IUBAT Review
A Multidisciplinary Academic Journal

Monirul Islam, Mahfuzur Rahman, Xiaoying Li and Nahidul Islam. 2018. "Vunerablility Analysis for Sustainable Development against Flood Hazard and Relief Distribution: A Case Study of 2017 for Bangladesh." *IUBAT Review* 1 (3): 38-47. iubat.edu/journal

Vulnerability Analysis for Sustainable Development against Flood Hazard and Relief Distribution:

A Case Study of 2017 Flood of Bangladesh

Monirul Islam[1,*], Mahfuzur Rahman[1,3], Xiaoying Li[2], Nahidul Islam[1]

[1] IUBAT – International University of Business Agriculture and Technology, Dhaka, Bangladesh

[2] Hohai University, Nanjing, Jiangsu

[3] PhD Research Fellow, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, Sichuan, P.R.China

*Corresponding author E-mail: mmislam@iubat.edu

ABSTRACT: *Floods are one of the most destructive natural hazards. Bangladesh and its neighbors in India and Myanmar are highly vulnerable to flood hazards. This study addressed a methodology to assess the relationship between flood hazard vulnerability and relief distribution based on the flood hazard event of 2017 of Bangladesh, using Geographical Information System (GIS). Flood vulnerability maps were developed through a vulnerability score, calculated on the basis of the interactive effect of observed vulnerabilities. Then, flood vulnerability ranks were determined using the ranking matrix of three-dimensional multiplication modes by the interactive effect of three vulnerability maps: flood-affected people, flood-affected infrastructure, and flood-affected crop land. The resulting map revealed the degree of vulnerability of districts to flood hazard events. The analyses exhibit that 49.9% of districts (31 districts out of 64) were to some extent vulnerable to a flood hazard event. Moreover, the GIS technique was used to identify the correlation of flood vulnerability (for people, infrastructure, and crop land) and relief distribution in terms of rice, cash, and dry food. The correlation was determined by overlaying relief distribution data on developed vulnerability maps. The correlation matrix between flood-affected crops land map and relief distribution (cash in BDT) showed the highest congruence (78.85%). Finally, flood vulnerability maps for administrative districts provide relevant information about mitigation techniques and countermeasures against flood damages.*

Keywords: *Flood, Geographical Information System (GIS), Hazard, Relief, Vulnerability*

Introduction

Bangladesh is a densely populated country of 165 million, residing on the delta of the Ganges and Brahmaputra river systems and highly prone to natural calamities. Riverine floods, cyclones, flash floods, riverbank erosion, groundwater arsenic, and drought have caused severe financial and communal disruption and considerable loss of human life in recent decades (Benson & Clay, 2003). The plane topography contributes to fast run-off and drainage congestion, floodplains, shallow river banks, severe rainfall, and huge discharge of sediments into the shallow Bay of Bengal. These are the major factors responsible for natural calamities in Bangladesh (Hossain, 2015; Rahman et al., 2007; Sinha, 2007). Among natural hazards, floods are considered the most devastating hazard in Bangladesh. The flood of 2017 (like floods in 1954, 1955, 1974, 1987, 1988, 1998, 2004, 2007, and 2009) caused enormous damage to property and considerable loss of life. In 2017, 31 of 64 districts were affected by flood. Heavy monsoon rain was the main reason for the flood in northern Bangladesh. The flood disrupted daily life; 121 people were killed and nearly seven million people were affected (Reliefweb, 2017).

In this study, we defined a flood vulnerability map based on data from the 2017 flood and the number of affected people, the extent of affected infrastructure (houses, institutions, and roads), and affected crop land. Development of the flood vulnerability map was enhanced by GIS techniques. In the next stage, this study observed the relation between the relief distribution pattern and flood vulnerability and found that the pattern of relief distribution was not well correlated with the loss of life or infrastructure damage. It was well correlated with crop damages. Many action plans have been undertaken in hazard mitigation and countermeasures. However, further development is required for comprehensive flood hazard management.

Vulnerability Analysis

Our vulnerability analysis was developed from a range of socio-economic approaches to hazards and what we could call the disaster of an everyday life. Vulnerability can be considered on a scale from high to low levels for a number of components (Blaikie, Cannon, Davis, & Wisner, 2014). In this study, vulnerability data were prepared in the form of GIS data by using ERDAS IMAGINE software. Vulnerability scores were estimated on the basis of estimated flood damage 2017 Bangladesh flood damage affecting people, affected infrastructure (houses, institutions, and roads), and affected crop land by flood 2017 of Bangladesh. The individual vulnerability score for affected people, affected infrastructure, and affected crops land was estimated by using Eq. (1), Eq. (2), and Eq. (3).

$$\left.\begin{aligned}&\text{Flood Affected People} = \frac{(\text{Fully affected people} \times 1) + (\text{Partially affected people} \times 0.5)}{1.5}\\&\text{Weighted Score} = (\text{Affected People} \times 1) + (\text{No of death} \times 10)\end{aligned}\right\} \quad (1)$$

$$\left.\begin{aligned}&\text{Affected House} = \frac{(\text{Fully damaged house} \times 1) + (\text{Partially damaged house} \times 0.5)}{1.5}\\&\text{Affected Institution} = \frac{(\text{Fully affected institution} \times 1) + (\text{Partially affected institution} \times 0.5)}{1.5}\\&\text{Affected Road} = \frac{(\text{Fully affected road} \times 1) + (\text{Partially affected road} \times 0.5)}{1.5}\\&\text{Weighted Score} = (\text{House} \times 5) + (\text{Instituition} \times 3) + (\text{Road} \times 2)\end{aligned}\right\} \quad (2)$$

$$\text{Affected Crops Land} = \frac{(\text{Fully affected crops land} \times 1) + (\text{Partially affected crops land} \times 0.5)}{1.5} \quad (3)$$

The calculated scores for flood vulnerability on the basis of affected people, affected infrastructure, and affected crops land for 31 districts of Bangladesh are shown in Table 1. Vulnerability points for each district were calculated on the basis of linear interpolation of weighted score from 0 to 100. The vulnerability points 0 and 100 corresponding to the lowest weighted score and highest weighted score. Vulnerability ranks for flood affected people were fixed by the corresponding value of the vulnerability point 0 to 10 corresponded to vulnerability rank 1, 10 to 55 for 2 and 55 to 100 for 3; for flood affected infrastructure vulnerability points were fixed by the corresponding value of 0 to 10 corresponded to vulnerability rank 1, 10 to 50 for 2 and 50 to 100 for 3; for affected crop land vulnerability points were fixed by the corresponding value of 0 to 10 corresponded to vulnerability rank 1, 10 to 40 for 2 and 40 to 100 for 3 which is shown in Table 1. Using the vulnerability rank from 1-3 for 31 districts, three vulnerability maps for affected people, affected infrastructure, and affected crops land were developed. Finally, the combined vulnerability map was developed by considering the interactive effect of these three maps. The new proposed vulnerability map was categorized by considering vulnerability rank from 1 to 27 using multiplication mode of three-dimensional matrix (3×3×3), suggested by Islam and Sado (2000) which is shown in Figure 1. The combined vulnerability ranks were obtained 1, 2, 3, 4, 6, 8, 9, 12, 18, and 27. But in the combined vulnerability map, vulnerability rank 3, 9, and 27 did not show the pixel value. Analyzing the vulnerability map, it was found that rank 1 covered 11.55% of the country, rank 2 covered 18.80%, rank 4 covered 2.48%, rank 6 covered 2.85%, rank 8 covered 2.70%, rank 12 covered 3.81%, and rank 18 covered 7.71%, respectively against the flood hazard event. Kurigram, Dinajpur, Naogaon, and Jamalpur exhibit the highest vulnerability index for flood hazard.

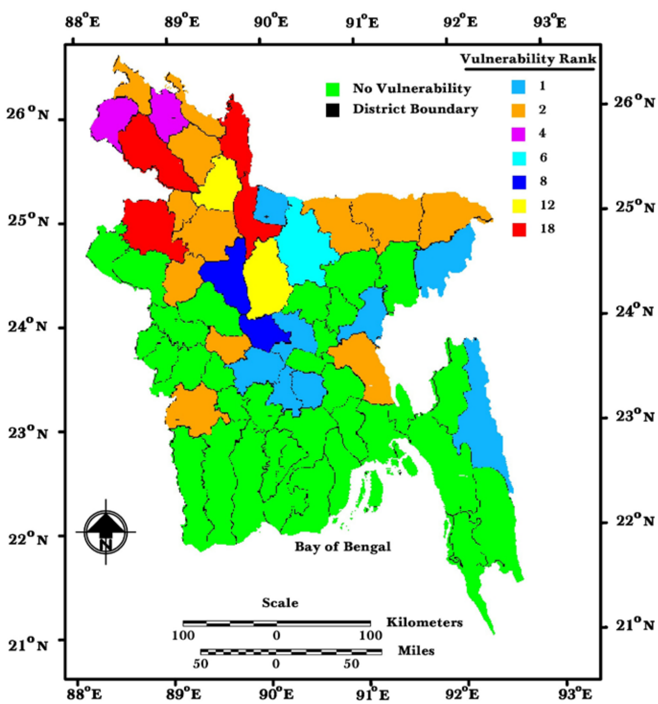
Table 1: Vulnerability score for affected people, infrastructure and crops land of 31 administrative districts of Bangladesh

Sl. No.	District	Affected People			Affected Infrastructure			Affected Crop Land		
		Weighted Score	Point	Rank	Weighted Score	Point	Rank	Land (Hec.)	Point	Rank
1	Panchagar	60406.67	17.34	2	0	0	1	417.33	1.03	1
2	Thakurgaon	38410	11.03	2	5000	2.16	1	4886.67	12.10	2
3	Nilphamari	39194.67	11.25	2	0	0	1	12683.33	31.40	2
4	Lalmonirhat	15809	4.54	1	20202.81	8.74	1	10466.67	25.91	2
5	Kurigram	170564	48.97	2	231228	100	3	16677	41.29	3
6	Rangpur	30	0.01	1	110	0.05	1	12938.33	32.03	2
7	Dinajpur	261374.67	75.04	3	98831.67	42.74	2	40390	100	3
8	Gaibandha	177505.33	50.96	2	190415.70	82.35	3	8312.33	20.58	2
9	Joypurhat	12303.33	3.53	1	4761.33	2.06	1	7553.33	18.70	2
10	Naogaon	150825	43.30	2	182075	78.74	3	24161.67	59.82	3
11	Bogra	45405.67	13.04	2	177.45	0.08	1	3506.67	8.68	1
12	Natore	88490.67	25.40	2	142	0.06	1	400	0.99	1
13	Serajgonj	137890.33	39.59	2	75637.33	32.71	2	5978.33	14.80	2
14	Jessore	39474.67	11.33	2	16821.33	7.27	1	2555.33	6.33	1
15	Rajbari	47647.67	13.68	2	1905.67	0.82	1	1141.33	2.83	1
16	Faridpur	18083.33	5.19	1	1422	0.61	1	193.67	0.48	1
17	Shariatpur	0	0	1	8	0	1	0	0	1
18	Madaripur	9753.33	2.80	1	0	0	1	7	0.02	1
19	Sherpur	1646.67	0.47	1	0	0	1	1196.67	2.96	1
20	Jamalpur	348334	100	3	35451.33	15.33	2	16262.33	40.26	3
21	Mymenshing	275276.67	79.03	3	34136.33	14.76	2	3700.33	9.16	1
22	Netrokona	41346.67	11.87	2	4190	1.81	1	3855.67	9.55	1
23	Sunamgonj	31270	8.98	1	24526.67	10.61	2	3491.67	8.64	1
24	Sylhet	44580	12.80	2	6819.67	2.95	1	2554.67	6.32	1
25	Moulvibazar	2914	0.84	1	0	0	1	195	0.48	1
26	Tangail	147586	42.37	2	131287.30	56.78	3	6144.33	15.21	2

Table 1 continued

Sl. No.	District	Affected People			Affected Infrastructure			Affected Crop Land		
		Weighted Score	Point	Rank	Weighted Score	Point	Rank	Land (Hec.)	Point	Rank
27	Manikgonj	61000	17.51	2	89091.33	38.53	2	5674	14.05	2
28	Dhaka	12503.33	3.59	1	276.67	0.12	1	20.37	0.05	1
29	Bramanbaria	138	0.04	1	140.33	0.06	1	671.33	1.66	1
30	Comilla	48844.67	14.02	2	1127.33	0.49	1	1058.67	2.62	1
31	Rangamati	10666.67	3.06	1	3266.67	1.41	1	790	1.96	1

Figure 1: Vulnerability map for administrative districts of Bangladesh



Analysis of Vulnerability and Relief Distribution

Floods are the most frequent among all natural hazards in the country and are a serious obstacle to development of Bangladesh. Moderate monsoon flooding deposits silt, which is essential to maintenance of crop land productivity. Severe and prolonged flooding, such as occurred in 2017, is a different matter. The people of 31 districts of Bangladesh were seriously affected. In this study, we construct a correlation matrix between the flood hazard vulnerability map and three relief distribution maps, using the two-dimensional matrix multiplication mode (Islam & Sado, 2000). In each of nine correlation matrices, the diagonal elements exhibit the desired relation between flood vulnerability and relief distribution – the more severely affected districts in terms of vulnerability realizes the most generous flood relief, the moderately vulnerability districts receive moderate flood relief, and the least affected districts receive the least generous. If there was 100% congruence among the vulnerability and relief rankings, then the matrix cells in Figures 2-4 representing either over- or under-distribution of relief would be zero. However, in none of the matrices illustrated in Figures 2-4 is it the case that the off-diagonal cells are all zero. The correlations show the deviation in the marginal distribution of relief among the affected people, infrastructure, and crops land compared with relief distribution map developed through the analysis of the relief packages; rice (MT), cash (BDT), and dry food (Packet) which is shown in Table 2.

Table 2: Distributed Relief in the context of flood 2017 of Bangladesh.

Sl. No.	District	Rice (Metric Ton)		Cash (BDT)		Dry Food (Packet)	
		Allocated	Distributed	Allocated	Distributed	Allocated	Distributed
1	Panchagar	650	445	2000000	1095000	2000	1950
2	Thakurgaon	750	305	1700000	1350000	2000	1760
3	Nilphamari	850	525	2000000	1750000	2000	2000
4	Lalmonirhat	1050	866	2800000	1795000	2000	2000
5	Kurigram	2000	1861	8000000	695000	6000	6000
6	Rangpur	1300	288	4200000	499000	0	0
7	Dinajpur	2195	1595	8600000	6250000	7000	5000
8	Gaibandha	1400	1136	4300000	3310000	2000	2000
9	Joypurhat	75	55	150000	80000	0	0

Table 2 continued							
Sl. No.	District	**Rice (Metric Ton)**		**Cash (BDT)**		**Dry Food (Packet)**	
		Allocated	**Distributed**	**Allocated**	**Distributed**	**Allocated**	**Distributed**
10	Naogaon	700	552	2400000	1825000	2000	2000
11	Bogra	550	524	1300000	10450000	2000	2000
12	Natore	150	90	600000	200000	0	0
13	Serajgonj	1200	716	3700000	1741000	2000	2000
14	Jessore	200	101	700000	185000	0	0
15	Rajbari	500	384	1650000	893000	0	0
16	Faridpur	550	185	1600000	540000	0	0
17	Shariatpur	400	21.76	1300000	104000	0	0
18	Madaripur	300	50	1400000	315000	0	0
19	Sherpur	300	34	1600000	430000	0	0
20	Jamalpur	1800	1668	4700000	3625000	2000	2000
21	Mymenshing	400	64	1500000	989500	0	0
22	Netrokona	500	80	2400000	375000	0	0
23	Sunamgonj	600	234	2300000	390000	2000	2000
24	Sylhet	300	267	1200000	500000	0	0
25	Moulvibazar	300	240	1500000	680000	0	0
26	Tangail	400	230	1600000	1250000	0	0
27	Manikgonj	500	372	1900000	1450000	2000	2000
28	Dhaka	250	119	400000	183000	0	0
29	Bramanbaria	130	46	600000	50000	0	0
30	Comilla	143	40	380000	21000	0	0
31	Rangamati	200	75	1400000	582000	1000	1000

Matrices in Figures 2-4 show correlations between generosity of relief distribution via three sources (rice in Figure 2, cash in Figure 3, dry food in Figure 4) and three measures of flood hazard vulnerability (flood-affected people, flood-affected infrastructure, flood-affected crop land).

Figure 2: Correlation Matrix

Relief Distribution (Rice MT)	Flood Affected People Map		
Rank	1	2	3
1	32.60%	31.35%	5.71%
2	1.75%	14.75%	0.00%
3	0.00%	5.92%	7.92%

∑ upper elements of diagonal matrix = 37.06%

∑ elements of diagonal matrix = 55.27%

∑ Lower elements of diagonal matrix = 7.67%

Relief Distribution (Rice MT)	Flood Affected infrastructure Map		
Rank	1	2	3
1	52.43%	12.62%	4.61%
2	8.41%	3.46%	4.62%
3	0.00%	7.93%	5.92%

∑ upper elements of diagonal matrix = 33.49%

∑ elements of diagonal matrix = 56.92%

∑ Lower elements of diagonal matrix = 9.59%

Relief Distribution (Rice MT)	Flood Affected Crops Land Map		
Rank	1	2	3
1	56.02%	13.65%	0.00%
2	4.25%	7.62%	4.62%
3	0.00%	3.02%	10.82%

∑ upper elements of diagonal matrix = 18.27%

∑ elements of diagonal matrix = 74.46%

∑ Lower elements of diagonal matrix = 7.27%

Figure 3: Correlation Matrix

Relief Distribution (Cash BDT)	Flood Affected People Map		
Rank	1	2	3
1	32.60%	23.25%	5.71%
2	1.75%	21.49%	0.00%
3	0.00%	7.28%	7.92%

∑ upper elements of diagonal matrix = 28.96%

∑ elements of diagonal matrix = 62.01%

∑ Lower elements of diagonal matrix = 9.03%

Relief Distribution (Cash BDT)	Flood Affected infrastructure Map		
Rank	1	2	3
1	48.01%	10.66%	2.89%
2	8.58%	5.42%	9.24%
3	4.25%	7.93%	3.02%

∑ upper elements of diagonal matrix = 22.79%

∑ elements of diagonal matrix = 56.45%

∑ Lower elements of diagonal matrix = 20.76%

Relief Distribution (Cash BDT)	Flood Affected Crops Land Map		
Rank	1	2	3
1	54.17%	4.51%	2.89%
2	1.86%	16.75%	4.62%
3	4.25%	3.02%	7.93%

∑ upper elements of diagonal matrix = 12.02%

∑ elements of diagonal matrix = 78.85%

∑ Lower elements of diagonal matrix = 9.13%

Figure 4: Correlation Matrix

Relief Distribution (Dry Food)	Flood Affected People Map			
	Rank	1	2	3
	1	27.65%	24.97%	5.71%
	2	6.70%	24.16%	2.81%
	3	0.00%	2.89%	5.11%

$\sum$ upper elements of diagonal matrix = 33.49%

$\sum$ elements of diagonal matrix = 56.92%

$\sum$ Lower elements of diagonal matrix = 9.59%

Relief Distribution (Dry Food)	Flood Affected infrastructure Map			
	Rank	1	2	3
	1	48.00%	5.71%	4.61%
	2	12.84%	13.18%	7.65%
	3	0.00%	5.12%	2.89%

$\sum$ upper elements of diagonal matrix = 17.97%

$\sum$ elements of diagonal matrix = 64.07%

$\sum$ Lower elements of diagonal matrix = 17.96%

Relief Distribution (Dry Food)	Flood Affected Crops Land Map			
	Rank	1	2	3
	1	49.21%	9.11%	0.00%
	2	11.06%	15.17%	7.44%
	3	0.00%	0.00%	8.01%

$\sum$ upper elements of diagonal matrix = 16.55%

$\sum$ elements of diagonal matrix = 72.39%

$\sum$ Lower elements of diagonal matrix = 11.06%

Result and Discussion

This study undertakes flood vulnerability and relief distribution mapping. Vulnerability mapping of accurate flood areas can be helpful to mitigate flood-induced losses and also can be used for countermeasures. Through the proper identification of flood-vulnerable areas, relevant authorities can take appropriate relief action. We have estimated the correlation between the severity of flood hazard vulnerability and generosity of relief distribution. The maximum congruence, summation of diagonal elements of correlation matrix, arises with respect to flood-affected crop land: all relationships exceed 70%. With respect to flood-affected infrastructure and flood-affected people the congruence with relief components ranged between 50% and 65%. (as shown in Figure 5). These results can be used as further guidance in designing disaster management.

Figure 5: Congruence of correlation matrix for flood vulnerabilities and relief distribution packages

		Flood Affected		
Relief Distribution	%	People	Infastructure	Crop Land
	Rice (MT)	55.27	56.92	74.46
	Cash (BDT)	62.01	56.45	78.85
	Dry Food (Packet)	56.92	64.07	72.39

Conclusions

In summary, our conclusions are as follows:

(1) We constructed a vulnerability map assessing the interactive effect of affected people, affected infrastructure (comprising three elements - housing, institutions, and roads), and affected crop land. To reduce vulnerability due to flood hazard, the relevant policy makers should take significant initiatives.

(2) We also constructed three relief distribution maps, constructed in terms of categories of relief. We assessed the correlation between vulnerability severity rankings and relief distribution maps. Policy-makers should be more concerned about distributing relief in a manner that provides most relief to the most affected districts.

References

Benson, C., & Clay, E. (2003). Economic and financial impacts of natural disasters: an assessment of their effects and options for mitigation: synthesis report. *Overseas Development Institute, London*.

Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (2014). *At risk: natural hazards, people's vulnerability and disasters*: Routledge.

Hossain, S. (2015). Local level flood forecasting system using mathematical model incorporating WRF model predicted rainfall.

Islam, M. M., & Sado, K. (2000). Development of flood hazard maps of Bangladesh using NOAA-AVHRR images with GIS. *Hydrological Sciences Journal, 45*(3), 337-355.

Rahman, A. A., Alam, M., Alam, S. S., Uzzaman, M. R., Rashid, M., & Rabbani, G. (2007). Risks, vulnerability and adaptation in Bangladesh. *Human Development Report, 8*.

Reliefweb. (2017). Bangladesh: Flood Situation -August 22, 2017. Retrieved September, 2017, from https://reliefweb.int/report/bangladesh/bangladesh-flood-situation-August-22-2017

Sinha, D. K. (2007). *Natural disaster reduction: South East Asian realities, risk perception and global strategies*: Anthem Press.