ABSTRACT: The present study aims at identifying and predicting landslide vulnerable areas in Bandarban District of Chittagong Hill Tracts (CHT) using weighted overlaying of the multiple geospatial layers to determine landslide hazard areas. The historical landslide inventory map was prepared using Google Earth image and through PRA technique. Then ten landslide triggering factors including landuse, rainfall, slope, elevation, cut-fill, soil types, geology, distance to rivers, roads and stream orders, population density, income, education of the inhabitants were chosen as effective factors on a landslide in the study area. Subsequently, the landslide vulnerability map was constructed using the weighted overlay model in Geographic Information System (GIS). Bandarban District has 348 landslides vulnerable locations. Among them, 6 are extremely vulnerable and 342 are highly vulnerable to landslides. Model results show that the Upazila Ruma and Thanchi are extremely vulnerable to landslides. About 91 percent of the landslides will occur within 10 degrees of slope, about 65 percent will occur within 50 meters elevation. The model shows that there is a strong relationship between landslides and physical, economic and social variables.

Keywords: Landslides vulnerability, Simulating, Spatial correlation, Weighted overlay, ArcGIS model builder
complex due to the different materials and the water interaction.
e) Finally, Flow is a movement of no consolidate materials and this movement can be fast or slow depends on the materials and the moisture (Summerfield, 1991).

Studies show that there are five factors in the landslides (Keller and Blodgett, 2004); materials, slope, climate, weather, vegetation, and water. These factors may act together or separately and they have different consequences in the landslides. The inclination of the slope is important as well because in general, when the slope is higher the driving force is also higher. If there is a high slope, fall is the more usual type and when the slope is low, flows are the most frequent. Climate is different around the world and mainly it has an important role in superficial landslides. In arid climates where vegetation is sparse, landslides are frequent like fall, debris flow, and superficial landslides because soil mass and rocks are exposed to high erosion. However, humid and sub-humid areas have abundant vegetation and soil mass cover most of the slopes and the landslides are more complex (Hildenbrand et al., 2003). Weather can be a complex problem in different types of landslides. Extreme weather events such as the high intensity of rainfall or long periods of rain may produce dangerous landslides.

Assessing and mapping landslide susceptibility is an established practice, often aimed at comparing different predictive methods, which offers the possibility for a dynamic, integrated and on-going management of the territory and its sudden modifications (Devkota et al., 2013; Kavzoglu et al., 2014; Pellicani et al., 2014; Shahabi et al., 2014; Pham et al., 2016). On the contrary, quantifying, in mathematical terms, the landslide risk can be very complicated, due to several aspects related to the complexity in assessing the temporal probability of a specific landslide event with given intensity (hazard) and the probability of damaging a given element at risk, i.e. vulnerability (Glade 2003; Uzielli et al., 2008; Pellicani et al., 2014; Abdulwahid and Pradhan, 2016).

The risk assessment in probabilistic terms requires the analysis of (1) the probability of occurrence of a rock fall event with a given magnitude, depending on the rock fall frequency–magnitude relationship and triggering event frequencies, (2) the probability that a boulder reaches the element at risk depending on the propagation process along the slope and mobility of element at risk, (3) vulnerability which depends on rock fall intensity and characteristics of exposed assets and (4) economic value of elements at risk, in terms of damaging of road and vehicles, interruption of traffic and loss of life (Corominas et al., 2005; Agliardi et al., 2009; Mavrouli and Corominas, 2010; Ferlisi et al., 2012; Wang et al., 2014).

In Bangladesh, level of precipitation is in increasing trend, while temperature has increased 1°C or less in the last fifty years (Sofiullah, 2018). Increase of pre-monsoon (7-8 percent) and monsoon rains (5-7 percent) is also remarkable (Sofiullah et al., 2017), which could have led to a significant rise in landslide incidence in the country in recent past (Figure 1). Furthermore, landslide risk period might be prolonged due to increasing pre-monsoon precipitation followed by heavy monsoon downpour and eventually would lead to a significant incidence of landslides.

Landslides occur almost every year; however, the scope and scale of 2007, 2010, and 2017 were some of the worst. The landslides of June 2007 killed 135 people and affected 1.5 million people when heavy monsoon rainfall intensified by a strong storm from the Bay of Bengal caused abnormal precipitation in the landslide area (BBS, 2011). During the landslides of June 2017, it was reported that 80,000 people were affected across all five districts of Chattogram Division. However, among these, 42,000 were considered severely impacted because their homes had been destroyed. The most affected districts were Chattogram, Rangamati and Bandarban. Though the number of people severely affected is quite large, there is a clear decrease in the affected population since 2007 (Table 1). This can be attributed to the resilience planning being done to address landslide risks.

**Table 1:** Landslide Affected Population

| Disaster and its Associate | June, 2017 | June, 2010 | June, 2007 |
|---------------------------|-----------|-----------|-----------|
| Severely affected population | 42,000 | 13,900 | 1,500,000 |

*Source: BBS, 2011*

Numerous studies were conducted for modeling and mapping landslide susceptibility based on the analysis of the relationships among the existing
historical landslides data and various factors predisposing instability as well as weighted according to their influence on the instability process (Soeters and Van Westen, 1996; Van Westen, 2000; Ayalew et al. 2005; Fell et al. 2008).

To perform a landslide susceptibility prediction model, GIS and Remote Sensing are the tools of paramount importance since it allows, because of their computational power, to manage data with a high degree of spatial variability (Van Westen, 2000). Therefore, GIS and Remote Sensing offer the possibility for a dynamic, integrated and on-going management of the territory and its sudden modifications.

Landslide is one of the most devastating hazards in the hilly areas and has increased in recent years. The effect of landslide can be significantly reduced by developing landslide probability model for the study area. However, the literature does not identify any such model for the study area even for the country.

The geospatial modeling on landslide vulnerability locations and establishing multivariate relationships will eventually help to meet the objective of poverty reduction of the local community at the micro-level. It is expected that the present study will facilitate in achieving the sustainable development goals (SDGs), and hope to meet the research gaps in the country. Therefore, the present study will be a milestone in the research fields.

THE OBJECTIVE OF THE STUDY

The study aims at modeling landslides vulnerability in Bandarban District of Chittagong Hill Tracts (CHT). The specific objectives are the following:

- to predict landslide vulnerable locations
- to simulate physical indicators correlated to the landslides
- to simulate social indicators correlated to the landslides
- to simulate economic indicators correlated to the landslides

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Figure 1: Landslide Scenarios in Bandarban and Rangamati District, Bangladesh (01) Landslide at Dalianpara of Ruma Upazila in Bandarban. New Age Bangladesh: Jul 28, 2017; (02) Landslide in Dolian Para of Bandarban. Photo: Sanjoy Kumar Barua: Daily Star: 24 July 2017; (03) Landslide in Ruma, Bandarban, Daily Ittefaq, 23rd July 2017; (04) Landslide in Bandarban, Bandarban-Ruma Road was Blocked, bdnews24.com; (05) Rangamati Landslide, Dhaka Tribune, 13 June 2017; (06) Rescue Workers Search for Bodies After a Landslide in Bandarban, Associated Press via AFP June 13, 2017, (07) Devastates Several Households in Rangamati District Dhaka Tribune, June 13, 2017; (08) Four People were Killed by Landslide in Bandarban: Daily Ittefaq, 3 July 2018.

STUDY AREA

The study area Bandarban, one of the three hill districts of Bangladesh and a part of the Chittagong Hill Tracts (CHT). It lies between 21º 11" and 22º 22" north latitudes and 92º 04" and 92º 41" east longitudes. It has 7 Upazilas, among them the present study considered 5 Upazilas for the study, and these are Bandarban Sadar, Lama, Rowangchhari, Ruma and Thanchi Upazila (Figure 2). Furthermore, the study area has 24 unions, 1670 villages, 2 Paurashavas and 1579 mahallas According to BBS, the total study area is about 3129.6 km², among them 1244. 78 km² (39.77 percent of the total land) is land area, 1881.66 km² is reserve forest area, and only 3.16 km² is riverine area (BBS, 2011).

Figure 2: Location of the Study Area

MATERIALS AND METHOD

Materials

Both primary and secondary data were used in the present study. Secondary data such as 1: 25000 scale topographic data were collected from Survey of Bangladesh (SoB). Last fifty years rainfall data were collected from Bangladesh Meteorological Department (BMD). Soil type data were collected from Soil Research Development Institute (SRDI). Soil compactness and geological formation data were collected from Geological Survey of Bangladesh (GSB). Different boundary data of the study area were collected from Bangladesh Bureau of Statistics (BBS). Household census such as household locations,
household income, education, tribal, non-tribal data were collected from HKI (Helen Keller International). Digital Elevation Model (DEM) data were collected from Shuttle Radar Topography Mission (SRTM) and Advanced Space borne Thermal Emission and Reflection (Aster) platforms. Besides, all kind of satellite data were collected from Landsat 4-5 TM and Landsat 8 oli/tirs sensors. High resolution 0.4 meter satellite images for the study area were collected from Google Earth platform. The following datasets were considered in the study (Table 2).

Table 2: Indicators of the Landslides Vulnerability

| Indicators                | Data Sources                                       |
|---------------------------|----------------------------------------------------|
| Historical Landslide Inventory | PRA through using 0.4 meters Google Images         |
| Elevation                 | SRTM DEM                                           |
| Slope                     | SRTM DEM                                           |
| Geology                   | Geological Survey of Bangladesh                   |
| Soil types                | Soil Resource Development Institute                |
| Streams                   | SRTM DEM Data                                      |
| Rivers                    | Survey of Bangladesh (SoB), 1: 25000 Scale Topographic Dataset |
| Roads                     | Survey of Bangladesh (SoB), 1: 25000 Scale Topographic Dataset |
| Land use                  | Survey of Bangladesh (SoB) and Landsat Satellite Images |
| Cut and Fill              | SRTM DEM and ASTER DEM                             |
| Rainfall                  | Bangladesh Meteorological Department (BMD)         |
| Population density        | Household Census Data by HKI                       |
| Education                 | Household Census Data by HKI                       |
| Income                    | Household Census Data by HKI                       |
| Landuse                   | Survey of Bangladesh and Landsat Images            |

Method

The method followed in this study is described in detail in the following sections.

Landslide inventory: Historical landslide inventory were completed using field level PRA (Participatory Rural Appraisal) techniques. A total 17 PRA were conducted in 17 unions. Each PRA was represented by all stockholders of the community (Figure 3).

Analysis of triggering events. An analysis of triggering events was carried out in order to be able to correlate landslide inventories of particular triggering events like slope in degree, elevation, stream, river, roads and landuse, rainfall, geology, soil types etc. From the available data, the landslide triggering events were identified (Figure 4).

A Digital Elevation Model (DEM) was used for generating derivative maps, such as elevation classes, slope steepness, slope direction and flow accumulation. Roads, stream and rivers were used to generate distance maps to evaluate the effect of landslide occurrence close to these features. Besides exiting geology, and soil types were used to assess the landslides vulnerability (Figure 4).
Figure 4: Workflow of Landslide Vulnerability Modeling

Figure 5: Landslide Modeling Data Validation Workshop Representing Expert of the Various Sectors

Bivariate statistical analysis. All data and investigation processes were validated through a workshop representing all related stakeholders (Figure 5). ArcGIS Model Builder model was used to identify landslides vulnerability in Bandarban. All datasets were weighted overlaid in a scale of 1 to 10 by 1 with 100 influence level (Appendix 1) where each influence was set according to the layer importance in the landslides respect (Figure 6).

RESULTS AND DISCUSSIONS

Model shows that, there are a total of six locations, those are extremely vulnerable to landslides in Bandarban District. The areal extend of the extreme landslide vulnerability is 37.45 hectares. Data shows that a total 44,434 sq meters area in Remakri Pransa union of Ruma Upazila, 13,3304 sq meters in Thanchi union of Thanchi Upazila and 196,746 sq meters in Tindu union of Thanchi Upazila area extremely vulnerable to the landslides (Table 2). There is one location in Remarkri Pransa union of Ruma Upazila, 3 in Thanchi union of Thanchi Upazila and 2 in Tindu union of Thanchi Upazila are extremely vulnerable to landslides (Figure 7).
Table 2: Extremely Vulnerable Landslide Locations in Bandarban District

| Upazila name | Union name       | No. of Locations | Landslide vulnerable area (sq meter) |
|--------------|------------------|------------------|------------------------------------|
| Ruma         | Remakri Pransa   | 1                | 44434.93                           |
| Thanchi      | Thanchi          | 3                | 133304.79                          |
|              | Tindu            | 2                | 196746.33                          |
| Total        |                  | 06               | 37.45 (HA)                         |

Source: Data simulation using geospatial model, 2018

Table 3: Highly Vulnerable Landslide Locations in Bandarban District

| Name of the Upazila | Total area (in hectares) | High vulnerable area (in hectares) | No. of locations vulnerable | Percent of vulnerable (based on total area) |
|---------------------|--------------------------|------------------------------------|----------------------------|--------------------------------------------|
| Thanchi             | 98564.93                 | 2031.37                            | 69                         | 0.62                                       |
| Lama                | 70335.85                 | 9274.43                            | 119                        | 2.83                                       |
| Ruma                | 62740.62                 | 517.88                             | 36                         | 0.16                                       |
| Rowangchhari        | 43608.71                 | 1063.52                            | 36                         | 0.32                                       |
| Bandarban Sadar     | 52794.83                 | 3590.75                            | 82                         | 1.09                                       |
| Total               | 3,28,044.94              | 16,477.95                          | 342                        | 5.02                                       |

Source: Data simulation using geospatial model, 2018

The results show that a total of 342 locations were found in Bandarban District as highly vulnerable to landslides (Table 3, Figure 7). The areal extent of the area is 16,477 hectares which are about 5.02 percent of the total area. In the vulnerability scale, the result shows that Lama Upazila is situated in the 1st position and Bandarban Sadar Upazila situated in the second position, then Thanchi, Rowanghahi, and Ruma (Table 3, Figure 7).

Figure 7: Landslides Vulnerability Locations in Bandarban District

Source: Geospatial model result, 2018

Figure 8: Landslides and Slope Relationship
Relationship between landslides and elevation: The elevation is the important factor related to the landslides vulnerability. The landslide probability model shows that about 65 percent of the landslides would occur within 50-meter elevation and about 27 percent of the landslides would occur between 50 to 100 meters elevation (Table 5 and Figure 9). Hence, about 92 percent of the landslides would occur in height about 100 meters. Data shows that there is a strong negative correlation regression between landslides and elevation, where r = – 0.83.

Table 5: Elevation of the Landslides

| Elevation (in meter) | Percentage of Landslide Locations |
|----------------------|----------------------------------|
| 50                   | 64.75                            |
| 100                  | 27.11                            |
| 150                  | 5.67                             |
| 200                  | 2.12                             |
| Above 200            | 0.35                             |

Source: Data simulation from landslide and SRTM DEM

Relationship between landslides and geological properties: The geological condition is a very important factor regarding landslides vulnerability. The present landslide model shows that about 30.19 percent of the landslides would occur at Boka Bil geology and the second probable condition would occur at Tipam Sandstone geology (28.67 percent) (Table 6 and Figure 10). Thirdly, about 25.72 percent of the landslides would occur at Dhiggi Dupi Tilla Formation geology and the rest about 15 percent landslides would occur at Bhuban Formation, Girujan Clay and Valley Alluvium and Coluvium geology (Table 6 and Figure 10). There is a strong positive correlation regression between landslides and geological compactness, where r = 0.65.

Table 6: Geology of the Landslides

| Types of Geology                        | Percentage of Landslide Locations |
|-----------------------------------------|----------------------------------|
| Valley Alluvium and Coluvium            | 0.16                             |
| Dhiggi Dupi Tilla Formation             | 25.72                            |
| Girujan Clay                            | 6.85                             |
| Tipam Sandstone                         | 28.67                            |
| Boka Bil                                | 30.19                            |
| Bhuban Formation                        | 8.41                             |

Source: Data simulation from landslide and geology

Figure 9: Landslides and Elevation Relationship

Table 4: Slope of the Landslides

| Slope (in degree) | Percentage of landslides |
|-------------------|--------------------------|
| 0-5               | 65.57                    |
| 5-10              | 25.20                    |
| 10-15             | 6.55                     |
| 15-20             | 1.90                     |
| 20 above          | 0.79                     |

Source: Data simulation from landslide and SRTM DEM

Relationship between landslides and slope: Landslides are related to the slope of the area. Model results show that about 66 percent of the landslides would occur in the slope about 5 degrees and about 25 percent of the landslides would occur in a slope between 5 and 10 degree (Table 4). Hence, about 91 percent of the landslides would occur within a 10-degree slope. And rest 9 percent of the landslides would occur above 10-degree slopes (Table 4 and Figure 8). Model shows that there is a strong negative correlation regression between landslides and slopes in degrees, where r = – 0.81.
**Relationship between landslides and soil types:** Among the landslides, the triggering factors, soil types are very important, which was established in the landslide model. The model result shows that about 25.12 percent of the landslides would occur in the sandy loam soil (Table 7, Figure 11); 15.56 percent would occur in sand and sandy soil; 43.28 percent would occur in loam soil, which is mixed soil of clay silt and sand; and lastly, about 15.75 percent of the landslides would occur in the clay loam soil (Table 7, Figure 11). Model shows that the soil types individually responsible for 40 percent landslides, where \( r = 0.40 \).

**Table 7: Soil Types of Landslides**

| Soil types         | Percentage of Landslides |
|--------------------|--------------------------|
| Sandy loam         | 25.12                    |
| Sand and sandy     | 15.56                    |
| Loam               | 43.28                    |
| Clay loam          | 15.75                    |
| Clay               | 0.30                     |

*Source: Data simulation from landslide and soil*

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**Figure 10:** Landslides and Geology Relationship

**Figure 11:** Landslides and Soil Types Relationship

**Figure 12:** Landslides and Education Relationship
where education level is 1-5 and 11.78% has found where education level is 6-10; 9.37% area has 11-15 education level; 9.67% area has 16-20 education level; 14.20% has 21+ education level and 22.36% area has education value null (Figure 13, Table 9). Education is negatively correlated with landslides. There is about 52 percent landslides story involved with education, where correlation regression, $r = -0.52$.

**Table 9: Education of the Landslides Area**

| Education of the Landslide Area | Percentage |
|---------------------------------|------------|
| No education                    | 15.41      |
| Very low educated               | 17.22      |
| Low educated                    | 11.78      |
| Moderately educated             | 9.37       |
| High educated                   | 9.67       |
| Very high educated              | 14.20      |
| No household                    | 22.36      |

Source: Data simulation from landslide and household education

**Relationship between education level and landslides:**
Model shows that 15.41% of landslides areas inhabitants have no education (Table 9, Figure 13). On the other hand 17.22% landslides area was found...
The model results show that 17.8 percent of the landslides area people have very low education and very poor; 27.27 percent of the landslides area people have low education and poor and 43.76 percent of the landslides area people have medium education and medium-income (Table 10, Figure 14).

CONCLUSION

Modeling landslides vulnerability is an important tool in facilitating the planners to manage landslides and support sustainable development in a particular area. The landslide model predicts 384 landslide vulnerable locations in Bandarban District. According to model results, 6 locations are extremely vulnerable and 342 locations were found as highly vulnerable. The model shows that about 3 percent area of Lama Upazila and 1.1 percent area of Bandarban Sadar Upazila are vulnerable to landslides. It is evident that though low slope (slope up to 10 degrees) and low elevations (up to 100 meters) are suitable for inhabitant to live but are most vulnerable to landslides because of human intervention. Geological formation Boka Bil (30.19%), Tipam Sandstone (28.67%) and Dhigi Duti Tilla formation (25.72 %) are involved with landslide vulnerability. Soil types are another important variable to landslide vulnerability. The model shows that loam soil (43.28 %), sandy loam (25.12 %) and sand and sandy soil (15.56 %) were involved with landslide vulnerability. Education and landslides are strongly related, no education triggered about 15.4 percent of landslides, very low education triggered about 17 percent landslides and low education triggered about 12 percent of landslides. Similarly, the model results show that poorness of the peoples are also the causal factor for land slide. Model illustrates that landslide occurs for 36.6 percent, 37 percent and 24 percent areas inhabited by very poor, poor and people with moderate income respectively. There is a strong negative correlation regression between landslides and slopes in degrees, where correlation regression, \( r = -0.81 \). Similarly, there is a strong negative correlation regression between landslides and elevation, where correlation regression, \( r = -0.83 \). There is a positive correlation regression between landslides and geological compactness, where correlation regression, \( r = 0.65 \). Similarly, 40 percent of the landslides are related to soil types. Besides physical factors, inhabitant’s income and education similarly correlated with landslides. 92 percent of landslides correlated with income, there is a strong negative correlation regression between income and landslides (\( r = -0.92 \)). Education is also negatively correlated with landslides. Hence the correlation regression, \( r = -0.52 \). Furthermore, less educated and low-income people are living under the poverty line. It has appeared that there is a strong relationship between poverty and landslide vulnerability. The poor people are utmost depended on the land cover to meet their necessary need. Therefore, the poorer intervened the land to their surroundings excessively and induces natural disaster such as landslides. Under the circumstances, attention should be given to the poor people to uplift their livelihood.

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### Appendix Table 1: Tabular Information of ArcGIS Weighted Overlay Procedure

| Variable                                      | Number/Values | Data Range   | Weighted Overlay 1 to 10 scale by 1 | Influence (100%) |
|-----------------------------------------------|---------------|--------------|-------------------------------------|------------------|
| Landslides Inventory (No. of historical landslides) | 0 to 6        | 0 to 6       | 1                                   | 15               |
| Elevation                                     | -1 to 1040    | -1 to 76     | 10                                  | 4                |
| Slope (in Degree)                             | 0 to 54       | 0 to 10      | 10                                  | 5                |
| Cut Volume                                    | 1 to 34981    | 1 to 2196    | 1                                   | 8                |
| Geological profiles                           |               |              |                                     |                  |
| Valley Alluvium and Coluvium                  |               |              |                                     | 5                |
| Dhighi Dupi Tilla Formation                   |               |              |                                     | 6                |
| Girujan Clay                                  |               |              |                                     |                  |
| Bhuban Formation                              |               |              |                                     |                  |
| Boka Bill                                     |               |              |                                     |                  |
| Tipam Sandstone                               |               |              |                                     |                  |
| Soil types                                    |               |              |                                     |                  |
| Clay                                          |               |              |                                     | 1                |
| Clay loam                                     |               |              |                                     | 2                |
| Loam                                          |               |              |                                     | 8                |
| Sand and sandy                                |               |              |                                     | 10               |
| Sandy loam                                    |               |              |                                     | 9                |
| River Euclidean Distance (meters)             |               |              |                                     |                  |
| 0                                             | 4796.44       | 10           |                                     | 7                |
| 4796.44                                       | 9592.88       | 9            |                                     |                  |
| 9592.88                                       | 14389.32      | 8            |                                     |                  |
| Variable | Number/Values | Data Range | Weighted Overlay 1 to 10 scale by 1 | Influence (100%) |
|----------|--------------|------------|-----------------------------------|-----------------|
|          | 0 to 47964.41| From       | To                                |                 |
|          |              | 14389.32   | 19185.76                          | 7               |
|          |              | 19185.76   | 23982.21                          | 6               |
|          |              | 23982.21   | 28778.65                          | 5               |
|          |              | 28778.65   | 33575.09                          | 4               |
|          |              | 33575.09   | 38371.53                          | 3               |
|          |              | 38371.53   | 43167.97                          | 2               |
|          |              | 43167.97   | 47964.41                          | 1               |
| Stream Line Euclidean Distance (meters) | 0 to 42407 | From       | To                                |                 |
|          |              | 0          | 100                               | 10              |
|          |              | 100        | 200                               | 9               |
|          |              | 200        | 300                               | 8               |
|          |              | 300        | 400                               | 7               |
|          |              | 400        | 500                               | 6               |
|          |              | 500        | 600                               | 5               |
|          |              | 600        | 700                               | 4               |
|          |              | 700        | 800                               | 3               |
|          |              | 800        | 900                               | 2               |
|          |              | 900        | 42407.1                           | 1               |
| Road Euclidean Distance (meters) | 0 to 64279.11 | From       | To                                |                 |
|          |              | 0          | 3781.12                           | 10              |
|          |              | 3781.12    | 9326.77                           | 9               |
|          |              | 9326.77    | 15376.57                          | 8               |
|          |              | 15376.57   | 21174.29                          | 7               |
|          |              | 21174.29   | 26972.02                          | 6               |
|          |              | 26972.02   | 33021.82                          | 5               |
|          |              | 33021.82   | 39071.62                          | 4               |
|          |              | 39071.62   | 45373.49                          | 3               |
|          |              | 45373.49   | 52935.74                          | 2               |
|          |              | 52935.74   | 64279.11                          | 1               |
| Monsoon rainfall standard deviation (1964 to 2017) | 29.38 to 61.87 | From       | To                                |                 |
|          |              | 29.382914  | 32.631968                         | 10              |
|          |              | 32.631968  | 35.881023                         | 9               |
|          |              | 35.881023  | 39.130077                         | 8               |
|          |              | 39.130077  | 42.379132                         | 7               |
|          |              | 42.379132  | 45.628186                         | 6               |
|          |              | 45.628186  | 48.877241                         | 5               |
|          |              | 48.877241  | 52.126295                         | 4               |
|          |              | 52.126295  | 55.37535                          | 3               |
|          |              | 55.37535   | 58.624404                         | 2               |
|          |              | 58.624404  | 61.873459                         | 1               |
| Land Use | Building/House | 1          |                                   |                 |
|          | Built Up Area | 1          |                                   |                 |
|          | Playground | 1          |                                   |                 |
|          | Stadium | 1          |                                   |                 |
|          | Sandy Char Land | 1          |                                   |                 |
|          | Beel | 1          |                                   |                 |
|          | Haor | 1          |                                   |                 |
|          | Lake | 1          |                                   |                 |
|          | Pond | 1          |                                   |                 |
|          | River | 1         |                                   |                 |
|          | Marsh Wetland | 1         |                                   |                 |
|          | Cultivation Land | 7         |                                   |                 |
| Variable            | Number/Values      | Data Range       | Weighted Overlay 1 to 10 scale by 1 | Influence (100%) |
|---------------------|--------------------|------------------|------------------------------------|-----------------|
|                      |                    | From  | To    |                                    |                 |
| Uncultivation Land  |                    | 0     | 27.5  | 1                                  | 8               |
| Vegetation          |                    | 27.5  | 55    | 2                                  |                 |
| Forest              |                    | 55    | 82.5  | 3                                  |                 |
| Garden              |                    | 82.5  | 110   | 4                                  |                 |
| Household density   | 0 to 275           | 110   | 137.5 | 5                                  |                 |
|                     |                    | 137.5 | 165   | 6                                  |                 |
|                     |                    | 165   | 192.5 | 7                                  |                 |
|                     |                    | 192.5 | 220   | 8                                  |                 |
|                     |                    | 220   | 247.5 | 9                                  |                 |
|                     |                    | 247.5 | 275   | 10                                 |                 |
| Education           | No education       |       |       | 10                                 |                 |
|                     | Very low education |       |       | 9                                  |                 |
|                     | Low education      |       |       | 8                                  |                 |
|                     | Medium education   |       |       | 7                                  |                 |
|                     | High education     |       |       | 6                                  |                 |
|                     | Very high education|       |       | 5                                  |                 |
| Income              | Very Poor          |       |       | 10                                 |                 |
|                     | Poor               |       |       | 9                                  |                 |
|                     | Medium             |       |       | 8                                  |                 |
|                     | Rich               |       |       | 7                                  |                 |