TECHNICAL REPORT

PROJECT NAME:

Developing Dynamic Web-GIS based Early Warning System for the Communities at Landslide Risks in Chittagong Metropolitan Area, Bangladesh

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1. INTRODUCTION

1.1 Background of the Project

The hilly areas of Bangladesh are vulnerable to landslide as like as the other hilly regions of the world. Every year landslide occurs in the port city of Chittagong in south-eastern part of Bangladesh (Table 1). Heavy rainfall during monsoon causes single and multiple landslides that destroy the houses as well as lives of slum dwellers around the hilly areas. Landslide causes damage to properties, death to people and collapse social life. To mitigate the death loss, it is necessary to develop a scientific warning system for the people of those areas so that they can move to the other places when there is a possibility to landslide (Figure 2).

In this connection, this project is being conducted namely 'Developing Dynamic Web-GIS based Early Warning System for the Communities at Landslide Risks in Chittagong Metropolitan Area, Bangladesh'. The project is funded by SERVIR-Himalaya, a joint initiative of USAID (United States Agency for International Development) and NASA (National Aeronautics and Space Administration). The International Centre for Integrated Mountain Development (ICIMOD) assists the project.

The aim of this project is to create a dynamic website that will warn the landslide vulnerable communities of Chittagong Metropolitan Area (CMA) in advance. To achieve this goal it is necessary to understand the mechanisms of landslides, lithology, the human ecology to landslides, decision making process, preparing the predictive susceptibility maps, and analyze the rainfall pattern of CMA. The website will incorporate all the relevant information and apply advanced geospatial technologies. This will help in reducing the impact of landslide risks on the people of Chittagong city.

Table 1: Major landslide events in CMA in recent years.
Source: Comprehensive Disaster Management Programme-II (CDMP-II), Ministry of Food and Disaster Management, Bangladesh; and Field Survey, September 2013.

Date	Location	Rainfall sequence (cumulated rainfall)	Consequences
13 August 1999	Gopaipur, Kotwali Thana, Chittagong	435 mm – 12 days 2 – 13 Aug 1999	10 people killed
24 June 2000	Chittagong University Campus	108 mm – 8 days 17 – 24 June 2000	13 people killed and 20 injured
29 June 2003	Patiya, Chittagong	658 mm – 10 days 20 – 29 June 2003	4 people killed
3 August 2005	Nizam Road Housing Society, Panchlaish area	25 mm – 2 days 2-3 August 2005	2 people killed and 12 injured
11 June 2007	Moti JharnaColony, Lalkhan Bazar	610 mm – 8 days 4 – 11 June 2007	128 people killed and 100 injured
10 September 2007	Nabi Nagar, Chittagong	452 mm – 7 days 4 – 10 Sept 2007	2 people killed
18 August 2008	Moti Jharna, Chittagong	454 mm – 11 days 8 – 18 August 2008	11 people killed and 25 injured
26 June 2012	Lebubagan area and Foy's lake surroundings	889 mm – 8 days 19 – 26 June 2012	90 people killed and 150 injured

1.2 Objectives of the Project

This project will extensively use geospatial information, latest techniques and tools related to geoinformatics and spatial statistics to achieve the following objectives:

(a) To establish the nature of relationships among land cover change, rainfall, climate change and landslide disaster.
(b) To produce the landslide susceptibility maps of CMA.
(c) To understand human adaptation to landslide risks under the condition of rapid urbanization and torrential rainfall.
(d) To assess community needs for effective implementation of early warning system for landslide.
(e) To create a web-based dynamic model to early warn the people living in landslide vulnerable zones in CMA.

2. METHODOLOGY

2.1 Study Area

Chittagong is the second largest and main seaport of Bangladesh. The city comprises of flat land, small hills and narrow valleys; bounded by the *Karnaphuli* River to the south-east, the Bay of Bengal to the west and *Halda* River to the north-east (Figure 1-b). The city has a population of about 5 million and is constantly growing [1]. The study area, CMA is situated within 22° 14′ and 22° 24′ 30” North Latitude and between 91° 46′ and 91° 53′ East Longitude (Figure 1-b). The total area of CMA is approximately 775 square kilometres.

Figure 1: (a) Location of the study area in Chittagong hill tracts and (b) Location of CMA.

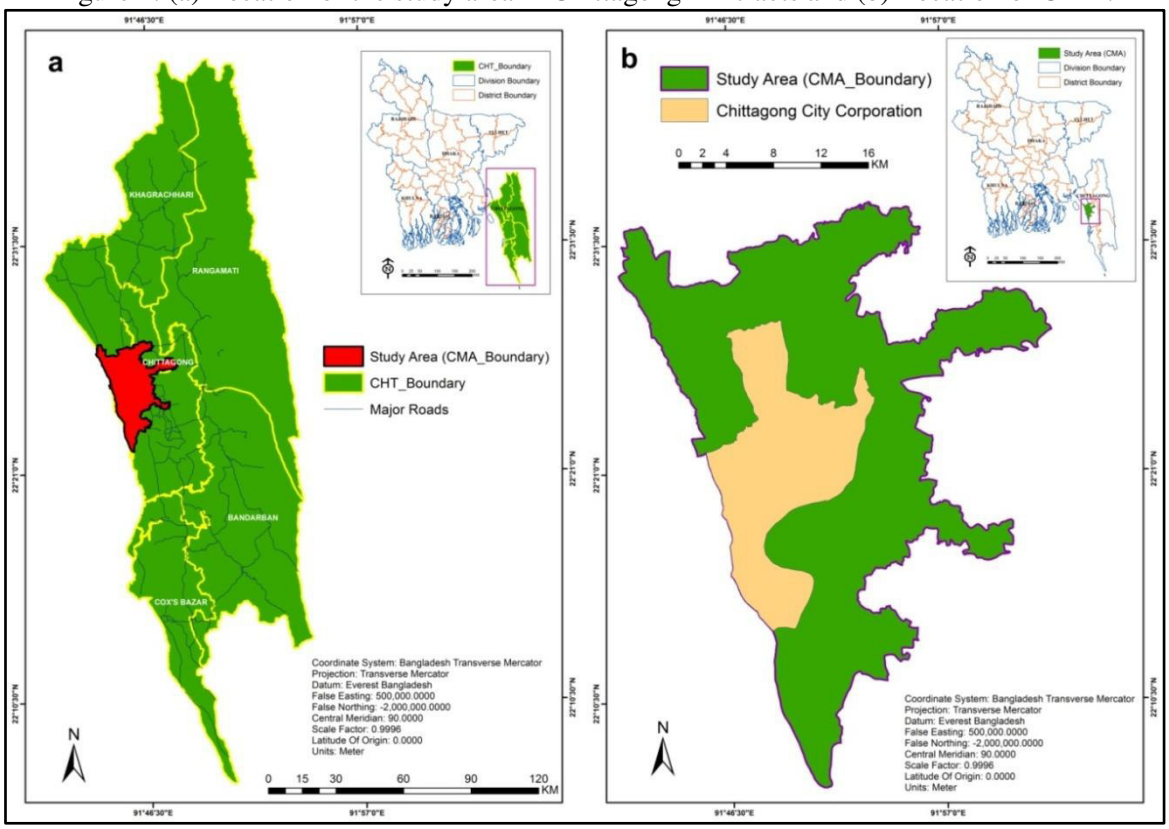
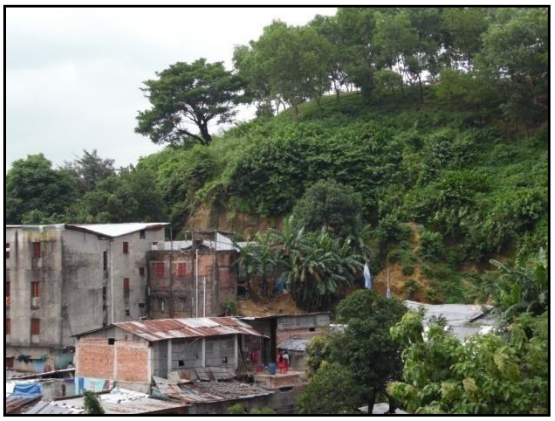


Figure 2: Landslide vulnerable areas in Moti Jharna, CMA
Source: Field Survey, September, 2014




2.2 Study Methods

The project was designed in different phases. At first, a detailed inventory of landslide locations was made. Then individual and community people were surveyed in social survey phase. The soil properties of the study area were tested. Then land cover modelling, rainfall pattern modelling was prepared for the study area. After that landslide susceptibility map and slope stability mapping are made for the same area. Finally, the web-GIS based early warning system is developed by coding and using these maps.

2.3 Data Collection and Processing

i) *Landslide Inventory:* In the inventory phase, after asking so many of the local people, 57 previous landslide locations were indentified and classified into 10 clusters. Location name, coordinates (latitude, longitude), datum and elevation, area of displacement mass, rainfall, 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.

ii) *Social Survey:* 57 locations from inventory stage were organized into ten clusters based on the landslide hazard locations, tentative similarity of the surroundings and landslide mechanisms. At this stage, Moti Jharna and Batali Hill of cluster 1, Golpahar of cluster 5 and Goachibagan Medical Hill of cluster 9 have been selected for social vulnerability analysis. These sites have been selected based on maximum numbers of previous landslide events and settlement density.

iii) *Soil Testing:* The soil properties like percentage of sand, clay, silt; liquid limit, plastic limit and specific gravity are tested after collecting soil sample from four selected areas.

iv) *Land Cover Modelling:*
The land cover map of the study area is prepared for 1990, 2000 and 2010 using the Landsat Satellite images. Based on the change detection and transition probabilities a projected land cover map is prepared for 2030.

v) *Rainfall Pattern Modelling:* The daily rainfall data from 1950-2010 is collected from the Bangladesh Meteorological Department (BMD). All the maps are projected in 'Bangladesh Transverse Mercator (BTM)' projection system and the datum is used as 'Everest 1830'. At first, the rainfall pattern based on the previous years is analyzed using "RClimDex". The RClimDex is developed and maintained by Xuebin Zhang and Feng Yang at the Climate Research Branch of Meteorological Service of Canada [2]. In the later section, based on the past trend, the future rainfall pattern is predicted using 'IDRISI Selva' and 'ArcGIS 10.2' software.

vi) *Landslide Susceptibility Mapping:* For this research purpose, 9 different GIS layers have been produced. They are: land cover map, precipitation map, landslide inventory map, elevation and slope map, NDVI map, distance to road map, distance to drain map, distance to stream map and distance to permeability map. The road network, drainage network and water body layers were collected from the Chittagong Development Authority (CDA). The distance images from all these layers were prepared using 'Euclidean Distance' technique which gives the distance from each cell in the raster to the closest source

vi) *Slope Stability Mapping:*

A slope stability map of the Chittagong Metropolitan Area (CMA) can be made based on the "infinite slope" model. Digital Elevation Model, Saturated Hydraulic Conductivity Map, Local Drainage Direction (LDD) Map, Soil Depth Map, Land Cover Mapping, Soil Related Map, Land Cover Map, Landslide location map etc. are used in this case.

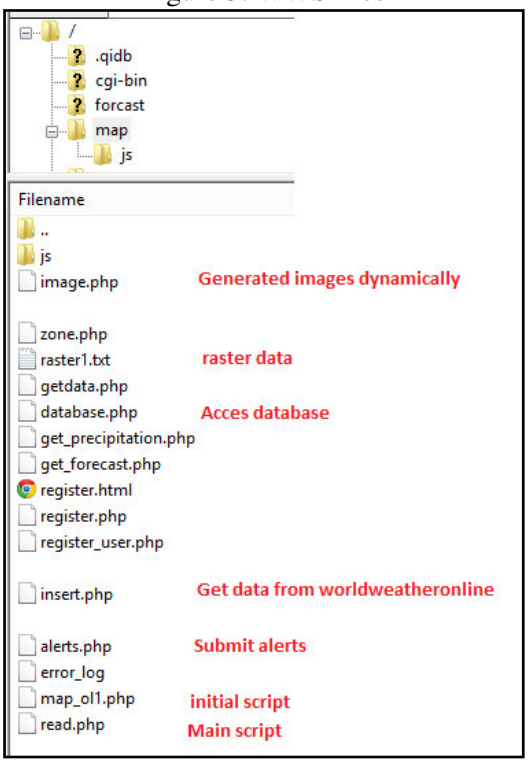
vii) *Developing the Web-GIS Early Warning System:*

At first, a website domain and hosting was registered for 3 years. Then the website was designed for developing the alert system. The alert system was developed combining the susceptible zones from susceptibility map and the rainfall threshold for corresponding zones. The Web Warning System (WWS) displays different risk areas according to precipitation in the study area. The precipitation data is updated from worldweatheronline.com once a day. The system is able to send warning emails to the registered users about the affected areas according to forecast precipitation. The WWS was developed using the following tools: PHP and javascript APIs: OpenLayes, W2UI and jQuery. The system receives a reclassified raster dataset to generate the risk areas. A special raster format was created to speed up the display of the risk areas using PHP. This new format is generated by a new plugin in dotspatial (http://codeplex.dotspatial.com) (Attached the c# solution and compiled version - Demomap.exe).

The precipitation and users data are stored in a MySQL dababase. Images of the raster dataset are generated dynamically using PHP using the raster1.txt file (generated by dotspatial-plugin). In order to update the system, it is just needed to upload a new version of raster1.txt file.

The read.php file contains all PHPscripts thatrequire WWS. The starting point of the application is the map_o11.php. The list of files require by WWS are shown in the figure 3.

Figure 3: WWS files



2.4 User Engagement

i) *Stakeholder Meeting:*

A Stakeholder meeting was arranged by Chittagong Development Authority (CDA) on September, 2014 (Figure 4). The meeting was held at CDA premises in presence of the Chairman and others personnel of CDA, journalists, interest groups, project team and a team of ICIMOD. The chairman of Chittagong Development Authority said that this project is a befitted initiative towards a planned Chittagong City. There was an open discussion among the people who were present in the meeting. They exclaimed that this initiative is appreciable and if this early warning system is open, the local people will be benefitted for sure.

Figure 4: Stakeholder Meeting in CDA (September, 2014)

ii) *Knowledge Sharing Meeting:*

A knowledge sharing meeting about landslide risk and early warning system for Chittagong City was held on 3rd March, 2015 at CUET Resource Center in Institute of Engineers Bangladesh (IEB), Chittagong (Figure 5). BUET-JIDPUS and the Department of Disaster and Environmental Engineering (DEE), CUET jointly organized this roundtable meeting. Dr. Ikuo Towhata, renowned Professor of The University of Tokyo, Japan was the main speaker. The experts from different organizations participated in the meeting. They said that this study will help to predict the loss of lives and structures due to landslide hazard.

iii) *Community Survey:*

The people in vulnerable hills are surveyed during the social survey phase (Figure 7). Beside the structured questionnaire survey, the project team talked about other related issues. The people were very cooperative. They discussed openly about their problems, wish and future plan. They gave idea about their life style, their coping with landslide etc. they emphasized in preserving the hills in a natural way like tree plantation, construct retaining wall etc. They expect that government and other organization will come forward with a mitigation measure rather than evict them.

Figure 5: Knowledge Sharing Meeting in IEB, Chittagong (March, 2015)

Figure 6: National Seminar at BUET-JIDPUS , Dhaka (September, 2015)

Figure 7: Community Survey (September, 2014)

Figure 8: Awareness Building Program (June, 2015)

iv) *Awareness Building Program:*

A social awareness building program on landslide risk and its early warning system for Chittagong City was held on June 13, 2015 at Ward Commissioner's office of ward number 14 in Chittagong City Corporation (CCC), Lalkhan bazaar (Figure 8). BUET-JIDPUS organized this meeting with the help of Ward Commissioner, ward number 14. Ward Commissioner Mr. A. F. Kabir Ahmed Manik was the main speaker. In addition, Md. Shahinoor Rahman, Assistant Professor of BUET-JIDPUS gave a brief description of Web-GIS Based Early Warning System, its application and usefulness. Moreover, people were made aware about what to do before, during and after landslide. The people of the landslide vulnerable communities were present there and they expressed their opinion about this early warning system.

v) *National Seminar:*

The National Seminar on the project was held on 17th September, 2015 at BUET-JIDPUS building and organized by BUET-JIDPUS (Figure 6). A total of 35 participants from different organizations related to landslide research and mitigation program were present on this occasion. The representatives from Chittagong Development Authority (CDA), Chittagong City Corporation (CCC), Department of Environment (DoE), Fire Service and Civil Defence (FSCD), Bangladesh Meteorological Department (BMD), Geological Survey of Bangladesh (GSB), The University of Chittagong, Chittagong University of Science and Technology (CUET), Bangladesh University of Science and Technology (BUET) were present on the program.

In the National Seminar the researchers, teachers and officials from different organizations appreciated the early warning system developed in this project. They congratulated BUET-JIDPUS for establishing this sophisticated system within the time and budget constraint. They hope that this system will be developed further with new budget after having the feedback from practical field and field calibration. They were very much satisfied with the presentation and happy for being a part of this program.

3. RESULTS/ OUTPUTS

The major outcome of this project is to develop a website (www.landslidebd.com) where anyone can access the project related information such as study area, reports, photographs, rainfall forecast data etc. If anyone enters to the website, he/ she can see the precipitation data (in mm) of the last 30 days and also the rainfall forecast for the next five days (Figure 9 and Figure 10). The website will give warning for landslide, based on the updated precipitation data from worldweatheronline.com. One has to register simply entering name and e-mail address to the website (Figure 11). After completing the registration he/ she will get the early warning through that e-mail address when there will be a possibility of landslide. The authority and the stakeholder can get a scientific early warning in this process.

After working as a pilot project, if this system is successful then it will be open for all. Through this system we can give warning for a particular area where there is a possibility to landslide (Figure 12). This model will be dynamic. It means the vulnerable zones of a certain area will be changed based on the intensity of rainfall and soil characteristics. We hope the

people residing in those areas will be warned through this system in near future and there will be no more death and property loss due to landslide.

Figure 9: Precipitation data for last 30 days.
Source: www.lanslidebd.com. (accessed on 29th July, 2015).

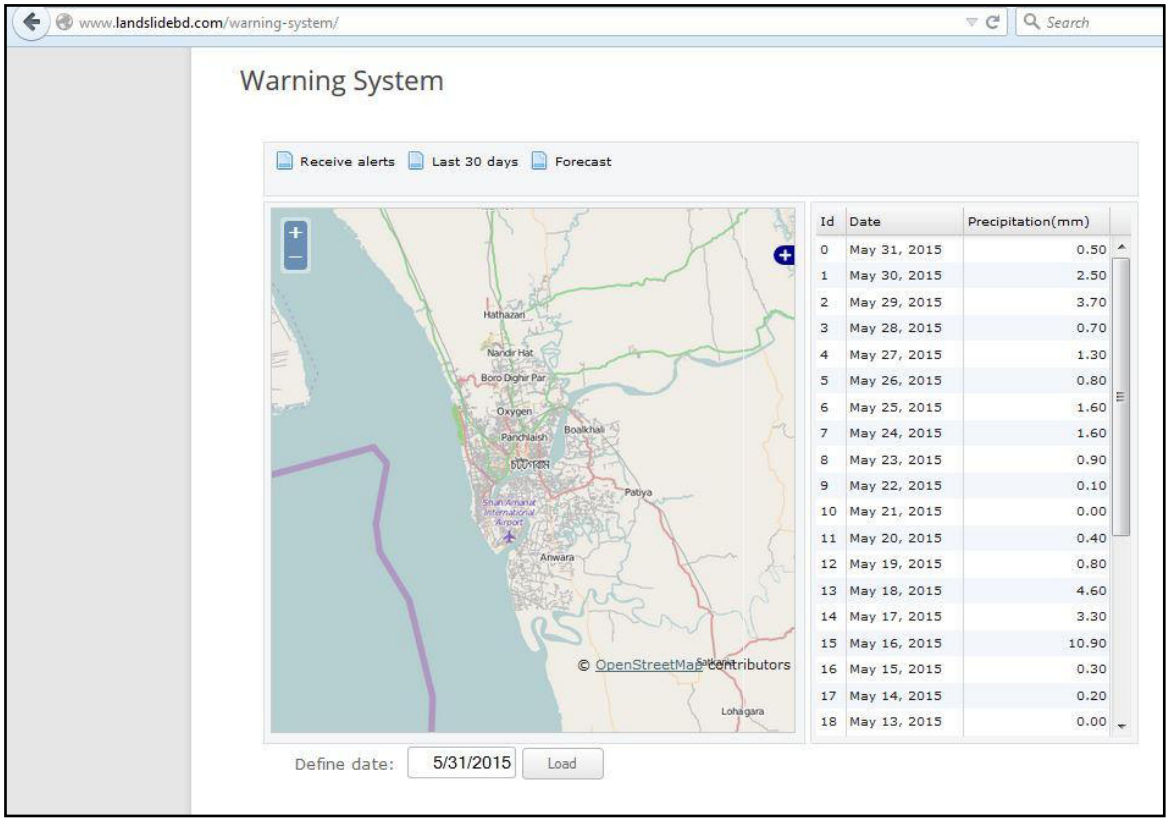


Figure 10: Forecast of precipitation data for next 5 days.
Source: www.lanslidebd.com. (accessed on 29th July, 2015).

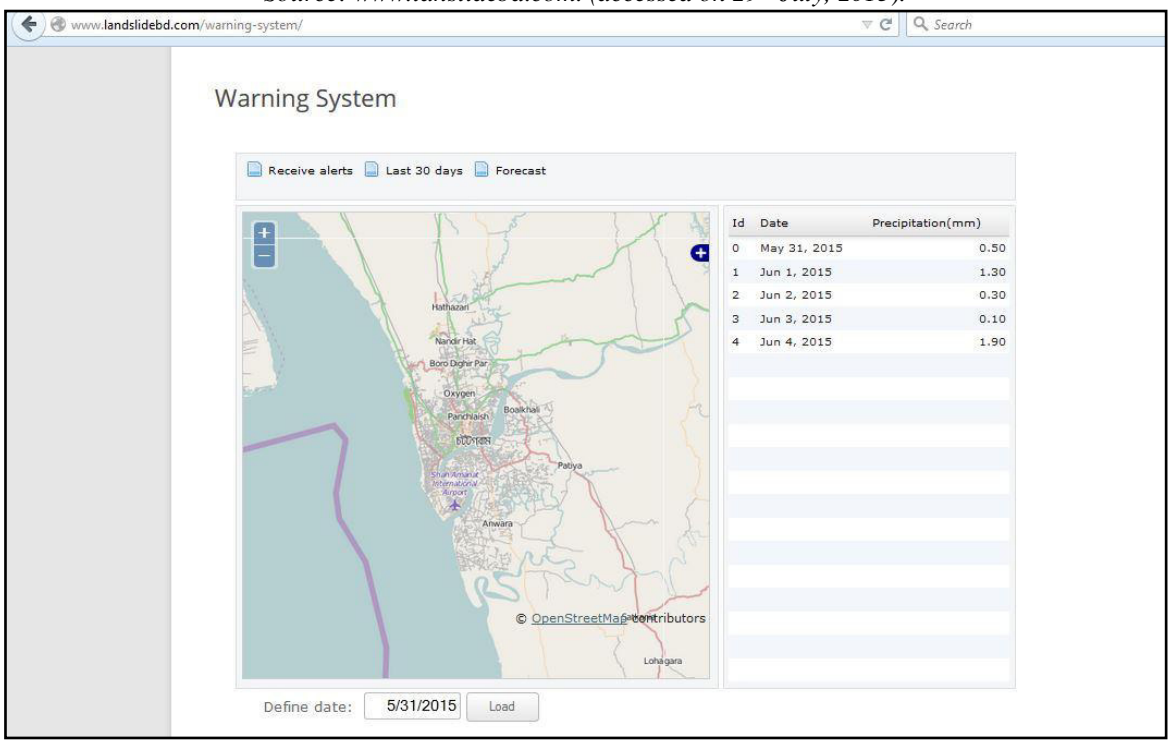


Figure 11: Registering process entering name and e-mail address.
Source: www.lanslidebd.com. (accessed on 29th July, 2015).

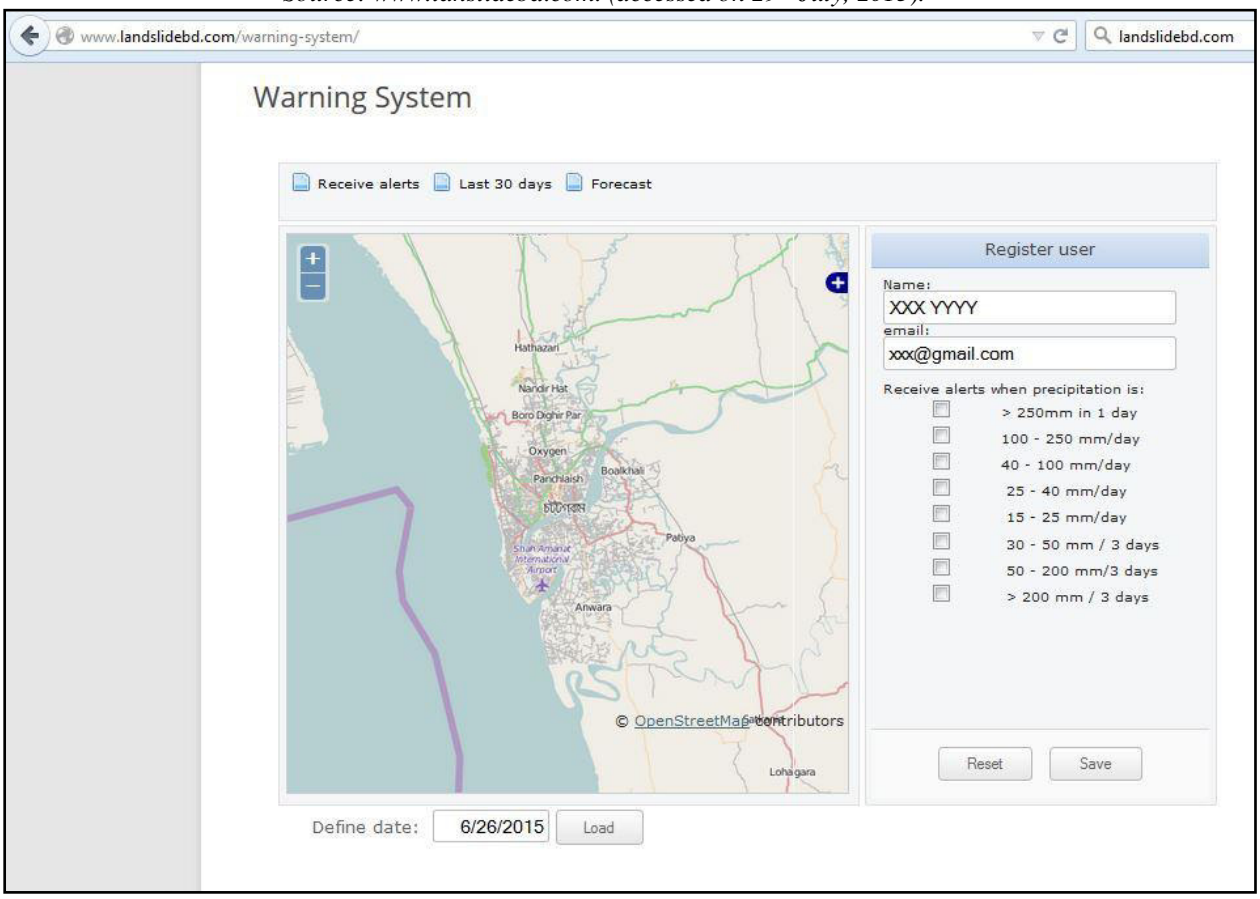
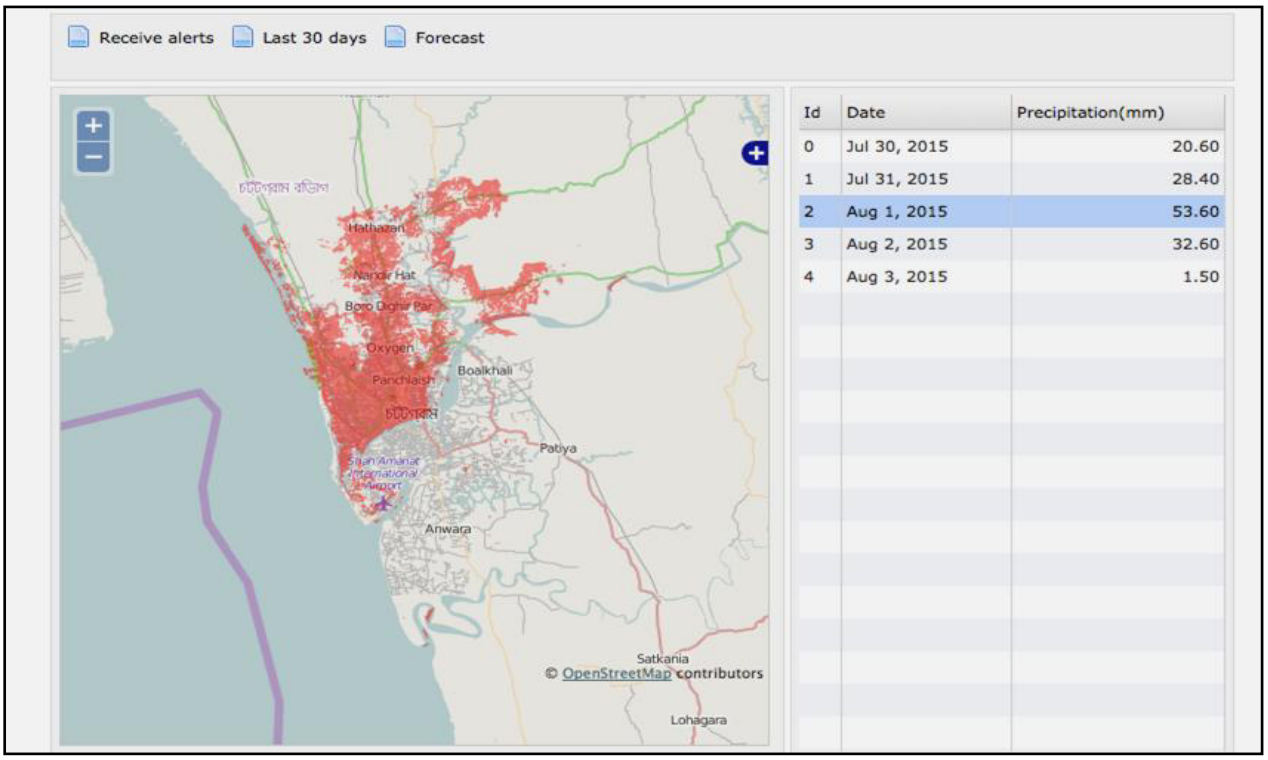


Figure 12: Map showing the areas with landslide probability for five days in advance.
Source: www.lanslidebd.com. (accessed on 29th July, 2015).



4. DISCUSSION ON THE RESULTS

The landslide early warning system, which is now operational and can be accessed *via* www.landslidebd.com, sends alert messages to the registered email addresses five days in advance. The rainfall data is obtained from www.worldweatheronline.com; a UK-based private company. Users can also access to the probable landslide location maps along with precipitation data for the last 30 days. The website contains different features and project related information on study area, reports, photos, videos, and newspaper links. Anyone can enter the website and download the reports on rainfall pattern analysis, land cover modeling, community vulnerability, soil investigation, slope stability and Web-GIS warning etc. People can get ideas on landslide risk scenario through the documentary videos, field level photographs and links related to landslide devastation in CMA. The website can assist the authorities like Chittagong Development Authority (CDA), Chittagong City Corporation (CCC), Department of Environment (DOE), fire services and others who are officially engaged in landslide warning, rescue and relief efforts.

The study found that majority of victims of landslide incidents are those who live in informal settlements, generally migrants who have come from other parts of Bangladesh in search of better livelihood options. Most of them work as day labourer, rickshaw puller, auto rickshaw driver or retail businessman. The rents in such places are generally lower but the buildings do not meet the standards set by the government.

Land cover modelling as conducted in this study finds that CMA went through a massive change (i.e. increase of urban builtup area) in land cover from 1990 to 2010. The basic soil characteristic is sandy, which is further aggravated by land cover change and deforestation activities. As a result, rainfall for 5-7 consecutive days can trigger the hills to initiate landslides.

Moreover, landslide susceptibility and slope stability modeling are also conducted in this project. The outcome of slope stability modeling can provide information on slope and geo-physical characteristics, and engineering properties of soil. The landslide risk sensitivity as found from the modeling repots will help the concerned authorities to carry out risk sensitive landuse planning for CMA.

The study also finds that pressure on hill slopes can be reduced if the people are relocated permanently following the hill protection policy and landuse control measures. As it is a long term procedure, therefore, it is suggested that the immediate response should be on raising awareness, providing effective early warning system, and construct retaining wall surrounding the hills to reduce the risk.

5. SUCCESS STORY AND KEY CHALLENGES

Every year during the rainy season landslides cause human casualties and property damage in Chittagong Metropolitan Area (CMA), Bangladesh. On 19th July 2015, landslides in Bayezid Bostami and Lalkhan areas of CMA killed 6 people. In 2011, landslide caused by a wall collapse in Lalkhan Bazaar area killed 17 people. The worst to hit was in 2012 that caused at least 110 casualties in CMA.

To address this issue, BUET-JIDPUS took an initiative in 2014 to develop an information system that can provide landslide early warning to the vulnerable communities. The project is administered by the ICIMOD and funded by the USAID and NASA.

Usually landslide warnings are conveyed with traditional practice of alerting people through a loud speaker within a couple of hours before a disaster event. The local authorities' predictions are based on observation of rainfall for the last few days. Such methods did not contribute much in saving lives and properties as the process is slow, and did not provide enough time for rescue and relief team to prepare and organize.

Through this warning system the registered authorities will receive automated email alerts from the website. The authorities in CMA recognize the need for an early warning system. "*Early warning system for landslide is a great initiative towards a planned Chittagong city, which can reduce the associated risks, and the natural condition of the hills will not be disturbed*," Said Abdus Salam, the Chairman of Chittagong Development Authority (CDA).

Finally, the outcome of the project and recommendations are already shared with the representatives from Chittagong Development Authority, Chittagong City Corporation, Dept. of Environment, Bangladesh Institute of Planners, Institute of Engineers Bangladesh, Chittagong University of Engineering & Technology, BUET, Dhaka University and local communities. It is highly expected that the activities and outcome of this project will help creating community and institutional awareness, and thus it will reduce the risks of future landslide disasters in CMA.

6. FUTURE POTENTIAL

BUET-JIDPUS has successfully completed the project and established an early warning system for landslide in Chittagong Metropolitan Area. This system will be useful for any area with landslide possibilities if the parameters are set up accordingly. Initially the team established this sophisticated system within a short time period and budget constraint. The project team has developed this early warning system with the image of 60 kilometres resolution for budget constraint. But they are confident enough to develop this system for a particular location and for this they will need high resolution satellite images. Moreover, we can have feedback of this warning system from the experimental launch. So, if there is a scope for further research with sufficient funding, the warning system will be able to give warning for more specifically incorporating the feedback.

7. ACKNOWLEDGEMENT

The project, 'Developing Dynamic Web-GIS based Early Warning System for the Communities at Landslide Risks in Chittagong Metropolitan Area, Bangladesh', is funded by SERVIR, a joint initiative of USAID (United States Agency for International Development) and NASA (National Aeronautics and Space Administration). The project team is thankful to these organizations for funding this project and supporting BUET-JIDPUS as well.

The authors express their gratitude to International Centre for Integrated Mountain Development (ICIMOD), an implementing partner of SERVIR-Himalaya for their all time guidelines, comments and support.

The team members are also grateful to Md. Zafar Alam, Director, Department of Environment (DOE); Md. Samiul Masud, Assistant Commissioner (Land) of Chittagong Sadar Circle; Architect Rezaul Karim, Chief City Planner (CCC); Shahinul Islam Khan (Deputy Chief Town Planner), M.A. Issa Anshary (Town Planner), Syed Fuadul Khalil Al Fahmi (Assistant Town Planner) and Md. Abutalha Talukdar (Assistant Town Planner) of CDA; Major Aftab, Chittagong Cantonment; Professor Dr. Khan Towhid Osman, Dean, Dept of Soil Science (University of Chittagong); and Muhammad Muhibubullah, Assistant Professor and Chairman, Dept. of Geography & Environmental Studies (University of Chittagong), Engg Ali Ashraf, Dept. of Civil Engineering (Southern University) for their cordial help, opinion and support regarding different issues.

The project team is really very thankful to the Chittagong Development Authority for their cordial response in arranging the stakeholder meeting in presence of the representatives of ICIMOD. Special thanks to Mr. Abdus Salam, Honorable Chairman of Chittagong Development Authority for his cordial presence and for giving his valuable suggestions during the meeting.

BUET-JIDPUS is grateful to Institute of Engineers Bangladesh (IEB), Chittagong and the Department of Disaster and Environmental Engineering (DEE), CUET for their cordial response and support during Knowledge Sharing Meeting in Chittagong.

The team is also grateful to Mr. A.F. Kabir Ahmed Manik (Commissioner, Ward no. 14, CCC) for supporting BUET-JIDPUS in arranging the awareness building program in his area.

Last but not the least, the authors are cordially thankful to the local people of the study areas (Moti Jharna, Batali Hill, Golpahar, Goachibagan) for their kind cooperation and help during the field work of this research project.

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