

Perceived Human-Induced Causes of Landslide in Chattogram Metropolitan Area in Bangladesh

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1 **Perceived Human-induced Causes of Landslide in Chattogram Metropolitan**
2 **Area in Bangladesh**

3 **Abstract**

4 This study investigates Land Use Land Cover changes in the Chattogram metropolitan area, the second largest city
5 in Bangladesh. Using a questionnaire survey of 150 local inhabitants, the study explores perceived human-induced
6 causes of landslides. Using time series Landsat images this study also analyzes Land Use Land Cover changes from
7 1990 to 2020. The analysis reveals built-up area extended rapidly during 1990 to 2020. In 1990, total built up area
8 was 82.13km², which in 30 years, stood at 451.34km². Conversely, total vegetative area decreased rapidly. In 1990,
9 total vegetation area was 364.31km², which reduced to 130.44 km² in 2020. The survey respondents identified
10 extensive rainfall, hill cutting, steep hill, and weak soil texture as several reasons for landslide. Findings show that
11 age and experience of facing landslide are two significant predictors to explain whether excessive hill cutting is
12 solely responsible for landslide. Level of education and experience of facing landslide are statistically significant in
13 explaining building infrastructure as solitary cause to landslide. Gender, age and income of the respondents
14 significantly explain deforestation as the only responsible for landslide. Finally, gender, level of education, and
15 income of the respondents significantly explain only excessive sand collection causes landslide.
16

17 **Keywords**

18 Landslide, Human-induced causes, Local perception, Bangladesh

19

1 **Introduction**

2 Bangladesh is one of the most disaster-prone countries in the world (Akhand, 2013). The physiographic and
3 morphological characteristics of Bangladesh are the primary reasons for the vulnerability of natural disaster. As a
4 type of major natural hazards, landslides have three significant causes: geological, morphological, and human
5 activity. Landslide is the third most crucial natural disaster in the worldwide that takes place over a broad range of
6 velocities (Zillman, 1999). This type of hazard causes severe damage to resources people's and nature's resources in
7 the world (Zumpano et al., 2018). According to the National Geographical Society, agricultural and infrastructural
8 development, Irrigation process, deforestation, and mining activities contribute to destabilize or weaken the slopes
9 of physical conditions of hilly regions.

10 In Bangladesh, most of the areas are floodplain on physiographic basis, with an exception of 18% of the hilly and
11 tracked regions where a significant proportion of citizens live (Islam and Uddin, 2002). Chattogram, the second
12 largest city, housed over 200 hills in the early 1910. As the commercial and business importance of the city had
13 substantially increased after the independence in 1971, the hill cutting activities severely increased to accommodate
14 excessive land demands. Since late 1990, unlike academic studies, traditional newspaper reporting explored the
15 problem of hill cutting as a major cause of water logging and landslide incidences in the city area of Chattogram
16 (Alam, 2017). In terms of frequency and magnitude of damage, Chattogram Metropolitan area is extremely
17 susceptible to landslide hazard. Alongside the natural cause, such as excessive rainfall, human-induced causes—
18 rapid urbanization, increased population density, inappropriate land use, modifications in the hilly regions by illegal
19 hill-cutting, random deforestation and agricultural practices aggravated the landslide vulnerability in Chattogram
20 Metropolitan area (Ahmed et al., 2014).

21 Changes in geomorphology in relation to land use, deforestation, hill cutting, and unplanned infrastructural
22 development trigger landslide related disasters (Shaw et al., 2013). In Bangladesh, north-eastern, north-south and
23 northern hilly regions are vulnerable to landslide due to lack of land use planning and weak enforcement by the local
24 authority (Sarker and Rashid, 2013). In the recent time, human activities of indiscriminate hill cutting for slum
25 expansion and residential housing development have resulted in many landslides in the Chattogram metropolitan
26 area. Landslides that occur because of rainfall pose a severe threat in the Chattogram Hill Districts (CHD) of
27 Bangladesh. Inhabitants living on the steep slopes are highly vulnerable to landslide disasters. A heavy rainfall in
28 2017 led to a major fatal landslide in Bangladesh history that caused 168 deaths and smashed around 40,000 houses
29 in Rangamati, Chattogram, and Bandarban regions (Ahmed et al., 2018).

30 ***Human-induced landslide***

31 Human-induced landslides (HIL) refer to landslide incidents that are directly triggered or partially aggravated by
32 anthropogenic activities. These anthropogenic causes are the modifications of topography, changes of water
33 circulations, land use changes, and constructions of infrastructure (Jaboyedoff et al., 2016). Studies have found that

1 the human and geomorphological factors are more significant to cause landslide hazards than geological influences
2 (Dahalet *et al.*, 2008). Landslides are poly-causal phenomena, in which it is very difficult to separate man-made causes
3 from natural ones, but human intervention has played a key role in stimulating the natural antecedents of landslides
4 (Alexander, 1992). Landslides are natural events that cause community disruptions, and direct and indirect costs.
5 Direct costs are the damages immediately attributable to the landslide, but the indirect costs include economic
6 constraints and ecological effects that often exceed the direct costs (Turner, 2018) which have crucial effects on the
7 socio-economic structure (Christopher, 2016).

8 Landslides result a major constraint on development, causing high levels of economic loss and substantial numbers
9 of fatalities each year (Petley *et al.*, 2007). It causes loss of life and injury to people and their domestic animals and
10 damage to infrastructure, agricultural lands and housing (Perera *et al.*, 2018). Different effects of landslides have
11 increased in the recent time because of the rapid expansion of urbanization in the developing world. Landslide
12 causes damaged in the many aspects of human life, and the natural environment and physical or socio-economic
13 losses seriously affect populated regions (Denis *et al.*, 2017). In many countries, socioeconomic losses because of
14 landslides are great and apparently are growing as human development expands into unstable hill-slope areas under
15 the pressures of increasing populations. The monetary losses from landslides are certainly underestimated, as
16 landslides often happen because of other natural hazards such as earthquakes or floods. It is difficult to separate the
17 losses from direct and indirect causes of landslide, because losses are not well documented (Kjekstad and Highland,
18 2009). In Bangladesh, Chattogram Metropolitan Area (CMA) is extremely vulnerable to landslide hazards, with a
19 growing tendency of frequency and damage (Ahmed, 2015).

20 Landslides are one of the most destructive and frequent disasters in the hilly regions of Bangladesh. In the last
21 decades, devastating landslides have constantly hit the hilly areas in Bangladesh, because of climate change along
22 with other anthropogenic influences such as high population density, indiscriminate land use, and uncontrolled hill
23 cutting (Sultana, 2020).The main causes for landslide in the Chittagong district are hill cutting, weak soil structure
24 and de-vegetation and major effects of landslide on the local communities are loss of natural scenic beauty,
25 economic loss, destruction of lives and environmental problems (Islam, 2018). There are many reasons aggravating
26 the landslide vulnerability in Chattogram Metropolitan Area such as rapid urbanization, increased population
27 density, improper land use, modifications in the hilly regions by illegal hill-cutting, random deforestation, and
28 agricultural practices (Ahmed, 2015 and Khan *et al.* 2012).

29 Land Use and Land Cover (LULC) change can enhance or reduce susceptibility of landslide in the mountainous and
30 hilly areas (Chen *et al.*, 2019). Landslides are influenced by different climatic and environmental factors such as
31 topography, morphology, hydrology, lithology, and land use. The changing magnitudes of Land use and land cover
32 potentially increase the quantity of unstable hillslopes (Reichenbach *et al.*, 2014). It is well known that stability of
33 slopes changes based on land use land cover changes because vegetation changes may influence the mechanical and
34 hydrological characteristics of slope (Greenway 1987). Forest clearing in the hilly area by human for infrastructure
35 and development of settlement increases the susceptibility of landslide hazards.

1 Further communication between government agencies and residents can lessen the risk. Perception of local people
2 help in the management plan (Mendonca and Gullo, 2020). This article identifies the perception of local people in
3 relation to human-induced causes of landslide in the Chattogram metropolitan area of Bangladesh. Other specific
4 objectives were to investigate land use land cover change of last forty years. To dive into the objectives, this study
5 uses primary (questionnaire from residential communities) and secondary (remote sensing) data collected from the
6 Chattogram metropolitan area of Bangladesh and US geological surveys. This study links spatial pattern of LULC
7 change and perception of inhabitants and investigates how human-induced influences increased the vulnerability of
8 landslide in the hilly region of Bangladesh.

9 **Materials and Method**

10

11 ***Study area***

12

13 Every year, landslide occurs in the south-eastern parts of Bangladesh (Mia et al., 2015). Compare to other regions,
14 Chattogram city has been known as one of the most susceptible cities to landslide. The most devastating case of
15 landfall occurred on 11 June 2007 in the Chattogram which is one of the major landslides in the history of
16 Bangladesh (Sultana, 2013). The present study explores anthropogenic causes on landslides in Chattogram
17 metropolitan areas (Figure 1) of Bangladesh. The population of Chittagong city is about 5 million and is growing.
18 This area is within 22° 14' and 22° 24' 30" north latitude and between 91° 46' and 91° 53' east longitude (Ahmed,
19 2015). As mentioned above, a landslide is a major geologic hazard in Bangladesh. Some specific areas of the
20 Chattogram Metropolitan area—locally called Motijharna, Baizid Bostami, Kushumbag residential area, Batali Hill
21 and Lichu Bagan—are vulnerable to landslide. Among the list, Batali hill, Motijharna and Lebu Bagan are most
22 populated and landslide-prone areas. For this reason, this study selects Lichu Bagan, Batali Hill and Motijharna.

23

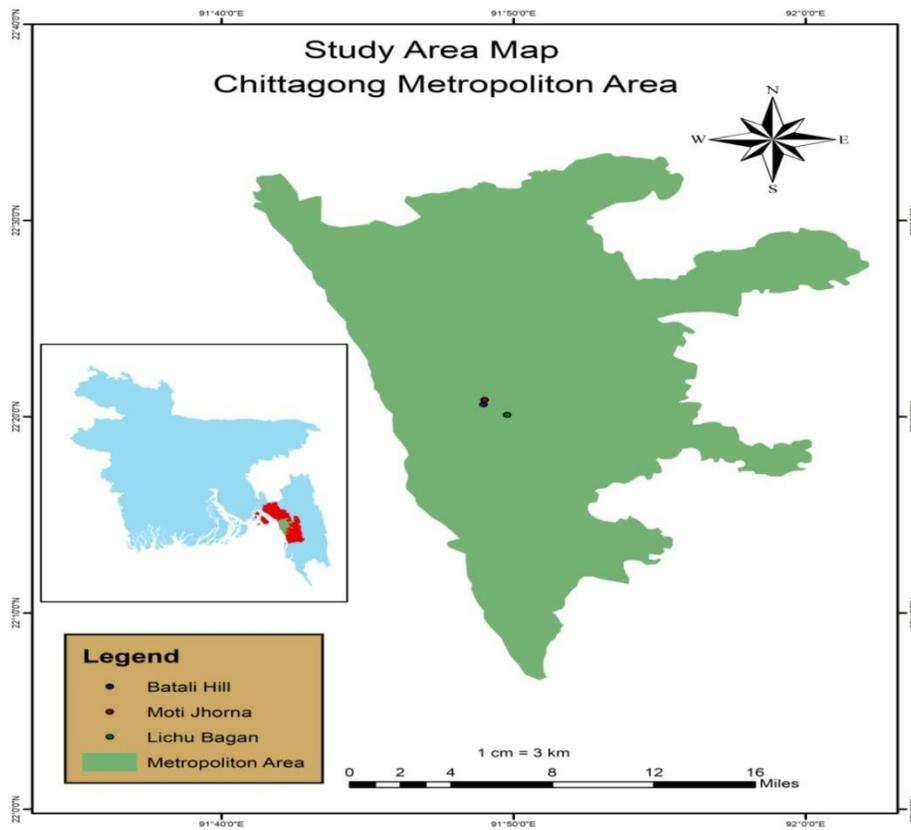
24 ***Data collection tools and techniques***

25

26 This study adopts descriptive-explanatory strategy (Babbie 2004; Islam 2008), combining a survey using a self-
27 administered questionnaire (Mugambiwa and Dzomonda 2018) technique and GIS approach. The questionnaire was
28 organized in a way to help achieve the aim of this study. The questionnaire had several parts highlighting the socio-
29 demographic characteristics of respondents. This study collected data from 150 respondents about their education,
30 age, income, occupation, breadwinners, family size, and housing patterns. In the next part, the respondents were
31 asked about their challenges and experiences related to landslide hazards in their area. The respondents returned
32 their understanding about causes of landslide, including human activities, how do they consider landslide effects
33 their life, do they follow any preventive strategy to mitigate landslide hazards, and do they experience any pre-
34 management activities the governmental and nongovernmental actors take. A categorical response was provided for
35 respondents to check off the option according to their own choice. In the last part of questions, each respondent was

1 asked about their more specific opinions regarding different causes of human induced landslide—excessive hill-
2 cutting, infrastructural development, deforestation and excessive sand collection.

3 In the GIS approach, to determine Land Use and Land Cover (LULC) change, this study collects secondary data
4 from the United States Geological Survey (USGS). The study collects Landsat images within ten-year intervals that
5 select the year 1990, 2000, 2010 and 2020 respectively. Each satellite image reflects the dry season and sensor was
6 Landsat TM and OLI/TIRS (Table 1).



7
8
9

Figure 1: Map of Study area

1 Table 1

2 *Data set information, sensors and their resolution*

Satellite Id	Sensor Id	Path/Row	Acquisition Date	Spatial resolution
Landsat 5	TM	136/44	31-10-1990	30
Landsat 5	TM	136/45	31-10-1990	30
Landsat 5	TM	136/44	29-12-2000	30
Landsat 5	TM	136/45	29-12-2000	30
Landsat 5	TM	136/44	23-11-2010	30
Landsat 5	TM	136/45	23-11-2010	30
Landsat 8	OLI/TIRS	136/44	04-12-2020	30
Landsat 8	OLI/TIRS	136/45	04-12-2020	30

3

4 *Measurement and data analysis*

5 In this study, the outcome variable is the local people's perception about human induced causes of landslide. The
6 questions about this variable attempt to measure whether excessive hill cutting is responsible alone for landslide.
7 The explanatory variables of this study include gender, age, level of education, income, housing pattern, and
8 landslide experience. The study employed Chi-square test and multinomial logistic regression models to determine
9 the effects of independent variables on the people's perception about human induced causes of landslide.
10 Researchers use these statistical techniques to analyze perceptions of local people (Manandhar et al., 2014, Brouder
11 and Lundmark, 2011).

12 *Pre-preparation of satellite images*

13 *Radiometric Correction*

14 In this study, only green and near infrared band of each image receive the radiometric and atmospheric corrections.
15 Using radiance value, we converted the respective DN value:

$$16 \quad L_{\lambda} = \frac{(L_{max} - L_{min})}{(Q_{cal_{max}} - Q_{cal_{min}})} \times (Q_{cal} - Q_{cal_{min}}) + L_{min} \text{-----}(1)$$

17

18

19

1 By aiding Erdas Imagine application, we created a model to perform the conversion.
2 $Q_{cal_{max}}$, $Q_{cal_{min}}$, L_{max} , and L_{min} values were taken from the Metadata file provided with Image file. We followed
3 the same procedure to convert the DN values for Green and NIR bands of each image. After converting the DN
4 value into radiance value (L_{λ}) equation 2 was used to get top of atmospheric reflectance.

5
$$\rho = \frac{\pi \times L_{\lambda} \times d^2}{E_{sun} \times \cos(\theta_s)} \text{-----}(2)$$

6 The value of the Earth-Sun distance, d was calculated using Julian calendar and solar zenith angle θ_s was taken from
7 MLT file. E_{sun} is the mean solar exo-atmospheric irradiance in $\frac{w}{m^2} \mu m$, the E_{sun} value varies with the super craft and
8 sensor of satellite. The E_{sun} values for Landsat 7 and Landsat 5 were collected from Landsat 7 handbook (Irish, R,
9 R. 2000 and Chander et al, 2009).

10 *Atmospheric correction*

11 Dark Object Subtraction is a simple image-based method of atmospheric correction which assumes that there are at
12 least a few pixels within an image which should be black (% reflectance) and suck black reflectance as dark object
13 which extracts clear water body and shadows with DN values zero (0) or close to the zero in the image (Chavez,
14 1988).

15 *NDVI Index*

16 Normalized Difference Vegetation Index (NDVI) is a globally accepted remote sensing index widely used to sense
17 the vegetation, forest extension and the water bodies over the surface using red and near-infrared light. An NDVI
18 value always ranges from -1 to +1 where a value of +1 shows heavy vegetation, while -1 implies an extensive deep-
19 water body, with 0 signifying the absence of any vegetation. NDVI equation is given below in equation 3.

20
$$NDVI = \frac{NIR-Red}{NIR+Red} \text{-----}(3)$$

21

1 Table 2

2 *NDVI value for present work*

Feature's Name	NDVI Value Range
Water Body	<0.08
Build Up Area	0.07- 0.30
Barren Land	0.30- 0.54
Vegetation Land	0.54- 1

3

4 **Results**

5 *Background of participants*

6 Table 3 demonstrates socio-demographic background of the respondents. In this study, 62.7% respondents are male
7 and 37.3% are female. Based on the respondents' age, we categorized three groups—middle-aged group (72%),
8 young-aged group (26%), and old-aged group (2%). In response to the question related to educational attainment,
9 this study finds that 45.3% people can read and write only, 36% of the respondents have primary education, and
10 10.7% have secondary education. Only 8% respondents have higher secondary education. Table 1 shows housing
11 types of participants where more than half of the respondents (54.0%) have tin shed house, while only 7.3% have
12 building and 32.7% have semi building. In this study, 65.3% respondents informed their monthly earning is below
13 10,000 Tk., while 34.7% people earn more than that. Most (46.7%) of the family have at least two earning members
14 followed by 37.3% and 16.6% have one and three breadwinners, respectively. A large (78%) percentage of
15 participants are local compared to only 22% non-local respondents. Additionally, 17.3% respondents are involved
16 with small business, 16% involve in service, and the remaining 6.7% people are engaged with other jobs.

17

18

19

1 Table 3

2 *Background information of participants*

Background Characteristics	Categories	Frequency (f)	Percentage (%)
Gender	Male	94	62.7
	Female	56	37.3
Age	Young (below 30)	39	26
	Middle Age (31-60)	108	72
	Old Age (more than 60)	3	2
Education	Illiterate	68	45.3
	Primary	54	36.0
	Secondary	16	10.7
	Higher secondary	12	8.0
Housing pattern	Building	11	7.3
	Semi-building	49	32.7
	Tin Shed	81	54
	Earthen	9	6
Income	Below 10,000 Tk.	98	65.3
	More than 10,000 Tk.	52	34.7
Earning members	1 person	56	37.3
	2 person	70	46.7
	3 person	24	16.6
Locale of the Area	Yes	117	78
	No	33	22.0
Occupation	Daily labor	56	37.3
	Small business	26	17.3
	Service	24	16.0
	Housewife	34	22.7
	Others	10	6.7

3

4 *Respondent understandings of landslides*

5 Figure 2 recapitulates respondents' understanding about landslide related issues. The results indicate landslide is a
6 familiar hazard in the study area as most of the respondents experienced landslide (62%) in their life. However, 32%
7 of the respondents reported that they do not have any such experience. Regarding causes of landslide, over two-
8 quarter of the respondents spoke of extensive rainfall as the major cause compared to almost one-quarter who
9 identified hill cutting as the principal cause. In contrast, some other participants replied steep hill (8%) and weak soil

1 texture (8.7%) as primary reasons for landslide hazards. The findings indicate 94% respondents believe different
 2 human activities cause landslide and 95.3% pointed out it has impact on local people. A more than half of the
 3 participants (51.3%) replied that they adopt any kind of strategy that can help to avoid risk of causing landslide. In
 4 contrast, 48.7% do not follow any such strategies. Most of the participants adhered to resettlement (68.5%) for
 5 avoiding risk whereas 24.6% respondents preferred stopping hill cutting and enhancing afforestation (6.9%) could
 6 be a better solution. Majority of the respondents opined they comply with pre-management initiatives by
 7 Government or Non-governmental Organizations (NGOs) to minimize the risk. Major policy actions that the
 8 respondents try to comply with are stopping illegal activities (40%), identifying landslide prone area (24%),
 9 expanding tree plantation (19.3%), and developing water drainage system (16.7%).

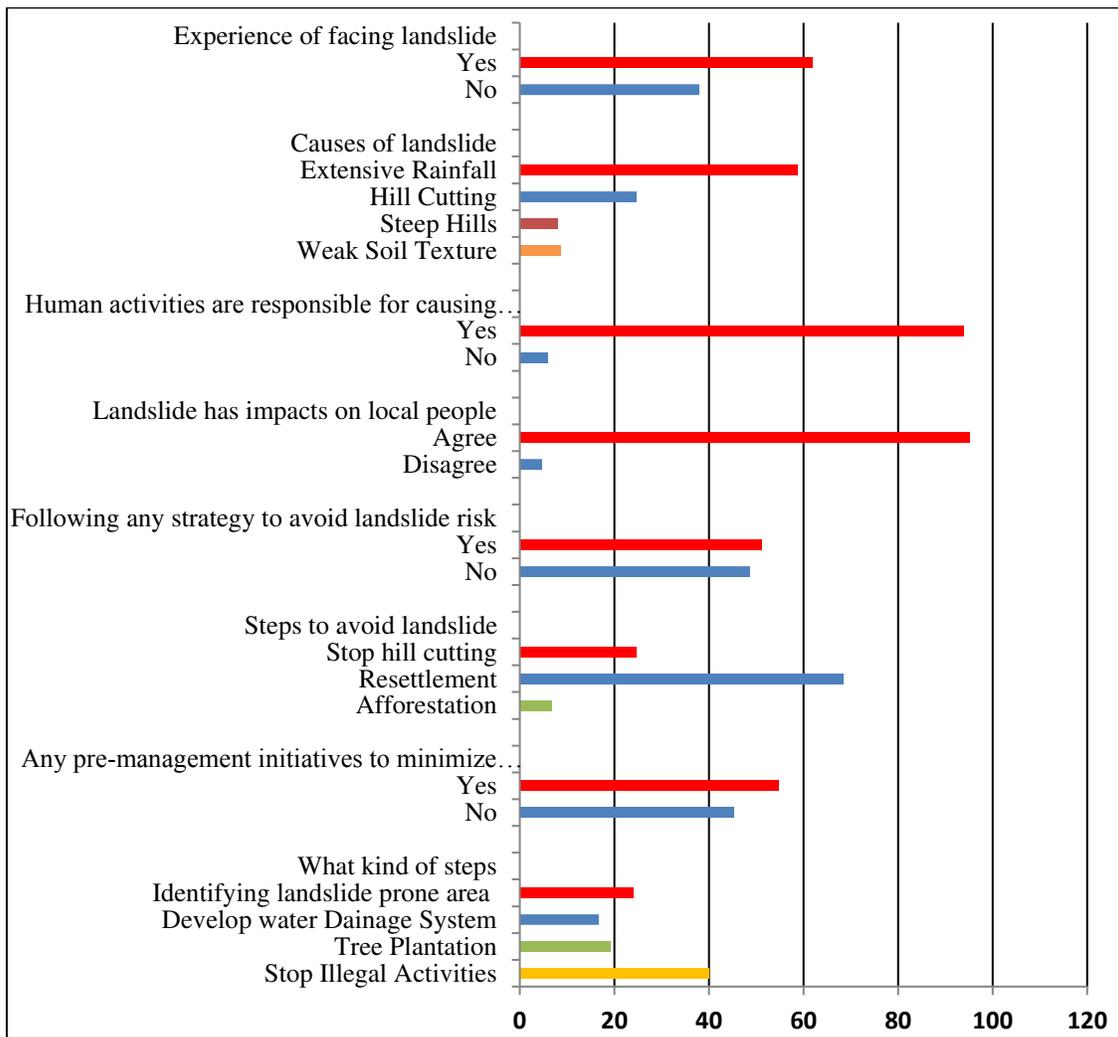


Figure 2: Respondents understanding of landslide related issues

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 11
 12
 13

1 **Locality and perception regarding human-induced landslide**

2 Most of the local and non-local respondents do not agree that excessive hill cutting is solely responsible for
 3 landslide (58.1% local and 63.6% non-local). In contrast, 41.9% local and 36.4% non-local respondents believe that
 4 excessive hill cutting is a solitary cause for this hazard. The test of significance (Chi-square test) suggests that there
 5 is a statistically significant difference between local and non-local participants regarding their perception of
 6 excessive hill cutting as the only cause for landslide hazard ($p < 0.05$). 75.2% local and 66.7% non-local respondents
 7 said they do not agree on infrastructural development as the only cause for landslide. However, this finding is not
 8 statistically significant ($p > 0.05$).

9 24.8% local and 33.3% non-local residents opine that building infrastructure is the only cause for landslide. Table 4
 10 also depicts that non-local respondents (78.8%) show more disagreement than local people (72.6%), when they were
 11 asked whether deforestation is the only cause for landslide. A good percentage of respondents agree that
 12 deforestation is only to blame for it (27.4% local and 21.2% non-local). Chi-square test result confirms a significant
 13 variation between the testimonies of local and non-local respondents ($p < 0.05$). Regarding excessive sand collection
 14 as the principal reason for landslide, there is no significant ($p > 0.05$) difference between the opinions of local and
 15 non-local respondents (94.0% local and 90.9% non-local). Only 6.0% of local and 9.1% non-local responders think
 16 excessive sand collection is the only reason for it.

17 Table 4
 18 *Locality of the respondents and perception on hill cutting*

Perception	Local		Non local		P value
	Agree % (n)	Disagree % (n)	Agree % (n)	Disagree % (n)	
Excessive hill cutting is alone responsible for landslide	41.9 (49)	58.1 (68)	36.4 (12)	63.6 (21)	.009
Building infrastructures solely causes landslide	24.8 (29)	75.2 (88)	33.3 (11)	66.7 (22)	.374
Only deforestation can be blamed for landslide	27.4 (32)	72.6 (85)	21.2 (7)	78.8 (26)	.032
Landslide occurs only due to excessive sand collection	6.0 (7)	94.0 (110)	9.1 (3)	90.9 (30)	.459

19

20

1 ***Perception regarding human-induced causes of landslide: multinomial logistic regression***

2 We try to examine the factors that affecting the perception regarding human induced causes of landslide by using
3 four multinomial logistic regression models. Outcome variables used for the models are statements asking whether
4 “excessive hill cutting was alone responsible for landslide”, “building infrastructures solely cause landslide”, “only
5 deforestation can be blamed for landslide”, and “landslide occurs only because of excessive sand collection.” The
6 response categories of the outcome/dependent variables are coded with ‘0’ if they agree with the statement and ‘1’ if
7 they do not agree with the statement. For all models, the reference category is ‘disagree’.

8 The result shows (Table-5) that two predictors—age and experience of facing landslide—have a significant effect
9 for the first model about “excessive hill cutting was alone responsible for landslide.” The result illustrates that
10 middle- and old-aged respondents compared to young respondents are less likely to agree with the statement that
11 excessive hill cutting is alone responsible for landslide. Respondents who do not experience landslide compared to
12 their counterpart are less likely to agree that landslide occurs mainly because of excessive hill cutting. Although the
13 result is not significant, but the table presented below also suggests that females compared to males, respondents
14 who earn over 10,000 Tk. per month compared to these who earn less than that and who obtained more than
15 secondary level study than who have below secondary level study are more likely to agree with the statement.

16 Two predictors—level of education and experience of facing landslide—are found statistically significant for the
17 second model about “building infrastructures solely causes landslide.” Respondents having more than secondary
18 level study are less likely to agree with the statement compared to their counterpart. The result also shows that
19 people who have no experience of facing landslide in their area are 2.5 times more likely to agree with the statement
20 “building infrastructures is the only cause for occurring landslide” compared to their counterpart. Although the
21 result is insignificant, the table below shows that middle and old aged people are 1.5 times more align with the
22 statement than young people do.

23 Table-5 illustrates that the three predictors—gender, age, and income significantly explain the model dealing with
24 “only deforestation can be blamed for landslide.” Females compared to males, middle- and old-aged respondents
25 compared to young and respondents whose monthly income over 10,000 Tk. compared to these who earn less than
26 10,000 Tk. per month are less likely to agree with the statement “deforestation is the only reason for landslide.” We
27 also found that respondents who have tin shed and earthen house compared to these who have building or semi-
28 building house and respondents who do not have experience of facing landslide compared to people who have
29 experienced landslide in their home area are more likely to blame deforestation as the sole reason for landslide. The
30 results are not statistically significant.

31 Finally, three predictors—gender, level of education, and income—significantly explain the model regarding
32 “landslide occurs only because of excessive sand collection.” Females are 4.8 times more likely to agree than males
33 that excessive sand collection causes landslide, and that is the only causes. Respondents having more than secondary

1 level study compared to having below secondary level study are 2.3 times more likely to agree with the statement.
2 Findings also show that respondents who earn over 10,000 Tk. per month are less likely to blame excessive sand
3 collection as a solitary cause to landslide compared to their counterpart. While the results are not statistically
4 significant, yet middle- and old-aged people compared to young people and respondents who have not experienced
5 landslide than respondents who have are more likely to agree with the statement.

6 ***NDVI analysis of Chattogram metropolitan area***

7 Table-6 reveals the value of NDVI analysis of CMA that shows a speedy increase in the built-up areas between 1990
8 to 2020. In 1990, built up area was 82.13km² which stood at 451.34km² in December 2020. However, the total
9 vegetative area decreased rapidly in the same period. In 1990, total vegetation area was 364.31 km², which came
10 down to the CMA of 130.44 km² in 2020. We conduct NDVI analysis with local people's perception to investigate
11 which process further intensifies the landslide process. NDVI result reveals that in CMA built up area increased
12 quickly in the last 40 years and total vegetative area decreased, which further intensify the landslide susceptibility in
13 the metropolitan area of Chattogram.

14

1 Table 5

2 *Parameter estimates for perception of human induced landslide*

Independent variables	Categories and coding	Excessive hill cutting is alone responsible for landslide	Building infrastructures solely causes landslide	Only deforestation can be blamed for landslide	Landslide occurs only due to excessive sand collection
		Agree	Agree	Agree	Agree
		Coefficient (Odds ratio)	Coefficient (Odds ratio)	Coefficient (Odds ratio)	Coefficient (Odds ratio)
Gender	Male = 0 Female = 1	.144 (1.154)	-.618 (.539)	-.089 (.915)*	1.587 (4.887)***
Age	Young Age = 0 Middle and Old Age = 1	-.320 (.726)*	.462 (1.588)	-.088 (.915)**	.145 (1.157)
Level of education	Below Secondary = 0 More than Secondary = 1	.381 (1.464)	-.807 (.446)*	-.073 (.930)	.850 (2.339)*
Income	Below 10,000 Tk. = 0 More than 10,000 Tk. = 1	.011 (2.011)	-.078 (.925)	-.157 (.855)*	-.616 (1.852)*
Housing Pattern	Building and Semi Building = 0 Tin Shed and earthen = 1	-.079 (1.803)	-.249 (.779)	.326 (1.386)	-.600 (.549)
Experience of facing landslide	Yes = 0 No = 1	-1.014 (.363)**	.953 (2.594)*	.111 (1.118)	.389(1.476)

3 The reference category is: Disagree.

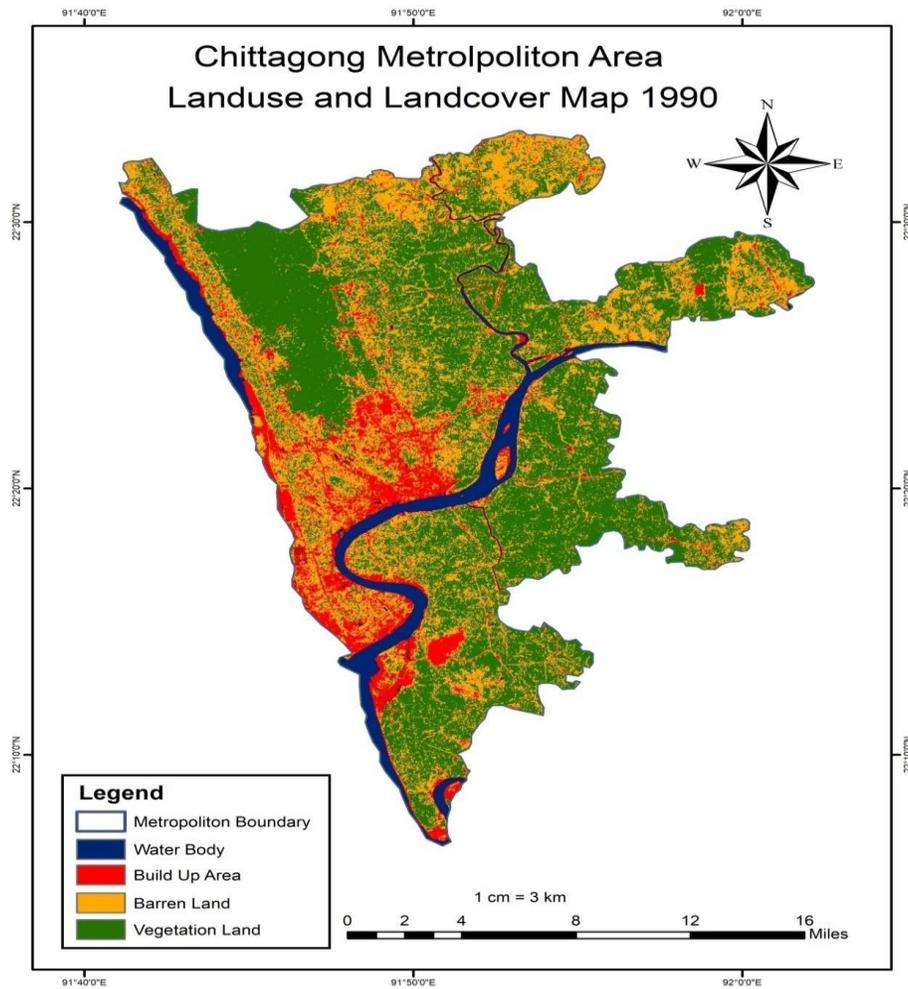
4 *** p<.005, **p<.010, *p<.05

1 Table 6

2 *NDVI analysis of CMA*

Year	Water	Built Up Area	Barren land	Vegetation
1990	50.8392	82.1367	234.0162	364.3155
2000	49.3344	167.2056	172.5705	342.1971
2010	52.3008	217.9719	238.7268	222.3081
2020	51.1668	451.3428	98.3502	130.4478

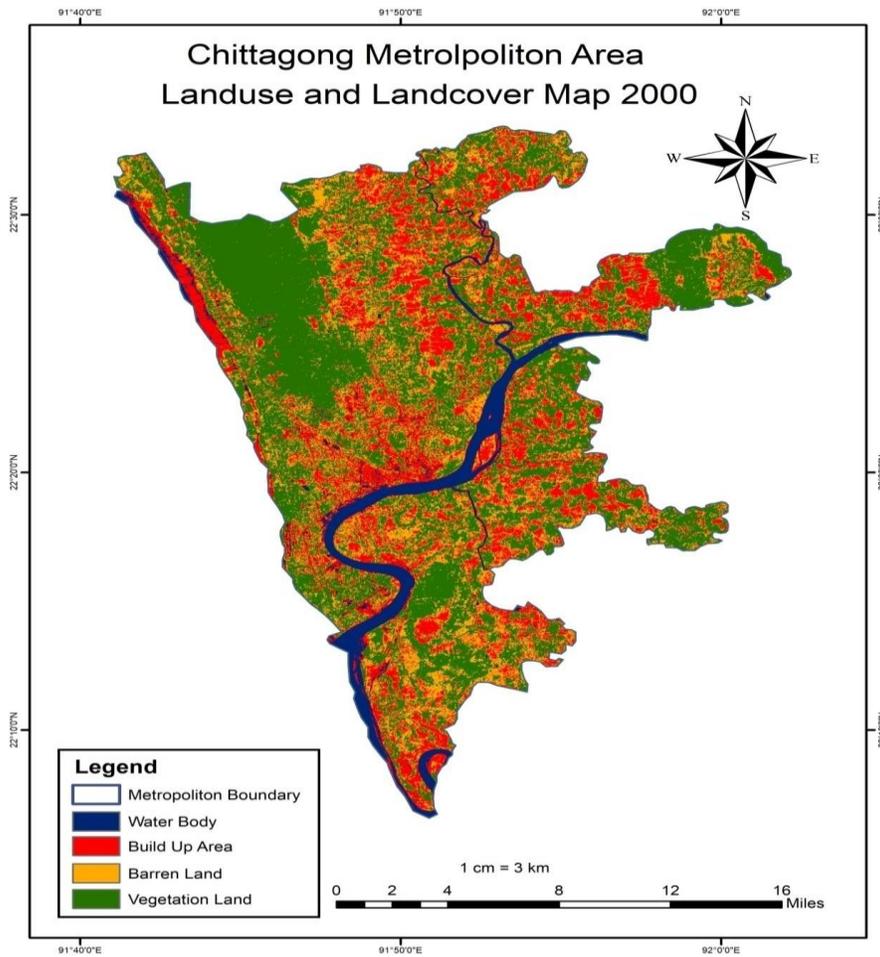
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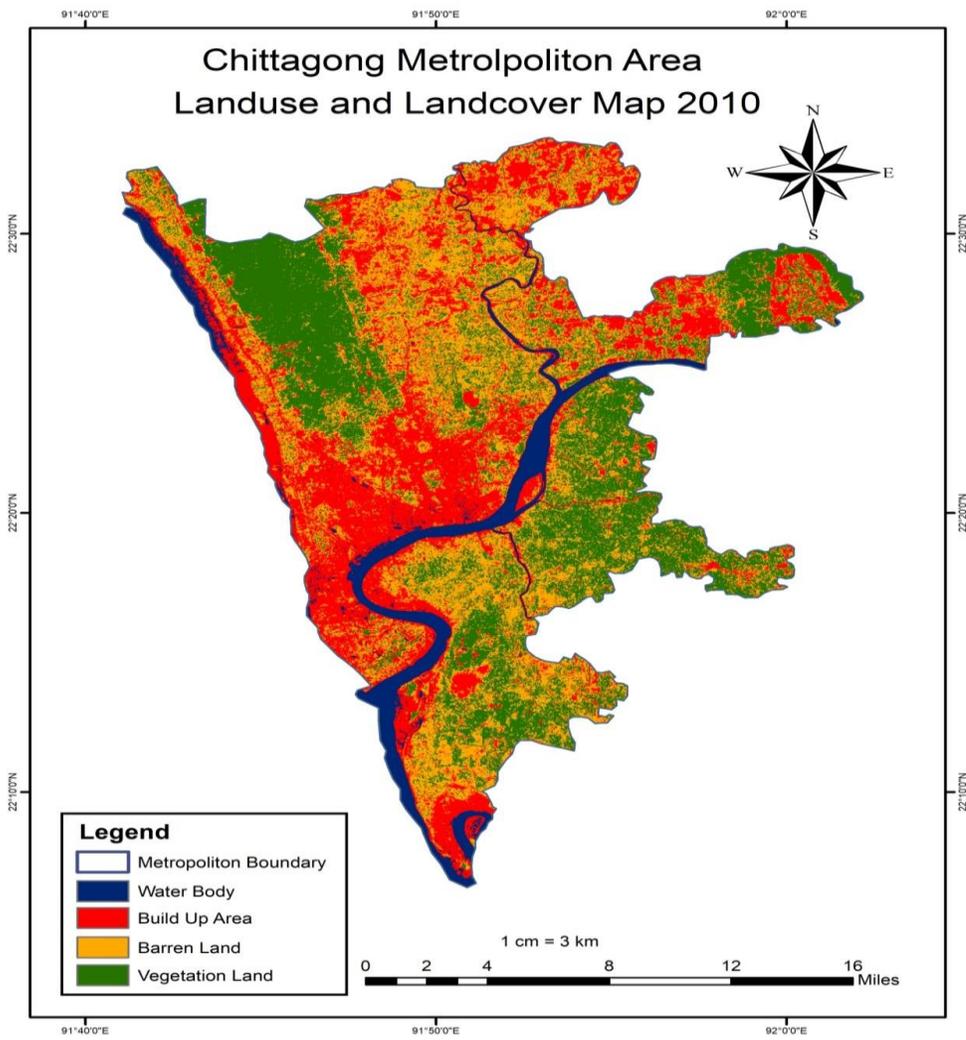
Figure 3: Land use of land cover map of 1990



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of land cover map of 2000

Figure 4: Land use



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Land use of land cover map of 2010

Figure 5:

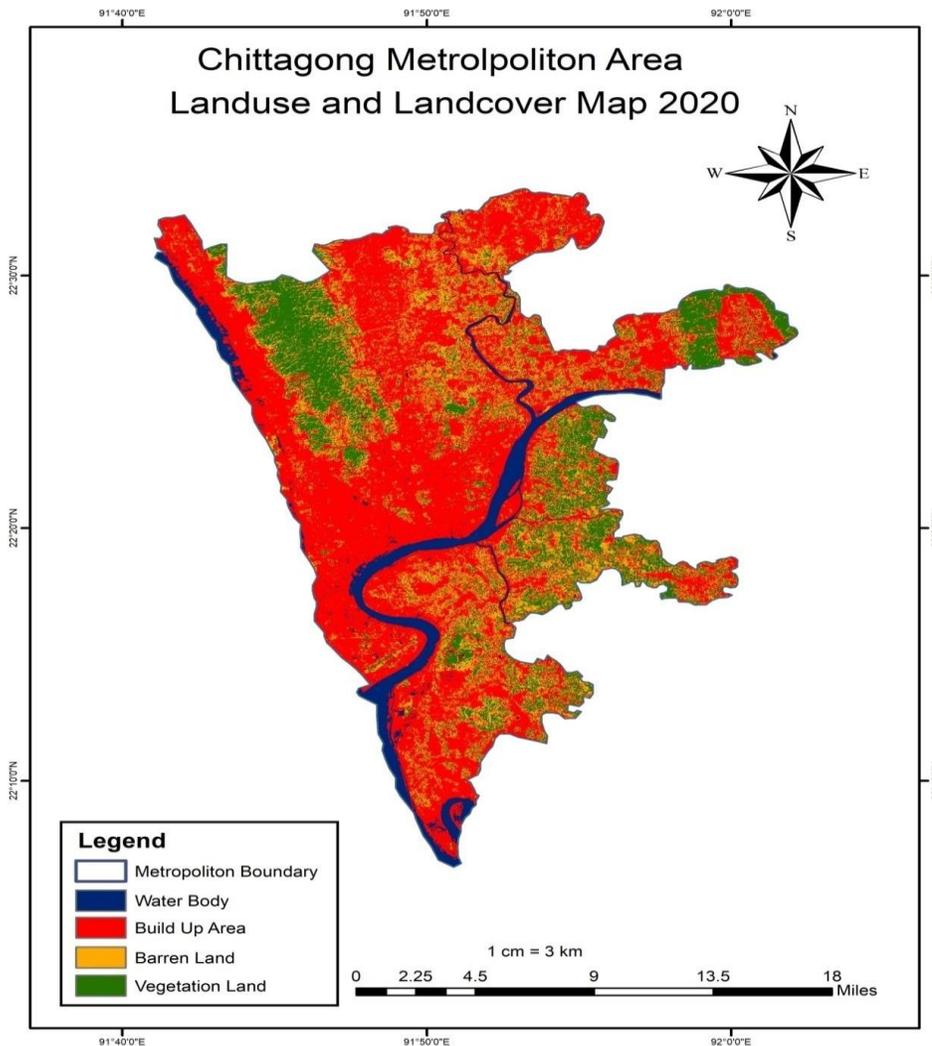


Figure 6:

1
2 Land use of land cover map of 2020

3 Discussion

4 For the last thirty years, Bangladesh has been experiencing hill cutting problems and consequent landslide incidence
5 in the southeastern hilly region (Alam, 2020). The present study finds that more than half (mention the %) of the
6 total participants have experience of facing landslide compared to the remaining 32% who do not have this
7 experience. This result clearly shows that landslide is not surprising among the inhabitants of the study area. Moreno
8 and Ayala (2017) argue in their study that a better understanding of how landslide is perceived is one of the most
9 important issues in enhancing landslide disaster risk awareness and knowledge. They suggest a knowledgeable
10 landslide perception among people to create a resilient community.

1 In terms of causes of landslide, extensive rainfall (58.7%) has been identified as the most critical cause followed by
2 hill cutting (24.7%), steep hill (8%), and weak soil texture (8.7%). This study also suggests that only 41.9% local
3 and 36.4% non-local respondents believe that excessive hill cutting is solely responsible for landslide, and there is
4 also a statistically significant difference found between local and non-local participants regarding their perception of
5 excessive hill cutting as the main reason for landslide. Hassan et al., (2015) found similar results where they
6 identified hill cutting as the principal reason for the subsequent landslide occurrence in Chattogram city area.

7 The findings in this study show that most of the local and non-local inhabitants opine that different human activities
8 cause landslide in the study area, which is detrimental to their local life. As landslide is not uncommon to most of
9 the respondents, more than half of the participants followed any kind of strategy, which helps them avoid risk of
10 happening landslide. Alam, (2020 and Burton (1993) hold in their study that it is crucial to recognize how people
11 living in the unstable environment perceive hazards and risks and to understand their indigenous knowledge and
12 awareness regarding particular hazards. The authors argue that this kind of perception may be critical to lessen the
13 consequent effects of natural hazards. The current study asked participants to mention what strategy particularly
14 they follow to avoiding risk of landslide. Most of the people responded they follow resettlement (68.5%) to avoid
15 risk followed by stopping hill cutting (24.6%) and enhancing afforestation (6.9%). They also recommended some
16 pre-management activities, such as blocking illegal activities, identifying landslide prone area, expanding tree
17 plantation and developing. In the risk mitigation approaches, hazard knowledge and risk discernment are vital
18 components (Gaillard, 2008). It is also suggested that human interference has played a key role in stimulating the
19 natural precursors of landslides occurring and risk appreciation does not promote adequate risk mitigation
20 (Alexander, 1992).

21 A study conducted by Hassan and Nazem (2016) about LULC change and urban growth in Chattogram city and
22 result of the study reveal that because of the increase of built-up areas 56% of the land cover have undergone
23 change. This change trigger further encroachment and degradation because of other human activities near urban
24 areas. Roy and Saha (2016) explore the temporal pattern of land cover change in Chattogram district that show that
25 urban area and barren land is rising, whereas the forestland is declining at an alarming rate during 2002 and 2014.
26 Gazi et al., (2020) conducted a study about Spatio-temporal changes of land cover in Chattogram metropolitan area
27 that reveals urban structures increased rapidly (from 20.83 to 58.93%) while vegetation area decreased from 56.54 to
28 20.24% in the study period. The present study also found that built up (in 1990 the area was 82.13 km². and in 2020
29 it was 451.34 km²) area increased rapidly and vegetation (in 1990 it was 364.31 km², but in 2020 it was 130.44 km²)
30 decreased in the study period.

31 We found that young respondents and respondents who experienced landslide in their local area are more likely to
32 agree that excessive hill cutting is the only reason for landslide compared to their counterparts. Respondents having
33 more than secondary level education and who have experienced landslide in their local area are more likely to agree
34 that building infrastructures is the only cause for occurring landslide than their counterparts. We also found that
35 females, middle and old aged and these to earn over 10,000 Tk. per month are comparatively less likely to think that

1 deforestation is the only reason for landslide. Females compared to man, respondents having more than secondary
2 level education compared to below secondary level education and respondents having less than 10,000 Tk. earning
3 per month compared to these who earn over 10,000 Tk. monthly are more likely to agree that excessive sand
4 collection is the alone cause of landslide. A study conducted on an indigenous community living in Taiwan by
5 Roder et al., (2016) where their results suggest that gender, age education and experience of natural hazards were
6 significant predictors in hazards knowledge and risk perception also paying attention to the indigenous perception of
7 a hazard and risk can increase the effectiveness of projects implemented by government or any organization. Rieux
8 et al., (2012) work on coping strategies and landslides in two villages of Central-Eastern Nepal and finding suggest
9 that importance of investing in organizational skills, while building on local knowledge about landslide mitigation
10 for reducing landslide risk.

11 **Conclusion**

12 This study explores the perception of local people about human induced causes of landslides. The results show that
13 human alteration influences natural causes of landslides and people's perception vary based on gender, age,
14 educational attainment, experience of facing landslide and their financial condition. As local inhabitants face the
15 effects of landslide directly, their perceptions and opinions important especially for making them more resilient.
16 This kind of information is significant for decision makers and authorities who need to recognize and take action for
17 effective landslide management at the local level in the hilly area of Bangladesh and beyond. Findings of this study
18 uncover the local perceptions regarding landslide causes that may be helpful for the policy makers and other
19 stakeholders in order to find a better solution to this problem and assist the responsible bodies for taking better plan
20 related to landslide. The present study can be an example for the future study which will be combined topography,
21 geology, geography, climatic data and land use and land cover change helps the decision-maker for the formulation
22 of rules and guidelines about human induced causes of landslide especially in hill cutting, infrastructure
23 development in the hilly area and sand mining in the hilly region and aid in minimizing negative effects on local
24 inhabitants.

25 One limitation of the study is that it only looks at one particular area and our sample size was 150, which are too
26 small to generalize the overall scenarios of perception regarding this issue. A comparative study among different
27 parts taking large samples could be an interesting work. However, these limitations will certainly pave the way for
28 future studies to overcome these weaknesses.

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Figures

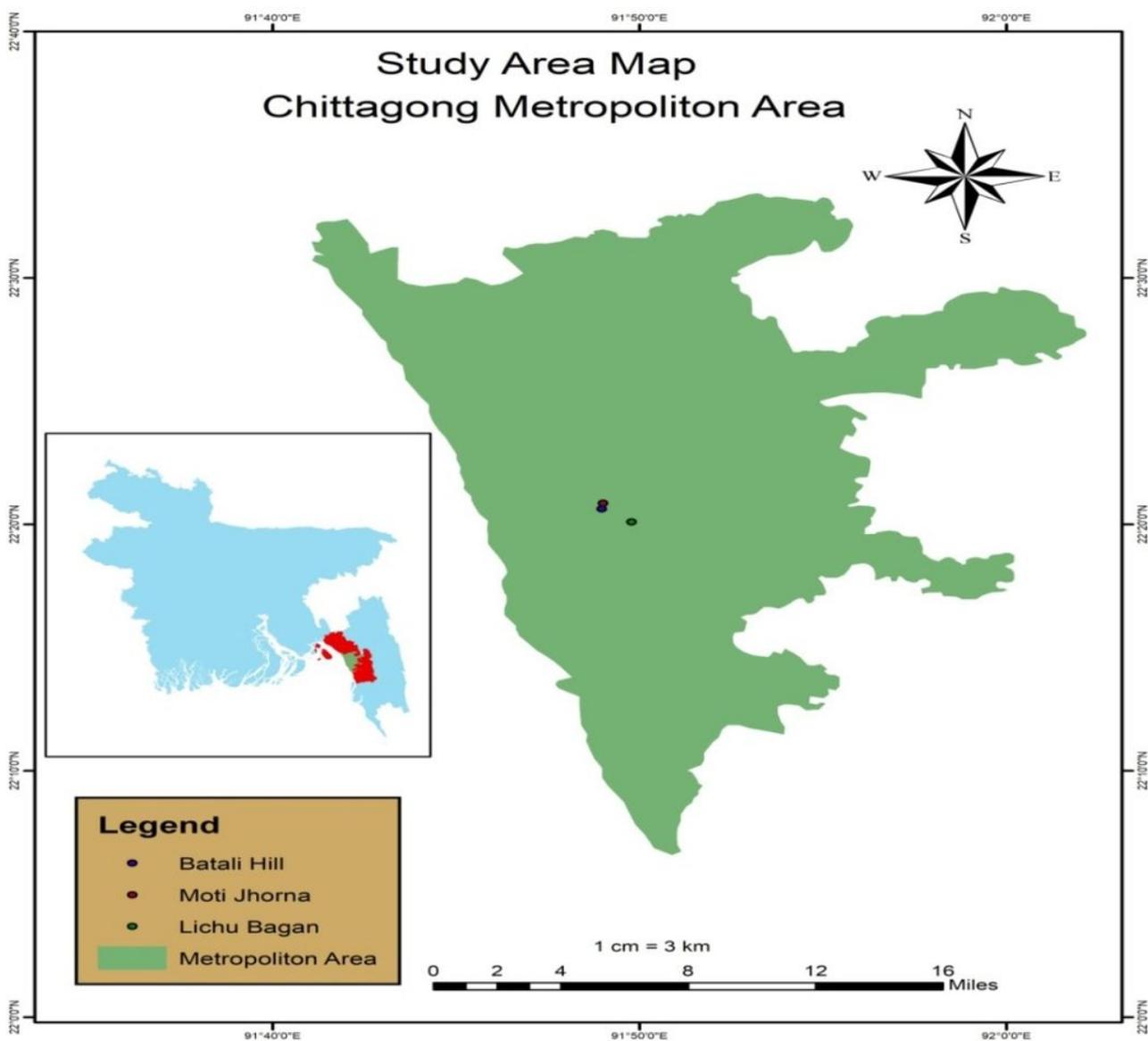


Figure 1

Map of Study area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

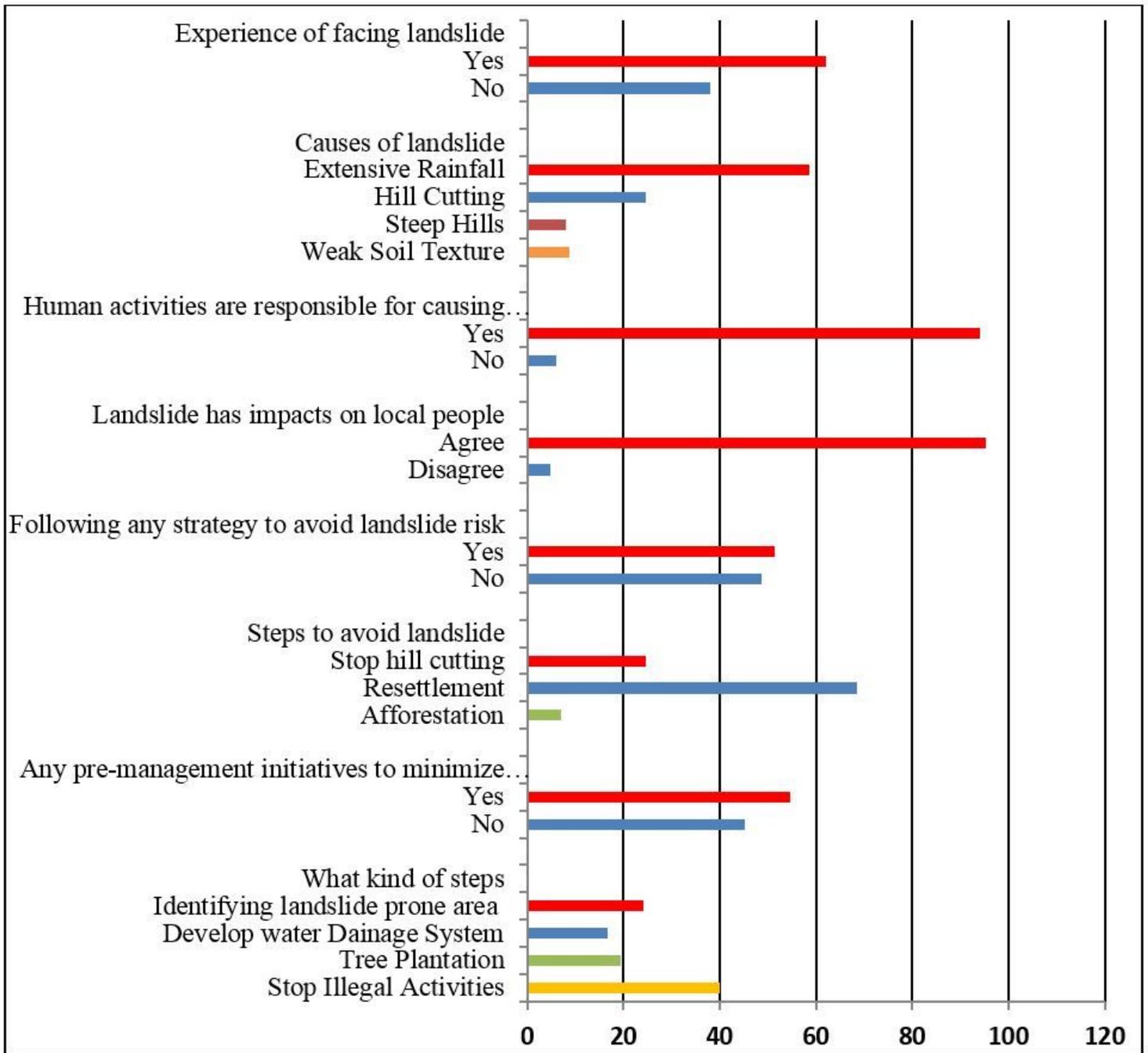


Figure 2

Respondents understanding of landslide related issues

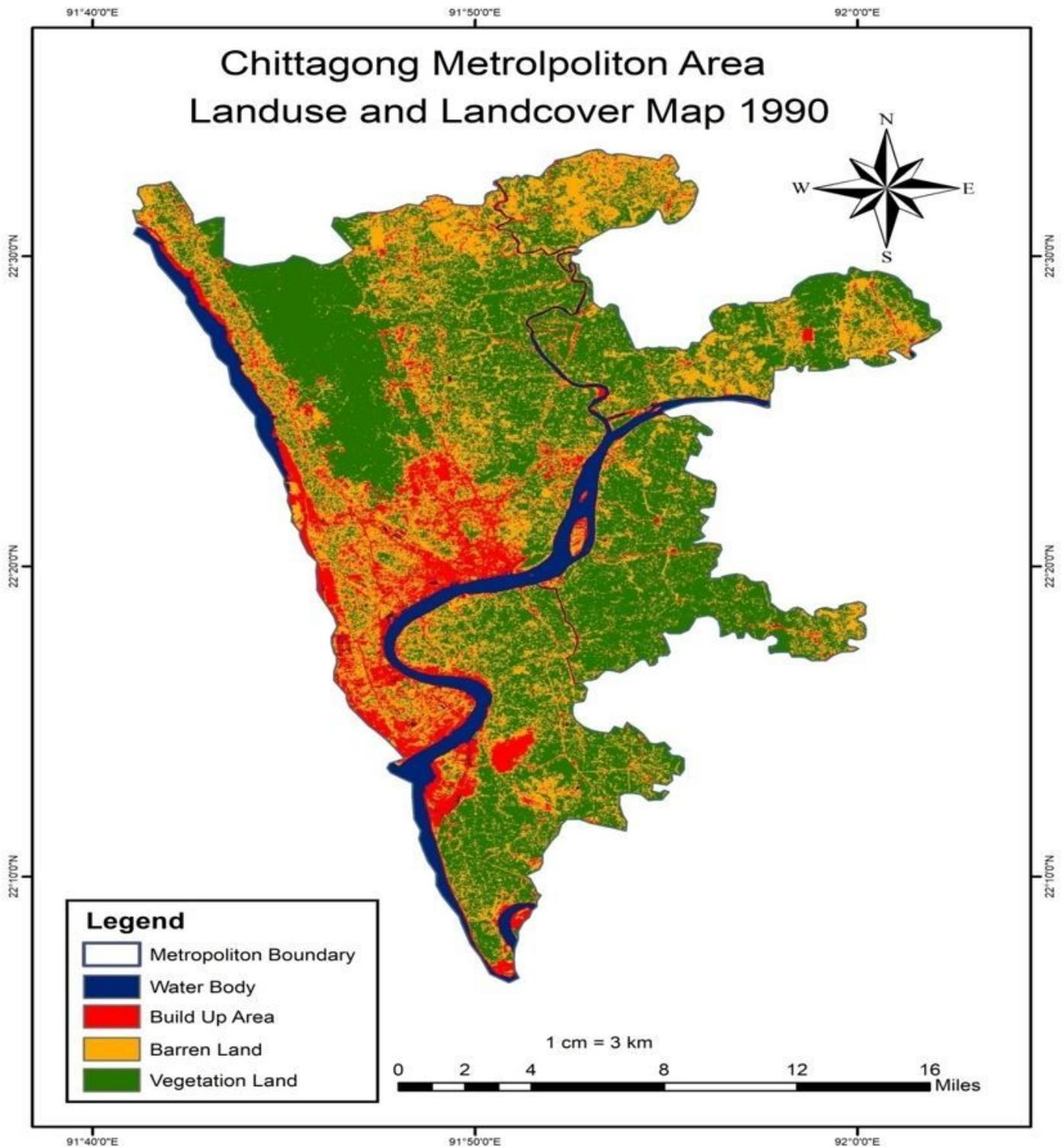


Figure 3

Land use of land cover map of 1990. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

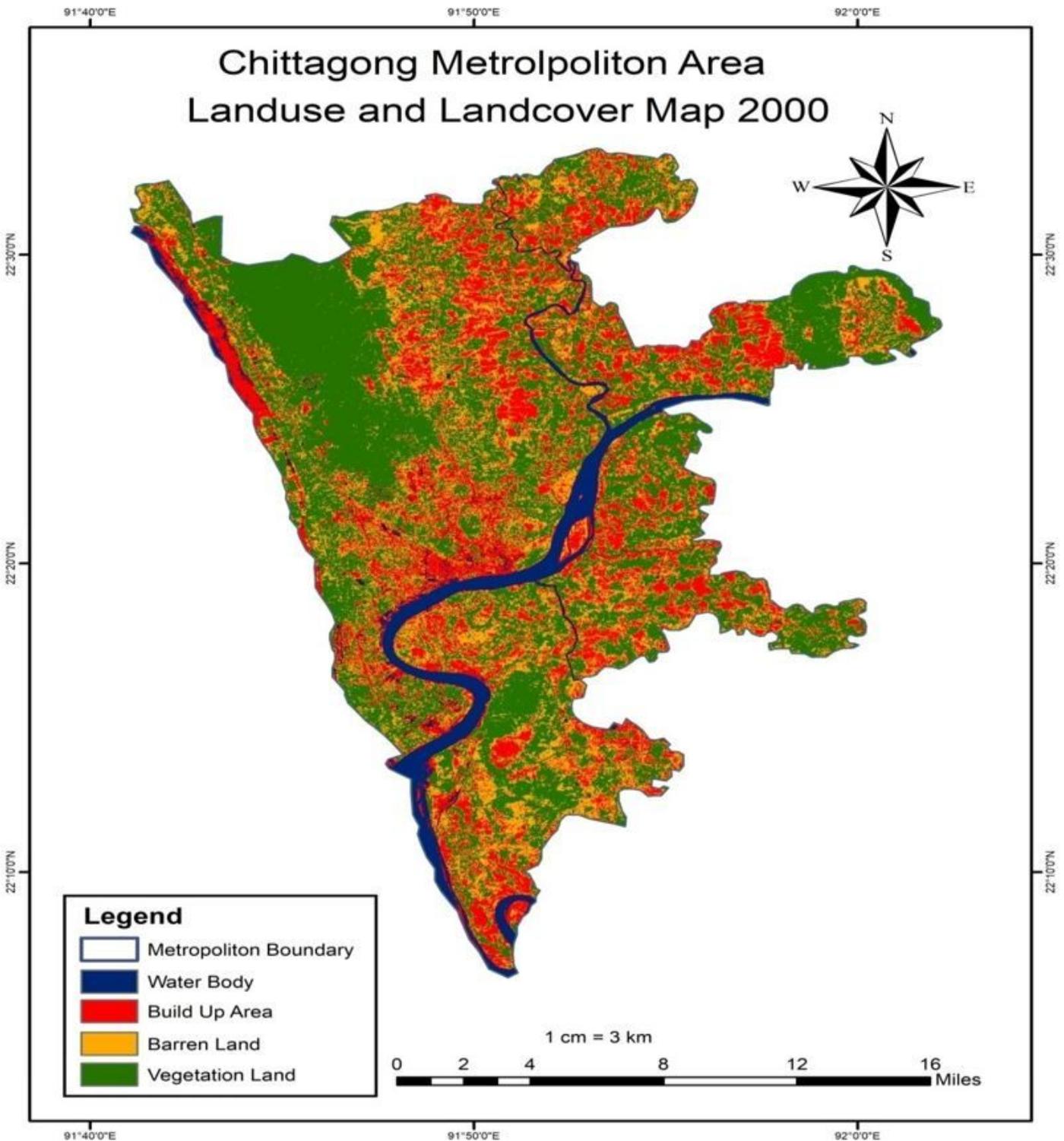


Figure 4

Land use of land cover map of 2000. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

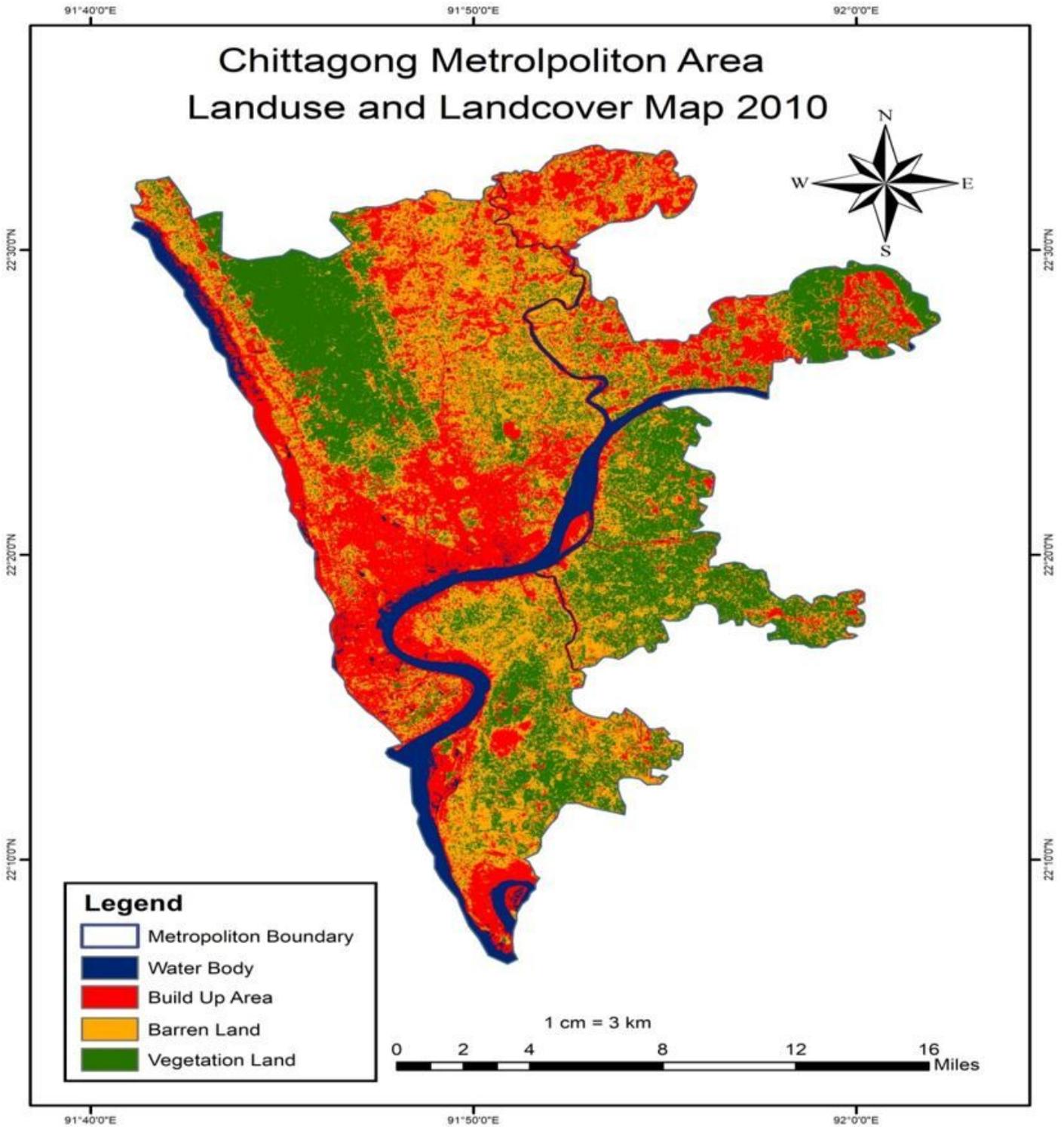


Figure 5

Land use of land cover map of 2010. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

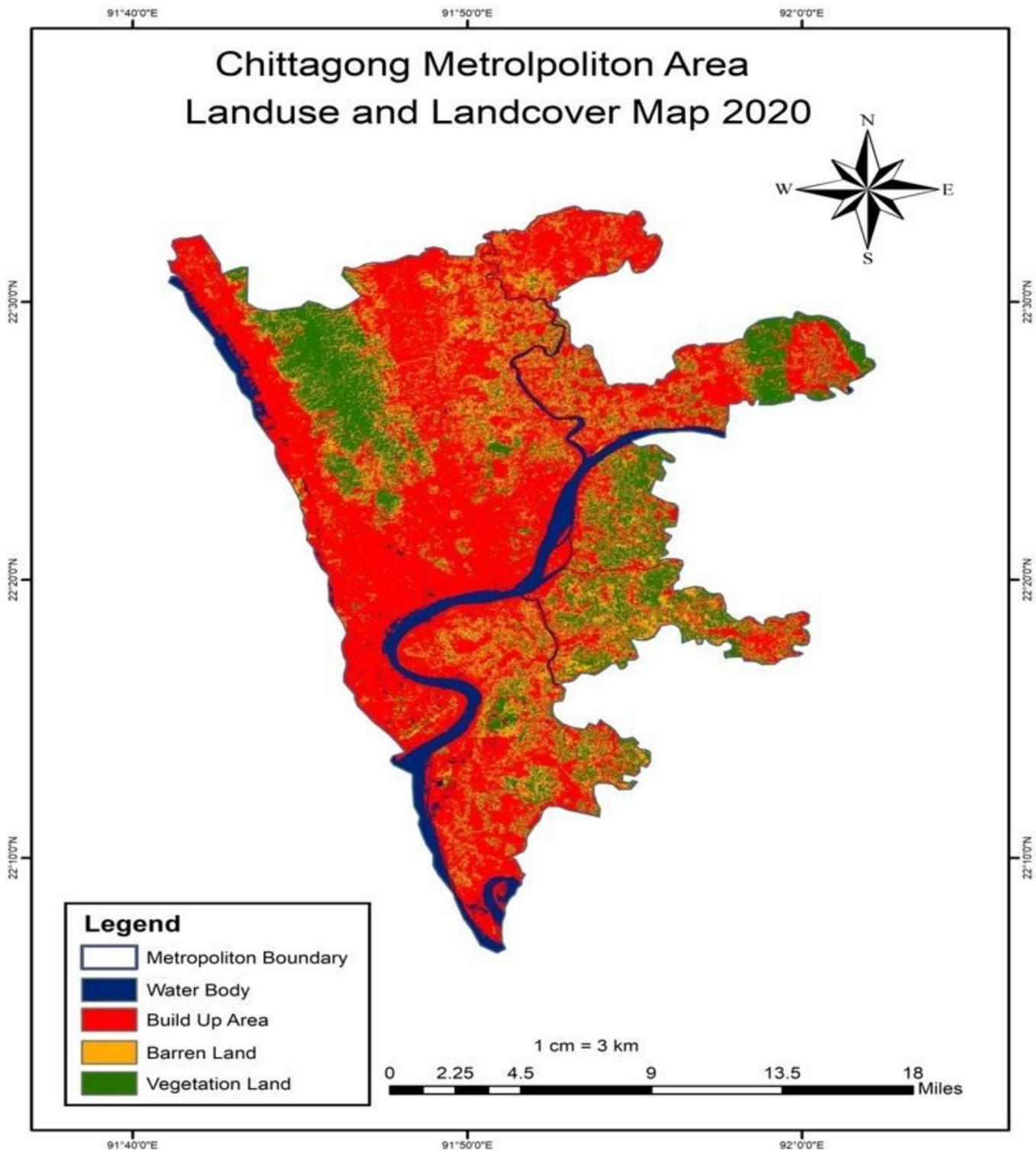


Figure 6

Land use of land cover map of 2020. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Supplementary Files

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- [LandslideDataset.csv](#)