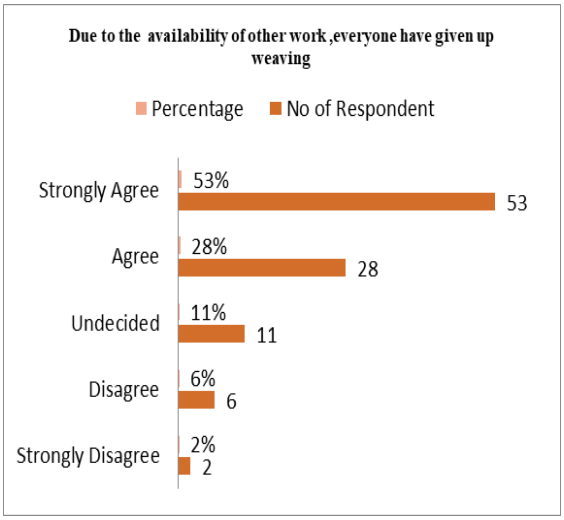
According to the area chart above, 41% of respondents agree or strongly agree that operating in the context of raw material demand and supply is important. Figure 4.b demonstrates that 30% of people are hesitant and agree with society's neglect. According to Figure:4.c, 54% of individuals believe that the work's durability is determined by the factory owner's demands. Finally, Figure:4.d reveals that 54 percent of the people believe there is no job security, whereas Figure:4.e shows that 42 percent strongly agree with decreased work opportunities.

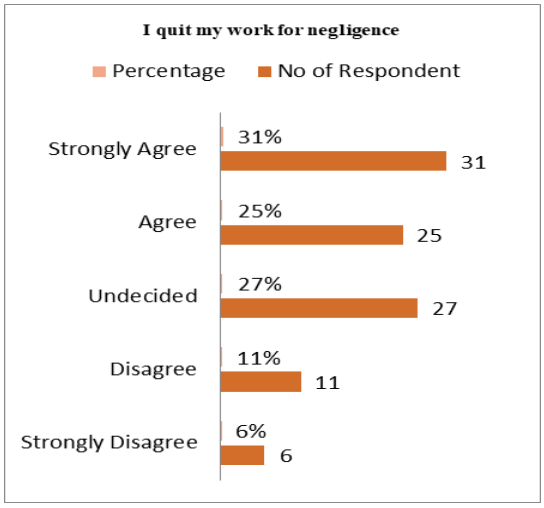
Handloom Worker Migration



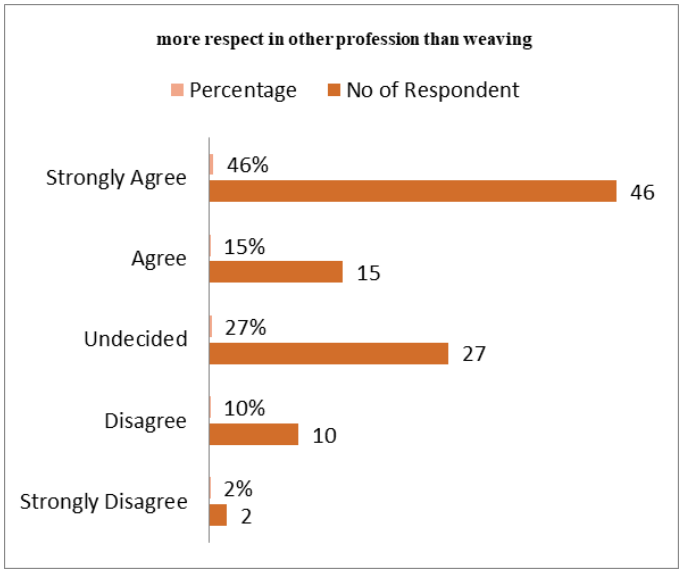












The graph depicts the responses to the question of handloom labour migration. According to Figure:5.a, 58 percent of respondents strongly believe that they stopped weaving as a result of rising power usage. Figure 5.b shows that 58 percent of participants strongly agree that workers are available. Figure 5.c illustrates that 49% of persons feel they have changed their career as a result of increased demand for work opportunities. Figure:5.d shows that 53% of people strongly agree that everyone has given up weaving owing to the availability of other work, and 31% strongly agree that they dropped their work due to negligence. Figure:5.f shows that 53% of people strongly agree that they abandoned their work due to negligence. 61 percent of individuals strongly agree that people quit weaving because of low income from manual labour, and 46 percent believe that more people should weave.

Recommendation:

In terms of the psychological element, the majority of weavers enjoy working with the same co-workers; yet, 42% of workers firmly believe that there is no opportunity to rest. Breathing and hearing issues are both valid reasons for workers to leave their jobs. Financial factors, such as the lack of financial benefits other than pay, are also crucial for employment migration. Work migration is exacerbated by rising demand for power looms. Because of the aforementioned rationale, I believe Weavers has changed his work.

Conclusion:

The large-scale movement of weavers, the introduction of shed weaving, and high indebtedness among weavers have all contributed to the professional weaver's in this area, according to the case study of Enayetpur (Niranjana and Vinayan, n.d.). The study's goal is to describe the current state of Bangladesh's handloom weaving industry. The research looked into the various facets and difficulties surrounding the handloom industry .The industry is facing a lot of problems that have been highlighted through our discussion ((Khan, n.d.) . This industry faces a number of difficulties such as Some of these issues are linked to market failure, while others include inability to satisfy capital cost of production, product diversification, and so on(Parvin and Haque, 2017). Our discussion offers some suggestions for getting the handloom sector to the next level of development(Rahman, 2013). Creating a central network to transmit critical information to weavers, enhancing weavers' understanding of the financing and sales processes, and establishing handloom institutes in every handloom town are just a few of the efforts that will help revitalize the industry and also the

government and non-governmental organizations should provide financial, technical, and policy support for the growth of Bangladesh's handloom sector.(Rabiul Islam Liton, 2016).For this result the sector will save a significant amount of foreign cash that is currently spent on the import of foreign cloth(Raihan, 2010).

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