Study of the Geomorphological and Meteorological Condition of Landslides in the South-eastern Hilly Region of Bangladesh

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Abstract

Bangladesh is an innocent victim of climate change in every way because, in comparison to wealthier nations, it has made virtually little contribution to the problem. The country is located at the base of the Ganges-Brahmaputra-Meghna (GBM) catchments, and the cancer tropic runs through the center of it. Due to this complex geographical position with Himalayas to the north, Bangladesh has the greatest average annual monsoon rainfall among the SAARC nations. Indian summer monsoon and tropical storms provide heavy rains that cause landslides in south-eastern hill areas. Landslides are increasingly common geological hazards in Bangladesh, particularly in Chittagong, the Chittagong Hill tracts, and the Cox's Bazaar area. From this vantage point, an effort has been made to build an inventory of landslides, as well as the topography, geology, and landuse change of some specifically chosen areas that are prone to landslides, as part of this research activity. More than 800 landslide locations have been identified through field survey, existing literature, scholarly articles, and newspaper and these are prominent in the northern and western parts of Chittagong Hill Tracts. GPM satellite based precipitation measurement proves it's better ability BMD rain gauge stations. Landslide spots in Chittagong's urban soil, which is based on the Dupitila, Tipam, and Bokabil Formation. The Brown Hill soil in Bandarban, however, changes the situation. settlement is the dominating landuse class and consistent for both years (62.26%) in Chittagong. Changes among five landuse classes are insignificant during the study period with maximum change in of vegetation area (13.75%). Significant constancy found in the settlement area. In Accuracy assessment analysis overall accuracy is 94.00% and overall kappa statistics is 0.8394 which is acceptable for satellite image supervised classification of 2016. And for the satellite supervised classification image of 2020 overall accuracy is 73.00% and the overall kappa statistics is 0.5730.

Keywords: Landslide, Digital Elevation Model, Geomorphology, Precipitation, Topographic Normalization, Geological Hazard, GPM.

Introduction

Bangladesh is a part of the Bengal Basin, which has been filled with sediments from the mountains that surround it on three sides, particularly the Himalayas. Because of the geographical location, Bangladesh experiences the highest amount of monsoon rainfall and annual average rainfall among the SAARC (South Asian Association for Regional Cooperation) countries (Ahasan et al., 2011). The Indian Summer Monsoon and tropical storms is source of intense rainfall which act as potent triggers for landslides in areas with steep slopes and poorly consolidated (Islam & Uyeda, 2007). Landslides are mostly sporadic and localized in nature that's why these do not receive maximum media attention like other hazards (earthquakes, floods, cyclones, and hurricanes). But statistics show this is one of the most catastrophic geological hazards causing extensive economic losses, physical damages, and fatalities all over the world. According to EM-DAT (2014), between 2000 and 2014 landslides killed approximately more than 6000 people in South Asian country whereas in the America and Caribbean region the death toll is 519 for twenty landslide events within this period.

Devastating landslides take put within the world due to a few reasons like human interventions, overwhelming precipitation, snow softens and deforestations. The activating components of landslides incorporate climatic conditions of a region, soil-water characteristics, ground water conditions, quality of soil, topography and slope adjustments. In most of the landslides that have happened within the past, the common reason watched for the slope failures is the overwhelming downpour at hilly regions (Kadamb et al., 2022). On account of this landslides have been the subject of various consideration to realize the hydrologic condition of failure initiation or mechanism of the failures. Knowledge from this study will play significant role to develop a system for predicting the occurrence of failures (A Tohari, 2018). It has been recognized that land-use and land-cover change is one of the most important factors stirring rainfall-triggered landslides. Great variations in the hydro-morphological functioning of hill slopes occur due to land cover changes (e.g., urbanization, deforestation), which ultimately affect rainfall partitioning, infiltration characteristics, and runoff production. All these factors trigger landslides in hilly areas.

On the other hand, Due to climate change worldwide heavy one or multiple-day precipitation events have increased alarmingly (Bayes et al. 2015). Sustainable hill management & development is a big challenge in Bangladesh because of changing precipitation patterns and increase in extreme rain events, short-term heavy rainfall, a small amount of rainfall for a longer period, the intensity of rainfall, and antecedent rainfall during the summer monsoon. The antecedent and major rainfall events play an important role in dropping the slope stability (Hossain, Toll, and Shushupti 2020). An essential component of global energy and water cycles is precipitation and it plays a significant role in the interactions between atmosphere, biosphere and hydrosphere. Precipitation data provides essential information to weather forecasters and climate scientists. Their valuable findings help decision makers including agronomists, hydrologists, industrialists and emergency managers. Hence, precise estimation and forecast of precipitation is vital for a wide range of applications, such as agricultural crop forecasting, monitoring freshwater resources, numerical weather prediction and disaster management (Wang et al. 2021).

In Bangladesh landslide is becoming one of the regular geological hazards especially in Chittagong, Chittagong Hill tracts, Cox's Bazaar region. A significant number of landslide hazard locations exist in these areas that make many communities vulnerable to slides which may result in severe damages and socioeconomic losses. Chittagong City and its surrounding areas have been classified into four landslide hazard zones are based on the locations of landslides, geology, and geotechnical properties of rocks. It is apparent that main reason of occurring landslide is heavy rainfall in a short period and geotechnical properties of the slope materials (loose, well-graded sand, high permeability and porosity, low internal friction angle, and weathering characteristics) are also responsible. This process further accelerates because of hill cutting but not the main cause of landslides in some cases. The primary triggering factor of landslides is rainfall (Reshad et. al., 2018). Due to landslides, the highest percentage of people died (279, 38.4%) in Chittagong followed by Cox's Bazar (179, 24.6%), Rangamati (110, 15.1%), and Bandarban (91, 12.5%) in terms of fatalities. On the other hand, almost 50% of injured people belong to the Bandarban district, and more than 40% belong to Chittagong and Cox's Bazar (Sultana, 2020).

Effective planning and management can reduce social and economic losses due to landslides. To predict landslide, first step is to know hot spots of landslide and then geomorphological, topographical (elevation, slope, aspect), and meteorological factors should be under consideration. It is essential to understand under which conditions of these factors are responsible for landslides. From this perspective, an attempt has been made to develop a landslide inventory, topographic condition, geology and landuse change of some selected landslide prone area under this research work.

Materials and Method

Study Area

Bangladesh is a 147,610 km2 south Asian nation that is heavily populated, low-lying, and riverine. The broad deltaic plain that makes up 80% of Bangladesh's physiography is often characterized as having low hills in the north-east and south-east region. Numerous hills and

hillocks (tilas) may be found in the region to the north-east of Sylhet, up to Srimangal and Moulvibazar. For hills, the elevation varies between 60 and 150 meters, and the height of hillocks (tilas) are between 30 and 90 meters. Chittagong Hill Tracts region, or CHT, is made up of three districts (Rangamati, Khagrachari, and Bandarban) in Bangladesh which is about one-tenth of the country's total land, where the vast hilly terrain is located. This area is from 600 to 900 meters above sea level in elevation. Between Chittagong and Cox's Bazar district is a sequence of short, coastal hills that range in height from under 200 to 350 meters above sea level(Islam et al.,2006; Sultana, 2020).

Chittagong Hill Tracts (CHT) the only extensive hill area in Bangladesh lies in southeastern part of the country (21°25'N to 23°45'N latitude and 91°54'E to 92°50'E longitude) bordering Myanmar on the southeast, the Indian state of Tripura on the north, Mizoram on the east and Chittagong district

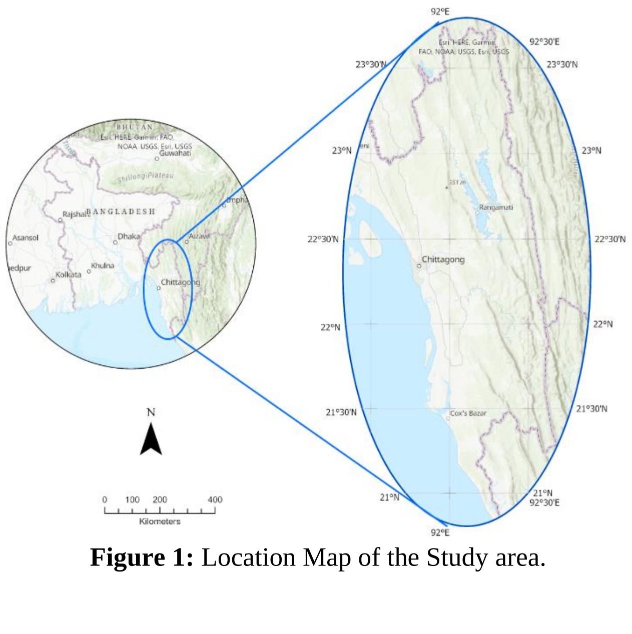

Figure 1: Location Map of the Study area.

on the west. The area of the Chittagong Hill Tracts is about 13,184 sq km, which is approximately one-tenth of the total area of Bangladesh. According to the physiography of Bangladesh the CHT falls under the Northern and Eastern Hill unit and the High Hill or Mountain Ranges sub-unit. This sub-unit covers most of CHT, some small parts of southern Habiganj and the south and eastern borders of Maulvi Bazar (Chittagong Hill Tracts - Banglapedia, n.d.).

Additionally, as a result of climate change, the nation has recently experienced extremely high rainfall intensities over shorter time periods, frequently resulting in landslides (Mutizwa-Mangiza et al., 2011), which is worsening the vulnerability in areas with unconsolidated rocks and steeper slopes in particular area (Mahmood & Khan,2010). Along with this, Bangladesh's hilly regions are becoming more vulnerable to landslides due to growing urbanization, unsustainable land use, mining operations, change of the hills by hill cutting, rapid deforestation, and traditional shifting agricultural methods (Mia et al.,2016).

In this study, the entire Chittagong Hill Tracts area has been considered for development of landslide inventory, precipitation analysis and geological information. On the other hand, Chittagong Metropolitan area and Bandarban Sadar Upazila have been selected selected for topographic, soil and landuse change analysis (Figure:1).

Satellite and Other Data Utilized

Table 1 provides a list of the satellite and other relevant data used in this study. Sentinel-2 multispectral satellite images of 2016 and 2020 along with Google Earth images of 2016 and 2019 have been utilized to study the geo-environmental changes in the study area. Multi-date Sentinel-2 satellite data have been obtained from Earth explorer site (http://earthexplorer.usgs.gov/) and Google images from Google Earth (Table 1). For topographic analysis NASA Shuttle Radar Topography Mission (SRTM) 30 m resolution is acquired from USGS Earth explorer site. Besides, Global Precipitation Measurement (GPM) satellite data of 9-14 June 2017 have been downloaded from Nasa Earth Data website (https://disc.gsfc.nasa.gov/).

Table 1: Data used in the Study.

			Acquisition Date	**Spatial Resolution**	**Source**
1	Satellite	Sentinel 2	January 2016 February 2020	10 M	earthexplorer. usgs.gov
		Global Precipitation Measurement (GPM)	9, 10, 11, 12, 13, 14 June 2017	0.1 ° x 0.1 °	Huffman, *et. al* 2019
2	DEM	SRTM	2010	30m	earthexplorer. usgs.gov
3	Google Earth Image		2016, 2019		
4	Precipitation		1961-2020		Bangladesh Meteorological Department
5	Geological Map				Geological Survey of Bangladesh
6	Geomorphological map				
7	Soil map				Bangladesh Agricultural Research Council

This dataset is the GPM Level 3 IMERG Late Daily 10 x 10 km (GPM_3IMERGDL) derived from the half-hourly GPM_3IMERGHHL. The derived result represents a Late expedited estimate of the daily accumulated precipitation. The dataset is produced at the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) by simply summing the valid precipitation retrievals for the day in GPM_3IMERGHHL and giving the result in (mm) (Huffman, et. al 2019). High-resolution precipitation product is available at the 30 min and 0.1◦ resolution in early mode (with a 4 h latency), late mode (with a 12 h latency) and final mode (with a 2.5 months latency), which run based on accuracy and latency. The early and late products are multi-satellite data. The final run is, instead, obtained taking advantage of a combination of information acquired from satellite and monthly rain gauges data (Wang et al. 2021).

The Geological Survey of Bangladesh provides geological and geomorphological maps in addition to these satellite data. Ground measured precipitation data was collected from Bangladesh Meteorological Department and soil map was downloaded from Bangladesh Agricultural Research Council (BARC) website.

Methodological Approach

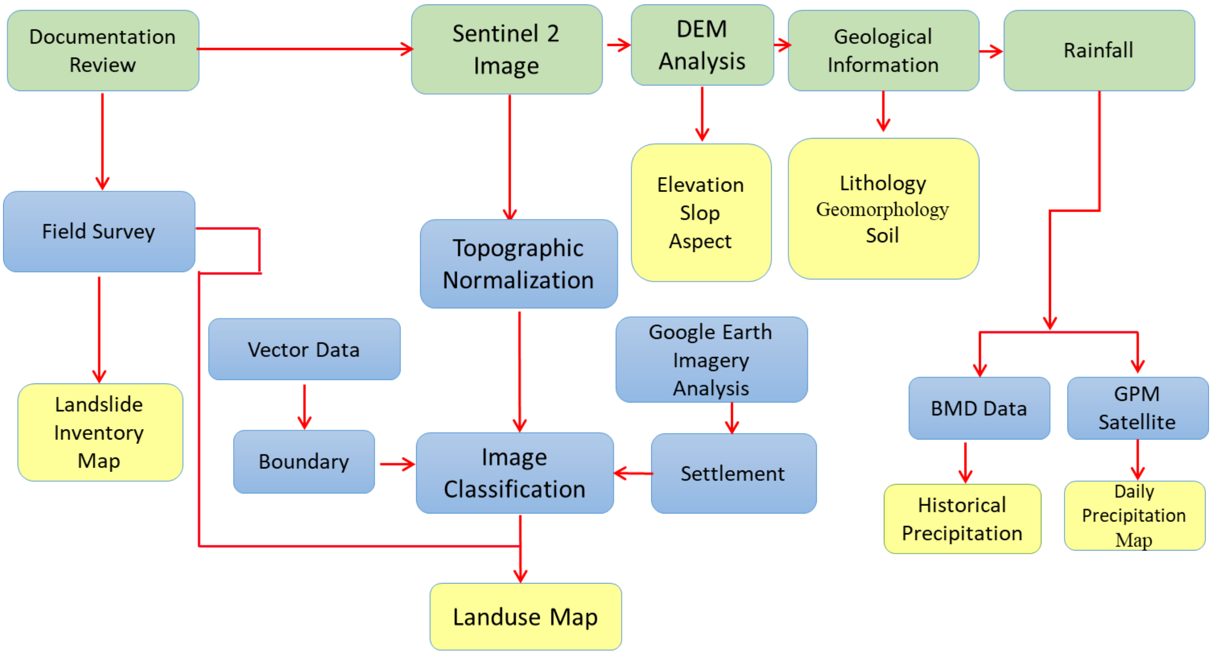

Figure 2: Flow chart of methodology under the present research.

Figure 2 shows the methodological framework as adapted for implementation of the present research study. The study area has been extracted from satellite images by using vector GIS boundary layer. Digital data processing, analysis and interpretation have been carried out to identify the surface features over the area. This research work extensively utilized the SNAP, ERDAS Imagine and ArcGIS Pro software for various geospatial application under the study theme.

Information has been collected as much as possible through documentation review on recent past landslides. This information has been verified through a detailed field survey. Rainfall data has been prepared regarding the meteorological conditions of recent past landslides through analysis of satellite-derived rainfall data and in situ rainfall data from Bangladesh Meteorological Department. Global Precipitation Measurement (GPM) satellite data are processed and analyzed using ArcGIS Pro software. Different layers are generated of study areas through scanning and georeferencing of a geological map, soil map, and topographic map.

Data Analysis, Interpretation and Classification

Data Analysis, Interpretation and Classification Sentinel-2 images were formatted into ERDAS Imaging IMG format. DN values were transformed into reflectance values. Necessary topographical corrections have been performed utilizing Sen2Core Processor using SNAP software. Post-processing of the images has been carried out following digital techniques in the ERDAS Imagine image processing software and ArcGIS Pro. Class-wise spectral characterization of classified images has been carried out and class properties have been investigated in terms of amplitude and pattern of spectral signature of individual class categories. Relatively insignificant class elements specially in terms of cluster size have been merged with the other relevant class category in order to keep mainly the distinct and meaningful class elements. Finalized thematic layers have been transformed into vector format in ArcGIS. Necessary attributes have been assigned to individual class elements.

Figure 3: Landslide scene during field survey at different places of Chittagong and Bandarban Sadar.

Ground Truthing and Filed Data Incorporation

Satellite data analysis has been combined with image based GPS-guided ground truthing, verification, and data gathering operations (Figure 3). Each of the thematic raster layers has been converted into a set of vector layers in the ArcGIS platform. Each of the vector layers has undergone the necessary arc correction and post processing. Each of these vector layers has been given certain properties. The statistics on LULC and its changes across the research area have been generated in the next phase. Individual map products have finally been created.

Result and Discussion

Landslide Inventory

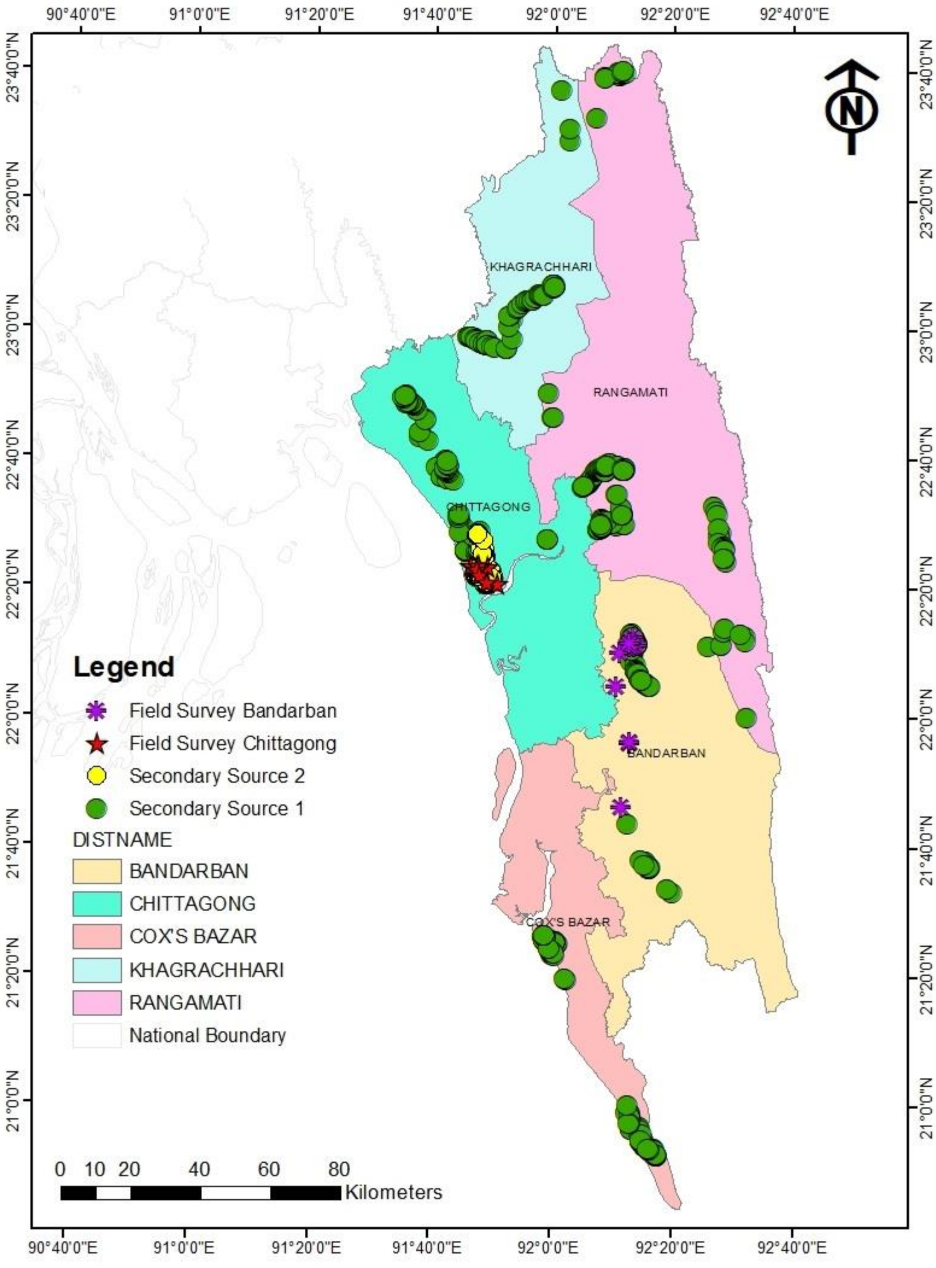

Figure 4: Landslide location map of the study area.

More than 800 landslide location and related information have been collected through field survey, existing literature, scientific article and newspaper and plotted in a map (Figure 4). Unexpected support was found from an article published on "Landslide inventory (2001–2017) of Chittagong hilly areas" by providing GIS shapefile

(Rabby and Li 2020). Finally, the prepared database was further cross-checked, verified, and updated from the responsible authorities such as Upazila Chairman, AC Land, local people etc. Field survey was conducted at some sites of previous and recent landslide locations in Chittagong Metropolitan Area, Bandarban Sadar Upazila and Lama Upazila. Inventory map has been prepared indicating of these all landslides locations. There were some other landslide locations that could not be identified as local people have little knowledge on landslide. From the Landslide inventory map, it is seen that landslide areas are located at the northern western part of Chittagong and Bandarban Sadar area.

Meteorological Condition of the Study Area

Most of landslides take place in Bangladesh during monsoon season due to excessive rainfall therefore precipitation has been chosen to investigate meteorological condition of the study area. Rain gauge stations are only source of precipitation data in the study area.

Accurate estimates of precipitation are needed by most operational hydrologic, climate or weather models as the primary input for purposes of assimilation, calibration, and validation (Omranian and Sharif 2018). In the same way it is also important for any kind of forecast like landslide. It obvious that in Bangladesh rain gauge networks are exists with coarse spatial resolution and coverage. Other limitations like technical issues in reporting data, especially during heavy storms, and lack of an integrated system in reporting gauge data these networks may not perfectly capture all details of an event (Garcia et al., 2008; Habib et al., 2009). Weather radars can be an alternative provider of real-time rainfall amounts at high resolutions, though they also have their particular types of errors. This may upset the accuracy of their products such as over/underestimation of rainfall amounts, truncation errors, and lack of radar networks at the global scale (Omranian & Sharif, 2018). Satellite-based products can be a great solution of these limitations. They have ability to capture precipitation amounts and continuously report data for most of the globe, especially those areas where it is not possible to install gauge or radar networks (Skinner et al., 2015; Wang et al., 2016).

The entire Chittagong division is covered by six rain gauge stations only. Out of these there are two stations each in Chittagong and Cox's Bazar districts, while Rangamati district has only one station. There are no rain gauge stations in Bandarban and Khagrachari districts (Figure 6). From these statistics it is definitely obvious that data from these stations are very low spatial resolution for any kind of forecast or weather model.

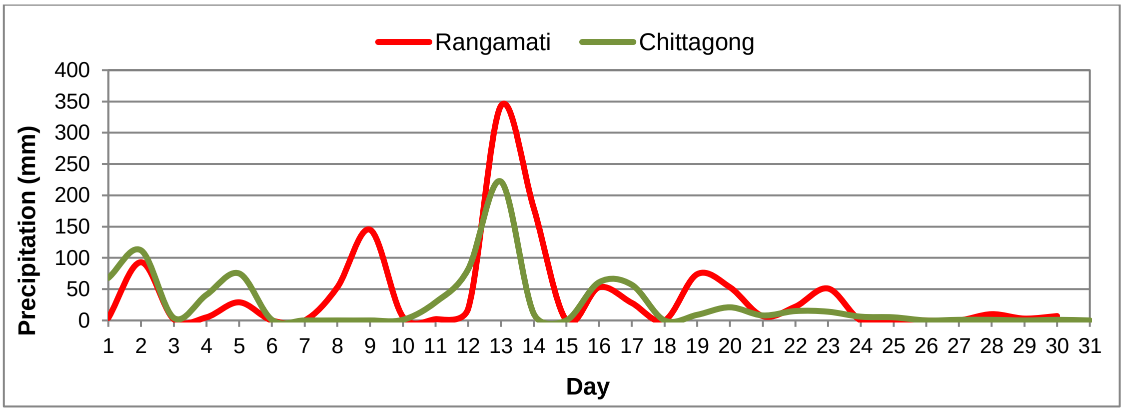

Fig 1: Daily precipitation of Rangamati and Chittagong (June 2017) from rain gauge station of Bangladesh Meteorological Department.

In this paper a comparative analysis has been done between ground measured precipitation of one station each in Chittagong and Rangamati districts with Global Precipitation Measurement (GPM) satellite-based precipitation. GPM satellite products perform better than other satellite products at national and continental scales.

Hundreds of landslides were triggered by heavy rainfall in June 2017 at Rangamati, Bandarban, and Khagrachari hill districts of Chittagong Hill Tracts (CHT). Three days of endless rainfall on 11, 12, and 13 June 2017 triggered these landslides that damaged roads and settlements in the Rangamati, Bandarban, and Khagrachari hill districts of Bangladesh (Bajracharya and Maharjan 2018). Daily precipitation data of June 2017 is plotted in figure 5 and precipitation data derived from GPM satellite is shown in figure 6. A comparison has been made between Precipitation data of BMD’s rain gauge stations and GPM satellite from 9 to 14 June 2017 (Table 2).

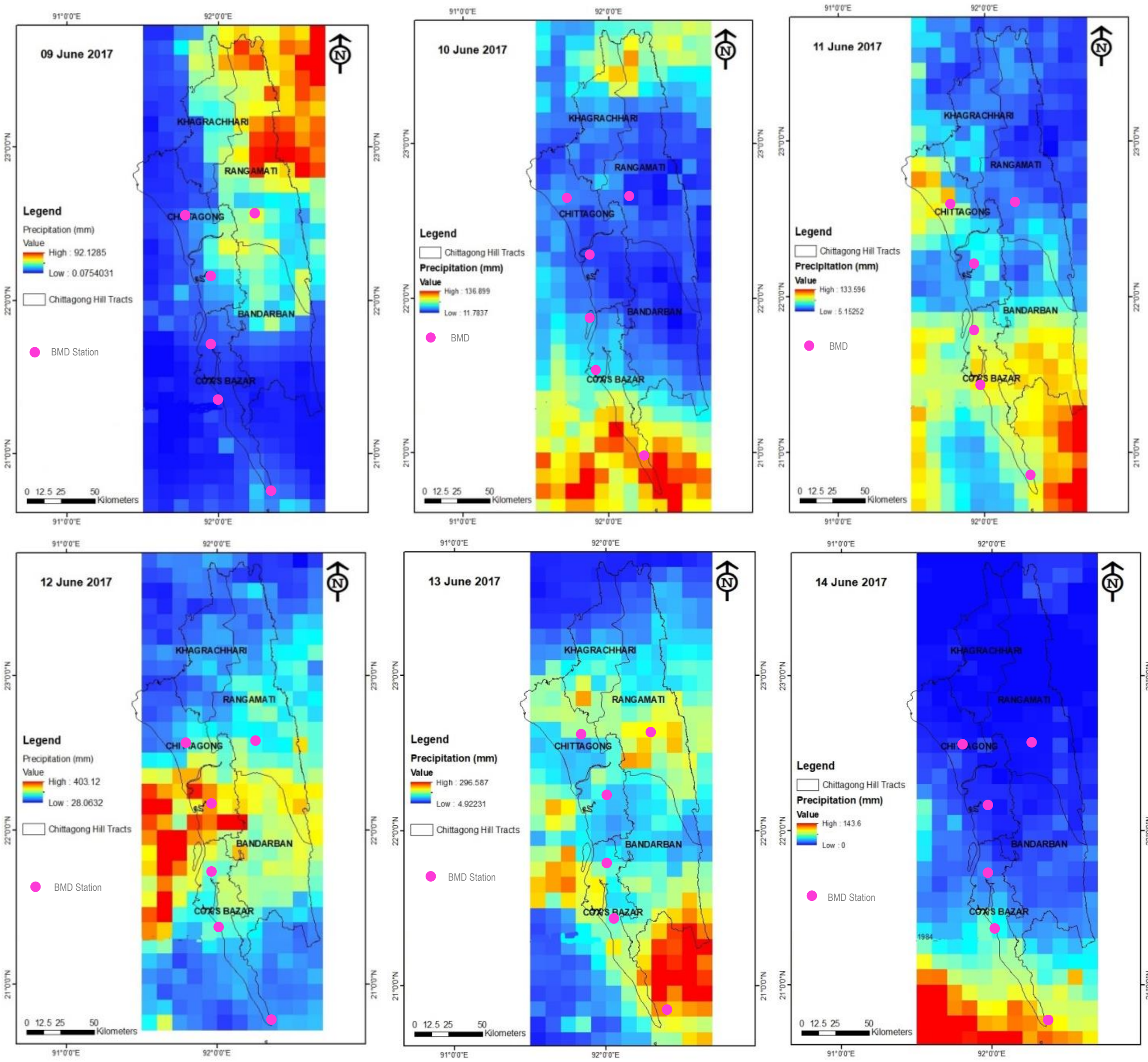

Figure 6: Precipitation (9-14 June 2017) of Chittagong Hill Tracts and surrounding areas derived from GPM satellite image.

It is clear that GPM satellite have high spatial resolution and variation over BMD's rain gauge stations. Rain gauge stations afford single precipitation value for a large area, whereas GPM satellite can provide data for an area approximately 10 km×10 km. Thus, this satellite is able to give precipitation data at local scale, which can significantly change any forecast or weather model. BMD rain gauge stations provide precipitation data for a single location only, but this single value represent for the entire district. Certainly, this type of estimation is not appropriate for a large area. On the other hand, GPM satellite products show high spatial resolution with a range of value per day. It delineates the real time scenario of precipitation. Table-2 gives a clear impression between ground and satellite observation. In 9 June 2017 Chittagong BMD rain gauge station record no precipitation but GPM satellite indicates that on that day minimum and maximum precipitation was 1.92 mm and 46.96 mm respectively. The opposite event was observed in Rangamati on the same day. BMD rain gauge stations of Rangamati record 145 mm precipitation but GPM satellite shows maximum 75.61 mm. There is a big difference between these two records.

Similar condition is observed on 13 and 14 June 2017. On these days BMD rain gauge stations record high precipitation value, whereas GPM satellite record very low value. Only BMD's records of 10, 11 and 12 June 2017 are within the range of GPM satellite. But these records are far from maximum value of GPM satellite. This observation strongly supports that GPM satellite based precipitation measurement is better than existing BMD rain gauge stations.

Table 2: Comparative statics between Bangladesh Meteorological Department (BMD) measured and GPM satellite derived precipitation (mm) of Chittagong and Rangamati.

Day	Chittagong		Rangamati	
	BMD	GPM Satellite	BMD	GPM Satellite
9 June 2017	0	Max: 46.96 Min: 1.92	145	Max: 75.61 Min: 20.19
10 June 2017	1	Max: 34.62 Min: 14.50	6	Max: 96.49 Min: 12.42
11 June 2017	29	Max: 81.68 Min: 18.16	2	Max: 41.25 Min: 7.27
12 June 2017	82	Max: 280.36 Min: 41.46	19	Max: 212.54 Min: 37.40
13 June 2017	222	Max: 125.77 Min: 50.47	343	Max: 188.45 Min: 12.08
14 June 2017	11	Max: 8.60 Min: 0	180	Max: 8.64 Min: 0

Geology, Topography and Soil Condition

The Bengal Basin, which includes the majority of Bangladesh and the eastern half of India, was formed when the Gondwana continental landmass was fragmented in the late Mesozoic (ca. 125 Ma) (Lindsay et al., 1991). The Himalaya ranges, which were created as a result of the collision of the Indian and Eurasian plates during 55–52 Ma and 27–17 Ma, are the principal sedimentary sources for the basin (Beck et al., 1995, Roy and Chatterjee, 2015). Bengal Basin's sediment has been compressed and uplifted after an oblique collision between the Indian and Burmese Plate resulting forming of the Indo−Burmese Range. The continuous subduction of the Indian Plate that has the thick sediment of the Bengal Basin formed the Chittagong-Tripura Folded Belt, located west of the Indo-Burmese Range. The Chittagong-Tripura Folded Belt, located west of the Indo-Burmese Range, was created by the continual subduction of the Indian Plate, which contains the dense sediment of the Bengal Basin. The study area is part of the Bengal Basin that receives a huge quantity of sediments through ancient fluvial systems (Curray, 1994).

In Bangladesh's Chittagong Hill Tracts, the Miocene Bhuban and Boka Bil formations of the Surma Group are well exposed (Uddin and Lundberg, 1998). The anticlines of Bandarban and Rangamati offers excellent exposure to the Surma Groups of rocks. On both flanks of the anticline, sandstone, siltstone, silty shale, and occasionally shale conglomerates are uniformly distributed. Based on the exposed rock sequences and association with the broader stratigraphic succession, the anticline's stratigraphy is determined (Khan and Muminullah, 1988; Reimann, 1993; Uddin and Lundberg, 1999; Geological Survey of Bangladesh, 1985). The sequence is divided into two principal units, the Boka Bil and Bhuban Formations, based on the lithology. The Boka Bil Formation rests on top of the Bhuban Formation, which is divided lithologically into three units: the Lower Bhuban Member (LBM), Middle Bhuban Member (MBM), and Upper Bhuban Member (UBM). The Boka Bil Formation is available in some sections above the UBM, especially on the top and hillslope (Haque & Roy, 2021).

Being a part of the hilly regions that branch out from the Himalayas, Chittagong is significantly different in terms of terrain from the rest of Bangladesh, with the exception of Sylhet and northern Dinajpur. This eastern offshoot of the Himalayas, turning south and southeast, passes through Assam and Tripura State and enters Chittagong transversely the river Feni. As it gets closer to Chittagong town, the range starts to lose height and fragments into tiny hillocks that are dispersed throughout the town. From one end of the district to the other, this range can be seen on the southern bank of the Karnaphuli River. The tallest mountain in the district is Chandra nath or Sitakunda, which rises 1152 feet above mean sea level. The 289-foot high Nangarkhana is located to the north of Chittagong town. The Batali Hill peak, which is located within the town, was formerly the town's highest point and rises to a height of 280 feet. Like other stunning hills and hillocks in the city of Chittagong, this well-known hill is gradually being leveled and having its height decreased to make way for homes.

From the SRTM DEM layer, elevation and slope maps are created. The maps were then divided into 5 classes using the Natural Breaks (Jenks) approach. Natural groupings included in the data serve as the foundation for

Natural Breaks classes. The features are divided into classes whose boundaries are set where there are relatively big differences in the data values. Natural breaks are data-specific classifications and not useful for comparing multiple maps built from different underlying information (Ahmed, 2013).

In the study area most of the landslide locations are situated in Urban Soil in Chittagong which lays on Dupitila, Tipam and Bokabil Formation. Elevation of Chittagong area ranges from 20-73m with 4-13 degree slopes. However, scenario of Bandarban is different with Brown Hill soil. Soil texture is mostly Silt Loam WS Sandy Loam Soil. And elevation of this area ranges from 80-266 m with 6-18 degree slopes (Figure 7-16).

The Tertiary period of the geological timescale marks the majority of the development of the regions, which have complex soil composition. The hilly soils are primarily made of yellowish-brown to reddish-brown loams, which are composed of unconsolidated sedimentary rocks such sandstone, siltstone, shale, and conglomerate with local unconformities (Y. A. Khan et al.,2012; Rashid,1991).

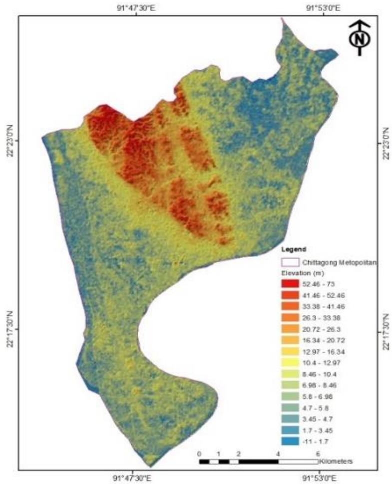

Figure 7: Elevation map of Chittagong area.

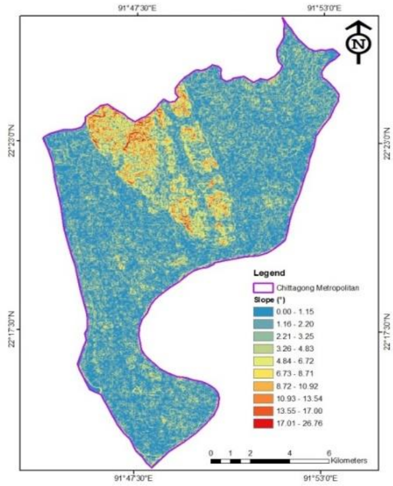

Figure 8: Slope map of Chittagong area.

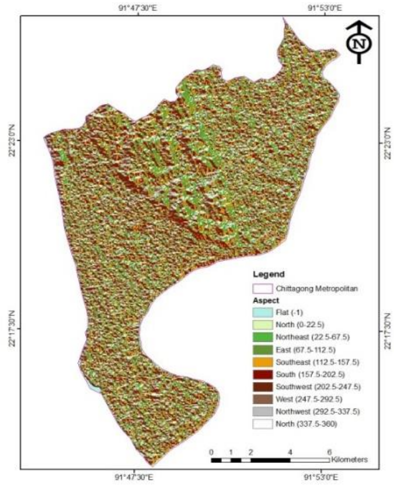

Figure 9: Aspect map of Chittagong area.

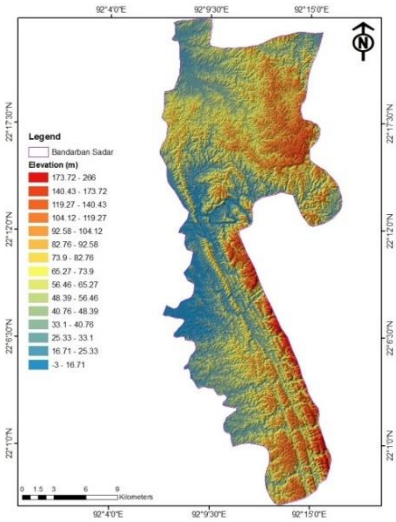

Figure 10: Elevation map of Bandarban Sadar Upazila.

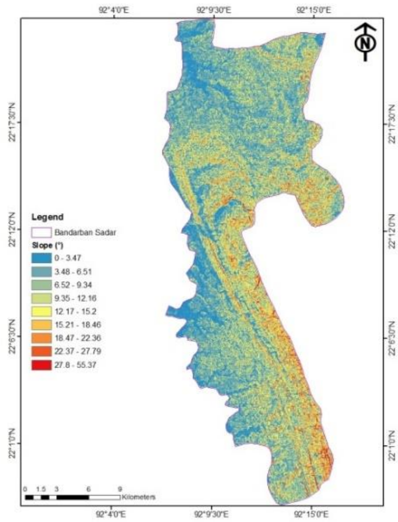

Figure 11: Slope map of Bandarban Sadar Upazila.

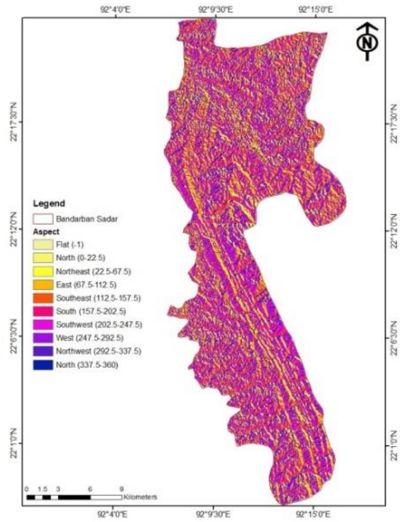

Figure 12: Aspect map of Bandarban Sadar Upazila.

In addition, the tertiary and quaternary sediments that gave rise to the hills were folded, faulted, and raised before being split apart by rivers and streams (Brammer,1996). Bangladesh's hills are therefore extremely prone to landslides since the geological formations and soil are unstable, weak, quickly saturated with water, and also have steep slopes (Sarker & Rashid,2013). These hills' fragile bedrock and soil structure, which is made up of hard red clay mixed with fine sand, are characterized by a steep slope, high permeability, and erodibility (Ahmed, 2014), making them particularly vulnerable to landslides (Mahmood & Khan,2010).

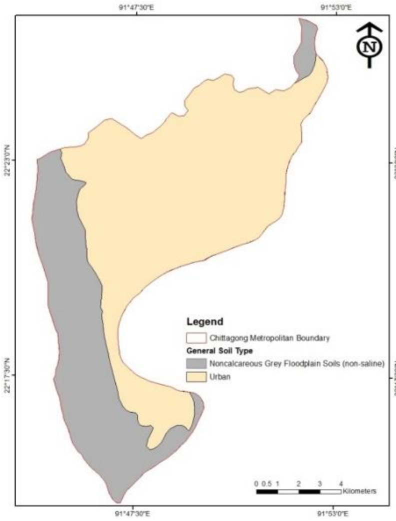

Figure 13: General soil type map of Chittagong area.

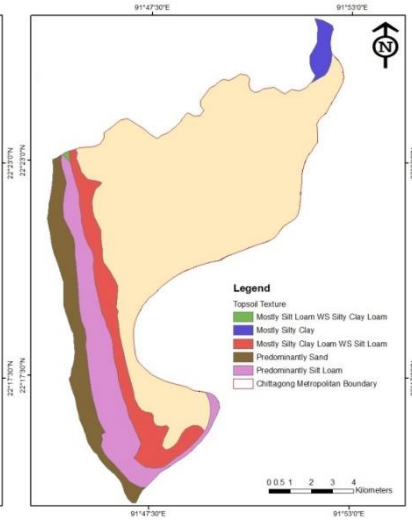

Figure 14: Top soil texture map of Chittagong area.

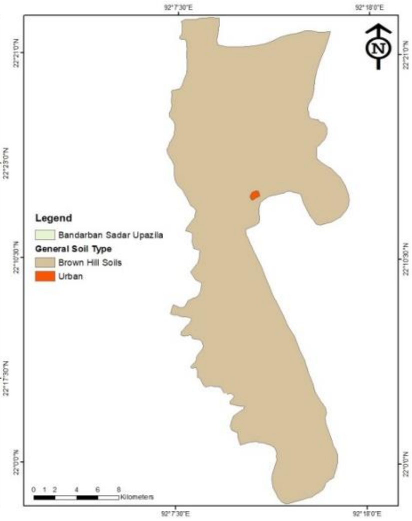

Figure 15: General soil type map of Bandarban Sadar.

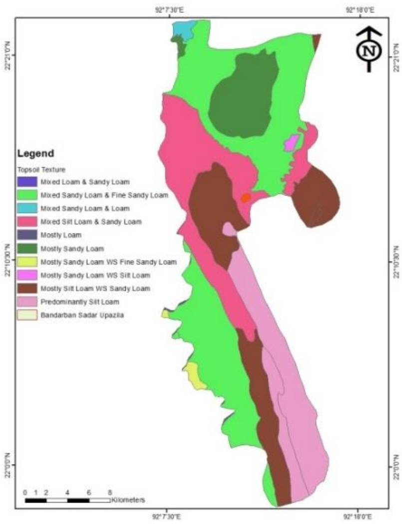

Figure 16: Top soil texture map of Bandarban Sadar.

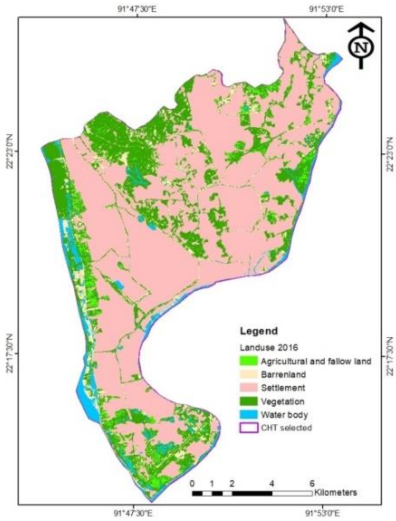

Figure 17: Landuse map of Chittagong area of 2016.

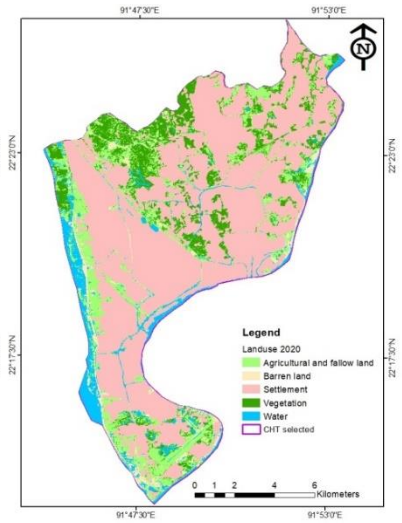

Figure 18: Landuse map of Chittagong area of 2020.

Landuse Classification, Accuracy Assessment and Change Detection

Landuse and land cover information is necessary for policymaking, business, and management purposes. Data with spatial detail is also important for environmental protection and spatial planning. Landuse classifications are especially important when dealing with the environment, as they provide data that can be used as input for modeling. For example, models deal with climate change and political situations. Remote sensing is often combined with Geographic Information Systems (GIS) technology to provide more useful land cover information (Rwanga and Ndambuki 2017).

Accelerated use of remote sensing data and technology has made geospatial processes faster and more powerful, but increased complexity also increases the potential for error (Murtya nd Tiwari, 2015). Previously, accuracy assessment was not a priority for image classification research. However, as the error probability of digital images has increased, accuracy assessment has become a very important process (Congalton, 1991).

Landuse change in land cover is influenced by various natural and human activities around the world. Landuse is the product of interactions between the cultural context, conditions and physical needs of a society on the one hand and the natural land potential on the other (Balak and Kolarkar, 1993). Landuse, on the other hand, is the intended development of land management strategies placed on land cover by human agents or land managers to exploit the land cover, such as industrial areas, residential areas, agricultural land, grazing, logging, etc. reflect human activity among many others (Zubair, 2006). Landuse /cover change is a dynamic process occurring on natural and physical surfaces over a long period of time. The dynamics of Landuse /land cover change is a key factor for monitoring, assessing, protecting and planning the surface of the earth and for finding changes in

Landuse /land cover over time. In this section the changes in landuse/land cover influenced by natural and human activities over time is analyzed and discussed (Anon n.d.-a).

Landuse/Landcover (LULC) Classification: Supervised

Only supervised classification was performed in this study. In supervised classification, "users create spectral signatures of known categories, such as water bodies, cities and forests, and the software assigns each pixel in the image to the cover type with which its signature most closely compares." Supervised classification is the most commonly used method for quantitative analysis of remote sensing images.” Supervised classification was applied according to defined areas of interest (AOIs) called training classes. Multiple training areas were used to represent specific classes. Training sites were selected in collaboration with Sentinel 2 and Google Earth.

The following sequence of operation was followed during supervised classification:

•Defining of Training Sites: The first step in performing supervised classification is to define areas that will be used as training areas for each land cover class. This is usually done using digitized features on the screen. The features created are called Areas of Interest (AOIs). Training locations were selected based on clearly identified regions in all image sources.

•Extraction of Signatures: After the training site (AOI) was digitized, the next step was to create a statistical characterization of each piece of information. These are called Signature Editor. The goal of this step was to create a signal file (SIG) for each information class. A SIG file contains a large amount of information about the described land cover class. After the entire signature is created, the SIG file is saved as a dialog.

•Classification of the Image (Supervised classification): Supervised classification was applied after defined training classes. One or more training areas were used to represent a particular class. During the supervised classification process, the entire signature editor was selected to be used for the classification process. Then classify was selected from the Editor Menu bar, classify/supervised. Non-Parametric Rule was used in this classification. The image was classified into five classes namely; Vegetation, Water body, Settlement, Agricultural and fallow land and Barren/bare land (Table 3).

Table 3. Landcover classification scheme.

Land cover	Description
Vegetation	Lands dominated by trees with a percent cover >60%, Deciduous Forest land and evergreen forest land and homestead vegetation
Water body	Lakes, reservoirs, stream, rivers, swamps
Settlement	Land covered by buildings and other man-made structures; Residential.,
Agricultural and fallow land	Lands covered with temporary crops followed by harvest period, Crop fields and pastures
Barren land	Lands with exposed soil, sand or rocks, and bare ground, bare exposed rocks, brick fields, quarries and gravel pits

Classification Results and Discussion

Supervised classification was carried out at Chittagong Metropolitan area. The area of each class was calculated taking into account the pixel count and total area (Chittagong). Below is a table resulting from the supervised classification of images from two years (2016 and 2020). Allocations of each classified area (hectare and percentage) are tabulated in Table 4. Landuse is the main focus and the landuse change also provide from these two years of image. Figure 17 and 18 show the Chittagong Metropolitan’s landuse on 2016 and 2020.

From the table 4 it can be said that Settlement areas occur in higher and same portion for both years (62.26%) of the total study area. Vegetation is the second dominant class which reduced 24.40% to 11.64% in 2020. After that Agricultural and fallow land is third dominating category which raise sharply from 2.54% to 15.35 % in 2020.

Table 4: Classified area in Chittagong area during 2016 and 2020.

Class	**Chittagong, 2016**		**Chittagong, 2020**	
	Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**
Agricultural and fallow land	410.8943	2.54	2479.91	15.35
Barren land	1050.717	6.50	596.55	3.69
Settlement	10056.48	62.26	10065.87	62.32
Vegetation	3941.631	24.40	1879.61	11.64
Water body	693.0071	4.29	1130.69	7.00
Sum	16153.00	100.00	16153.00	100.00

Source: Image analysis

Classification Accuracy Assessment

In the analysis of remote sensing data accuracy assessment is the final step to verify how accurate our results are. Accuracy assessment determines the quality of information derived from remotely sensed data. The need to assess the accuracy of maps produced by remote sensing products has become a universal requirement and an integral part of any classification. The user community needs to know the accuracy of the classified images used. Additionally, each project has different accuracy requirements, and only classified images that exceed a certain level of accuracy can be used. In addition, accuracy becomes a critical issue when working with Geographic Information System "GIS" frameworks that use multiple layers of remotely sensed data. In such cases, knowing the overall accuracy becomes very important. This relies on knowing the accuracy of each data layer. Without assessing accuracy or validity a map cannot be regarded as the final product (Anon n.d.-b).

Information or prior knowledge about the ground truth is required to assess the accuracy of the classified images. This information is collected via Google Earth and compared to derived classified maps. For this evaluation, 100 random points were acquired by the software to cover the whole image. Then all selection points are checked one by one and the correct values are set based on the ground truth and Google Earth information.

Table 5: Accuracy Assessment of 2016 supervised classification image.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Vegetation	78	78	77	98.72%	98.72%
Water body	1	1	1	100.00%	100.00%
Settlement	5	10	5	100.00%	50.00%
Agricultural and fallow land	14	9	9	64.29%	100.00%
Barren land	2	2	2	100.00%	100.00%
Totals	100	100	94		
Image Accuracy and Kappa Statistics					
Overall Classification Accuracy = 94.00%					
Overall Kappa Statistics = 0.8394					

Table 6: Accuracy Assessment of 2020 supervised classification image.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Vegetation	40	54	38	95.00%	70.37%
Agricultural and fallow land	47	31	28	59.57%	90.32%
Settlement	4	7	1	25.00%	14.29%
Water body	3	4	2	66.67%	50.00%
Barren land	5	4	4	80.00%	100.00%
Totals					
Image Accuracy and Kappa Statistics					
Overall Classification Accuracy = 73.00%					
Overall Kappa Statistics = 0.5730					

Table 5 and 6 show the producers, users accuracy as well as overall classification accuracy and kappa statistics for classified image of the year 2016 and 2020. Producer's accuracy stands for the percentage of correct signature points with respective to real time points. On the other hand, user's accuracy stands for the percentage of real of points which were correctly classified in the image. Overall accuracy is the simple statistical sum of the accurate points for supervised classified satellite images. Kappa statistics is considered as the most popular tool to compare overall accuracy among different classifiers.

From accuracy assessment of 2016 classification it is found that the producer's accuracy is varied from 64.29% of agricultural and fallow land area to 100% of water body and user accuracy is varied from 50.00% of settlement area to 100% of barren land area. Overall accuracy is 94.00% which is pretty good and acceptable. The overall kappa statistics is 0.8.394 which is acceptable for satellite image classification.

The producer's accuracy is varied from 25.00% of settlement area to 95.00% of vegetation and user accuracy is varied from 14.29% of settlement area to 100% of barren land area. Overall accuracy is 73.00% which is good and acceptable. The overall kappa statistics is 0.5730 which is acceptable for satellite image classification.

Change Detection

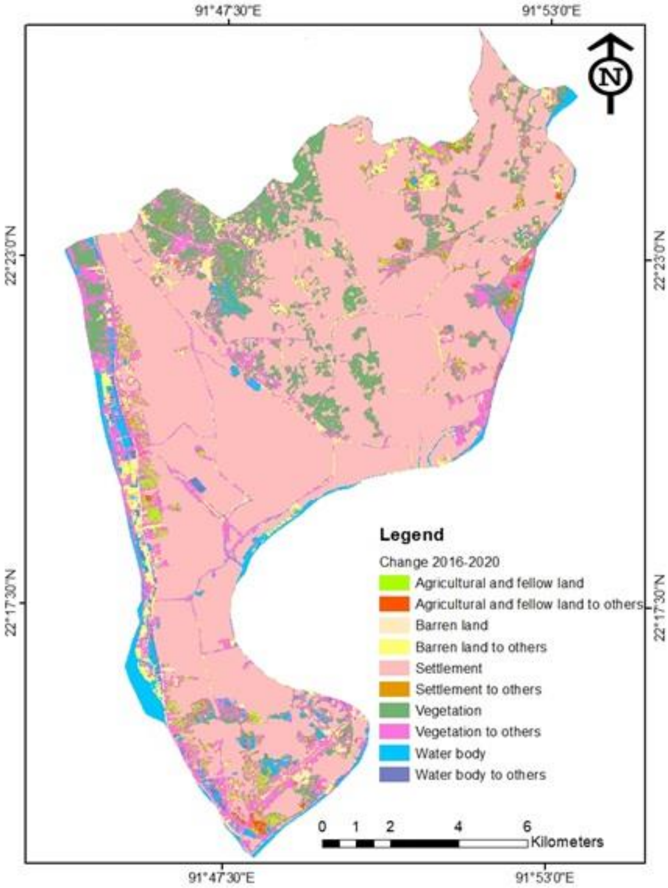

Figure 19: Landuse change map of Chittagong area (2016-2020).

Landuse change analysis map is shown in figure 19 and how much landuse change is occurred between 2016 to 2020 in Chittagong Metropolitan area that are shown in the table 7. From these figures and table, it is clear that changed area is not so high. Low or less changed occur in the study area. Here purple color shows changed area of vegetation class to others at 13.75%. Then little change occurs from barren land to other classes (4.91%). Remaining changes are very negligible. Only settlement area shows strong stability. From 2016 to 2020, 76.14% area remain unchanged.

Table 7: Landuse change statistics of the Chittagong area from 2016-2020.

Class	Area (ha)	Area (%)
Agricultural and fallow land	291.15	1.80
Agricultural and fallow land to others	119.14	0.74
Barren land	256.92	1.59
Barren land to others	793.71	4.91
Settlement	10055.42	62.25
Settlement to others	1.06	0.01
Vegetation	1719.72	10.65
Vegetation to others	2221.64	13.75

Source: Image analysis

Conclusion

The research mainly focusses on creation of landslide inventory, hydrometeorology, geology, topography and landuse of the study area. More than 800 landslide locations and related data have been collected through field survey, existing literature, scholarly articles, and newspaper. Landslide locations are mainly prominent in the northern and western parts of Chittagong and the Bandarban Sadar area. BMD rain gauge stations only provide information for a particular site, but this single value represent for the entire district. This kind of calculation is undoubtedly inappropriate over a broad area. The GPM satellite products, on the other hand, exhibit excellent spatial resolution and a range of value per day. It outlines the precipitation scenario in real time. In terms of accuracy and spatial resolution, GPM satellite based precipitation measurement is better than existing BMD rain gauge stations. The majority of the landslide spots in the research area are found in Chittagong's urban soil, which is based on the Dupitila, Tipam, and Bokabil Formation. The Chittagong region has an elevation range of 20–73 m with a slope of 4–13 °. The Brown Hill soil in Bandarban, however, changes the situation. The majority of the soil is silt loam WS sandy loam soil. And the slopes here range from 6 to 18 ° at a height between 80 and 266 meters. Analysis reveals that settlement is the dominating landuse class and consistent for both years (62.26%) in Chittagong. The second dominating class is vegetation, which fell from 24.40% to 11.64% in 2020. The third dominant group, which includes agricultural and fallow land, is then followed by a rapid increase from 2.54% to 15.35% in 2020. From change analysis it is clear that transformation among five landuse classes are insignificant during the study period. Maximum change occurred in of vegetation area to others at 13.75%. Then little change occurs from barren land to other classes (4.91%). The remaining alterations are hardly noticeable. There is substantial stability just in the settlement area. 76.14% of the total area was not change between 2016 and 2020. In Accuracy assessment analysis overall accuracy is 94.00% which is pretty good and acceptable. The overall kappa statistics is 0.8394 which is acceptable for satellite image supervised classification of 2016. And for the satellite supervised classification image of 2020 overall accuracy is 73.00% and the overall kappa statistics is 0.5730.

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