GIS-BASED LANDFILL MAPPING OF DHAKA CITY AREA, BANGLADESH, USING REMOTE SENSING DATA

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ABSTRACT

On the basis of the interpreted geomorphological units, a detail and accurate distribution of landfills in Dhaka city area has been figured-out in this study. The attainment of the geomorphological map is based on the interpretation of the oldest available aerial photographs (1:40,000) acquired in 1955. In addition to the aerial photographs, old topographic maps (1:7920) and soil profiles obtained from available borehole data have been used to further support and improve the interpretation. The fills on the low-lying geomorphic units of urban ground are mapped using a Fused Color Composite Image (FCCI) created through the integration of IRS-1D PAN and Landsat ETM^{+} bands 5, 4 and 3, acquired in February, 2000 and 2002, respectively. The statistics of fill area map reveal that out of 194 sq. km. low-lying areas of the geomorphic units, 79 sq. km. experience urbanization with different fill thickness. The fills are classified into four classes taking into consideration their approximate relative thickness. The fill thickness information on each geomorphic unit is estimated from the soil profiles of the borehole data and the elevation contours as drawn on the old topographic maps. As final stage of our study, we overlaid the geomorphological map with fill thickness map in order to obtain an updated and accurate ground conditions map of the Dhaka city area.

1. BACKGROUND

The creation of artificial landforms, particularly through land filling processes for urban growth, is a widespread phenomenon in the mega-cities around the world. It has been proved that land fills are particularly vulnerable to the occurrence of earthquake-related hazards, such as ground-shaking and soil-liquefaction. Moreover, uncontrolled filling processes also give rise to other natural disasters such as urban flooding, ground water pollution, air pollution and subsidence. So, in an area of rapid urbanization, the accurate delineation of the landfills on the urban ground is highly desirable in order to provide basic information for mitigation of different types of geo-hazards derived structural damages settled on filled-up ground.

Onwards 1971, Dhaka has been experiencing a rapid urbanization through land filling practices with a rather insufficient consideration in mitigating the potential damages could be gotten place from geo-hazards and the impact on the environment. According to Chowdhury (1989), the growth of Dhaka city in 1950s could well be treated as slow and gradual; in the 1960s the pace picked up and onward 1971, after the emergence of Bangladesh it would be phenomenal.

Dhaka has got the experience of historical earthquake damage. Its vicinity is seismically active in recent days, such as, in December, 2001, an earthquake with a magnitude of 4.8 M_b occurred around 40 km west of Dhaka which caused leaning in a four story building constructed on fills in city area. So, to combat the damages derived from the probable geo-hazards and to produce a sustainable plan for further urban growth, the city demands a detail and accurate geomorphic map covering landfill sites. Presently available geomorphological map (Asaduzzaman, 1999) with eight geomorphic units of Dhaka city area appears too gross to these authors. Furthermore, the landfills as shown in this map are found unrealistic and incomplete when compare with the recently acquired remote sensing data.

Keeping the above problems in mind, an attempt is taken to delineate the geomorphic unit-based landfills of Dhaka city area using recently acquired satellite images.

As shown in Figure 1, the study area is located in the centre of Bangladesh between longitude 90^{0} $19^{/}$ 10.37"E (BTM-618601m) and 90^{0} $31^{/}$ 1.61"E (BTM-644389 m) and latitude 23^{0} $40^{/}$ 49.9"N (BTM-532863 m) and 23^{0} $54^{/}$ 46.5"N (BTM-552923 m) which covers a 305 square kilometers and is surround by the river system, namely, Buri-Ganga, Turag, Tangi and Balu.

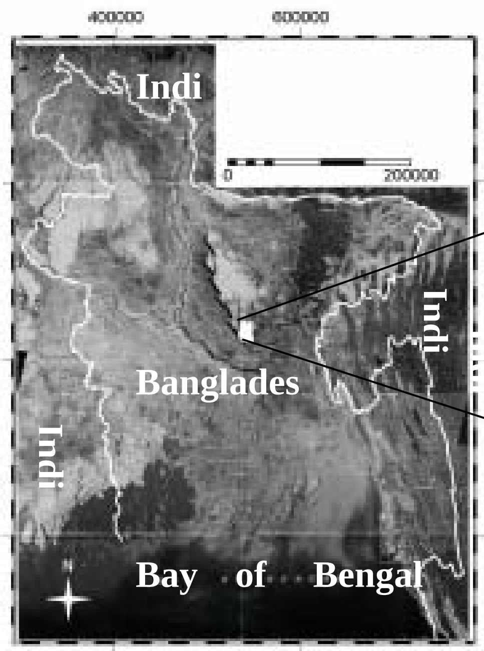

Figure 1: (A); Mosaic Landsat TM image of Bangladesh shows Dhaka city area studied in white polygon

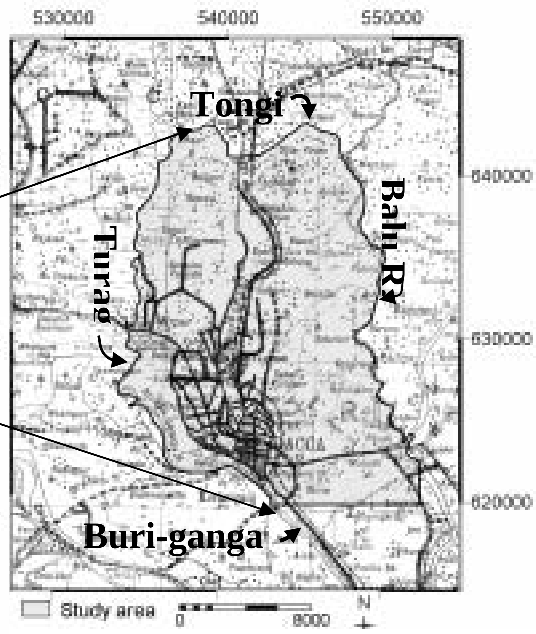

Figure 1: (B): Study area on Survey of Bangladesh topographic map no. 79 I

2. METHODOLOGY

To delineate the geomorphic unit-based landfills, firstly, we need to prepare a detail geomorphological map. The stereo-pairs of the oldest available aerial photographs (1:40000), 1955 are interpreted to prepare the geomorphological map Dhaka city area. Moreover, the oldest available large scale (1: 7920) topographic maps compiled from the aerial photographs (1:19800) taken in 1958, and published in 1967 as well as borehole data are collected and used in order to improve geomorphic photo-interpretation. The topographic maps are scanned, geo-referenced, and a photo-mosaic is created. By overlaying the digitized geomorphic interpretation on the mosaiced topo-maps the interpretation is further improved. A number of one hundred and sixty randomly distributed borehole data of the study area are collected from different soil and foundation engineering companies. A GPS survey has been conducted to locate the geographic position of each borehole. A point map of the borehole position is created and overlaid as a triangle symbol on the geomorphic interpretation by which the soil profiles of the geomorphic units are investigated.

A Fused Color Composite Image (FCCI) is created for landfill mapping integrating the IRS-1D PAN with landsat ETM$^+$ bands 5, 4 and 3, acquired in February (dry season), 2000 and 2002 respectively. The spatial resolutions of Landsat TM and IRS-1D PAN are respectively 30 and 5.8 meters which have been resampled to 10 meters. A three steps image processing procedures followed for the generation of FCCI is shown in Figure 2.

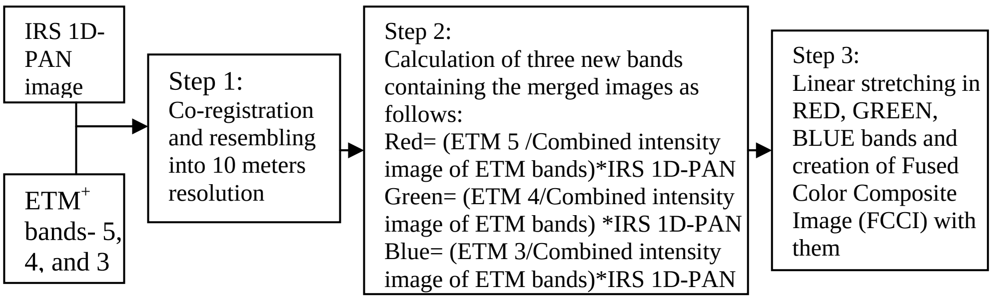

Figure 2: The image processing procedures for the preparation of FCCI

This integration has proven useful in wide range of applications in various earth science disciplines including geologic, land cover and vegetation mapping (Harris et. al., 1990; Chavez et. al., 1991; Grasso, 1993). The FCCI shows a distinct colour contrast between urban and non-urban area. The urban area attains a pinkish purple to orange- purple colour where as non-urban area appears green and blue. The fills are depicted based on the idea that an area belonging in a 'low-lying' geomorphic unit, appeared as a built up ground on FCCI; might indicate a fill-based built up area. The term 'low-lying' refers to those geomorphic units whose average surface elevation is less than 4.5 meters and definitely demand ground filling before civil works.

Before fill area mapping, the polygons of each low-lying geomorphic unit are masked from the geomorphological map and converted into independent segment map. By overlaying and editing the segments of polygons of each geomorphic unit on the FCCI, the fills are visually interpreted by on screen digitization. The interpreted fills are grouped into four classes based on their relative fill thickness which is envisaged from the soil profile of borehole data and elevation contours of topographic maps.

Finally, fill thicknesses map is overlaid with the geomorphological map, the resulting map represent the updated geomorphological ground condition of the city area. The ‘narrow waterway’ has been depicted from the aerial photographs as a line feature and is overlaid on the geomorphological maps.

A field survey has been conducted at August, 2002, in some places, already mapped as fill sites for urbanization for knowing the unaltered geomorphological conditions and thickness of fills to improve the interpretations. All the data processing, integration and analyses works are conducted using ILWIS 3.1, a Remote Sensing and GIS software.

3. RESULTS

3.1. GEOMORPHOLOGICAL MAP

As shown in Figure 3, the geomorphological map is prepared dividing the ground of Dhaka city into eighteen geomorphic units, based mainly upon the relief differences, slope break, geomorphic origin and processes as conceived from the study of stereo-pairs under stereoscope. The geomorphic units with the average elevation equal or less than 4.5 meters are comprised of deep marshy land, deep alluvial valley, moderately deep alluvial valley, shallow alluvial valley, shallow marshy land, highly erosional lower Pleistocene terrace, gently sloping erosional terrace edge, younger floodplain, younger natural levee, abundant channel bed, inundated abundant channel and river system. They cover an area of 194 square kilometers which are combinedly named as ‘low-lying’ geomorphic units in this study. The rest of the geomorphic units, viz., higher Pleistocene terrace, moderately high Pleistocene terrace, moderately erosional lower Pleistocene terrace, old natural levee and relatively old inactive floodplain lying between 4.5-14 meter above mean sea level. These units are named as a whole ‘higher landmass’ comprising an area of 111 square kilometers which covers 37% of the study area.

The low-lying geomorphic units intrinsically related to the higher landmass, such as, highly erosion lower Pleistocene terrace and gently sloping erosional terrace edge comprise an area of 8%. The valley system in higher-landmass, such as, deep alluvial valley, moderately deep alluvial valley and shallow alluvial valley, has been acting as the natural outlet of urban runoff cover an area of 15%. On the contrary, the deep marshy land, shallow marshy land and younger active floodplain lying at the periphery of the higher-landmass constitute 33% of the study area. The rest of the units are not so significant in term of areal extent other than the River system (3% of the area studied) which mostly surrounds the study area.

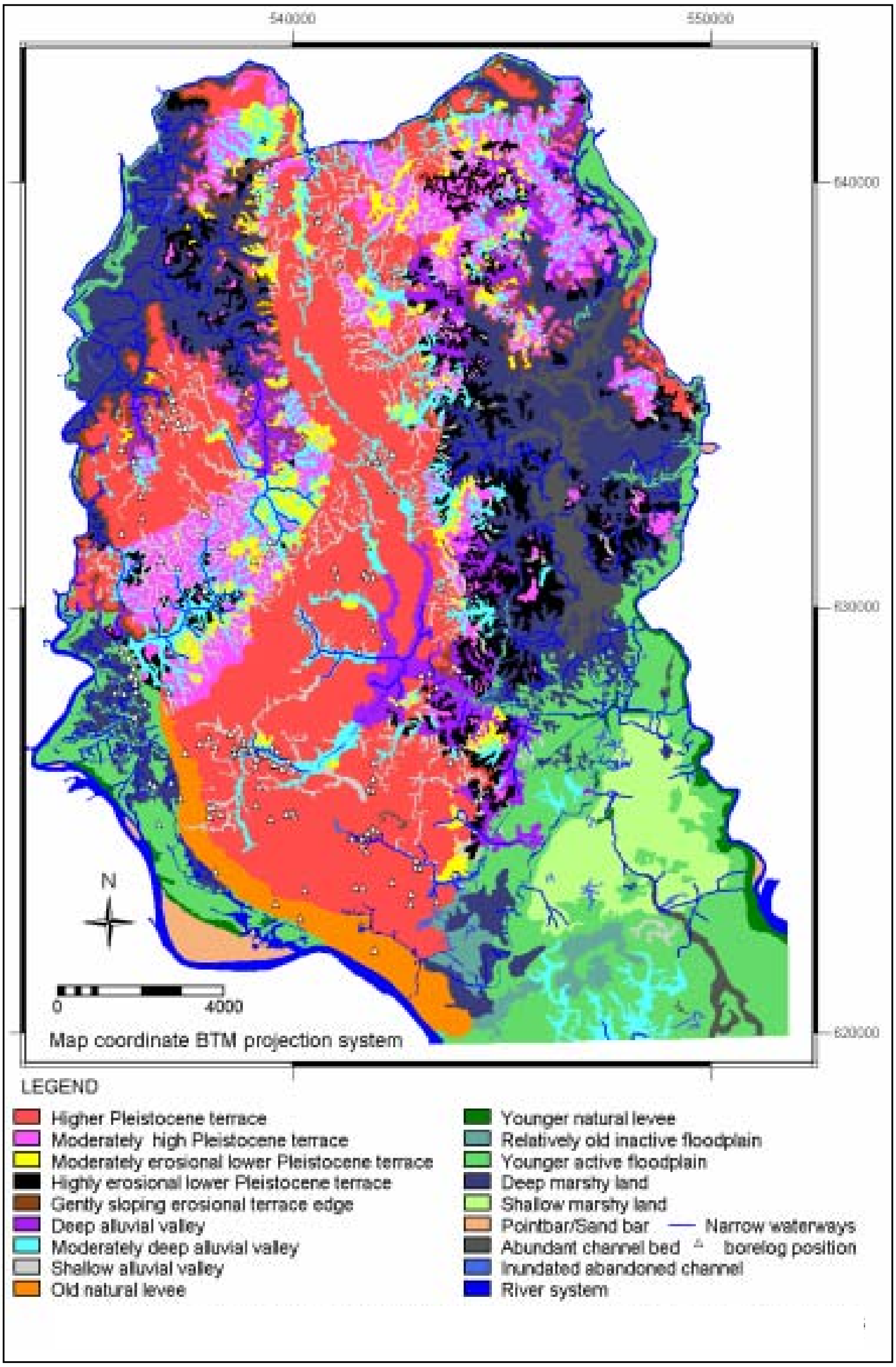

Figure 3: Geomorphological map of Dhaka city area using 1954 aerial photographs

3.2. MAPPING OF FILLS

The fills are mapped using FCCI (Figure 4) as shown in Figure 5. The box A of Figure 4, shows the enlarge representation of fills and non-fills on deep alluvial valley as an example. The fills and non-fills areas are represented by the black and red boundary respectively.

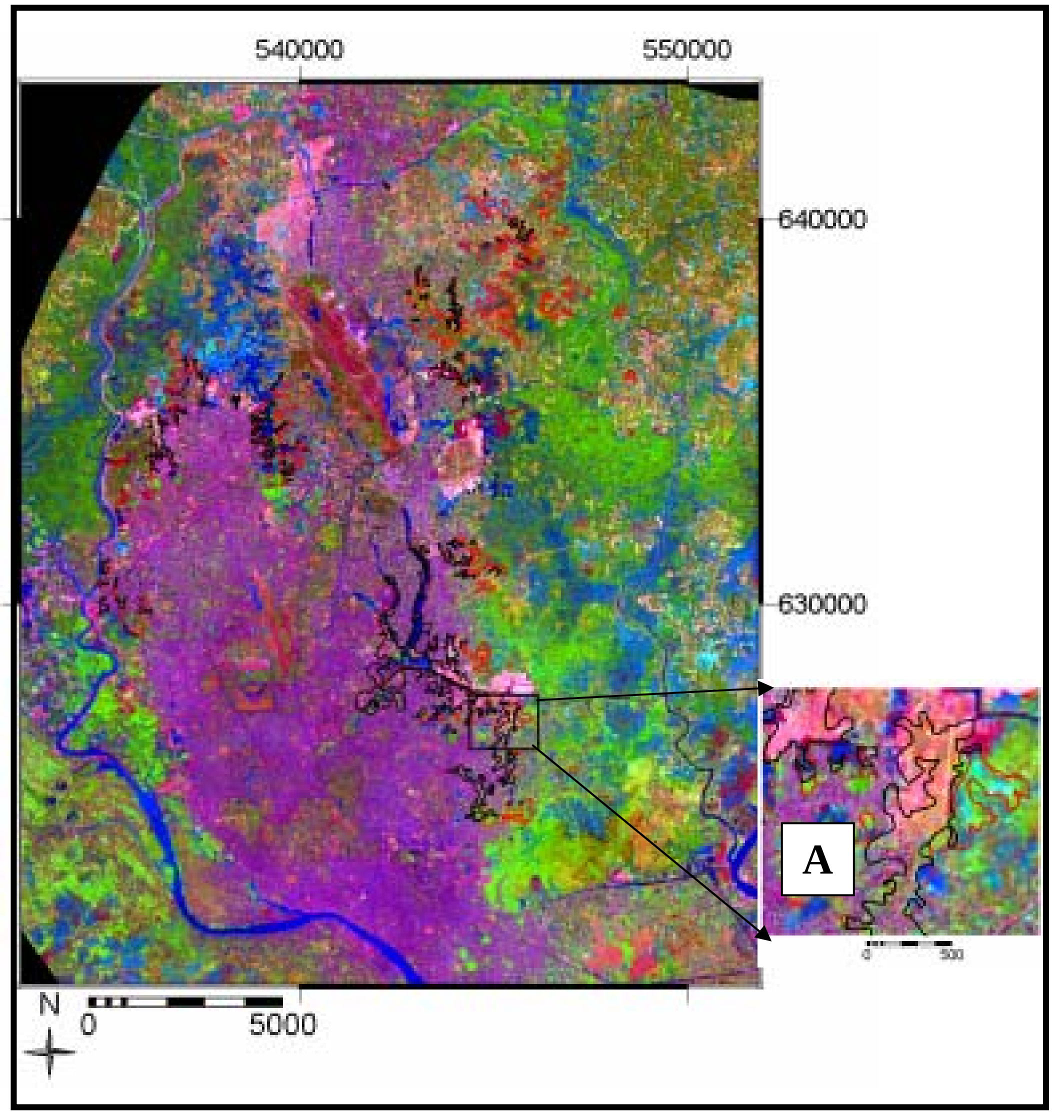

Figure 4: Fused Color Composite Image (FCCI) of IRS-1D PAN and Landsat ETM bands 5, 4, 3. As an example, digitization of fill area is shown in box A, where black and red lines represent the boundary of fills and non-fills in deep alluvial valley

The statistics (Table 2) of fill area map (Figure 5) show that out of 194 sq. km. low-lying areas, at least 79 sq. km., i.e., 41% have been experienced urbanization by filling process. In Table 2, the fill areas of the corresponding geomorphic units are shown with respect to the total area of their individual.

Table 2: Table shows the statistics of fills on low-lying geomorphic units

Low-lying geomorphic units	Unit area (sq. km)	Fill area (sq. km)	% of fill area
Deep marshy land	46.7	7.66	17
Deep alluvial valley	12.4	5.54	45
Moderately deep alluvial valley	19.9	13.52	68
Shallow alluvial valley	13.8	11.59	84
Younger active floodplain	42.6	19.29	45
Shallow marshy land	11.7	2.91	25
Gently sloping erosional terrace edge	7.8	4.07	52
Highly erosional lower Pleistocene terrace	17	8.73	51
Point bar/Sand bar	2.3	2.18	95
Younger natural levee	2.3	1.2	52
Abundant channel bed	7.2	0.63	9
Inundated abundant channel	1.4	0.44	31
River system	10.1	1.1	11

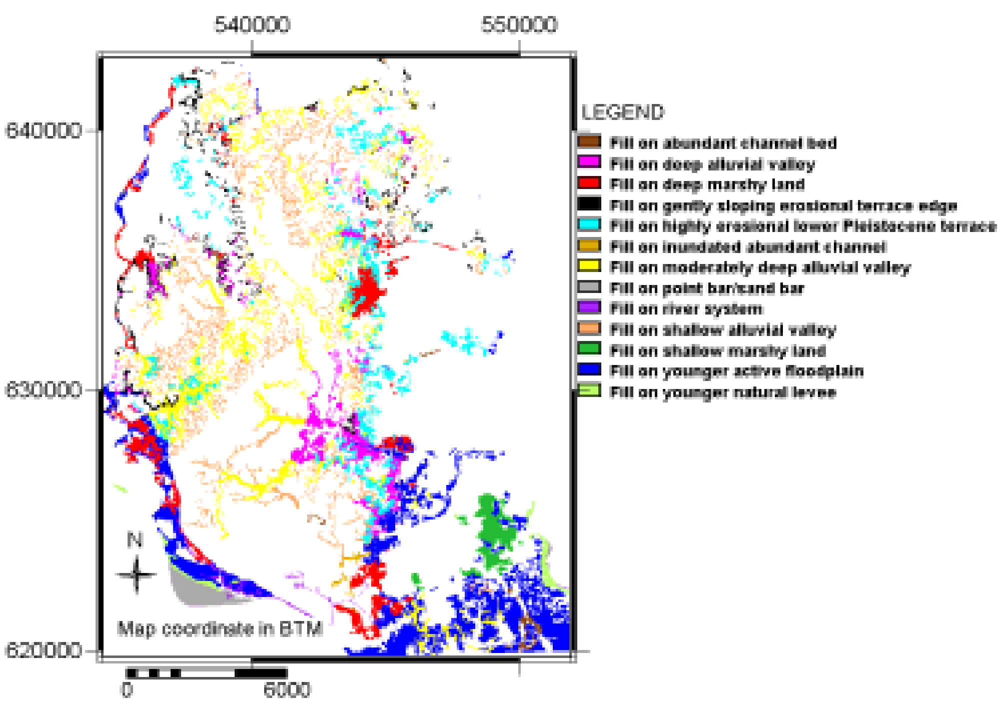

Figure 5: Fill area map on low-lying geomorphic units

It is observed in Table 2 that the low-lying geomorphic units within the higher landmass, viz., shallow alluvial valley, moderately deep alluvial valley, highly erosion lower Pleistocene terrace and gently sloping erosional terrace edge have been subjected to significant amount of fill based urbanization. The Table also implies that the filling processes are presently advancing towards the lowest elevated geomorphic units stretched from the fringes of higher landmass, for instance, deep alluvial valley and deep marshy land.

The fills is classified into four classes as shown in Figure 6, namely, thick, moderately thick, moderately thin and thin fills according to thickness of fills on each geomorphic unit based on the information of soil-profile of borehole data and contour information of topographic maps. The geomorphic units with corresponding relative fill class and their approximate fill thickness in meters are shown in the table 3 below.

Table 3: Fill class versus geomorphic units with fill thickness and fill area

Fill Class	Approx. fill thickness (m)	Fill on Geomorphic units	Fill area (Sq. km.)
Thick fill	>6	Deep marshy land, Deep alluvial valley, Inundated abundant channel and River system	15
Moderately thick fill	4 to 5	Moderately deep alluvial valley, Younger active floodplain, Shallow marshy land and Abundant channel bed	36
Moderately thin fill	3 to 4	Shallow alluvial valley, Gently sloping erosional terrace edge and Highly erosional lower Pleistocene terrace	25
Thin fill	<2.5	Younger natural levee and Point bar/sand bar	4

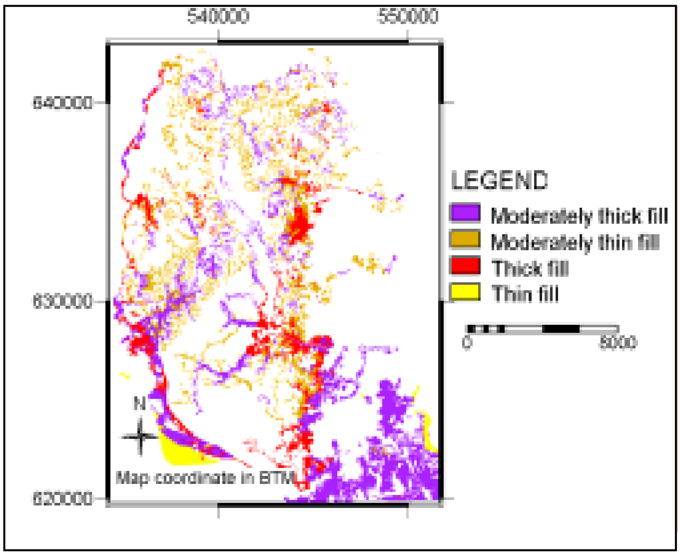

Figure 6: Fill thickness map

In the final stage, we overlaid the geomorphological map with fill thickness map in order to obtain an updated and accurate ground conditions map of the Dhaka city area as shown in Figure 7.

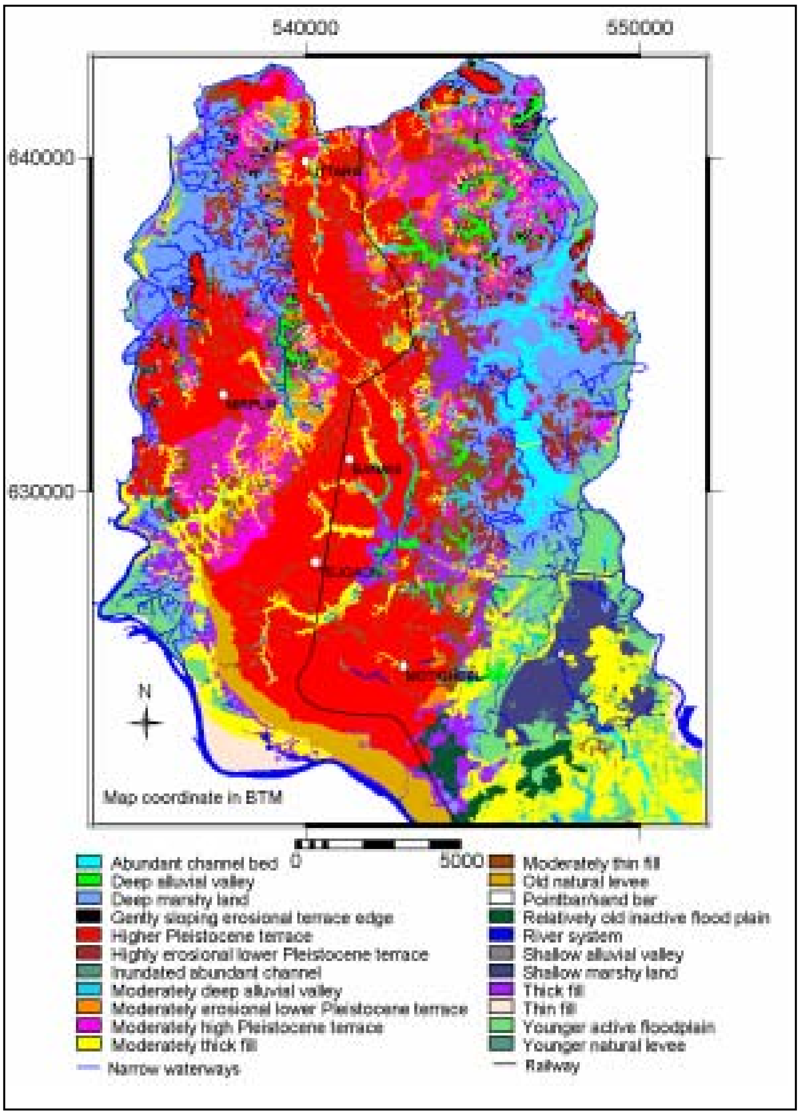

Figure7: Updated ground conditions of Dhaka city area

4. CONCLUSIONS

Both airborne and orbital remote sensing data, namely stereo-pairs of aerial photographs and high resolution satellite images are mainly used in interpreting the geomorphological map and landfills of Dhaka city area. The studied geomorphic units are grouped into 'low-lying area' and 'higher-landmass' with respect to their elevations. The elevation of 'low-lying' geomorphic units is measured equal or less than 4.5 meters where we have found that filling practices are common during civil constructions.

To delineate the fill sites of the city, the Fused Color Composite Image (FCCI) comprised of IRC-1D PAN and landsat ETM$^+$ bands 5, 4, and 3 found potential. The statistics of fill area map show that out of 194 square kilometers low-lying areas, 79 square kilometers, i.e., 41% have been experienced urbanization by filling processes. It is also observed that the low-lying geomorphic units with in higher-landmass have already undergone fill-based urbanization. As a consequence, presently, the urban areas are expanding toward the lowest elevated low-lying geomorphic units located at the fringes of higher landmass, such as; the deep alluvial valley, deep marshy land, etc.

The narrow waterways mapped from aerial photographs are crossed with fill area map which shows that out of 23 kilometers waterway, 8 kilometers are died-out so far by filling activities.

Considering the existed problems and studying the probable forthcoming geo-hazards in fill sites, the engineers, planners and decision makers can take appropriate decision for applying the engineering measures against damages to the structures settled on fills. In addition, upon the consultation of this detail geomorphic map, the planners could provide a sustainable and environmentally friendly plan for further urban landuse growth.

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