REGIONALIZATION OF FLOOD PRONE AREAS IN BANGLADESH: A STERN FOCUS ON RAJSHAHI, NATORE, AND SIRAJGANJ DISTRICT

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ABSTRACT

Bangladesh is a country with a high susceptibility to floods due to its location on the Brahmaputra River Delta and the many distributaries flowing into the Bay of Bengal. Flood hazard varies spatially and is influenced by several factors such as climate change, precipitation, low land, inland water bodies, cyclones, deforestation, and urbanization. However, very few works have been done to identify the areas with high risks of flood and analyze its impacts. This study intends to do exactly that using the composite index method and Reilly's law of gravitation to determine the influenced area. Information about lowland, riverine areas, rainfall, and flood frequency were used to delineate the geographic areas having different flood frequency. However, the impact of floods on people's lives cannot be defined only by the geographical boundaries of the district. Factors such as access to flood shelters, having enough knowledge about flood and different services as well as facilities provided by the districts and upazilas can make a huge difference in the functionality of the districts. The study shows that there are significant variations in the flood hazard across different districts, with some districts being at a higher risk than the rest. The functional gap of the upazilas that were identified by measuring the unserved areas can help to find out its lackings which can help further research and policy interventions to mitigate the damage caused by floods throughout the country and emphasize the importance of considering factors beyond administrative boundaries when assessing flood impact.

***Keywords**: Flood, Precipitation, River Bodies, Influence Area, Mitigation Facilities*

1. INTRODUCTION

Bangladesh, being a densely populated and river-rich country situated in the delta region of the Ganges, Brahmaputra, and Meghna rivers with numerous intricate river systems, has been facing the threat of floods for decades. The country's unique geography and topology make it particularly vulnerable to flooding, which has resulted in the loss of thousands of lives and the destruction of property. In Bangladesh, there are several causes of flooding, including massive inflows from upstream catchments, low slopes in the floodplain, cyclonic storm surges, effects of the conflux of the major rivers, siltation during dry seasons, and more. Some of the catastrophic flood of Bangladesh happened in 1987, 1988, and 1998.

These floods significantly hamper infrastructural growth and agricultural productivity while also causing great human misery. However, the impact of floods on the population cannot be evenly distributed across the districts of the country. This is due to the varying levels of services provided by the districts and upazilas in terms of flood shelters, riverine areas, and other factors. A clear idea about the existing condition on these various matters will help to mitigate the hardship and losses faced by people. Yet, still, there's no such work following which one will be able to comprehend this matter.

This study aims to address the issue of regional inequality by analyzing flood risk based on four indicators: precipitation, low land, riverine areas, and flood frequency. The objective is to prepare a district-categorized map based on flood risk, which will help people to know about the flood-prone regions. The second objective is to analyze the functional gap in upazilas of some districts in Bangladesh in terms of flood management to identify the areas that lack sufficient services to mitigate the effects of floods and evaluate the influence areas of regional centers.

Region means a large tract of land; a country; is a more or less defined portion of the earth’s surface, as distinguished by certain natural features, climatic conditions, special fauna, and flora (Biswas, 2014). The formal region is a geographical area that is uniform or homogeneous in terms of selected criteria such as topography, climate, and industrial or agricultural type (Chowdhury, 2019).

Regionalization is the process of delineating regions. Regionalization can also be defined as a means of arranging the number of points on the earth's surface to observe the uniformities and regularities of phenomena upon it and to establish definite theories, models, systems, and structures (Chowdhury, 2019). Delineation of formal regions entails putting local units together that share certain traits in accordance with certain specified criteria and that differ considerably from the region's neighboring units based on certain selected criteria (Mukhopadhyay, 2020).

The interdependencies between the various regions are identified with the goal to identify any low-productivity areas that existed through formal regionalization. The entire nation has been divided into four areas in the research, which will be useful for determining policies for the growth of agriculture based on output levels. In this study, the Crop Productivity Index and Moran-I concept were employed. They take four classes into consideration while doing data analysis. According to this study, the southeast region of the nation has poor productivity due to its steep topography and proximity to natural disaster hotspots (Bhuiya, 2013).

Tingsanchali et al. focused on determining the priority locations in Bangladesh's southwest for flood mitigation, flood hazard, and risk assessment was carried out using a hydrodynamic model. The maximum flooding depths at various places in the rivers and floodplains were established after model calibration and testing. Flood damage risk is just assumed to be as proportionate to population density due to a lack of data on flood damage. The sum of the flood hazard factor and the vulnerability factor was used to calculate the flood risk factor for each land unit. Understanding the flood risk factors for the land units allowed for the development of a flood risk map based on the risk factors, which is

highly helpful for the locals and the authorities in charge of managing the floodplain to reduce flood damage and fatalities (Tingsanchali & Karim, 2005).

Different local news of Bangladesh published about the damages of flood in different areas. In 2020 around 50000 families were affected by flood in Sirajganj (The Daily Star Report, 2020). In Natore 45 villages were trapped by water in 2017 (Tribune, 2017). Being on the bank of mighty Padma, Rajshahi, also lies in danger zone such as some areas of Charghat (Bangladesh Post, n.d.).

Based on the secondary resources and from the result of formal regionalization, three districts: Rajshahi, Sirajganj, and Natore were selected for further analysis. These three districts were selected because they are of the same division having similar characteristics but falls into three different categories according to the output of this research;which are:
Rajshahi falls to the region of extremely flood-affected areas, Sirajganj district is badly affected by flood and Natore is moderately affected by flood. Because they all are from the same division it will help in identifying the reason for their dissimilarities among different factors which ultimately results in different influenced and unserved areas.

To minimize flood damages measures may include establishing a proper flood protection, warning, and evacuation system in time. This study seeks to determine how the various districts throughout the country differ in their flood risk and the reasons behind the functional gap of adjacent upazilas will be analyzed based on the Retail Gravitation Analysis Method following Reilly's Gravitational Theory. The results of this study will help policymakers take appropriate measures to improve the flood management infrastructure and services in the country.

2. METHODOLOGY

2.1 Formal Delineation of Districts

The study produces the amalgamation of formal and functional regionalization of Bangladesh on the basis of flood-prone areas. The latter focuses in-depth analysis of three districts to find out their inter and intra-impact on their inhabitants.

To do that, first, all 64 districts of Bangladesh will be delineated according to four factors that are positively correlated with the flood. The factors are as follows:
X_1= area of lowland
X_2= riverine areas
X_3= precipitation in mm
X_4= flood Frequency

After collecting the data from the Bangladesh Bureau of Statistics website for all 64 districts of Bangladesh, it was analyzed in Excel Worksheet to calculate the composite score of all four factors. Formulas for calculation are shown below:

$$W = \frac{\left(\log_{10}(x_1) \times W_1\right) + \left(\log_{10}(x_2) \times W_2\right) + \left(\log_{10}(x_3) \times W_3\right) + \left(\log_{10}(x_4) \times W_4\right)}{W_1 + W_2 + W_3 + W_4}$$

(Source: Glasson, 1984)

Using these formulas, the composite score for each district has been calculated. Three methods were followed to analyze the data which are:

- Equal Class Interval
- Mean Standard Deviation

- Arithmetic Mean

Table 01 shows the comparison among the three methods:

Table 1 Comparison among the three method

Statists				
		Equal	Mean SD	**Arithmetic mean**
N	Valid	64	64	64
	Missing	0	0	0
Mean		5.16	3.61	5.5469
Std. Deviation		.718	.847	.75445
Skewness		-2.903	-.112	-3.598
Std. Error of Skewness		.299	.299	.299
Kurtosis		17.276	.292	20.089
Std. Error of Kurtosis		.590	.590	.590
Range		5	4	5.00
Minimum		1	1	1.00
Maximum		6	5	6.00

(Source: Author's Preparation)

The skewness and kurtosis value of the three methods will determine the preferred class interval to use. The kurtosis and skewness of mean standard deviation are both closest to zero, thats why, mean standard deviation is the most suitable method for this analysis which was followed in this study.

2.2 Functional Regionalization

The influence area of all districts and upazila has been calculated by the GIS tool. The normal gravity model can be described as the interaction between two centers being directly proportional to the mass (here flood risk) and inversely proportional to the distance between the center.

The analysis was done by calculating the influence area following Reilly's law of retail Gravitational Method, the equation is as follows:

$$\text{Influencing area of region A} = \frac{\text{Distance between A \& B region}}{1+\sqrt{\left(\frac{\text{population of region A}}{\text{Population of region B}}\right)}} \quad (1)$$

(Source: Glasson, 1984)
To analyze the final output three factors were selected which are:

- Geographic location
- Existing water bodies
- Development indicators (*e.g.* Number of NGOs, Educational Institute, and Health Facilities)

Basis of factor selection:

Rivers flowing in, around, and by the side of the districts can contribute to flood which can be understood easily with the map of that district showing the geographic location. The same can be said about Dighees, or existing water bodies, as they also contribute to floods.

Development of an area also puts an impact as it can indicate the facilities served during and after the flood. A more developed area will provide more facilities and take more initiatives to cope with the aftermath of floods. Then again if people knew about the terrible effects of flood and how to minimize their loss, they are likely to take preventive measures. So the factors in these regards can be narrowed down to educational institutes which can also be used as flood shelters when the time comes, different NGOs that provide different kinds of support to the people, and health centers which can provide them with necessary supplements.

The information on these factors in all three districts: Rajshahi, Natore and Sirajganj was collected from the Bangladesh Bureau of Statistics; Banglapedia; and the Ministry of Disaster Management and Relief, Bangladesh for further analysis.

3. ANALYSIS OF FLOOD PRONE AREAS WITH GRAPHS AND CHARTS

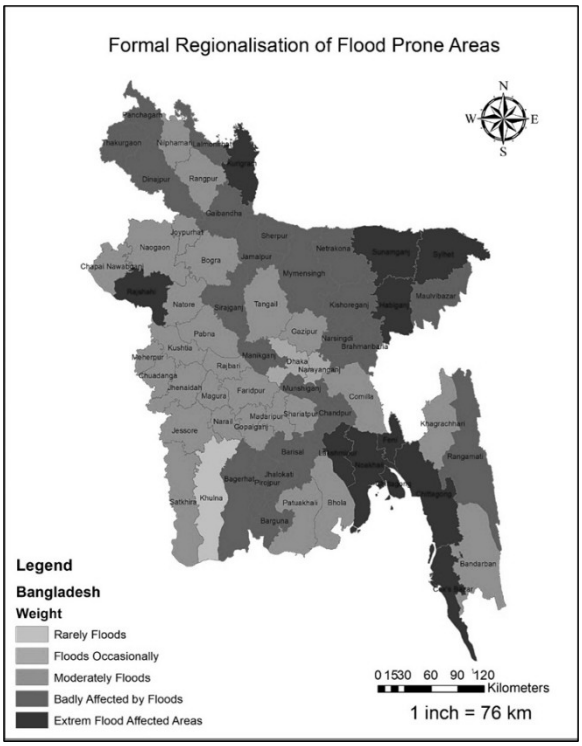


Figure 1: Formal Regionalisation

(Source: Author's Preparation)

Figure 1, gives an overview of all 64 districts of Bangladesh which have been classified into the following five regions based on flood-prone areas:

- The areas that are rarely affected by the flood
- The areas where it occasionally floods (*e.g.* only in monsoon season and not in every year)
- Areas that are moderately in the risk zone of a flood
- Areas that are badly affected by the flood, and lastly

- The areas which are in extreme danger of flood.

For better understanding and better representation, these five regions are divided in the following two ways:

Areas with Less Probability of Flood

The only district that is rarely affected by the flood is Khulna. Dhaka and Narayanganj are the zillas where it occasionally floods. It can be described as there are fewer rivers and fewer lowlands in these districts the possibility of flood also decreases along with these factors.
The next region has been categorized as the moderately affected flood areas; the districts are Bandarban, Bhola, Bogra, Chapai Nawabganj, Chuadanga, Comilla, Faridpur, Gazipur, Gopalganj, Jessore, Jhenaidah, Joypurhat, Khagrachhari, Kushtia, Madaripur, Magura, Meherpur, Naogaon, Narail, Natore, Nilphamari, Pabna, Patuakhali, Rajbari, Rangpur, Satkhira, Shariatpur, Tangail. These districts show a moderate amount of rainfall. Some districts have high riverine areas and some low riverine areas. Even highly urbanized cities fall in this region because of a comparatively lower number of river bodies.

Areas with a High Probability of Flood

Barguna, Barisal, Bagerhat, Brahmanbaria, Chandpur, Dinajpur, Gaibandha, Jamalpur, Jhalokati, Kishoreganj, Lalmonirhat, Manikganj, Maulvibazar, Munshiganj, Mymensingh, Narsingdi, Netrakona, Panchagarh, Pirojpur, Rangamati, Sherpur, Sirajganj are the districts which are badly affected by a flood. The reason can be interpreted as some of these districts are surrounded by many rivers and is situated closer to the sea results in more rainfall, increasing the probability of flood.
Chittagong, Cox's Bazar, Feni, Habiganj, Kurigram, Lakshmipur, Noakhali, Rajshahi, Sunamganj, Sylhet are the districts with extreme risk of Flood because of heavy rainfall, situated in the hilly region and the sea; some are also situated on river banks whereas others have a lot of rivers within (*e.g.* Sylhet-87, Habiganj-36) (BBS,2011). All these factors and being situated by the main rivers of Bangladesh: Padma, Brahmaputra, Surma; lead to a high probability of flood making these districts most prone to flood. The terrible scenario of how devastating a flood can be; became vibrant in front of Bangladesh in October 2022 in Sylhet.

3.1 Detailed Analysis of the Districts

For further analysis as to how the districts are serving the inhabitants, three districts from different regions were selected, and the following result from GIS was collected showing their inter impact on other districts:

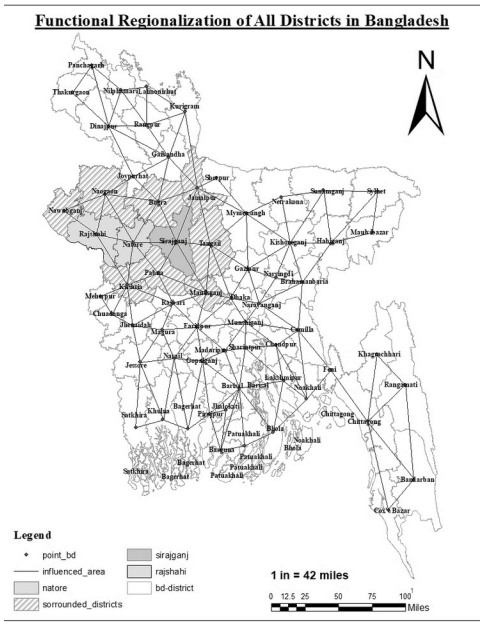


Figure 2 Inter Impact of the Three Districts

(Source: Author's Preparation)

To know the intra impacts of the districts, a second map showing the functionality of the Upazilas has been shown below

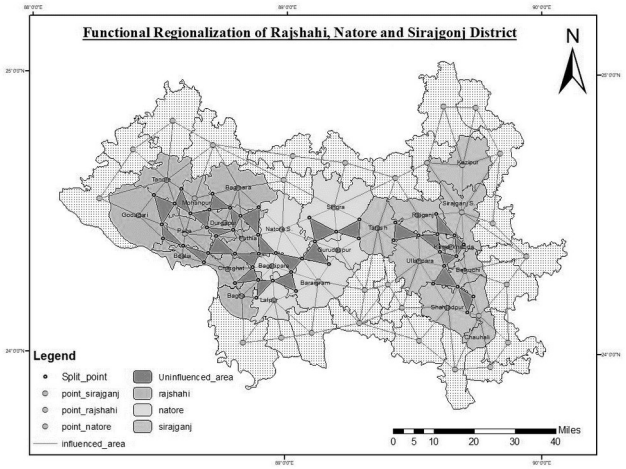


Figure 3 Impact of individual Upazilas

(Source: Author's Preparation)

From figure 2 and 3, the influenced area of the three districts (intra and inter) was collected and shown in the Table 2.

Table 2 Comparison among three selected districts

District Name	Served Area (Upazila considered)	Served Area(whole zila considered)
Rajshahi	2075.973778	1973.639995
Natore	1731.661713	1260.618577

Sirajganj	2272.155435	1824.936205

(Source: Author's Preparation)

The table presents data on three districts in Bangladesh: Rajshahi, Natore, and Sirajganj. The "Served Area (Upazila considered)" column shows the total area served by each district when only taking into account the upazilas within its jurisdiction. The "Served Area (whole zila considered)" column, on the other hand, shows the total area served by each district when considering the entire zila with respect to other districts. The intra-district functionality is higher than the inter-district. Because the Upazilas have to depend on the main districts for different services. But when it comes to inter-district analysis, the people living in the border area between two districts can choose, and they can go to the surrounding districts of the study area for their convenience. Which can be described as the reason for smaller influenced areas in inter-district analysis.

3.2 Intra Impact of: Rajshahi, Natore and Sirajganj

In the map from figure 3, it can be clearly seen that the geographic area and the served area (influenced area) are not the same. The analysis of the influenced area and unserved area of the districts followed by the reason behind their change is going to be described in the next section.

Upazilas of Rajshahi

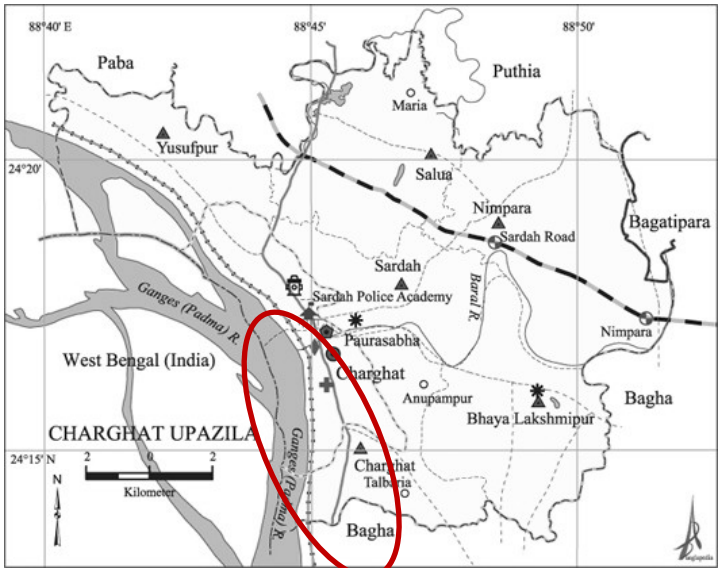
Population, Geographical area, and Served area of the Upazilas of Rajshahi are shown in Table 4 The ranking has been done according to the highest to lowest unserved areas.

Table 3:Intra Impact of Rajshahi District

District	Upazila	Population	Geographical area(sq km)	Served Area(sq km)	Ranking in unserved areas
Rajshahi	Boalia	191711	106	121.31247	1
	Baghmara	319968	364	370.06564	2
	Charghat	183921	173	162.33185	3
	Godagari	279545	446	416.50348	4
	Paba	262251	242	218.57704	5
	Bagha	169527	197	176.89248	6
	Tanore	173495	299	264.5835	7
	Mohanpur	152896	162	126.66706	8
	Puthia	188864	196	145.66023	9
	Durgapur	167596	196	73.380035	10

(Source: Author's Preparation)

Figure 4; shows the geographic location of some Upazilas of Rajshahi. It can be seen that the Charghat Upazila is mostly surrounded by rivers, that's why Charghat Upazila is the most affected by



flood. But in Table:3; it can be seen that Charghat is in the third position in terms of having the most unserved areas.

The result differs from the real scenario because, the distance from surrounding Upazilas to the first two ranking Upazila: Boalia and Bagmara is more than the distance of Charghat and its surrounding Upazila.

Upazilas of Natore:

The served area which is calculated by GIS, showed Singra with the least amount of served areas; the reason can be explained through the following figures:

Figure:5 shows the Upazilas of Natore where the river flows through Singra upazila, making the area at a high risk of flood. Next, Figure:6 tells about the existing waterbodies in the Upazils of Natore. Singra has the highest number of Deghees which also vouches for the data collected from the GIS map.

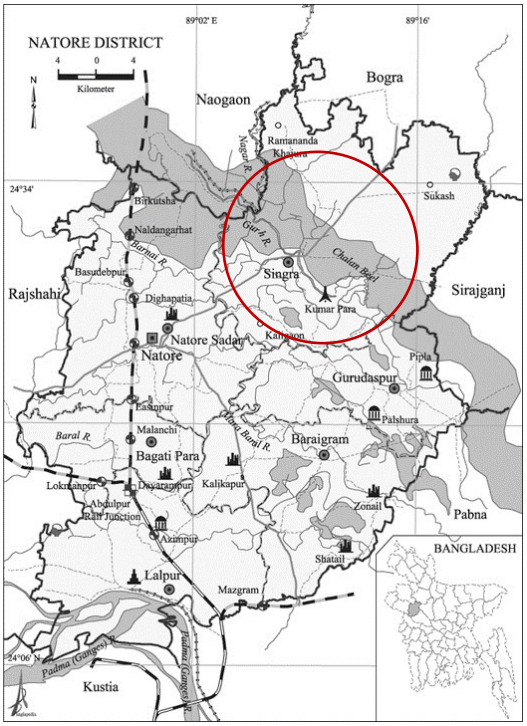


Figure 5: Map of Natore

(Source: Banglapedia)

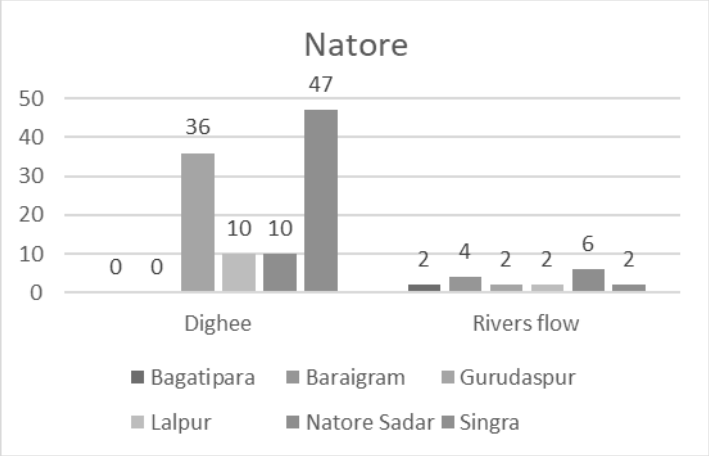


Figure 6: Natore waterbodies

(Source: Author's Preparation)

Upazila of Sirajganj District:

Information analyzed from GIS has identified Kamarkhanda with the highest number of unserved areas. Again from the Figure 7, the number of Dighees is the highest in Kamarkhanda Upazila. And the district map (Figure:8) also shows Kamarkhanda closely situated with the river and many branches of the river passing through the Upazila.

The influenced area of Kazipur, Sirajganj Sadar, Chauhali, and Belkuchi has increased. The reason behind this scenario is that the surrounding areas of these Upazila lacks different service facilities.

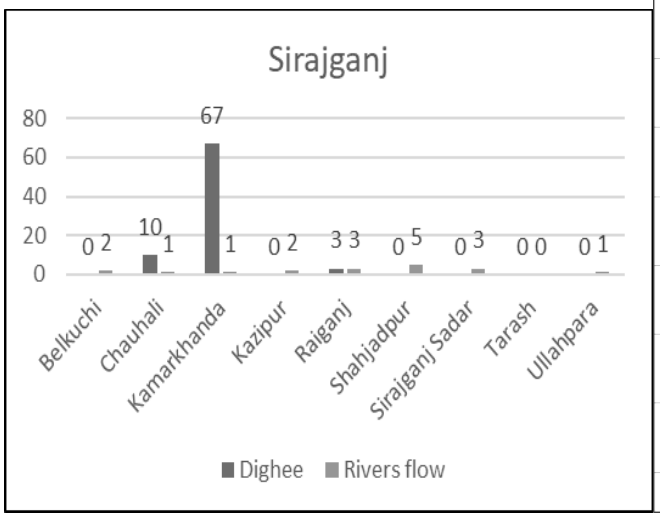


Figure 7: Sirajganj waterbodies

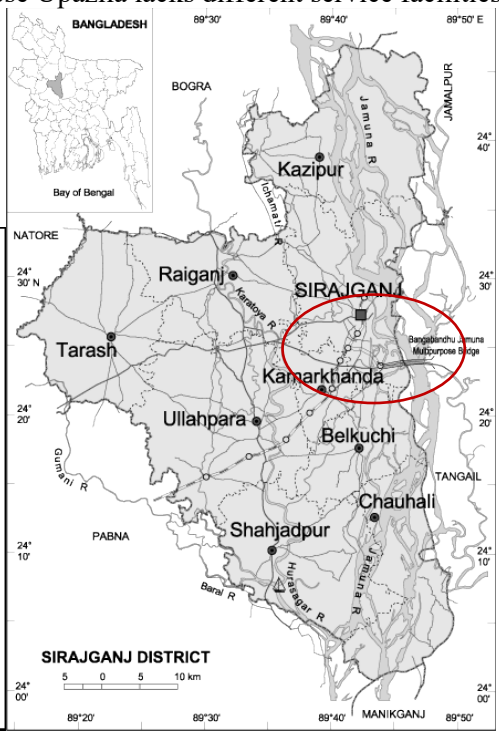


Figure 8: Sirajganj

(Source: Author's Preparation)

Comparison among the worst three Upazila

Three Upazila which had the highest number of unserved areas were selected for further evaluation to find out the reasons behind these lackings. Further analysis was done with the development factors including educational institutions, NGOs and the number of institutes giving health facilities like clinics, hospitals, and Upazila health centers. The data was collected from the Ministry of Disaster Management and Relief, Bangladesh. The existing scenario of these factors can be described accordingly with the followings:

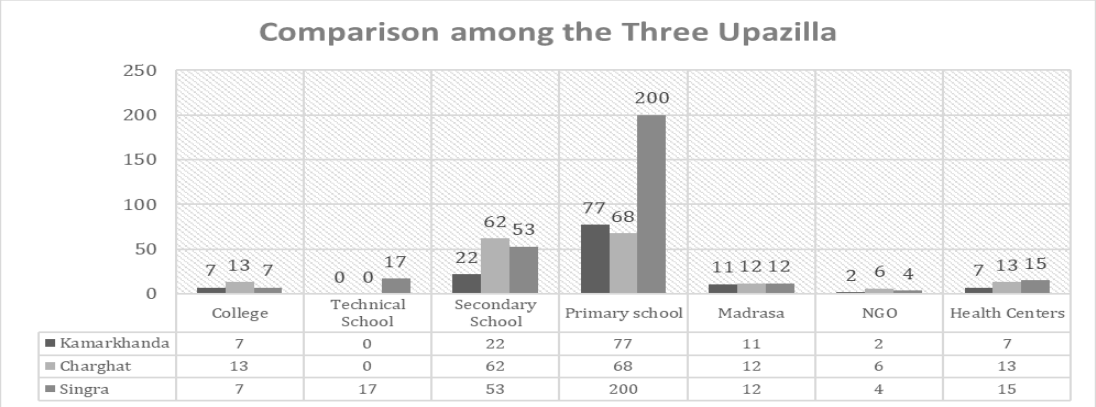


Figure 7:Comparison among the Three Upazila

(Source: Author's Preparation)

Singra, which has the highest number of unserved areas in Natore, has four NGOs working and fifteen Health centers for medical facilities. Then Kamarkhanda which has the worst scenario among all the Upazila, has only two NGOs working there and only seven health centers which is the lowest of them all. Being affected by the flood before, the situation in Charghat slightly increased, having six NGOs which is the highest of them all, and thirteen health centers.

4. CONCLUSIONS

While delineating the regions based on flood-prone areas some factors seemed to be more important than others like existing riverine areas, and lowlands. Although rainfall cannot be described individually as an important factor in this regard, but where rainfall is higher, along with existing river bodies and low land areas it can be proved to be a vital factor that causes floods. Districts like Sylhet, Rajshahi, and Habiganj have more rainfall, and rivers than any other districts thus they have a higher possibility of being affected by a flood. This study also gives a crystal clear picture of the inter and intra impact of Rajshahi, Natore, and Sirajganj emphasizing the need to develop infrastructure and improve the functionality of adjacent upazilas to better serve the people during flood. Rather than assuming the reasons, the information was cross-checked from BBS, Banglapedia, and the Ministry of Disaster Management and Relief, Bangladesh to analyze the result of the GIS map. It also shows that the unserved areas cannot serve the people or residents during the flood, rather it creates a burden on the served areas. It highlights the functional gap of adjacent upazilas and finds out the regional gap between them showing the existing facilities available for the people while also indicating the areas that need more attention in order to better serve the inhabitants. In short, the study highlights the importance of utilizing the findings to identify suitable locations for different specialized activities, optimizing resource allocation, and planning in flood-prone areas.

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