LANDSLIDE INVENTORY IN AN URBAN SETTING IN THE CONTEXT OF CHITTAGONG METROPOLITAN AREA, BANGLADESH

M. S. Rahman[1,3*], B. Ahmed[2], F.F. Huq[1], S. Rahman[1] & T. M. Al-Hussaini[1]

[1] BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS), Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
[2] Institute for Risk and Disaster Reduction, University College of London (UCL), UK
[3] Center for Spatial Information Science and System, George Mason University, Fairfax, VA, USA
**Corresponding Author; Email:mrahma25@masonlive.gmu.edu*

ABSTRACT
Chittagong Metropolitan Area (CMA) is vulnerable to landslide hazards with an increasing trend in frequency and damage. Devastating landslides have hit CMA repeatedly in recent years. Under a project financed through ICIMOD of Nepal, detail survey has been conducted to prepare an inventory of landslides in CMA. Landslide events have been observed to occur at times of much higher rainfall amount compared to the monthly average. Moreover, rapid urbanization, increased population density, improper land-use, cutting of hills, indiscriminate deforestation and agricultural practices are aggravating the landslide vulnerability in CMA. A landslide inventory is helpful for landslide modelling, runoff modelling and urban land-use planning. A three step methodology, identifying past landslide events from news archive, information from local people and satellite image interpretation has been followed. An inventory of 57 landslide events has been prepared which includes landslide locations, types, dimension, activity, potential causes of landslides, triggering mechanism and slope stabilizing mechanism. This inventory is expected to be a useful resource for future landslide studies in this port city of Bangladesh.

Keywords: Landslide; Inventory Map; Chittagong City; Urban Setting; Remote Sensing.

INTRODUCTION
In Bangladesh landslide events mainly occur in the hilly parts of Chittagong Division. Chittagong is the largest port and second largest city of Bangladesh and plays a substantial role in the economic development of Bangladesh. Locational advantages and opportunities lead to rapid urbanization and compact urban form (Rahman, 2012). Landslides have occurred frequently in Chittagong city due to extreme rainfall. The devastation aggravates with weak geological structure, unplanned and erratic use of hills and settlement development. The unplanned and haphazard urbanization (Rahman et al., 2012), land-cover change, coupled with the increased intensity and frequency of heavy rainfall, is causing landslides in Bangladesh. Land cover changes (e.g. urbanization, deforestation) cause large variations in the hydro-morphological functioning of hill-slopes, affecting rainfall partitioning, infiltration characteristics and runoff production (Chau et al., 2004). Many urban dwellers and their livelihoods, quality of life, property and future prosperity are being continuously threatened by the risks of rainfall triggered landslides (Ahmed et al., 2014a). The development authority of Chittagong has identified 30 risky hills (Chakraborty and Uddin, 2014) among 88 hills of 18304 acre (Chisty, 2014). More than 10,000 people are currently living in such vulnerable areas. People are living at the toe and on the slopes of hills with high risk of landslides and associated damage (Mia et al., 2016). Many devastating landslides occurred in these hills in recent past. Landslides triggered by heavy rains in Chittagong claimed at least 185 lives in the last seven years.
Landslide is a term generally used to describe the downward movement of a portion of a hill slope containing soil, rock, and organic materials under the effects of gravity and also the landform that results from such movement (Highland et al., 2008). Landslide inventory can be seen as datasets of multiple events which may include but are not limited to landslide locations, date of landslide, type of the landslide, potential causes, and damage information (Hervás, 2013). A past disaster event can be

seen as an opportunity to learn the lesson to enhance future disaster mitigation capacity (Rahman and Kausel, 2012). Thus, it is important to have a critical evaluation of past landslides to understand the causes and issues related to these events. Landslide inventory is one of the most important data for many landslide studies such as susceptibility mapping (Ahmed, 2015; Cardinali et al., 2006), landslide hazard zonation (Anbalagan et al., 2015), slope instability recognition (Soeters and van Westen, 1996), spatial distribution of mass movement. This kind of information can also be useful for urban land-use planning (Rahman and Islam, 2013). A detail landslide inventory for Cox′s Bazaar and Teknaf Municipalities has been prepared by Comprehensive Disaster Management Program (CDMP II, 2012) which can be considered as first attempt for this kind of study in Bangladesh. This attempt mentioned many challenges to prepare landslide inventory in small and medium towns. Preparation of landslide inventory is much more challenging in a fast growing large urban area.
It is important to understand the process and pattern of all landslides of a particular area from published records of landslide events of previous years. But there is no such record for Chittagong Metropolitan Area (CMA). Only the landslide events with casualty receive the attention through newspaper and media (Ahmed et al., 2014b). Therefore, the aim has been to prepare a detailed landslide inventory of CMA by incorporating the information from published media, information from local witness of the event, and from satellite image. This is probably the first attempt to prepare a landslide inventory for the second largest metropolitan city of Bangladesh. This paper presents the methodology, challenges and key findings of the landslide inventory work carried out in CMA under a project financed through International Center for Integrated Mountain development (ICIMOD), Nepal.

METHODOLOGY

Any study related to landslide hazard and risk begins with the investigation where previous landslide occurred. It is difficult to identify and characterize past events for variety of reasons. People might forget the event; an event may not be documented. Small landslide may not catch the attention to be documented properly, if this event did not involve casualty. Finding old document is much more challenging in developing countries where detailed documentation is overlooked in many cases. Furthermore, landslide inventory is challenging in an urban setting because rapid urbanization takes place on the site of landslide. The hills in Chittagong are small and in between urban area. Thus the signature of these landslides disappear quickly.
There are four fundamental assumptions summarized by Guzzetti et al., (2012) on which landslide inventory relies on. These assumptions are (i) landslide leave discernible signs, most of which can be recognized, classified and mapped in the field by image interpretations techniques. (ii) Landslides can be identified and mapped using a variety of techniques and tools, including the morphological signature depend on the type and the rate of mass movement. (iii) Landslide do not occur randomly or by chance. (iv) For landslides, geomorphologists adopt the principle that "the past and present are keys to the future". Many techniques for landslide inventory are available depending upon location, scope and purpose, scale of the map, and available resource for inventory preparation. Among these available tools and techniques, some of these techniques are popular and applied by many scientists around the world. These approaches are geomorphological field mapping (Brunsden, 1993), information collection on landslide from published documents (Guzzetti et al., 1994), visual image interpretation and stereo vision (Tsai et al., 2010; Cheng et al., 2004), surface or digital elevation monitoring (Tarchi et al., 2003; Farina et al., 2006). With the improvement of GIS and GPS technology, landslide inventory mapping is being facilitated by the location accuracy and mapping capacity of these advance technologies. Digital landslide inventory can be built using satellite based GPS system and GIS software. These mapping techniques have multiple benefits such as it can easily be incorporated with other data set, landslide can be visualized by type or other parameters, and the inventory data can also be used for data driven hazard and risk analysis. Guzzetti et al., 2012 suggest different techniques based on the scale of the map. Small scale inventory can be completed using data from literature, inquiries from public and from private organizations, searching journal, newspaper as well as from interview of experts and local people. Medium scale inventories can be done by systematic interpretation of images, photo interpretation, digital elevation monitoring and extensive field investigations.

This study is aiming for large scale inventory in an urban setting. The limited budget, limited access to aerial photograph and satellite image, as well as limited documentation has made this inventory mapping complex. This study integrates all of the techniques mentioned above except digital stereo interpretation.

Landslide Information Searching

The information on landslides have been searched in documents, reports, newspaper, digital archives etc. The information on date and casualty are available in news media for those landslides which have casualty. Therefore, the information on these events such as location, intensity, damage have been listed for further crosscheck and additional information. An initial field visit has been conducted to collect available information on past landslide events. During this initial visit, documents on landslide events and management have been collected from different government authorities, organizations and stakeholders. A list of vulnerable hills in CMA has been made with the help of the information from Department of Environment (DoE) and Chittagong Development Authority (CDA). Following a major landslide event, a committee comprising members from different stakeholders has always been formed to investigate that event. The investigation reports on such landslide events were also helpful for the documentation. A questionnaire was prepared to gather landslide information from local people and witness of the landslide events.

Field Survey

During the field survey, it was difficult to identify the exact landslide occurrence locations. Landcover alteration process remove the signature of landslides. In this field visit, information on location name, coordinates (latitude, longitude), area of displacement mass, rainfall information, landslide mechanism (type of movement, state, distribution, style, water content, material), existing land cover/ use type, causes of movement, landslide history (date of occurrence, duration of rainfall), consequences (casualties, injuries, damages, impacts) and future risk of landslide were collected as much as was available. Location name was collected by interviewing people. Coordinate values of landslide locations was determined by using GPS [Fig.1-a]. In case of some restricted/unreachable places, information was collected through interpreting Google earth image. The displacement of mass has been measured where possible [Fig.1-b]. Ground photographs of landslide site taken during field visit has also been added to the inventory [Fig.1-c]. Besides, landslide mechanism, causes of movement, landslide history and consequences have been collected from the local people as the collected documents could not provide sufficient information. The daily rainfall during and before the event from Bangladesh Meteorological Department is added to the inventory. However, for some landslide events, the exact date could not be found, as a result the rainfall data could not be provided for those landslide events in the inventory.

Figure 1: Field Survey (a) Taking GPS measurement (Latitude, longitude, and elevation) (b) Measuring displacement of mass, (c) Taking Photographs; Source: Field Survey, August, 2014

Visual Image Interpretation

Many landslides have been identified, however some of the information was difficult to find, for instance the surface area of displaced mass. The signatures of past landslide have been removed through land cover alteration and morphological change [Fig.2]. The goal is to draw the polygon of displacement mass to support landslide studies based on landslide density (e.g. empirical modelling such as information value, weights of evidence). The Google Earth time slider tool is providing free access to fine resolution (pan-sharpened submitter originally 2.5m DigitalGlobe image) historic image. The visual image interpretations technique has been applied to draw the polygon around the displacement mass. The figure 2 shows Kaichaghona area near Chittagong cantonment where a devastating landslide in June 2007 took many lives from foothill slum. Documentation of such landslide events in these restricted area is much more challenging. The remote sensing imageries are useful to deal with these challenges. Landslide signature extraction from visual or digital interpretation of remote sensing time series imagery can help landslide mapping.

Figure 2: Image shows the signature of October 29,2007 landslide (left) and the current situation during field visit in October 19,2014 (right); Source: Google Earth

Preparation of Inventory Map

The final step is to prepare landslide inventory. The coordinate pairs from field survey collected by GPS have been plotted using geographic coordinate system WGS 1984. The Google Earth historical images have also been downloaded. Polygons around displacement mass have been drawn based on the signature on satellite image captured after the event. The polygons are then projected to UTM 46 N system to map with other database such as Digital Elevation Model (DEM) and surface geology. Other attributes such as landslide types, activity area of displacement mass have been built with IDs related to spatial locations. The inventory is a GIS data layer shown as inventory map [Fig.3] which is handy and useful for landslide related studies.

RESULTS

The outcome of this study is an inventory of total 57 past landslide events in CMA. Majority of the area in this metropolitan are flat plains with no landslide activity. Hills are located in only central and north-west parts of the city. Landslides are accrued mainly between 30 to 60 m elevation above mean sea level. The natural slope of the area is gentle slope, however hill cutting activity makes some slopes steeper. Based on the slope calculated from Aster Global DEM (GDEM) data, landslides have mainly occurred between 30-40-degree slope. Because of the course resolution (30m) of ASTER GDEM, slope value may be showing lower slope than the actual. Thus these landslide locations might be actually steeper slope condition. During the field survey it has been observed that there are many landslide locations whose slope is near vertical. Most of the landslides are located in Dupi tila formation or Tipam sandstone geological class [Fig. 3]. It is difficult to judge the landslide state, style and types of movement after several years of occurrence where most of the signs of landslide have been removed. Therefore, most of the judgements are subjective and based on the description of the witness of the event. These witness are not the landslide expert, therefore the confidence of these judgement is not very high. From these subjective judgements, the types of the mass movement are mainly slide, fall and topple. Many of the landslides are still active because mud is falling down every year from these locations. Some of the sites are stabilized by the structural measures. Few of the landslide location became dormant because no activity took place after the event. The style of the landslides movement is single in most of the cases. The possibility of multiple landslide is very low due to the small hill area in urban setting. The landslide map [Fig. 3] and attribute table [Appendix A] show the detail information of each event.

Factors Affecting Landslide Distribution

The rainfall characteristic in Chittagong district is different from the other districts in Bangladesh because of its geographical location and orographic effect. Usually in the monsoon period the rainfall shows highest precipitation. Most of the landslides in this region occurred during incessant and prolonged rainfall. A heavy rainfall, 70 mm or more over a shorter period of time may lead to a fatal landslide event in this hilly area. Rainfall less than threshold value but over many consecutive days may also lead to landslide. The months of June and July show most landslide occurrences in Chittagong and show strong correlation between heavy rainfall and landslides in the country.

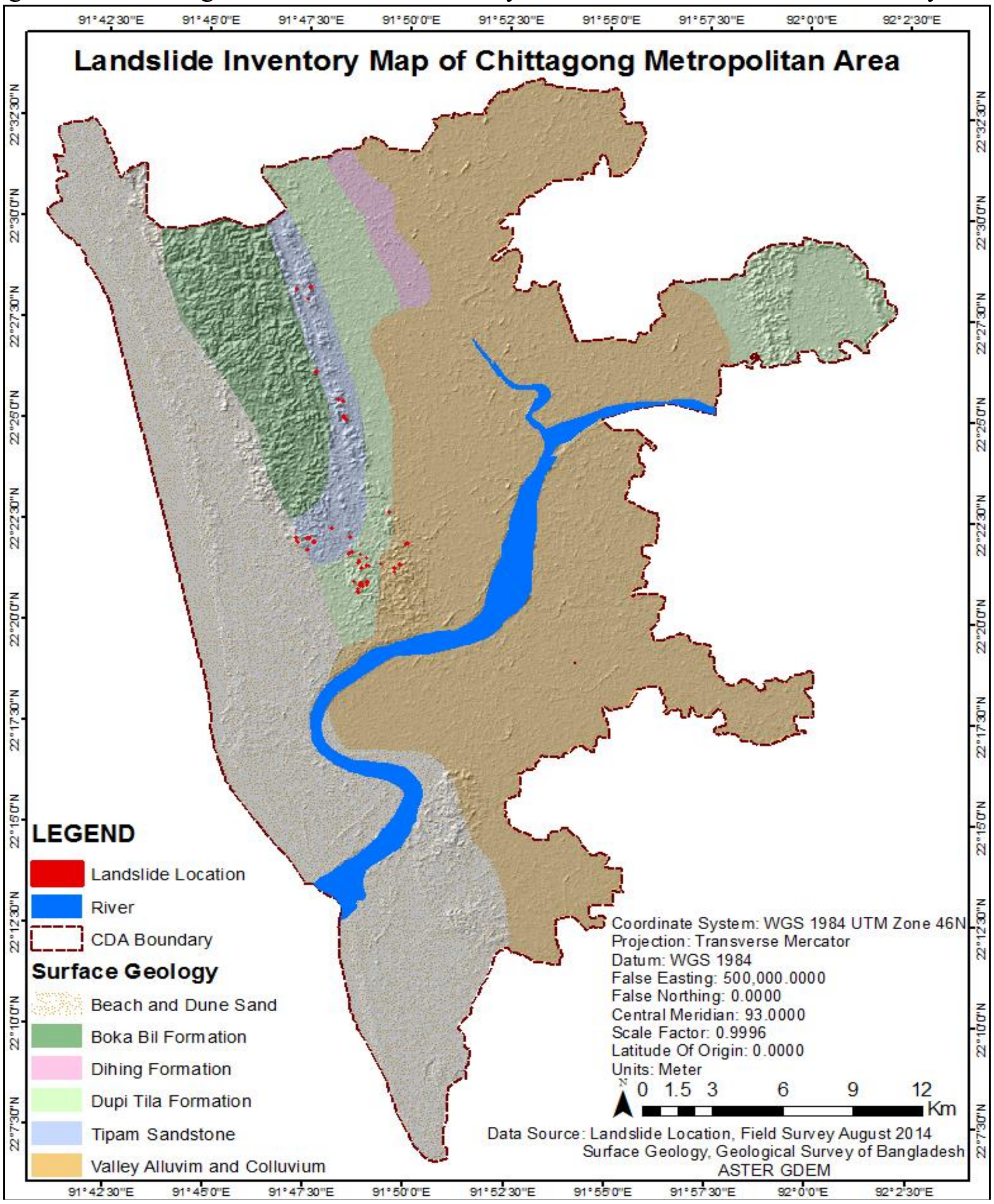

Figure 3: Land slide Inventory Map of Chittagong Metropolitan Area

Some Hills in CMA are indiscriminately being flattened and are diminishing due to building construction, residential development, road network development, soil mining. Some of the hill slopes are being steepened day by day and where hill cutting exists the slopes varies from 70-80 degrees which makes slopes unstable. The recent landslides in CMA were the result of hill cutting and steep slopes of the hills. The most affected areas are Khulshi, Panchlaish, Baizid Bostami, Kotowali, Lalkhan Bazar, Sholoshahar, Foy's Lake, Pahartali and Polytechnic area. Most of the landslide have occured in the heart of the city because informal settlements, high class residential area and commercial buildings are being established in the hill cutting context. The soil is mainly composed of silt and sand content. During the monsoon, heavy rainfall water can create significant pore water pressure in cracks which can destabilize the hill slope. Deforested areas of hills are easily exposed and top soils are eroded by surface run-off or by wind erosion. The vegetation covered areas are less vulnerable to landslide than deforested area. Seismic activities can also destabilize the hill slope triggering landslides. Besides hill in the Chittagong city in one third area are in low land which experiences abnormal tidal flow during monsoon period affecting its bottom.

CONCLUSIONS

A detail landslide inventory has been developed for the Chittagong Metropolitan Area. Landslides have appeared to be one of the most significant natural damaging disasters in CMA. The rapid hill cutting coupled with land cover change and increased intensity of rainfall has been causing devastating landslides in the port city. The landslide risk is very high in the city due to the vulnerability of homes built at the bottom of risky hill slopes. The landslide inventory is expected to be useful for future studies such as susceptibility modelling, slope stability modelling as well as urban land use planning. It is useful either for data driven modelling or for the validation of the result from deterministic or heuristic modelling. This study may be considered as first attempt for the documentation of landslides in Chittagong city from 1990 up to 2014. Dates of some landslides are not known. A total of 57 landslides are documented and mapped in this study. This inventory shows all landslide prone locations, historical landslides, landslide mechanism, elevation, area of displaced mass, casualty and future risk. Documentation of past event is always challenging. Rapid change in land cover, hill cutting activity in a fast growing urban context, poor documentation in a developing country like ours have made the inventory preparation a challenging task. Considering all challenges, it was a formidable job to prepare the first landslide inventory for the port city of Chittagong.

ACKNOWLEDGMENTS

This study was supported by a grant from the SERVIR-Himalaya Small Grant Program of International Center for Integrated Mountain development (ICIMOD) of Nepal. The project has been implemented by BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS) of Bangladesh University of Engineering and Technology (BUET). The authors would like to express their gratitude to USAID and NASA for their financial support to the SERVIR-Himalaya Program. The authors also would like to thank all urban planners working in Chittagong Development Authority (CDA), Director of DoE Chittagong, Chittagong Cantonment, and local people for their assistance and support during the field investigations.

REFERENCES

Ahmed, B. (2015). Landslide susceptibility mapping using multi-criteria evaluation techniques in Chittagong Metropolitan Area, Bangladesh. Landslides *12*, 1077–1095.

Ahmed, B., Rahman, M.S., Rahman, S., and Bejoya, F.F.H. (2014a). Social Survey Report on Landslide Vulnerability in Chittagong Metropolitan Area, Bangladesh. BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS); Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh. http://www.landslidebd.com/reports/ (last accessed on 30 July 2016)

Ahmed B, Rahman MS, Rahman S, Huq FF, Ara S (2014) Landslide inventory report of Chittagong Metropolitan Area, Bangladesh. BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS); Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh. http://www.landslidebd.com/reports/ (last accessed on 30 July 2016)

Anbalagan, R., Kumar, R., Lakshmanan, K., Parida, S., and Neethu, S. (2015). Landslide hazard zonation mapping using frequency ratio and fuzzy logic approach, a case study of Lachung Valley, Sikkim. Geoenvironmental Disasters 2, 1–17.

Brunsden, D. (1993). Mass movement; the research frontier and beyond: a geomorphological approach. Geomorphology 7, 85–128.

Cardinali, M., Galli, M., Guzzetti, F., Ardizzone, F., Reichenbach, P., and Bartoccini, P. (2006). Rainfall induced landslides in December 2004 in south-western Umbria, central Italy: types, extent, damage and risk assessment. Nat Hazards Earth Syst Sci 6, 237–260.

CDMP II (2012). Landslide Inventory and Landuse Mapping, DEM Preparation, Precepitation Threshold Value and Establishment of Early Warning Device (Ministry of Food and Disaster Management (MoFDM) Disaster Management and Relief Division (DMRD) Government of the People′s Republic of Bangladesh: Comprehensive Disaster Management Programme-II (CDMP-II)).

Chakraborty, P., and Uddin, M. (2014). Living in danger of landslide,The Daily Star.

Chau, K.T., Sze, Y.L., Fung, M.K., Wong, W.Y., Fong, E.L., and Chan, L.C.P. (2004). Landslide hazard analysis for Hong Kong using landslide inventory and GIS. Comput. Geosci.30, 429–443.
Cheng, K.S., Wei, C., and Chang, S.C. (2004). Locating landslides using multi-temporal satellite images. Adv. Space Res. 33, 296–301.
Chisty, K.U. (2014). Landslide in Chittagong City: A Perspective on Hill Cutting. J. Bangladesh Inst. Plan. 7, 1–17.
Farina, P., Colombo, D., Fumagalli, A., Marks, F., and Moretti, S. (2006). Permanent Scatterers for landslide investigations: outcomes from the ESA-SLAM project. Eng. Geol. 88, 200–217.
Guzzetti, F., Cardinali, M., and Reichenbach, P. (1994). The AVI Project: A bibliographical and archive inventory of landslides and floods in Italy. Environ. Manage. 18, 623–633.
Guzzetti, F., Mondini, A.C., Cardinali, M., Fiorucci, F., Santangelo, M., and Chang, K.-T. (2012). Landslide inventory maps: New tools for an old problem. Earth-Sci. Rev. 112, 42–66.
Hervás, J. (2013). Landslide Inventory. In Encyclopedia of Natural Hazards, P.T. Bobrowsky, ed. (Springer Netherlands), pp. 610–611.
Highland, L., Bobrowsky, P.T., and others (2008). The landslide handbook: a guide to understanding landslides (US Geological Survey Reston, VA, USA).
Mia, M.T., Sultana, N., and Paul, A. (2016). Studies on the Causes, Impacts and Mitigation Strategies of Landslide in Chittagong city, Bangladesh. J. Environ. Sci. Nat. Resour. 8, 1–5.
Rahman, M.S. (2012). Quantifying Urban Form-Compactness versus Sprawl: An Analysis of Chittagong and Sylhet Metropolitan Cities. Jahangirnagar University Planning Rev.10, 39–50.
Rahman, M.S., and Islam, M.A. (2013). Decentralization in Urban Land-Use Planning in Bangladesh: Rationality of the Scene Behind a Screen. Planned Decentralization: Aspired Development, Bangladesh Institute of Planners. 5-14.
Rahman, M.S., and Kausel, T. (2012). Disaster as an Opportunity to Enhance Community Resilience: Lesson Learnt from Chilean Coast. J. Bangladesh Inst. Plan. ISSN 5, 1–11.
Rahman, M.S., Islam, B., and Ahmed, B. (2012). An Overview on Rapid Urbanization and Induced Disaster Risk Factors in Bangladesh. In World Town Planning Day 2012, Bangladesh Institute of Planners. 56–64.
Soeters, R., and van Westen, C.J. (1996). Slope instability recognition, analysis and zonation. Landslides Investig. Mitig. Transp. Res. Board Natl. Res. Counc. Spec. Rep. 247, 129–177.
Tarchi, D., Casagli, N., Fanti, R., Leva, D.D., Luzi, G., Pasuto, A., Pieraccini, M., and Silvano, S. (2003). Landslide monitoring by using ground-based SAR interferometry: an example of application to the Tessina landslide in Italy. Eng. Geol. 68, 15–30.
Tsai, F., Hwang, J.-H., Chen, L.-C., and Lin, T.-H. (2010). Post-disaster assessment of landslides in southern Taiwan after 2009 Typhoon Morakot using remote sensing and spatial analysis. Nat Hazards Earth Syst Sci 10, 2179–2190.

Appendix A: Detail Landslide Inventory of Chittagong Metropolitan Area

ID	Latitude	Longitude	Elevation (m)	Date (d-m-y)	Hill Name	Area of mass (m2)	Types	State	Style	Rainfall (mm)	Casualty
1	22.3476	91.8138	55.95	28/07/2013	Motijhorna	89.91	Fall	Stabilized	Single	26	2
2	22.3473	91.8147	51.79	28/07/2013	Motijhorna	116.32	Fall	Stabilized	Single	26	2
3	22.3480	91.8165	44.46	11/6/2007	Tankir Pahar	11.02	Topple	Active	Single	88	0
4	22.3493	91.8166	32.56	22/06/2014	Chanmari Bi Lane	15.03	Topple	Stabilized	Single	54	0
5	22.3484	91.8143	41.18	1998, 2013	Tankir Pahar	331.84	Slide	Reactivated	Single	26	22
6	22.3488	91.8139	47.04	15/06/2010	Tankir Pahar	211.06	Slide	Reactivated	Single	77	11
7	22.3479	91.8131	44.26	23/8/2008	Batali Hill	59.1	Fall	Active	Single	50	0
8	22.3464	91.8127	55.03	1/7/2011	Batali Hill	126.7	Fall	Active	Successive	55	0
9	22.3451	91.8128	31.66	1/7/2011	Tiger Pass	427.04	Topple	Active	Single	55	17
10	22.4174	91.8064	30.82	11/6/2007	Lebu Bagan	757.61	Slide	Dormant	Single	88	30
11	22.4179	91.8062	41.22	11/6/2007	Lebu Bagan	84.56	Slide	Dormant	Single	88	5
12	22.4180	91.8062	40.19	11/6/2007	Lebu Bagan	50.17	Slide	Dormant	Single	88	2
13	22.4246	91.8041	37.64	11/6/2007	Kaichaghona	145.5	Slide	Stabilized	Single	88	2
14	22.4239	91.8058	24.71	11/6/2007	Kaichaghona	582.27	Slide	Stabilized	Single	88	7

ID	Latitude	Longitude	Elevation (m)	Date (d-m-y)	Hill Name	Area of mass (m2)	Types	State	Style	Rainfall (mm)	Casualty
15	22.4330	91.8073	46.07	11/6/2007	Lebu Bagan	1359.5	Slide	Dormant	Single	88	40
16	22.4360	91.7949	40.68	11/6/2007	Sekandar Para	181.7	Slide	Stabilized	Single	88	3
17	22.4358	91.7946	45.36	11/6/2007	Sekandar Para	198.89	Slide	Stabilized	Single	88	2
18	22.4362	91.7948	48.51	11/6/2007	Sekandar Para	211.61	Slide	Stabilized	Single	88	4
19	22.3551	91.8141	32.39	-	Espahani Hill	233.06	Fall	Active	Successive	-	0
20	22.3559	91.8172	26.98	-	Kusumbagh	152.79	Fall	Active	Successive	-	0
21	22.3560	91.8167	36.68	-	Goribullal Shah	241.79	Topple	Active	Successive	-	0
22	22.4711	91.7920	39.81	11/6/2007	Ctg. University	390.34	Topple	Active	Single	88	0
23	22.4702	91.7861	38.64	11/6/2007	Ctg. University	1134.77	Slide	Active	Single	88	0
24	22.4706	91.7921	35.18	11/6/2007	Ctg. University	313.42	Topple	Active	Single	88	0
25	22.4660	91.7910	37.92	24/06/2000	Ctg. University	212.7	Topple	Active	Single	46	0
26	22.3672	91.7869	58.72	1990	Gol Pahar	105.38	Fall	Active	Successive	-	0
27	22.3653	91.7876	45.69	1990	Gol Pahar	157.07	Fall	Active	Successive	-	0
28	22.3657	91.7872	45.12	1990	Gol Pahar	77.81	Slide	Active	Successive	-	0
29	22.3624	91.7917	28.41	11/6/2007	Akbar Shah Hill	213.26	Fall	Active	Single	88	7
30	22.3658	91.7943	38.51		Lal Pahar	153.55	Topple	Active	Successive	-	0
31	22.3672	91.7924	45.42	26/06/2012	Foy'z lake Obser.	456.7	Slide	Active	Successive	111	0
32	22.3673	91.7918	46.51	26/06/2012	Foy’z Lake Zoo hill	209.12	Slide	Active	Successive	111	0
33	22.3667	91.7914	34.63	26/06/2012	Foy’z Lake Zoo hill	45.86	Slide	Active	Successive	111	0
34	22.3672	91.7912	48.67	26/06/2012	Foy’z Lake Zoo hill	75.88	Slide	Active	Single	111	0
35	22.3675	91.7915	56.36	26/06/2012	Foy’z Lake Zoo hill	232.52	Slide	Active	Single	111	0
36	22.3575	91.8129	19.84	3/8/2005	Nasirabad Housing	208.57	Slide	Active	Single	25	1
37	22.3592	91.8160	23.5	3/8/2005	Nasirabad Housing	242.53	Slide	Active	Single	25	1
38	22.3609	91.8137	35	28/07/2013	Jakir Hossain Road	56.05	Fall	Active	Single	26	0
39	22.3617	91.8102	26.57	28/07/2013	Holy Crescent	52.3	Slide	Active	Single	26	0
40	22.3679	91.8092	13.93	-	AKS Brick Field	301.06	Slide	Active	Single	-	0
41	22.3715	91.8016	15.93	-	Krishnochura	145.06	Slide	Active	Single	-	0
42	22.3716	91.8013	15.11	-	Krishnochura	76.43	Topple	Active	Single	-	0
43	22.3583	91.8131	32.44	-	Nasirabad Housing	175.81	Topple	Active	Single	-	0
44	22.3610	91.8090	19.33	28/07/2013	Holy Crescent	50.26	Topple	Stabilized	Single	26	0
45	22.3551	91.8278	46.4	-	Finley Hill	130.32	Slide	Stabilized	Successive	-	0
46	22.3556	91.8277	50.12	-	Finley Hill	118.34	Slide	Stabilized	Single	-	0
47	22.3536	91.8281	29.28	-	Dolphin Hill	47.04	Slide	Active	Single	-	0
48	22.3564	91.8303	27	May-14	Medical Hill	16.5	Fall	Active	Single	-	0
49	22.3564	91.8302	23.12	May-14	Medical Hill	31.67	Fall	Active	Single	-	0
50	22.3650	91.8333	18.1	28/07/2013	The King of Ctg.	184.13	Slide	Active	Single	26	0
51	22.3651	91.8326	18.1	28/07/2013	The King of Ctg.	191.64	Slide	Active	Single	26	0
52	22.3566	91.8299	21.59	01//07/2011	Medical Hill	226.23	Fall	Active	Single	55	0
53	22.3566	91.8301	22.64	01//07/2011	Medical Hill	136	Fall	Active	Single	55	0
54	22.3493	91.8113	48.36	28/07/2013	AK Khan hill	33	Fall	Active	Single	26	0
55	22.3782	91.8255	37.54	-	Amin Textile	71.93	Topple	Active	Single	-	0
56	22.3782	91.8256	34.21	-	Amin Textile	71.93	Topple	Active	Single	-	0
57	22.3568	91.8256	21.31	28/07/2013	Blossom Garden	188.59	Slide	Stabilized	Single	26	0

***Note: GIS database of this inventory can be released on request for any research purpose. Please contact with corresponding author for the GIS database.*

Appendix B: A Sample of Detail Inventory

<table>
<tr><th colspan="2">Basic Information</th></tr>
<tr><td>Landslide ID :05
Landslide Location: Tanker Pahar, Motijhorna
Coordinates: 22˚ 20’54.27’’N, 91˚ 48’51.60’’E</td><td>Datum: WGS 1984
Elevation (m): 41.18
Area of Displaced Mass (sqm): 331.84
Rainfall: Unknown</td></tr>
<tr><td>
Source: Field survey, August 2014</td><td>
Source: Field survey, August 2014</td></tr>
<tr><th colspan="2">Landslide Mechanism</th></tr>
<tr><td>Type of Movement: Slide
State: Active, Reactivated, Suspended
Distribution: Advancing</td><td>Style: Single
Water Content: Moist
Material: Soil/Earth</td></tr>
<tr><td colspan="2">Land Cover/Use Type (%):
Herbaceous vegetation is the Primary land cover of Tanker Pahar. Forest/ woodland type is also visible in this hill.</td></tr>
<tr><td colspan="2">Causes of Movement:
Hill cutting is the major issue that caused landslide in this area and intense rainfall acted as a triggering factor for landslide.</td></tr>
<tr><th colspan="2">Land Slide History and Future Risk of Landslide</th></tr>
<tr><td colspan="2">Landslide in this site occurred in 1982, 1989,1991,1994,1996 and 2013. 10 houses got damaged and almost 22 people died due to landslide at different periods. Utility facilities were highly damaged in this incident. Economic activities were hampered so does the social life of people. Environment has been found to be severely damaged. Still there are many houses located at the down slope of the hill. Soil of this site has been found to be sandy. The escapement slope is found to be near vertical. The failed mass is a part of upper portion. Vertical Slope characteristics can be considered as a contributing factor to future landslide for this hill. Settlements located at the down slope of this hill are at a huge risk of massive landslide. The risk is high (Field survey, August 2014).</td></tr>
</table>

*** Note: For more details please see the technical report of the project (Ahmed et al., 2014b)*