Landslide in Chattogram City: Spatial Vulnerability and Risk Mitigations Options

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Abstract

Landslides have been among the most alarming disasters in the hilly regions of Bangladesh for the past few years. This hazard has become an unprecedented cause of human and economic losses. This paper attempts a spatial vulnerability analysis of landslides in the hilly regions of Bangladesh using hotspots, cluster and time-series analysis. It also discusses the risk mitigation options practiced by the inhabitants of landslide vulnerable areas of Chattogram City. Deadly landslides are found to be concentrated in South-eastern hilly towns and cities of Bangladesh. Larger clusters of landslides are found in Chattogram City, Teknaf, Cox's Bazar cities, followed by Bandarban,Chattogram university area and Rangamati. Landslide hotspots are especially prominent in Chattogram city and Bandarban districts. Both landslide incidents and fatality have been increasing with highest number deaths of 162 in 2012. From the late 90s, the rate of landslide occurrences began to increase sharply at an average annual growth rate of 132.75 percent. Landslides are found prominently in urban settings. Growing rural-urban migration of low -income population leads to occupation of hills, unplanned urban growth and risks. Poor economic condition, lack of awareness and education, poorly built structures are some sources of vulnerability. There is severe lack of awareness, motivation and training about personal and community preparations and interventions to reduce landslide vulnerability. Most vulnerable populations know very little about techniques of avoiding landslide risk, prevention and mitigation options. They are only aware of emergency evacuation during heavy rainfall and are dependent extremely on external assistance and relief.

Keywords: Landslide in Bangladesh, Landslide vulnerability, Hotspot analysis, Landslide risk mitigation.

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1. Introduction

Bangladesh is the largest delta in the world with eighty percent floodplains (Goldsworthy and de Vareis, 1994). This country is severely affected by floods, storms and riverbank erosion each year. Landslide was a less noticed hazard in this region until June 2007 when attention started being drawn to

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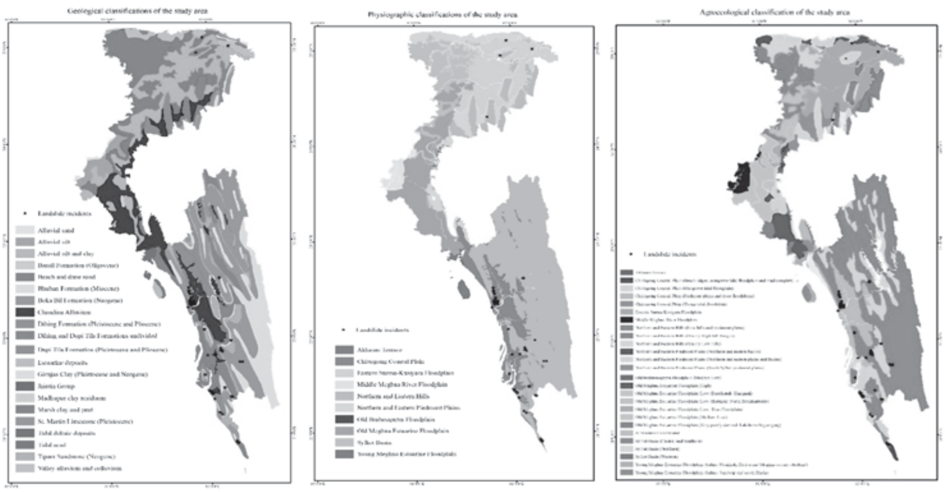
the severity of landslide after a devastating incident in Chattogram city which took 129 lives. In recent years, devastating landslides have occurred in several parts of Chattogram City, Bandarban, Cox's Bazar, Teknaf, and Sylhet regions (Sarker and Rashid, 2013).

In Bangladesh landslides are prevalent in Northern-eastern and South-eastern areas, physiographically identified as terrace and hilly area that consist 12% of total landform of Bangladesh. These hilly regions are underlain by sandstone, siltstone and shales of Tertiary and Quaternary ages (Brammer, 1999). These hills have been folded, faulted and uplifted (Brammer, 1999) into a series of anticline and syncline during the collisions between the Indian and the Eurasian plates in the Miocene period (Khan, 1991). Soil composition is mainly of Brown Hill Soils with some Grey Piedmont and Grey Floodplain Soils (Rashid, 1991). Brown Hill Soil have been developed over consolidated and unconsolidated rocks or yellow to strong brown subsoil with friable, porous, sandy loam to sandy or silty clay loam texture. These subsoils are imperfectly to excessively drained (Brammer, 1999; Banglapedia, 2008). Soils become unstable in wet condition and are unable to support more than 25.9° angle of slope in wet condition (Islam et al., 2014). Rainfall ranges from 2,200 mm to 5,800 mm annually with an average of 2,919 mm in Chattogram division. The highest precipitation occurs in June and July consecutively, 607.06 mm and 726.44 mm (BBS, 2009).

In 2012, Comprehensive Disaster Management Programme (CDMP) developed a landslide inventory, mapping, vulnerability and early warning system for Cox's Bazar and Teknaf. An early history and locational database of landslide can also be found in Banglapedia (2008), which has data of until 2000. Khan and Chang (2007) did a landslide hazard mapping for Chattogram City by the weighing-rating system based on field observation. Mahmood and Khan (2010) have attempted to identify vulnerable places in Chattogram City for landslide hazards based on the events of 2007.

Khan et al. (2012) found that there is a correlation between major landslide events and extreme precipitation over a short period in Chattogram. Sarker and Rashid (2013) have indicated locations of some major landslides in Bangladesh since 1968, but they only focused on major landslides and their relative locations. Ahmed (2015) did landslide susceptibility mapping of Chattogram city based on multi-criteria decision analysis of physical factors of the landslide. Islam et al. (2014) tried to determine engineering and geological properties of landslide vulnerable locations of Chattogram city. This paper accumulates all reported landslide occurrences from multiple sources until 2012 for a spatio-temporal analysis.



Source: BARC (2014)

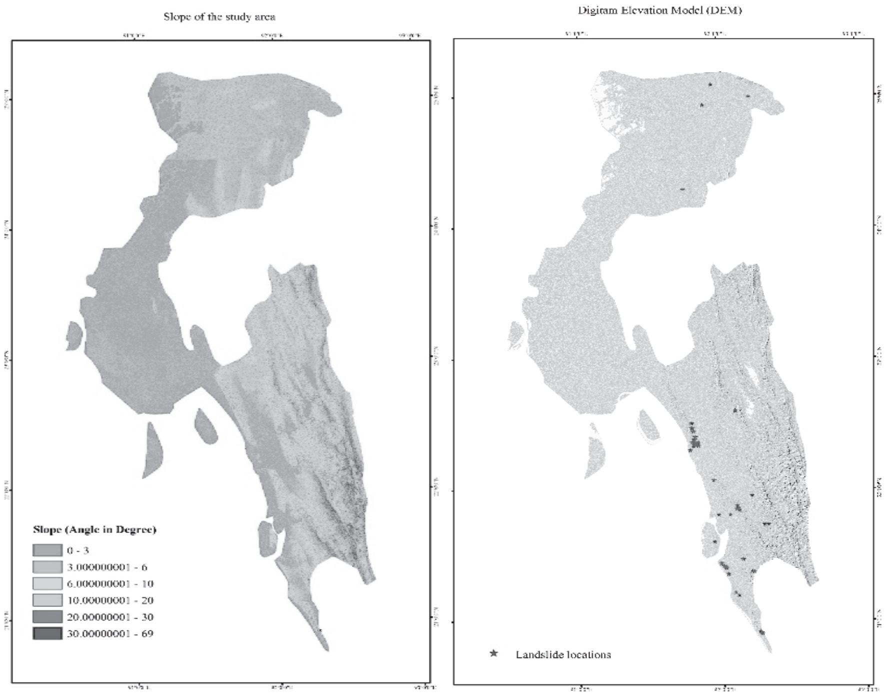
Figure 1: Geological, physiological and agro-ecological zones of the hilly region of Bangladesh

2. Objectives of the Study

The aim of this paper is twofold. First, it aims to carry out a spatial vulnerability analysis for landslide incidents of the hilly region of Bangladesh. Then, it aims to understand how people perceive landslide hazards, their awareness of the issue, and the mitigation and adaptation strategies practiced by them. This paper also sheds light on the socio-economic and living conditions of people living around landslide vulnerable locations to determine their sources of vulnerability and possible mitigation strategies to reduce them.

3. Methodology

This paper has taken note of all possible landslide events reported until 2012 from secondary databases, and provides insight into the spatiotemporal and statistical trends of landslide distributions in Bangladesh following the approach of Kirschbaum et al. (2010). The compilation has been done from different secondary sources and hazard databases similar to the study of Westen et al. (2008) and presents a combination of techniques of landslide inventory analysis following the methods of Westen et al. (2008) and Guzzetti et al. (2012). CDMP (2012) databases of Cox's Bazar and Teknaf have contributed a good deal at identifying notable recent landslides in these two towns. Government databases often ignore small-scale landslides while sometimes situation reports are not available. In such cases, local and national newspapers may work as good complementary sources of information. Hotspot, spatial cluster and time-series analysis of landslide incident has been done to ascertain spatial and temporal characteristics of landslides. Detail methodology and techniques of analysis are presented in the following sub-sections.



Source: BARC (2014)

Figure 2: Digital elevation model (DEM) and slope of the study area

3.1 Landslide Inventory

Landslide inventories are simplest form of landslide mapping (Malamud et al., 2004; Hansen, 1984; Wieczorek, 1984) which record location, date of occurrence, type of mass movement, along with resultant damages and casualties (Guzzetti et al., 2012; Malamud et al., 2004). There are essential to identify and document extent of landslides from local to nationwide range (Guzzetti et al., 2012; Brabb, 1991), as a preliminary stage of susceptibility, hazard and risk assessment of landslides (Cardinali et al., 2006; Westen et al., 2006 & 2008) and for any spatiotemporal statistical analysis (Malamud et al., 2004). There are several techniques for landslide inventory like archiving historical information of individual landslide events or analysis of aerial photographs (Malamud et al., 2004). Techniques for inventory depend on the purpose, extent and scale of the study area (Guzzetti et al., 2012) and availability of data.

Landslide inventory presented in this paper is an event inventory triggered mainly by rainfall (Guzzetti et al., 2012; Cardinali et al., 2006; Tsai et al., 2010) and at times by earthquakes in the hilly regions of Bangladesh. Based on the guideline for landslides inventory mapping of Guzzetti et al. (2012), this paper presents a small-scale, synoptic inventory of landslide.

The inventory collects data examining secondary literatures like chronicles, journals, technical, scientific reports, newspapers, government situation reports, local governments reports etc. This intensive archive study was carried out for spatiotemporal data and other information on deaths and damages caused by landslides. Subsequently, aerial photograph analysis (Malamud et al., 2004; Cardinali et al., 1990) was done to locate landslide incidents based on this archived information. To identify historical landslides, this paper has had to depend only on historical documents and archive study. Several field investigations following the method of Khan and Chang (2007) and Westen et al. (2008) were carried out in the Chattogram areas in 2008 and 2011. In these field surveys, handheld GPS and base maps were used to identify geographical locations of landslides. Household interviews using questionnaires (Westen et al., 2008) and group discussions with local government representatives and community leaders were carried out to gather this information.

Landslides have been identified according to their date and location. Sometimes there were several slides in a locality within a short span of time –a day or two; are counted as a single incident. Several small non-distinguishable slides within a small area or within same administrative boundaries have been identified as a single incident. Landslides in the same day or occurring within a short span of time, but in different identifiable locations, are counted as separate incidents.

Developing landslide inventory with temporal information is a difficult and a tedious process (Ibsen and Brunsden, 1996; Westen et al., 2006). In Bangladesh, landslides are most often confused with flash-floods. It is obvious that, a high-quality remote sensing based (e.g., using satellite images, and aerial photographs, DEMs) inventory mapping is much more accurate than field-based mapping (Guzzetti et al., 2012), but this method is far too expensive for this kind of large area. Human settlements and development structures often work as barriers in identifying landslides from remote sensing data. And these processes are unable to document historical landslides. With available resources, information and manpower this is probably the best possible combination of techniques available for large area inventory.

3.2 Spatial Cluster Analysis

Landslides tend to occur in clusters. A cluster may contain several landslides of different sizes, and types (Malamud et al., 2004). Cluster analysis is a statistical classification technique for dividing a population into relatively homogeneous groups (ESRI, 2014). Clusters analysis of incidents is based on spatial autocorrelation of a set of spatial features and their associated data values that tend to be clustered together (positive spatial autocorrelation) or dispersed (negative spatial autocorrelation). This paper follows unsupervised *k*-means clustering approach of Melchiorre et al. (2008).

In ArcGIS, clusters analysis of incidents can be done using a Cluster Analysis tool based on spatial autocorrelation, which is a measure of the degree to which a set of spatial features and their associated data values tend to be clustered together in space (positive spatial autocorrelation) or dispersed (negative spatial autocorrelation) (ESRI, 2014). In this research spatial autocorrelation was measured using Global Moran's I statistics based on both landslide's locations and the number of fatalities simultaneously. Equation for Global Moran's I statistics is:

$$I = \frac{N}{\left(\Sigma_i \Sigma_j W_{ij}\right)} \frac{\Sigma_i \Sigma_j W_{ij} \left(X_i - \bar{X}\right)\left(X_j - \bar{X}\right)}{\Sigma_i \left(X_i - \bar{X}\right)}$$

Where, N is the number of spatial units indexed by i and j; X is the variable of interest; $\bar{X}$ is the mean of X, and W_{ij} is an element of a matrix of spatial weights.

3.3 Hotspot Analysis (Getis-Ord Gi*)

Nadim et al. (2006) has done global landslide hotspots mapping based on global datasets of climate, lithology, earthquake activity, topography and areas with the highest hazard intensity. Bianchini et al. (2012) and Lu et al. (2012) did landslide hotspot identification using the synthetic aperture radar (SAR) interferometry (InSAR) technique, and Van Den Eeckhaut et al. (2010), using a sampling strategy that enabled statistical modelling.

So far, there has been no inventory based hotspot analysis for landslides for Bangladesh. Identification of hotspots in local scale can be a useful tool for landslide preplanning and mitigations measures. In this paper inventory based hotspot analysis has been done using Getis-Ord Gi* statistics. The Getis-Ord Gi* statistics is a spatial statistics that represents the association of event(s) (e.g., landslides occurrences) up to a specified distance. Getis-Ord Gi* statistics have been applied to evaluate spatial clustering of neighbouring landslide incidents weighed by the number of fatalities.

The Getis-Ord Gi* (Getis and Ord, 1996) statistics is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij} X_j - \bar{X} \sum_{j=1}^{n} w_{ij}}{s \sqrt{\frac{n \sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2}{n-1}}}$$

The G^*i statistics is itself the z-score. Where x_i is the attribute value for feature j, w_{ij} is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$

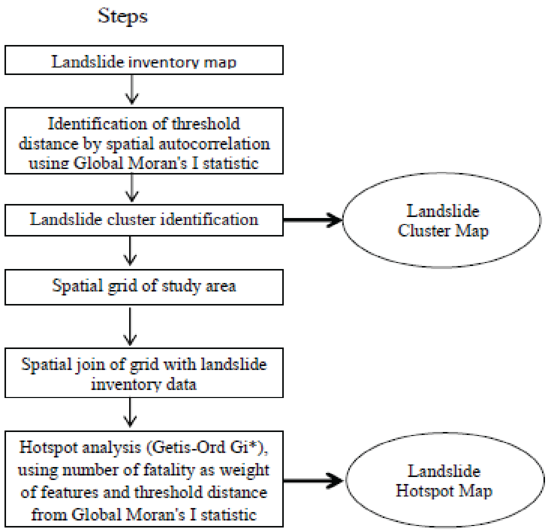


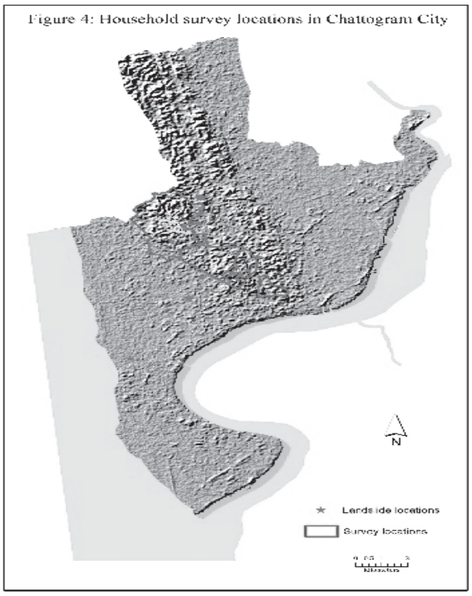
Figure 3: Steps for landslide hotspot and cluster analysis

The Hotspot Analysis tool of ArcGIS 10.2 calculates the Getis-Ord Gi* statistics for each feature in a weighed set of features (ArcGIS Resource, 2013). This tool works by looking at each feature within the context of neighbouring features. If a feature's value is high, and the values for all of its neighbouring features are also high, it is a part of a hot spot. The resultant Z score signifies whether features are spatially clustered, dispersed or random and P values indicate its statistical significance (ESRI, 2014). These two values together indicate the confidence level of the hotspots. For this research, the study area has been divided into grids and spatial information of landslide occurrence and fatality has been spatially joined with this grids. Steps for hotspot and cluster analysis have been briefed in Figure 3.

3.4 Household Survey

For the second objective, data from a household survey of landslide prone locations of Chattogram city were collected. Study locations (Figure 4) were selected purposively based on the history of landslides of the city. All the surveyed areas were prone to landslides recently and are within Chattogram City, which is the second largest city in Bangladesh and is situated within 22°14′and 22° 24′30′′ N Latitude and between 91°46′ and 91°53′ E Longitude, on the bank of the Karnafuli river.

Data was collected as part of an academic research carried out by the Department of Geography and Environment, University of Dhaka in 2008. Eighty-four (84) students from the undergrad program were trained to conduct this survey in seven locations of Chattogram city. As already noted these locations were selected, as there were landslide incidents in previous years and in the surveyed year.



Source: BARC (2014), Field survey of 2008 and 2011

Figure 4: Households survey location in Chattogram City

A questionnaire was developed containing both closed and open-ended questions for household survey. It collected social-economic data along with peoples' perception of landslide hazards, vulnerability and mitigation strategies. Households were selected based on their experience of the landslide incidents. Priority were given to houses located close to the past landslide incidents spreading outwards. Snowballing techniques were used to identify landslide vulnerable households from one to another. Local people also assisted in the process of identifying most landslide-prone locations and households. Questionnaires were mainly distributed among the household heads, if not, available preference was given to the oldest responsible household member. The survey was conducted during weekends to maximize the possibility of interviewing household heads. Three hundred and thirty two (332) households were surveyed in this process. The survey lacks any systematic selection or sampling strategy; rather, preference was given to maximise the number of landslide vulnerable respondents.

4. Analysis and Discussion of Results

4.1 Landslide Inventory

Identification of reliable landslide inventory map is essential for the spatial and temporal analysis of landslide hazard and risk assessment (Westen et al., 2008). Therefore,developing a detail and precise landslide inventory is the prerequisite of any landslide research (Westen et al., 2008; Pellicani et al., 2013; Ibsen and Brunsden, 1996). So far, 65 landslide hazard incidents were identified in Bangladesh from 1968 to 2012 (Table 1). Most incidents in this inventory took place in human occupied areas; this is because landslides in uninhabited remote hilly areas often go unnoticed and hence can not be found through archive studies.

In this inventory, place names or administrative names of landslide incidents areas are stated in as much detail as possible. An inventory map of 1:2,000,000 scale is shown in Figure 5, indicating geographical locations of these landslides. Landslides on map are shown using points (Guzzetti et al., 2012) with weighed circles of number of fatalities. This weighing gives an idea about damages done by landslides. The number of fatalities is an important variable indicating massiveness and impact of these landslides on human life and society. Chattogram City and adjacent Chattogram University record most landslides occurrences and fatalities (28 landslides, 238 fatalities), followed by Cox's Bazar (20 landslides, 103 fatalities) and Bandarban districts (9 landslides, 166 fatalities). Sylhet and Rangamati districts have the fewest incidences of landslides.

Table 1: Landslide inventory of Bangladesh (1968-2012)

Year	Date	Area	Place Name	Fatality
1968	---	Rangamati	Kaptai - Chandraghona Road	0
1970	---		Ghagra- Rangamati Road	0
1974	---	Chattogram	Chattogram University Area	2
1997	---	Bandarban	Sarai	0
1999	13-Aug	Chattogram	Gopaipara of Chattogram Kotwali Thana (Enayet Bazar, Railway Pahar)	10
	13-Aug	Cox's Bazar	Cox's Bazar Sadar	0
	11-Aug	Bandarban	Lama Thana, Aziz Nagar Union (Chittaputti, Monargiri, Chionipara, Muslimpara, Sonaisari, Bazapara, Kalargiri, Maishkhata, Aungratali, Meounda, Kariungpara)	7
	15-Aug		Lama Upazila (Chittaputti)	0
2000	---	Chattogram	Baghghona	2
	24-Jun		Chattogram University Area	13
2003	8-Jun		Ghonapara	1
	8-Jun		Lalkhanbazar	3
2004	10-Jul		Lalkhanbazar	3
	10-Jul		Bayojid Bostami Majar Area	2
2005	17-May	Chattogram	Bayojid Bostami Majar Area, Atturpara Dipo	1
	31-Oct		Bayojid Bostami Majar Area, Shantinagar slum	3
	11-Jun		Chattogram, Pahartoli	12
	11-Jun		Motijhorna	2
	11-Jun		Halishahar	1
	11-Jun		Baghghona	1
	11-Jun		Hathazari Thana, Sekandar Para, Sikandar Colony	1
	11-Jun		Panchlaish	1
2007	11-Jun		Debarpara	7
	11-Jun		Muradpur	1
	11-Jun		Khulshi (Kusumbag, Lalkhan bazar)	14
	11-Jun		Mohammad Ali Road	1
	11-Jun		Chattogram Cantonment Area, Lebubagan Area	72
	11-Jun		Chattogram University Area, Adjacent slum area	5
	17-Aug		Motijhorna	11
	8-Aug	Sylhet	Sylhet, Osmani Bimanbandar Area	0
2008	3-Aug	Cox's Bazar	Cox's Bazar	7
	6-Jul	Teknaf	West side of Upazila Parishad Office, Tuinna Pahar	4
	3-Aug		Teknaf	7
2009	19-May	Moulavibazar	Srimangol. Kalighat Union, Lakhai Tea state, Zerin Tea State	0
	19-May	Bandarban	Bandarban, Lama Upazila, Ajijnogor, Bandarban Sadar, Kalaghat	51
	19-May		Bandarban, Bandarban Sadar, Kalaghat	30
	15-Jun	Teknaf Upazila	West side of Upazila Parishad Office, Tuinna Pahar	33
	15-Jun		West side of Upazila Parishad Office, Fokirmura Pahar	0
	15-Jun		Boiddoghona Pahar	0
	15-Jun		Nila Union, Uluchamri	0
	15-Jun		Howaikeng Union, Bazar Para	0

2010	15-Jun	Cox's Bazar	Ukhiya, Palongkhali Union, Dokkhin Rahmoter Bill Gram and Dhamonkhali	6
	15-Jun		Cox'sbazar, Teknaf, Ukhiya	0
	15-Jun		Himsori, Army Camp	6
	15-Jun		Cox's Bazar,Ghunghum Union, Bajbania, Mohajer Para	0
	15-Jun	Bandarban	Bandarban, Naikkhongsori, Bajabania , Uttor Para	4
	15-Jun	Cox's Bazar	Cox's Bazar Sadar	2
	15-Jun	Bandarban	Bandarban	0
2011	1-Jul	Chattogram	Tiger Pass Area, Batali Hill	5
	1-Jul		Lalkhan Bazar Slum	17
2012	17-Jun		Khulshi	11
	23-Jun	Bandarban	Akbar Shah Mazar area	35
	23-Jun		Naikhanchari	47
	23-Jun		Lama	27
	23-Jun	Cox's Bazar	Ukhia	10
	23-Jun		Chakaria	10
	23-Jun		Ramu	7
	23-Jun		Maheshkhali	5
	23-Jun		Cox's Bazar Sadar	3
	23-Jun		Pekua	3
	23-Jun	Chattogram	Bangshkhali	3
	23-Jun		Hathazari	1
	27-Jun	Sylhet	Gowainghat	0
	27-Jun		Kanaighat	0

Sources: NBCnews 2007; Banglapedia 2008; Mahmood and Khan 2010; Reuters 2012; Yahoo News 2012; Sarker and Rashid 2013; Wikipedia 2013; archive study by author, and numerous other newspapers and magazines

4.2 Spatiality of Landslides Incidents

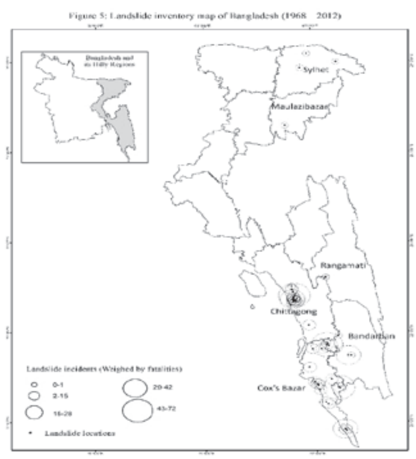
For spatial analysis, North-East region of Sylhet has been excluded since only a few landslide occurrences have occurred there with reported causalities. South-East region of Chattogram division has been considered as the study area for analysis below.

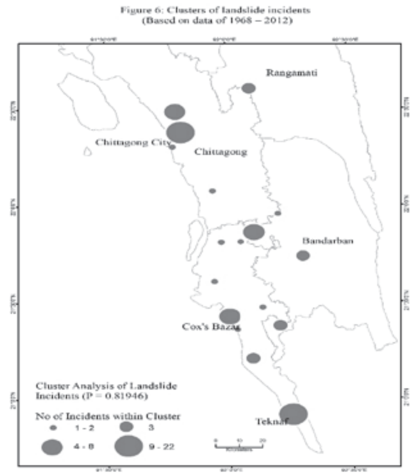
4.2.1 Clusters of Landslide Incidents

A cluster may contain several landslides of different sizes and types (Malamud et al. 2004). Landslide hazards were found spatially clustered within a radius of 2400 metres in the study area. Figure 6 shows these clusters for landslide incidents. The largest cluster of landslide incident is found in the Chattogram City area. The second most prominent cluster of landslide is located at Teknaf, Cox's Bazar. Cluster analysis gives us a good understanding of the spatial behaviour of landslide occurrences. In Bangladesh, most landslide occurrences are found spatially clustered within some hilly towns and cities of the South-east. Densely populated areas of these hilly regions are more prone to landslide hazards due to unplanned human interventions in hills.

4.2.2 Hotspot Analysis (Getis-Ord Gi*)

The result of hotspot analysis is shown in Figure 7. There are several landslide hotspots within the study area and most of them are at 99.9 percent significant level. This type of unusual high significance level occurs because of the interaction of natural and social factors (Chainey, 2012).

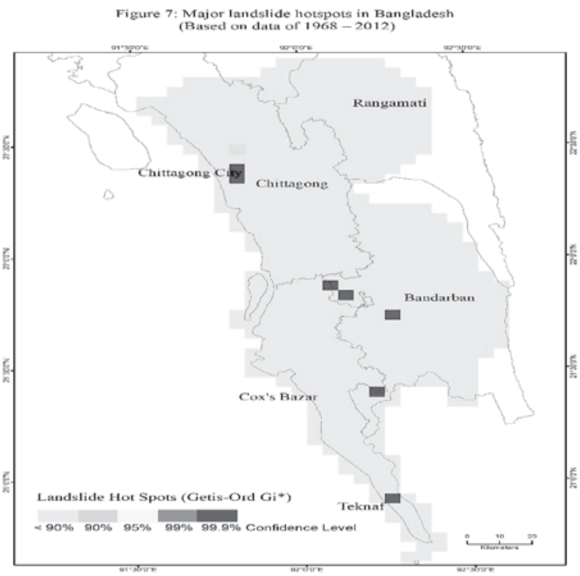




Source: Based on the field surveys of 2008, 2011 and the inventory presented in table 1
Figure 5: Landslides inventory map of Bangladesh Figure 6: Clusters of landslide incidents

Hotspots are profound in hilly areas with poor infrastructure, drainage facilities and in areas prone to deforestation, soil erosion, and hill cutting. Highest numbers of landslide hotspots are located in Bandarban District, followed by Chattogram City and adjacent areas.

In the current analysis, the number of incidents for analysis is very low (65 incidents) and many of these incidents have zero as weighed value (number of fatalities). A better result can be expected if this method is replicated in places with more incident data and detail damage information. Another option would be identifying landslides using latest remote sensing techniques and use of hotspot analysis. As landslides are isolated events, therefore, most parts of the study area have been identified as non-significant area (green areas in map) for landslide hazards. The significance of this study is: physiographic characteristics and other social features of these hotspots landscapes can lead futures researchers to identify probable landslide hotspots in hilly regions of Bangladesh. Landslides also might occur in less populated areas, but remain unnoticed in most cases. It causes casualties and major damage, especially when occurring in populated urban areas. The importance of this analysis is that, it shows how vulnerable urban hilly locations can be. Cox's Bazar and Bandarban experienced fatal landslide recently, corresponding with their urban growth. Similar situation is eminent for other urban areas, if extensive preventive measures are not taken.

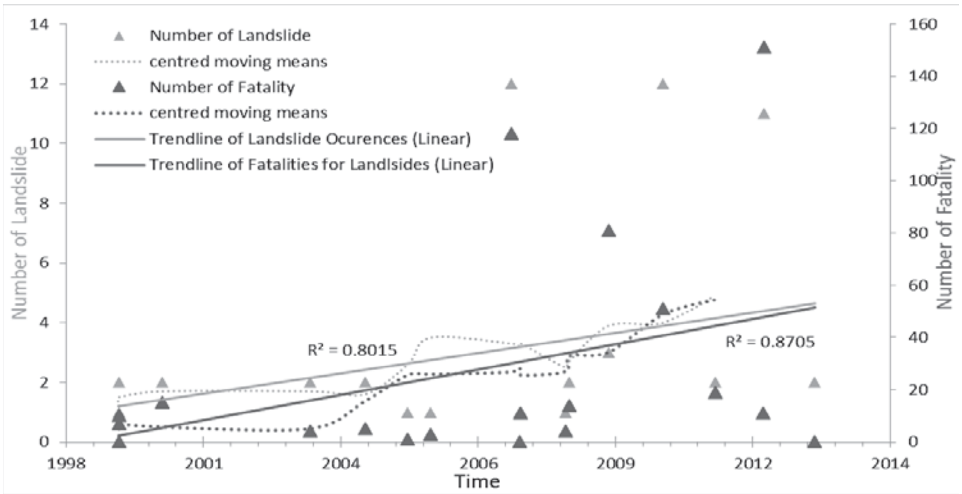


Source: Based on the field surveys of 2008, 2011 and the inventory presented in table 1

Figure 7: Major landslide hotspots in Bangladesh

4.3 Temporal Analysis of Landslide Incidents

During our study period, mortalities have noticeably increased due to the upsurge of landslides occurrences. There have been 510 deaths recorded from landslides in Bangladesh so far, 88 % of which are from 2007 onwards with a record of 162 deaths in 2012. Seventy percent of all landslides occur within the last 20 days of June, which is the peak season of the monsoon in Bangladesh, and 91.67 % from June to August. In Bangladesh, landslide incidents are alleged to be closely related to intensive rainfall occurrences (Khan and Chang, 2007; Mahmood and Khan, 2010). Time-Series analysis (Figure 8) of landslide occurrences and number of deaths reveal upward trend for both. From the late 90's, the rate of landslide occurrences began to increase sharply at an average annual growth rate of 132.75 percent. Both the trend of landslide occurrences and fatalities are showing an upward trend with strong R-square values. These portray the future vulnerability of this region to landslides and illustrate that both numbers of landslide and fatality counts will increase in coming days if the present scenario persists. It can be assumed that urbanization, and populations increase in urban areas can act as factor for this growing trend of landslides. Hilly urban areas are not prepared to accommodate rapid growth. If the current trend of urbanization persists, other small urban areas will also be in risk of facing this disaster in the future.



Source: Prepared by the author based on the field surveys of 2008, 2011 and the inventory presented in table 1.

Figure 8: Landslides incidents and associated fatalities in Bangladesh

4.4 Factors behind Landslides in Chattogram City

Excessive rainfall within a short period is considered as the main triggering factor for landslides in hilly areas (Sarker and Rashid, 2013; Mahmood and Khan, 2010, Islam et al. 2014). Unsustainable landuse, construction, deforestation and hill cutting are major anthropogenic causes (Mahmood and Khan, 2010) aggravating susceptibility of this hazard. These factors work to make vulnerable locations more vulnerable. CDMP (2012) have identified some general causes of landslides for Bangladesh. These are removal of lateral support, addition of weight to the slope, removal of underlying support and anthropogenic activities.

Survey respondents identified two types of factors for landslides: anthropogenic and natural. One-third of the populations cite intensive rainfall as the main triggering factor, followed by hill cutting.Water logging, cultivation, deforestation and infrastructure development are some other anthropogenic factors. Only a very few have identified steep slope, soil erosion, sandy soil texture, crack or faults, water leaching, earthquake as possible factors. Absence of protective walls and poor infrastructure development are also attributed by respondents as causes of landslides.

4.5 Households' Vulnerabilities to Landslide

Among the survey population, majority of the households are from very poor to lower-middle income status. One-third of the households have less than 4000 BDT (50 USD) per month as income, which is only enough for sustaining a poor living condition, because of high rents and other living costs in the city. Another 26.44% have income of up-to 6000 BDT, and can manage to save some money after meeting all costs. Main source of income here are wages from day labor (34.07 %) of different types. Socio-economic status of the survey population is comparatively poorer than the national urban average.

Around 62 percent of the population living in the study area are temporary settlers. To understand their vulnerability, it is imperative to understand the reason of resettlement of these populations in their present vulnerable location. Half of the respondents reported coming here in search of job or sources of income. These people came mostly from outside the city, from surrounding rural areas. Though majority of the migrants came from nearby areas, some have also migrated from the remote areas of the country. People, living here often act as source of inspiration and help for migrants. As the second largest city of the country, Chattogram provides opportunities for day laborer, small jobs and businesses-which attract people from surrounding rural and peripheral urban areas. Less transport cost, known places, and people influenced them to take the decision to migrate. Poverty, unemployment, lack of basic social facilities and natural hazards work as push factors for migration. Poor income and job uncertainty create vulnerable situation for families. However, they tend to live in these places because of better job opportunities than in rural areas.

There are structural vulnerabilities too. Only 2.43% houses are entirely brick built, along with 27.36% half brick built (wall made of bricks with occasional concrete floor and tin-shed roof). Rest of the houses have non-concrete structures and are made of wood, bamboo, tin or straw. Most of these houses are very poorly built without architectural design to reduce vulnerability. These houses are exposed to heavy rain, storms, floods and landslides due to their poor structure, construction quality, weak and old construction materials and overdue restorations. Communications around houses are also poor. Although, main pathways are built of concrete, thought these roads often do not continue all around. Major portions of these are mud ways and unable to provide safe communication for dwellers, especially during torrential rain and storm. Sixty percent of the houses are located at the bottom of hills. These families migrated from low-lying flood plain areas, so they tend to live as close to the plain land as possible. They are unfamiliar with techniques of living in hilly regions like the indigenous people in hilly areas. Indigenous households are usually built on elevated platforms, so they need far less hill cutting to construct plain platform.

Three-fourth of the population studied uses sanitary and unsanitary toilets.

About 85.7% of these households have electricity, though majority of these connections are illegal. These amenities are one of the benefits of living in a big city. Access to toilet and water sources are often difficult, as they are away from houses, have poor communication and no lighting. Especially for women, and the aged– these facilities are inaccessible during heavy rain or at night. Because of the illegal electricity connections, people also fear losing them. Thirteen percent of the households live illegally in government lands and around 63 % in rented houses owned by other people, companies, or the government. Illegality of tenancy creates vulnerability among tenants about fear of eviction. Tenants also complains about owners of houses, as they are often abusive and do not support them during disaster periods.

4.6 Mitigation and Adaptation Strategies

From 2007, after the massive landslides in several places of Chattogram city, people become more aware of landslide disaster, especially during the Monsoon season. Though only 16.10% people faced landslide experiences in their life, half the population consider themselves at risk of landslide. They can differentiate clearly between flash floods and landslides. To them a landslide is “break down of soils from hills due to excessive rainfall “or “vertical movement of soil caused by heavy rainfall”. People also use the term “old hills”, indicating hills where people are living for long, have little vegetation coverage and are susceptible to landslides. The inhabitants of hilly areas principally take preparation for landslides based on their experience and observation. For example, they identify intensive precipitation over short periods as the main reason for landslide, and become alert when heavy rainfall continues for long. They also look for small breakages and faults to predict landslides. These are some signs that help them predict landslide. Soil breakage from hills often creates roaring noise, which also alarm people in surrounding areas. Sometimes people are reluctant to express this risk for fear of eviction, as there is always pressure from the government to remove human settlements from landslide risky areas. They think it is rather wise to overlook risks to avoid possible eviction. This problem can only be solved with raising awareness among all level of people.

Two-thirds of the inhabitants have been alerted during heavy rainfall in recent years. Mainly, government agencies play the core role of sounding alarms and evacuation calls during heavy rain. Almost all survey respondents have mentioned these procedures as effective. They also sometimes move vulnerable families to safer places. NGOs, landowners, and owner of houses engage in this process. Most sub-urban areas are not alerted through warning broadcast.

From the survey, it is evident that every household has at least a television, radio, or both. These mediums could be useful for landslide warning and evacuation training broadcasts. Announcements from religious institutions over mikes can be a very useful tool of early warning. Motivational training for priests could be useful to keep the awareness process alive and effective. They can announce early warning by themselves when necessary, and can alert people during weekly prayers in the rainy season.

People take different steps to save their lives and properties from landslides. Evacuation to safer shelters is the most common step. People move out either to relatives' house or to temporary shelters created by the government or NGOs during the rainy season. This relocation is a temporary measure but is unable to reduce vulnerability permanently. Though relocation saves life, it cannot save property and household materials. Majority of people do not know what to do to save household materials, mainly because of lack of training. Some families move out suddenly, leaving everything behind. Their belongings are sometimes stolen and damaged. Sometimes men try to guard them, but these become impossible during extreme weather condition. Only a few can relocate their furniture and household utensils things mostly in relative or neighbors' houses. Some also try to reinforce their houses with concrete or sand bags. The government is now more proactive and attempts to evacuate people temporarily during heavy rainfall to prevent any human losses.

People expect different responsibilities with different priorities for individuals, communities, NGOs and governments. People think they have nothing to do at the individual level to prevent or mitigate this vulnerability. Majority of them think external intervention and help is mandatory in this process. Almost three-fourth opined that they do not know what they can or should do to avoid such hazards. They think themselves to be helpless in face of such hazards. Similar responses are also found for communal responsibility. Majority were unable to mention any techniques or approach they could take collectively to reduce vulnerability. Only a few (7.54 %) have acknowledged that peer help among households and individuals can be useful in reducing vulnerability.

Land and hill owners have some responsibilities in order to reduce risks too. Building fortified walls, raising awareness, tree plantations, making strong houses at safe distances is prescribed as some of their responsibilities. As they are economically solvent, they are thought as more capable and responsible for immediate and costly interventions when necessary. Landowners actually could contribute in reducing vulnerability by restricting themselves from constructing risky houses.

People think the government has not done enough for them except provide emergency rehabilitation and relief. Fifteen percent of the population think government organizations should arrange to relocate families to risks free areas permanently. Raising awareness, arranging for emergency logistics, providing early warning is mentioned by some others by some others (7.72%) as essential steps that government authorities should take. Building fortified walls and proper drainage, weather forecasting and tree plantations were also mentioned as structural measures to reduce landslide risk. People also think that government should be stronger in applying laws to stop hill cutting, deforestation, and unplanned development in risky areas. They suggest that these operations could discourage people from living in risky areas and thus minimize risks. They also urge stopping gas and electricity supplies to illegal households. Although these actions seem radical, necessity of enforcing government acts and rules to stop illegal occupation in risky areas is necessary. Government authorities have already taken steps in this regard, but they lack firmness and as well as popularity among people. In parallel to executing these rules, the government should take steps to popularize their policies so that people fill encouraged to obey them. NGOs could help by providing training and credit facilities and by ensuring livelihood security. Awareness raising is identified as a major role for NGO to take, by loan and relief activities.

Survey respondents proposed some mitigation and adaptation strategies. More than 92 percent respondents think that permanent relocate to safer plain lands is the best option to reduce their vulnerability. Relocation and building houses in safer places (especially government places) are the most popular option among people. Government residences for poor people and control over high rent of private houses were also suggested. Low house rent is the major pull factor for population living here as house rents in cities are often a burden for the low and middle-income population, and Chattogram city is no exception. Safer places tend to be more expensive, and poor people have no other option than living in these cheap places, despite risks of landslide. Housing facility by government or donor organizations for poor and low-income population could be viable options to encourage people to leave these risky areas. They also emphasize building strong houses and concrete walls. Government authority could help them by providing them with construction material and urging them to build resilient houses. Respondents also wanted job opportunities for them. Financial help as loans could also be very useful for them. Training to reinforce houses with landslide adaptive technology could be useful too. People do not know how to build houses in slopes and appropriate training in this regard is necessary for them. Making drainage system to let water pass, setting plantations around the house and building concrete walls are other suggested measures mentioned by respondents.

Some respondents suggested awareness building along with firmness in applying laws to reduce havoc from landslides. In this society, landowners, local musclemen and politicians play vital roles. They build house to rent them out, and this is often a source of easy money for them. Respondents often say that it is for this group of people (landowners and local musclemen), the government cannot stop illegal land grabbing and settlement development in hills. Therefore, any initiative to stop deforestation and hill cutting need to include local musclemen and powerful people like politicians to ensure the successful execution. These local powerful people are often responsible for deforestation and hill cutting for their construction projects. Most respondents have suggested motivating these people against deforestation and illegal land grabbing.

There is severe lack of awareness, motivation and training about personal and collective preparations and interventions to reduce landslide vulnerability. They know very little about techniques of avoiding landslide risks as well as prevention and mitigation options.

Training for inhabitants of all ages is highly recommended. People should know about these preparation, evacuation and post disaster rehabilitation processes in detail. They should be made personally and collectively aware. Help with necessary tools for evacuation like, torchlights, raincoats, emergency dry foods, shovels (for drainage) could be useful for the community. Reserve of tents, plastic sheets, and sleeping bags in communal places (clubs, schools, and mosques) could be useful for emergency shelter development.

5. Conclusion

Spatial analysis reveals that hotspots of landslide incidents are prominent in the cities that are going through the development process in the hilly regions of Bangladesh. From the late 90s, numbers of deaths and damage to assets have been increasing at an alarming rate. Anthropogenic and physical features of these hotspots and clusters need to be recognised in order to identify other potential landslide-vulnerable places and vulnerable communities to pre-plan for landslide disasters and for reducing landslide vulnerability.

The government has taken some initiatives to mitigate this hazard in Chattogram City and Cox's Bazar. However, with limited resources, it is impossible for them to cover all vulnerable areas. Using mass communication media to disseminate landslide awareness, arrange training and form voluntary groups with suggested responsibilities during landslide risk times could be useful tools to reduce risks. Locally influential landowners and politicians should be included in the process too.

Evacuation is merely an emergency tool to save life practiced now, but it is unable to save property and reduce continuous fear of living in risk. Managing land and housing for a large population is a challenging task, as plain lands tend to be scarce and expensive there. To prevent future occurrences, landslide resilient urban planning is essential in hilly urban areas. Anthropogenic and physical features of landslide vulnerable places and vulnerable communities need to be identified in detail to pre-plan for landslide disasters and for reducing vulnerability. Training for resilient structure construction, awareness about mitigation and adaptation practices, and engaging people at all levels is essential for effective landslide mitigation.

Data limitation is a major challenge for landslide research in Bangladesh. Historical data is scarce; moreover the necessary parameters of incidents are not recorded, which are critical in landslide analysis. Data used in this paper is also not sufficient as it is 8-10 years old, and landslides have occurred almost every year in the last decade. Landslides are also occurring in new locations across the Chattogram Hill Tracts. Therefore, this paper is unable to present analysis of recent incidents, and is spatially limited. Moreover, the analysis presented here is only a general representation of the landslide vulnerable population living in Chattogram City. Future studies need to focus on the comprehensive vulnerability of different landslide prone locations with comparative analysis. Last but not least, lack of access to landslide research studies of Bangladesh is an acute problem. Only a few Bangladeshi researches are available online; most of them (thesis, reports, university journal publications) are only hardcopy publications and difficult to get access.

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