Application of GIS for Multi-hazard Mapping at Dakshin Khali Union, Bagerhat

Md. Humayun Kabir, S. M. Shafi-Ul-Alam and K. Maudood Elahi

Abstract: *Natural hazards are almost regular phenomena for Bangladesh. It is the potential threat for life, property and environment. Dakshin Khali union is under Bagerhat district that is more vulnerable to different types of natural hazards. This research analyzes the hazards of Dakshin Khali union based on historical analysis, mapping and questionnaire survey combined with elements at risk inventory to derive a multi-hazard risk map. Geographical Information Systems (GIS) have been mostly used to conduct this research. Further, primary data were collected through Focus Group Discussion (FGD), questionnaire survey and field observation. Secondary data have been collected from Survey of Bangladesh (SoB), Local Government and Engineering Department (LGED), Center for Environmental and Geographic Information Services (CEGIS), Google Earth, United State Geological Survey (USGS), books, journals published by a number of national and international organizations. The results reveal that people of the Dakshin Khali union are affected by nine types of natural hazards almost every year. Canal siltation is the major problem that occurr five months (December to April) in a year that increases the water scarcity which ultimately hampers the agricultural production in the study area. River bank erosion is the second most devastating hazard that makes the people homeless and contributes to migrate from their homes. The damage intensity of cyclone is the highest compared with other hazards of the study site. Among the nine wards of Dakshin Khali union, ward 1 and 3 are more vulnerable than the others. This research provides a complete picture of the vulnerability of hazards that would be helpful to plan and make polices for disaster risk reduction in similar other areas.*

Key words: Erosion, migration, mouza, risk, siltation, union, vulnerability, GIS, RS.

Introduction

Hazard is potentially damaging physical event, phenomenon or human activity that may cause loss of life, damage of properties, social and economic disruption as well as environmental degradation. Hazards include latent conditions representing future threats and can have different origins, such as natural (geological, hydro-meteorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability (Smith, 2004). The process of multi- hazard mapping integrates different hazard related information for specific areas to convey a composite picture of natural hazards in varying magnitude, frequency and areas of effect. Combination of spatial analysis and local knowledge of communities are essential inputs in producing multi-hazard maps. Local knowledge of communities is gathered through Focus Group Discussion (FGD) where community

Md. Humayun Kabir, Lecturer, Department of Environmental Science, Stamford University Bangladesh, Dhanmondi, Dhaka-1209, Bangladesh. Email: humayun.ju3@gmail.com (Corresponding author).

S. M. Shafi-Ul-Alam, MS Research Student, Department of Environmental Science, Stamford University Bangladesh, Dhanmondi, Dhaka-1209, Bangladesh.

Dr. K. Maudood Elahi, Professor, Department of Environmental Science, Stamford University Bangladesh, Dhanmondi, Dhaka-1209, Bangladesh.

members develop community hazard and resource maps. Using GIS, maps are produced through the integration of spatial data and local community knowledge. GIS aids in efficient development, storage, updating, access and sharing of multi-hazard mapping information. The availability of reliable multi-hazard maps are important risk assessment tools providing relevant information essential for community planning and decision making, especially in emergency response, disaster preparedness and mitigation (ACF International, 2004).

Aim and Objectives

The broad aim of this research is to analyze the hazards of Dakshin Khali union based on historical analysis, mapping survey and questionnaire survey combined with elements at risk inventory to derive a multi-hazard risk map, which can be used as base map for reallocation of facilities and infrastructure, formulation of plans for future expansion and emergency planning.

To fulfill the aim, two objectives are identified;

- Mapping individual hazards that take place in the Dakshin Khali Union and
- Preparing of a composite map considering the hazards of the study area.

Study Area

Dakshin Khali (also known as South Khali union) is the union of Sarankhola Upazila under Bagerhat district. The extent of the union spreads within the latitude of 22°13′00″ to 22°17′30″ North and longitude 89°47′30″ to 89°51′30″ East (Figure 1). The total area of this union is 36.57 Sq. km (BBS, 2011). This union is bounded by the Boleshwar River on the east, Terabeka khal and Sundarbans on the south, Rayanda union on the north and the Bhola River on the west. There are nine villages in this union under two mouzas and the mouzas are turned into nine new wards instead of earlier three (BBS, 2011). The natural hazards occurring in different parts of the country are not similar. For instance, the south-western coast of Bangladesh faces mostly cyclones, salinity intrusion, tidal surges, drainage congestion, etc. Dakshin Khali union has been taken into consideration as the study area.

Data and Methods

This research examines the hazards of Dakshin Khali union through multi-hazard mapping that could be very effective for planning and also for disaster risk reduction. The FGD plays a major role in accomplishing Multi-Hazard assessment. Collection of primary information through FGD with respective to stakeholders (i.e. farmers, landless, women, disable/elderly) and collection of the pertinent secondary information from relevant public and private bodies including the Union Parishad are included in this Multi-Hazard assessment activity. This information is used as the basis for conducting the research, generate spatial and non-spatial data using MS office environment (MS Word, MS Excel) and GIS techniques (ArcGIS Software) respectively from primary and secondary sources prior to multi-hazard mapping. All data collected from different agencies i.e. Upazila Parishad, Bangladesh Water Development Board (BWDB), Land Record and Survey Department (DLRS), Roads and Highways Department (RHD), Water Resources Planning Organization (WARPO), Local Government Engineering

Department (LGED), Soil Resource Development Institute (SRDI), Bangladesh Bureau of Statistics (BBS) and Bangladesh Meteorological Department (BMD) in different format. Indian Remote Sensing (IRS) with 6-meter resolution panchromatic images and Landsat TM images were considered as the base of data capturing. The images were geo-referenced. Maps were presented to and reviewed by Union Disaster Management Committee (UDMC) members who involved with local development planning and disaster management and disaster related agencies like Department of Disaster Management (DDM), Comprehensive Disaster Management Programme (CDMP). Revisions were incorporated based on inputs gathered. Maps were printed and published in an interactive GIS stand-alone environment.

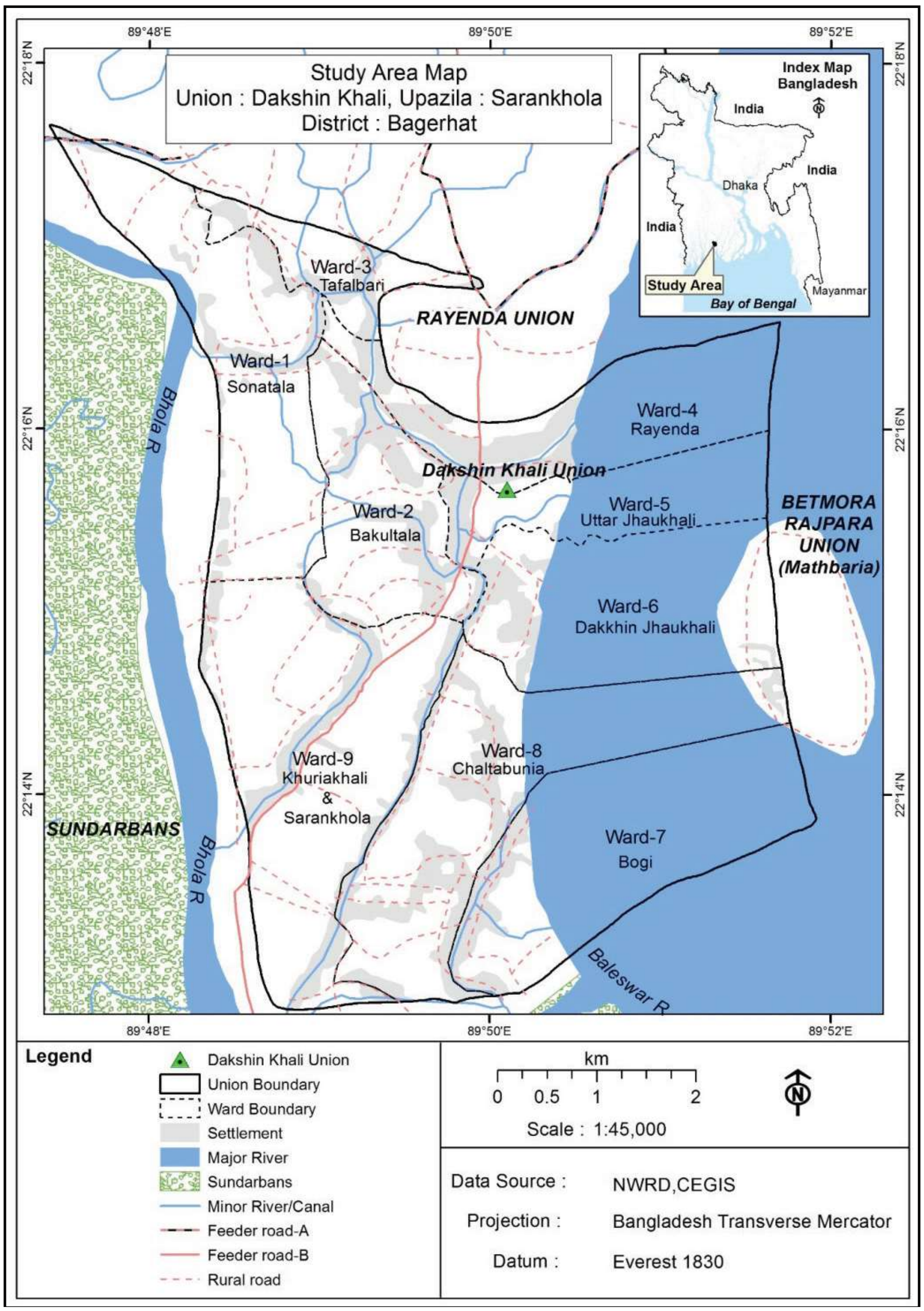

Figure 1. Study area (Source: CEGIS, 2017).

Results and Discussion

A hazard is something that has the potential to cause significant negative impacts on community elements (such as social, environmental and economical). A hazard may not have any impact until it meets a vulnerable element, such as the community and its belongings. The extracted data from satellite images along with field survey data have been incorporated for preparing multi-hazard mapping.

Location/ Base Map Preparation

Location/ Base Map were prepared by using geospatial techniques. The basic information of the union, like administrative boundaries, roads and river system, water bodies etc. have been incorporated in the base map. Word wise information has been collected for preparing base map (Figure 2).

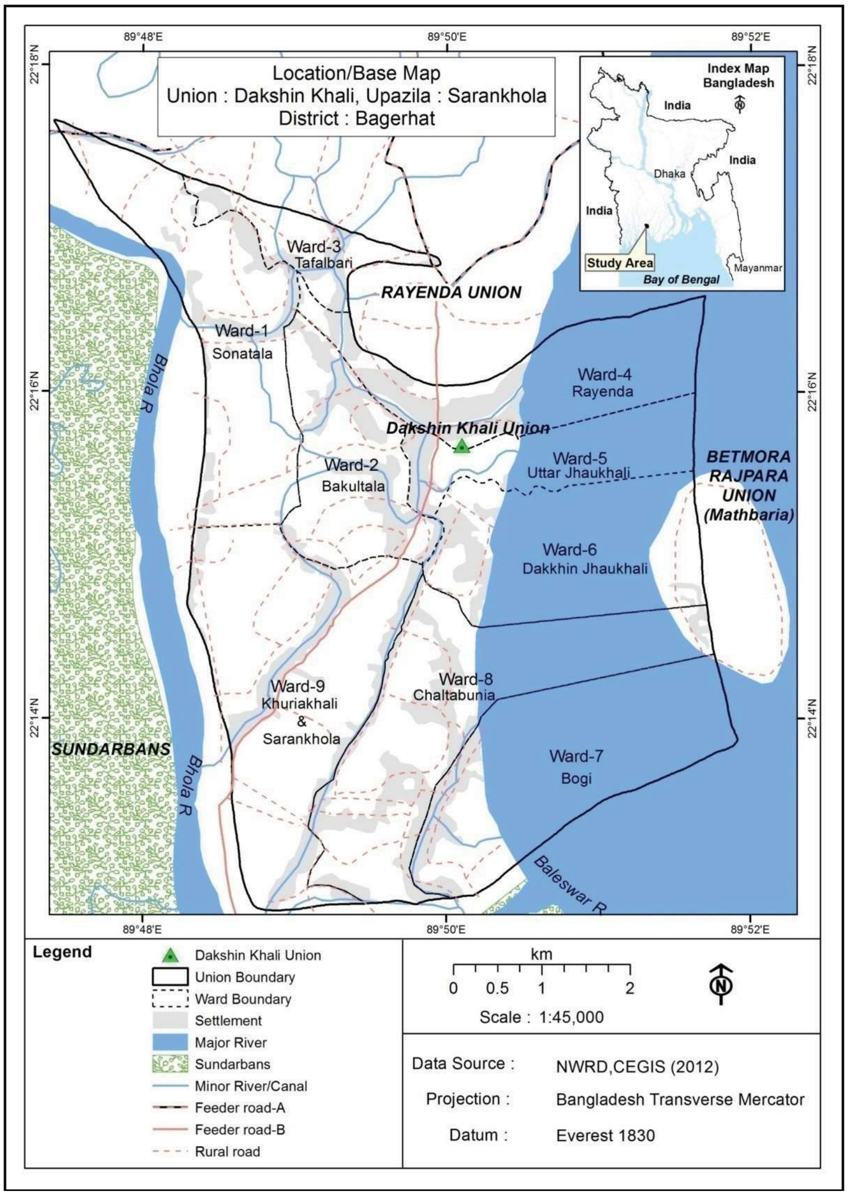

Figure 2. Location/base map of the study site (Source: CEGIS, 2017).

Social Map Preparation

Social mapping is a process of collecting spatial information on the existing physical infrastructure, educational institutes, local government institutes, growth centers, hat/bazars, religious centers, post office, banks, cultural centers, historic places, villages/settlement, place names, common places, and many more (Figure 3).

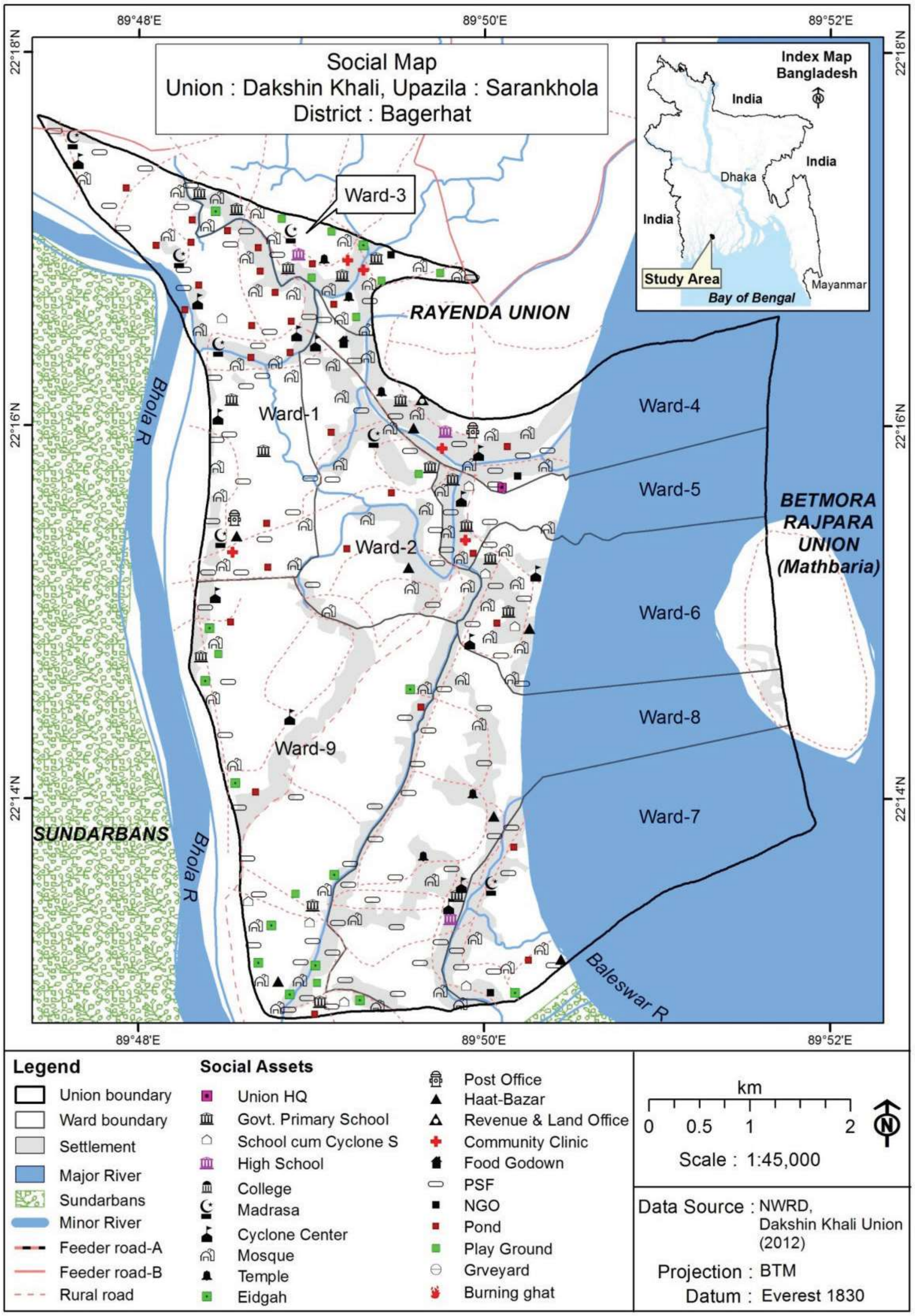

Figure 3. Social map of the study site.

Risk Map Preparation

Risk map indicates the super imposing of social on base map which illustrates the social assets of different ward are vulnerable within multi-hazard risk zone. Therefore, the risk map may be utilized for risk assessment. Figure 4 shows the risk map of the study site.

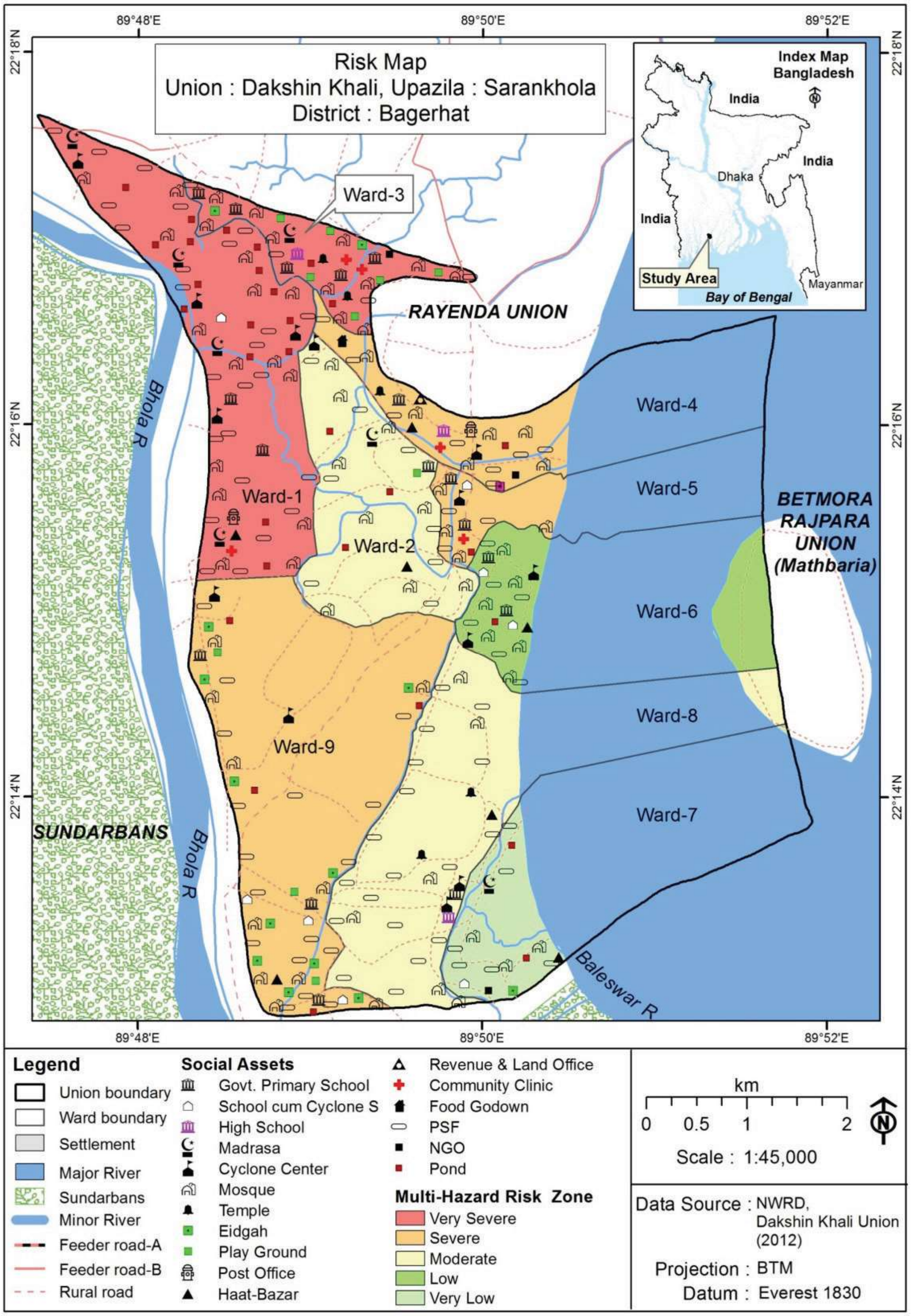

Figure 4. Risk map of the study area.

Hazard Calendar

The hazard depends upon the climate of an area. As the months roll, the intensity and extents of the hazard change according to change of time. The participants were asked during FGD to give their opinion on when and what types of hazards strike in the study site. Based on their opinions, the season and severity of different hazards are presented in Table 1.

Table 1: Hazard Calendar of the study site.

Hazard	Hazard Seasonality																							
	April	May		June		July		August		September		October		November		December		January		February		March		April
	Boisakh		Joistha		Ashar		Sraban		Vadra		Ashin		Kartik		Agrahaon		Poush		Magh		Falgun		Chaitra	
Cyclone & Tidal surge	High	High	High	High	Low	Low	Low	Low					High	High	High	High								
Water Logging					High	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Low	Low	Low						
River Erosion					High	High	High	High	High	High	High													
Salinity	High	High	Medium	Medium																	High	High	High	High
Heavy Rainfall			Low	Low	Medium	Medium	High	High	High	High	High	Medium	Low	Low										
Drought	High	High	Medium	Medium																	High	High	High	High
Canal Siltation	High																High	High	High	High	High	High	High	High
Seasonal Tide (Joba)				Medium	Medium	Medium			High	High	High	High												
Insects Infestation							High	High	High	High	High													

High | Medium | Low | No

Source: Union Disaster Management Committee (UDMC), 2017.

Developing Hazard Venn

The venn diagram is used to depict the types, the extents and the trends of incidence. As in Figure 5, various hazards are depicted through circles, while their sizes are determined considering the nature and destructive powers of the individual hazards. The hazard circles are placed depending on how frequent these are.

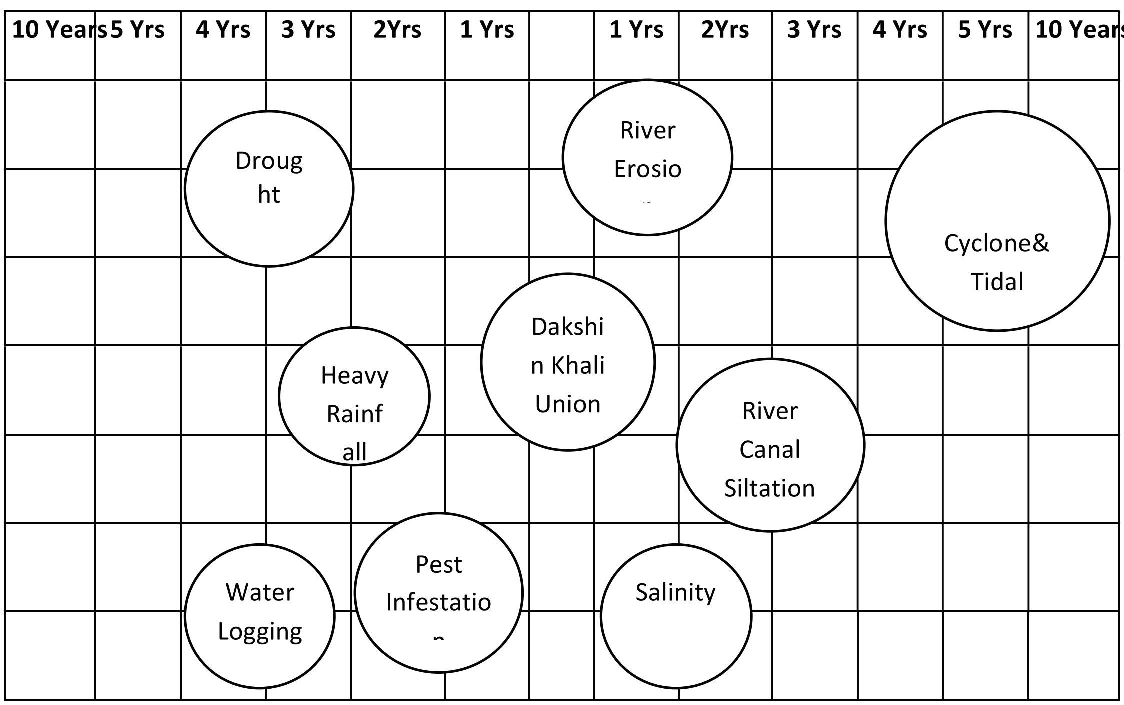

Figure 5. Hazard Venn of Dakshin Khali Union.

In the Figure, the rates of incidence and the extents of destruction of the calamities are graphically presented. These are relentlessly bringing havoc to the people (UDMC, 2017).

It is seen from the venn diagram of South Khali that the most severe natural hazard is cyclone and tidal surge, which occur in every ten years. The next in rank is pest infestation which is observed throughout the year. Besides, water logging causes damage to the area in every year. The damage from excess rainfall occurs in every two to three years. The next hazards in order of succession are salinity and river bank erosion, which visit the union more or less every year.

Identification and Ranking of Local Hazards

Then the participants from each ward of Dakshin Khali union identified major hazards felt by them and defined their ranking for every three wards based on the intensity of damage created by the specific hazard (Table 2). From Table 2 it is found that cyclone and tidal surge ranked one in ward no 1, 2, 3 and 7, 8, and 9 and river bank erosion ranked one in ward no 4, 5 and 6.

Table 2: Identification and ranking of local hazards

Sl No	Hazards	Ward wise ranking of hazard		
		Ward 1, 2 and 3	Ward 4, 5 and 6	Ward 7, 8 and 9
1	Cyclone and Tidal Surge	1	2	1
2	Salinity	2	3	2
3	Pest infestation	3	4	3
4	River bank erosion	-	1	4
5	Drought	5	5	5
6	River/Canal siltation	4	-	-

Note: Right column of the above table 1,2,3,4 & 5 indicates ranking of hazard (ward-wise) based on damage. Explanation: 1 = intensity of damage is highest, 2= intensity of damage is less than 1, 3= intensity of damage is less than 2, 4= intensity of damage is less than 3, 5= intensity of damage is less than 4, 6= intensity of damage is less than 5.

Hazard Intensity and Frequency Estimation

The severity and trends of hazard frequency vary as per land forms and variation in topography. In Table 3, the severity of calamities is projected as high, moderate and low.

Table 3: The severity of calamities is projected as high, medium and low.

Mouza	Hazard								
	Cyclon& Tidal surge	River Erosion	Canal Siltation	Salinity	Seasonal Tide (Joba)	Drought	Heavy rainfall	Insects Infestation	Water Logging
Ward-1	H	L	M	M	L	M	M	H	M
Ward-2	H	-	L	M	L	L	L	M	M
Ward-3	M	-	M	L	L	H	L	M	M
Ward-4	H	L	L	L	H	M	H	M	L
Ward-5	H	L	M	L	H	M	H	M	L
Ward-6	H	M	M	M	H	M	H	M	L
Ward-7	H	M	M	M	H	M	H	L	M
Ward-8	H	M	H	H	H	M	H	L	M
Ward-9	H	L	M	H	H	M	M	H	M

From the Table 4, it is observed that high intensity of hazard is scored as 8, medium intensity as 4 and low intensity as 2. Absence of information for any ward is denoted by hif-fan (“-”).

Table 4: Rating the Intensity of hazard.

Mouza	Hazard								
	Cyclon& Tidal surge	River Erosion	Canal Siltation	Salinity	Seasonal Tide (Joba)	Drought	Heavy rainfall	Insects Infestation	Water Logging
Ward-1	8	2	4	4	2	4	4	8	4
Ward-2	8	-	2	4	2	2	2	4	4
Ward-3	4	-	4	2	2	8	2	4	4
Ward-4	8	2	2	2	8	4	8	4	2
Ward-5	8	2	4	2	8	4	8	4	2
Ward-6	8	4	4	4	8	4	8	4	2
Ward-7	8	4	4	4	8	4	8	2	4
Ward-8	8	4	8	8	8	4	8	2	4
Ward-9	8	2	4	8	8	4	4	8	4

The frequencies (year of occurrence) of the hazards are also given Table 5. In Table 5, the frequency values were multiplied by its respective intensities Ward-wise.

Table 5: The frequencies (year of occurrence) of the hazards.

Hazards	Intensity (a)	Frequency (b)
Cyclone & Tidal Surge	H	0.10
River Erosion	M	0.10
River & Canal siltation	M	0.03
Salinity	L	0.05
Drought	M	0.20
Heavy Rainfall	M	0.14
Pest Infestation	L	0.20
Water logging	M	0.14

Analysis of Hazard Information into Digital Number and Weightage

Table 6 shows that this ward is affected by eight hazards of which only one is with high intensity five with medium intensity and two with low intensity. Based on this frequency and its intensity, hazard score and intensity factor is calculated. There are three different intensity factors for high, medium and low intensity for a specific ward. Then the hazard score for each specific hazard are multiplied by its respective intensity factor. Finally, adding these values, a value that is hazard with intensity are obtained for each ward.

Table 6: Hazard information converts into digital number and weightage.

Hazards	Intensity Score (c)	Hazard Score (d = b x c)	Intensity Factor (e)	Hazard with intensity (d x e)
Cyclone & Tidal Surge	8	0.8	0.25	0.20
River Erosion	4	0.4	0.13	0.05
River & Canal siltation	4	0.1	0.13	0.02
Salinity	2	0.1	0.06	0.01
Drought	4	0.8	0.13	0.10
Heavy Rainfall	4	0.6	0.13	0.07
Pest Infestation	2	0.4	0.06	0.02
Water logging	4	0.6	0.13	0.07
	32			0.55

Preparation of Draft Multi-hazard Map

Following the same procedure, the hazard with intensities is obtained for each ward, which is given in Table 7. From the table, maximum and minimum values of a union are identified also. Then all the values are normalized using the following formula:

Hazard with weightage (Hwt)= 1+(X-Xmin/Xmax- Xmin)*9

X= Value of Hazard with intensities of a particular ward

Xmin = Minimum value of Hazard with intensities

Xmax = Maximum value of Hazard with intensities

Table 7: Ward wise weightage of the union based on hazard intensity and frequency.

Ward	Hazard with intensities	Hazard with weightage
Ward-1	0.55	3
Ward2	0.62	6
Ward3	0.75	10
Ward4	0.58	4
Ward5	0.49	1
Ward6	0.64	6
Ward7	0.73	9
Ward8	0.69	8
Ward9	0.5	1

Finally using the normalized values for each ward in ArcGIS software, a draft multi hazard map of a union is prepared (Figure 6). From the map, it is found that based on the vulnerability to multiple hazards, the whole union is classified into five vulnerability/risk zones very severe, severe, moderate, low and very low. The hazards and intensity of hazard of each ward are shown in bar diagrams in the map.

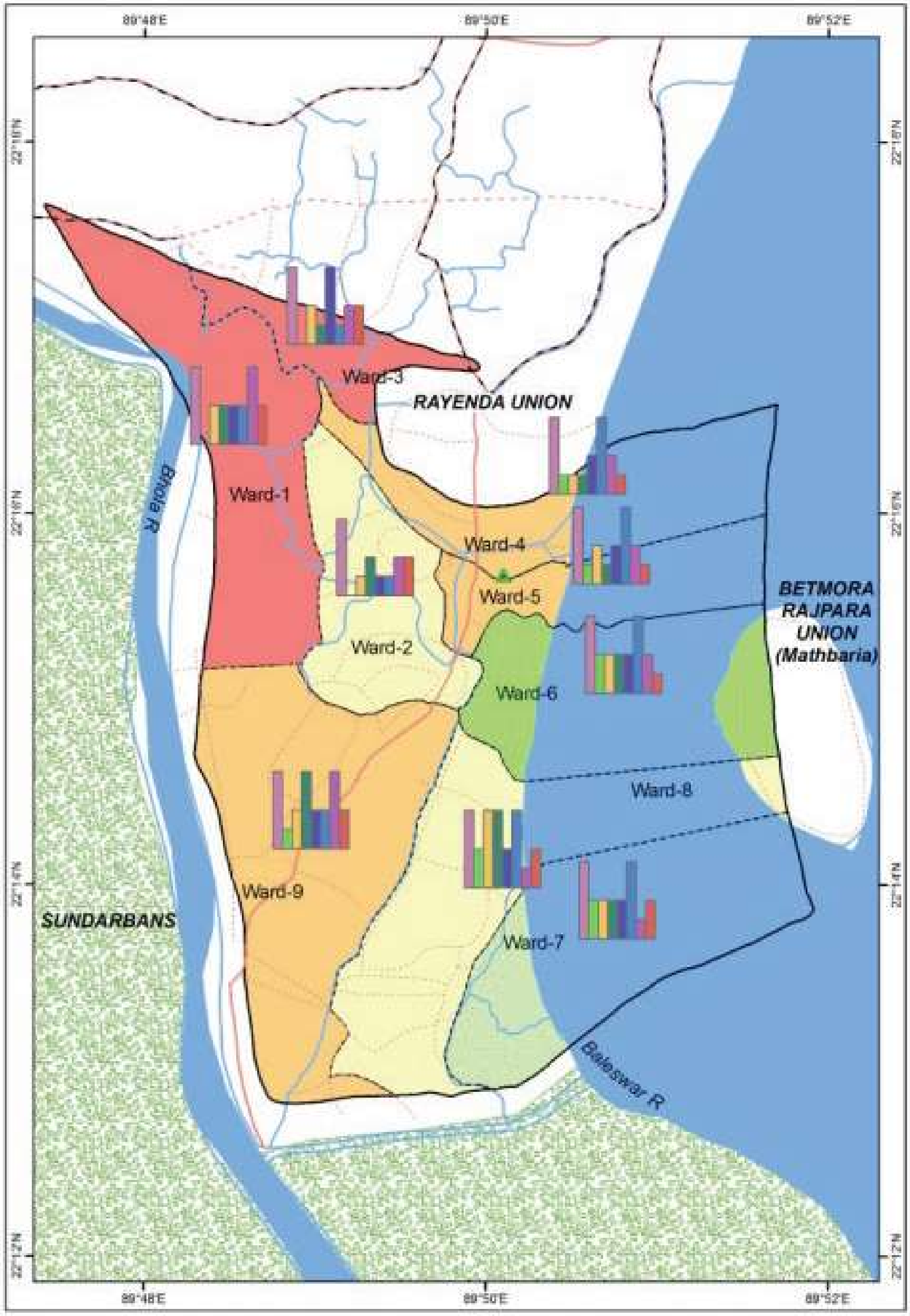

Figure 6. Draft multi-hazard Map of Dakshin Khali Union.

Validation through Consultation

In this stage, facilitator clearly explained the hazard definition, type of multi-hazard intensity and risk zone to UDMC members. Then the UDMC members from the union asked to verify whether the list of hazards identified from participants are relevant to their community or is there any modification needs. According to their suggestions, the final Multi-hazard map are prepared.

Figure 7. Validation of the draft multi-hazard map through consultation.

Composition of final Multi-Hazard Map

The finalization of the Multi-hazard map after considering the comments and feedbacks from UDMC members are prepared as final documents (Figure 8).

In the present case, multi-hazard mapping analysis was done using the GIS overlay techniques to compute the resource elements exposed to different hazard conditions. The assigned weightage were used for developing the Multi-hazard map as shown in Figure 8. The map illustrates a ward-wise picture of multi-hazard risk zone. In this particular case the Ward 1 and 3 is the very severely affected areas. Ward 4, 5 and 9 are the severely affected areas. Ward 2 and 8 are moderately affected and ward 6 and 7 are low and very low affected areas respectively.

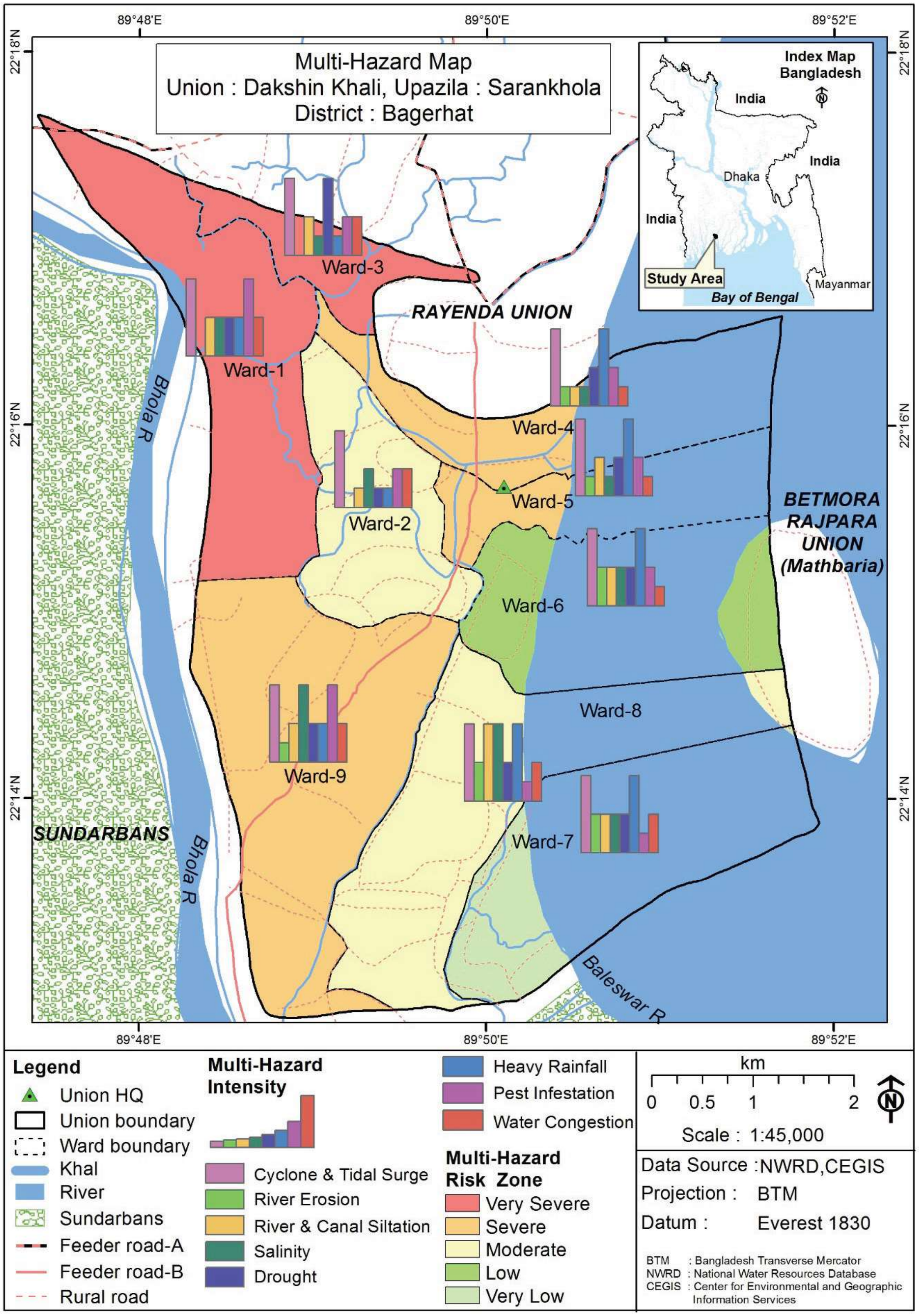

Figure 8. Final multi-hazard map of the Dakshin Khali Union.

Conclusion

The Multi-hazard mapping program is a model of GIS based database. The study output contains: (i) a complete picture of multiple hazard of the community, (ii) basic socio-economic information, associated risks, of the vulnerable population of the locality, (iii) planning (Government and Non-government) analyze vulnerability and risk, (iv) likelihood information for decision-making process, (v) visualizing the natural hazards at the local level to plan and act accordingly. All these information will be useful for multi-hazard identification and risk reduction planning.

References

ACF International, (2004). Community-based Disaster Risk Reduction Project, Bicol Region, Philippines.

BBS, (2011). Population Census of Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the People Republic of Bangladesh, Dhaka.

CDMP, (2008). From follower to recognized world leader. Retrived, September 19, 2003. fromhttp://www.undp.org.bd/projects/products/CDMP

CEGIS- CDMP, (2007). CRA Report: Community Risk Identification and Risk Reduction Work Planning in Dadpur Union, Boalmari, Faridpur.

CEGIS-CDMP, (2008). Development of Hazard Zoning Maps using CRA Process, CDMP EC – Funded Component 3d (Support for Livelihood Security-Hazard Awareness).

CEGIS-PCI, (2012). Modified CRA Methodology and Its Testing, pp. 20 - 21.

CEGIS, (2017). GIS data of Mouza and Union boundary. Dhaka: Center for Environmental and Geographic Information Services.

Smith, K. (2004). Environmental hazards: Assessing Risk and Reducing Disaster. Newyork: Routledge, pp. 22-37.