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# Application of Remote Sensing and GIS for Geomorphological Mapping around Tangail Sadar Upazila, Bangladesh

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**Abstract**

Geomorphological mapping is the base of land use planning and fundamental technique of geomorphological practice. In this paper, for generating a proper geomorphological map, aerial photographs (1:50,000 in 1954) have been used to get previous detail information and Google Image of 2012 to get recent information. So, ancient aerial photographs are used here for proper land feature and probable hazard assessment. Old topographic maps and borehole data have also been used to support and improve the interpretation. The Landsat ETM+ imagery was also used in this study. Geometrically corrected imagery was obtained from USGS and later was adjusted in the field using GPS. The widespread distribution and extended graphical capabilities of GIS-software as well as the availability of high resolution remote sensing data such as aerial and satellite imagery are mainly used in interpreting the geomorphological characteristics of the Tangail Sadar area. Geomorphic units are interpreted on the basis of interpretation element keys as -tone, texture, size, shape, color etc. and extract the specific information from panchromatic aerial photo images. These units are classified on the basis of differential erosion processes and their texture, tone and association. Geomorphic unit's flood plain, natural levee, point bar, lateral bar, ox-bow lake, Backswamp, abundant channel and active channel are mapped using aerial photo satellite imagery using visual interpretation technique along with field check. Therefore, the research work will certainly provide some valuable clues to solve the hazard prone areas to save properties, infrastructure and will help future engineers and city planners to build up engineering structures safely and economically.

**Keywords:** Geomorphology, Aerial photograph, Remote Sensing, GIS, Tangail.

## Introduction

Geomorphological maps can be considered graphical inventories of a landscape depicting landforms and surface as well as subsurface

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materials [1]. In Bangladesh the practices of using geomorphological and engineering geological study before planning were ignored in past decades. Nowadays, the need for geomorphological and geological studies of the ground before initiating large-scale works is fully recognized before planning of engineering construction [2]. Geomorphological maps can act as a preliminary tool for land management and geomorphological and geological risk management as well as providing baseline data for other applied sectors of environmental research such as landscape ecology, forestry or soil science [3, 4]. In this study, Remote Sensing and GIS, tools and techniques are used to identify landform and geomorphic units mapping because geomorphology is the base of land use planning. Geomorphological maps are amongst the best tools for understanding the physical context of the Earth's surface [5]. Remote sensing data and aerial photographs offer such information to the science of geomorphology that cannot be obtained from any other source [6, 3]. In this study, remote sensing images have been analyzed by the visual interpretation technique, as this technique is economical, easy to learn as compared to the digital analysis technique [7, 8]. Tangail is the oldest and one of the fast growing cities of Bangladesh. The area is close to the capital Dhaka and is developing rapidly both industrially as well as agriculturally. The purpose of the study is to prepare a geomorphological map to proper development of Tangail city plan. The mapped area lies between longitude 89º 51″ E to 90º E and latitude 24º 08″ N to 24º 19″ N and covered by the Survey of Bangladesh Topographic sheet no 78 H/15 & 78 H/16 in the scale of 1: 50,000. The area of Tangail Sadar is an area of 29.24 sq km. The area is mainly dominated by fluvial landforms and deposits due to Jamuna–Dhaleshwari River. Geologically, the study is situated in the Jamuna-Dhaleshwari flood plain of Holocene age. Pleistocene uplifted Tract (Madhupur block) is just east of the study area. The area is characterized by a number of faults along the Jamuna River. They are trending NNW-SSE. Madhupur fault [9] controlling the tectonics of Tangail and its environs. The geotectonics and its structural arrangements in the area control the geomorphology, geology, stratigraphy and hydrogeology of the area. Physiographically, Tangail Pauroshava situated on the Jamuna-Dhaleshwari flood plain and is bounded by the Jamuna-Dhaleshwari River in the west. Tangail Paurashava is now protected from flood by an embankment around the city. Water drainage is controlled by some sluice gate. But the rest of the area of Tangail sadar upazila is affected by flood almost every year. The elevation of the area varies from 8.83to 11 m above PWD reference Level.

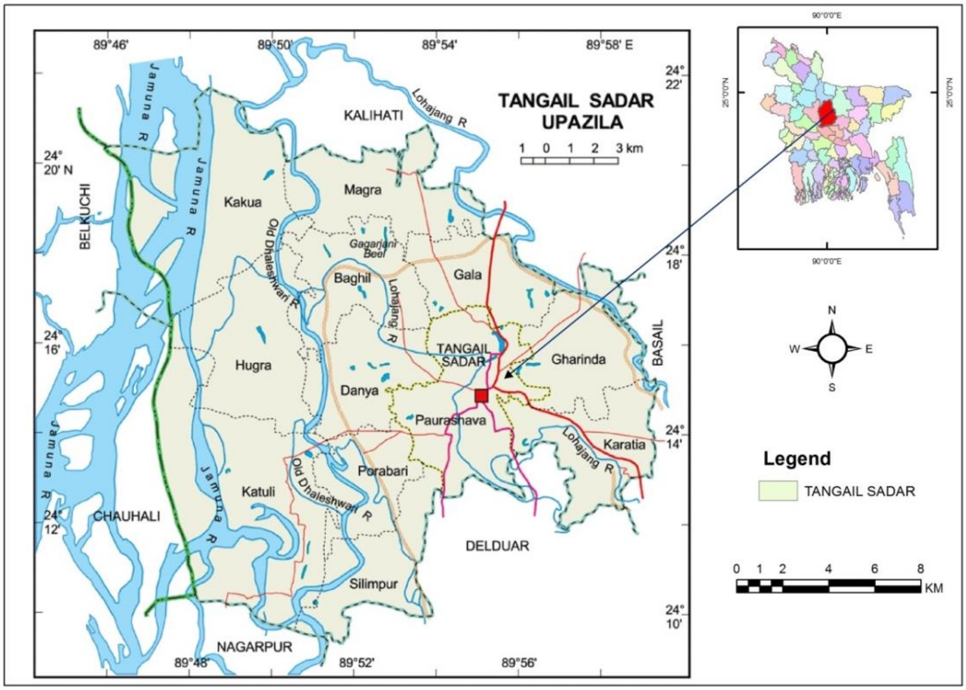


**Figure 1:** Location map of Tangail Sadar and adjacent areas.

## Materials and Methods

For the purposes of this study the data from satellite imagery (i.e., Aerial Photographs, Landsat-7, SPOT and Google Maps), topographic sheets (78 H/15 & 78 H/16 at scale 1: 50,000) and base maps (GSB's) are incorporated first to prepare a geomorphology map. Geomorphological map has been prepared by visual image interpretation of aerial photographs key elements like tone, shape, size, pattern, texture, shadow and association**.** Remote sensing and geographic information system (GIS) techniques have used to prepare geomorphological knowledge base aerial photo interpretation maps of the studied area. Image interpretation is the process of examining an aerial photo or digital remote sensing image and manually identifying the features in that image. This interpretation is based on elements that are inherent in imagery. Sketches and maps of landscapes and landforms [10] have been fundamental methods to analyses and visualize Earth surface features ever since early geomorphological research.

## Elements of Visual Interpretation

The aerial photograph is best accomplished by visual interpretation techniques with the understanding of spectral property of rock material and image characteristic of landforms. The aerial photographs or images are valuable historical records of the spatial distribution of natural and manmade phenomena. The study of change increases our understanding about the natural and human-induced processes in the landscape. To obtain a 3-dimensional view of the terrain by viewing the two images of the terrain from two slightly different vantage points at the same time. Stereoscopic analysis process provides us the information of object's height, depth, and volume. The six primary elements of visual interpretation are tone or colour, size, shape, texture, shadow and pattern [11]. In addition of those heights, size and association may be added [12]. Tone refers to the relative brightness or colour of objects on imagery. Size, shape and position (site), are combined under the term contextual information. Shape relates to the configuration or the general outline of objects as recorded on imagery. Texture is the frequency of tonal change on the photographic image. It determines the overall visual 'smoothness' or 'coarseness' of image features. Pattern relates to the spatial arrangement of objects. Association refers to the occurrence of certain features in relation to others [13]. Detailed information can be extracted accurately from high-resolution satellite data and large-scale aerial photographs. Landsat-7 data was used for cross checking the identifying objects only. SPOT image gives a good detail of different geomorphic features of classify different geomorphic units, depending upon different visual photographic elements. Recent Google Image is used to delineate the changes in city boundaries, growth of infrastructures and land use pattern, especially, land filling.

The study has different steps: digitizing creating a database, converting to the data and comparing to the map layer. In the first step, all unit boundaries in each test area were digitized using ArcGIS 10.1 open software. This digital layer was the projection in the UTM, WGS 84, and zone number 45. In some cases two or more units were merged into one unit or new units were added after field examination by re-interpretation of aerial photographs in the field. GIS layer is storage and retrieval of all types of data at a particular location in space and identifying data needs acquisition of data, management, processing and decision making [14].

## Result and Discussion

### *Geomorphological Mapping*

The use of remote sensing technology for landform studies has certainly increased its importance due to its direct relationship with the branches involved, such as geology, soil, plant/land and hydropower [15]. Today, all land use planning processes are based on geomorphological units [16]. The geomorphological map has been prepared on 1:50000 scales based on visual interpretation. Remotely sensed data have capability to map geomorphic units [17]. On the satellite image these are identical on the basis of the interpretation of the image elements such as size, shape, texture, tonal variation association etc. Geomorphic units are classified on the basis of differential erosion processes [18]. The geomorphological units (i.e. floodplain, natural levee, bars, backswamp and ox-bow lake etc.) are identical on the basis of the fluvial features and their sedimentary characteristics formed in the areas. The landform which is produced by lying down of rock forming material by any natural agent (like water, wind and air) is termed as depositional landform. The area also divided in low-lying (flood basin, backswamp, ox-bow lake) and higher landmass (natural levee, flood basin) areas. Moreover, geomorphological maps can be considered graphical inventories of a landscape depicting landforms and surface as well as subsurface materials. Detailed aerial photo imagery interpretation and their characteristics are shown in table 1. And aerial extent of the identified geomorphic units of the study area is in table 2.

**Table 1:** Geomorphic units of Tangail Sadar and their characteristics

| Sl. No | Mapping Units | Tone | Texture | Association | Pattern | Size | Shape | Probable rock type |
|---|---|---|---|---|---|---|---|---|
| 1 | Active Channel | Dark grey | smooth | - | meandering | wide | Linear &Curved | Sand with silt and clay |
| 2 | Natural levee | Light to medium grey | coarse | Along the river bank | - | elongated | Linear& wedge | Medium to fine sand, silt with clay |
| 3 | Point Bar | Light grey | smooth | Along the meander channel | - | - | Crescent or oval shape | Sands and silt clay |
| 4 | Lateral Bar | Light grey | smooth | Beside the channel | - | long | Elongated | Medium to coarse sand and silt with clay |
| 5 | Flood plain | Medium gray | Blocky | Within two river | - | flat | geometric | Medium Silty clay, clay, organic clay and peat |
| 6 | Flood basin | Light grey | blocky | - | - | flat | irregular | Silt, fine sand and peaty clay |
| 7 | Back swamp | Dark grey | patchy | Behind a stream & natural levee | - | - | Irregular or bowl | Clay and peaty clay |
| 8 | Ox-bow lake | Dark to medium grey | smooth | Cut off channel | Meander loop | - | Curved | Sand ,silt with clay |
| 9 | Abandoned /channel Scar | Medium grey | smooth | Shifting of streams course | - | Elongated & narrow | lenticular | Silty clay & organic clay |

**Table 2:** Aerial extent of the identified geomorphic units of the study area

| Geomorphic Units | Lateral Bar | Point Bar | Natural Levee | Flood Plain | Flood Basin | Back swamp | Ox-bow Lake | Abandoned/ Channel Scar | Active Channel |
|---|---|---|---|---|---|---|---|---|---|
| Areal extent (in Sq. km) | 10.279 | 1.054 | 10.359 | 181.986 | 7.563 | 3.709 | 1.048 | 0.38 | 4.429 |

### *Lateral Bar*

Lateral bar deposits are long shaped bars deposited along the river. On aerial photo imagery these are identified by light gray tone with smooth texture and elongated shape in river. Lateral bar deposits are composed of loosely medium to coarse sand and silt with clay. Lateral bars are found in the both sides of Dhaleswari and Lohajong Rivers of the study area and the unit covers about 10.279sq.km in geomorphic maps (Figure 2) and (Table 2).

### *Point Bar*

Point bar deposits are crescent bodies which are developed on the convex side of the meander belt attached to the main channel. On aerial photo imagery these are identified by light gray tone, smooth texture and crescent or oval shape in river. Some of the old bars or elevated parts of bars are inhabitable and remains above normal flood water level. This unit is situated along the meandering river. Important point bars are identified along the Dhaleshwari and Lohajong River. Ckakbaria, Porabari, Dhighirpar are on this unit. Point bar deposits are composed of sands, and silt clay. Point bar covers an area 1.054 sq. km in geomorphic maps (Figure 2) and (Table 2).

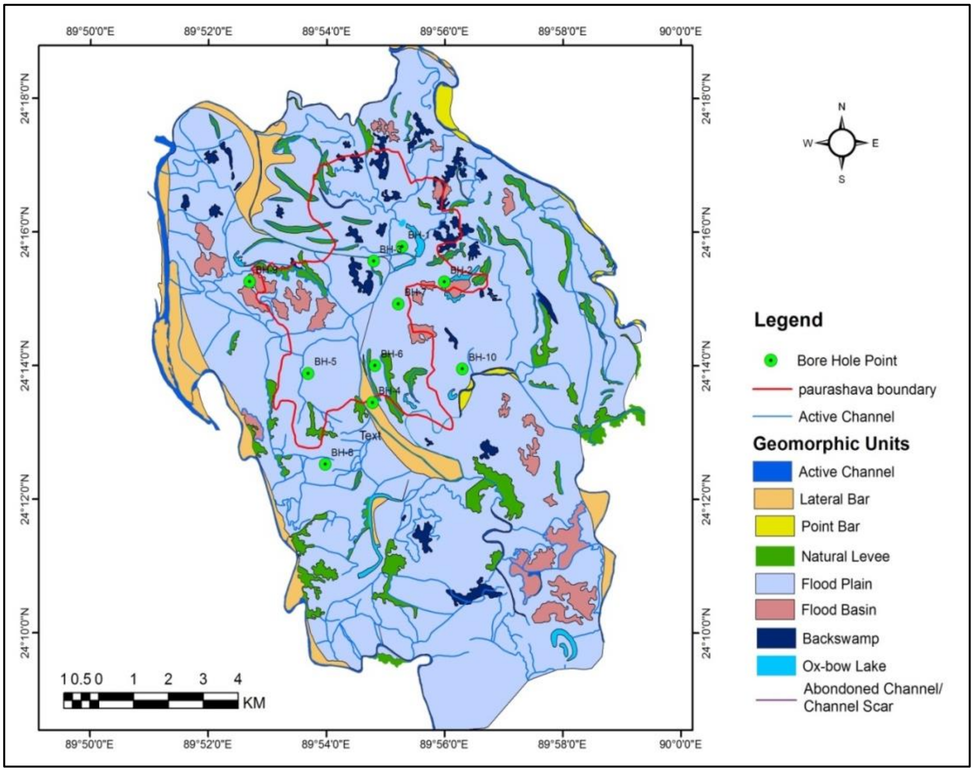


**Figure 2:** Geomorphological Map of the study area

### *Natural Levee*

Natural levee deposits are linear, somewhat irregular wedge-shaped ridges having silt and fine sand. They are elongated deposits parallel to the channel and settled on both sides of the river. In time of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load along the banks as natural levees. Levees are elevated at the channel bank and pinches out towards the floodplain. On the aerial photo imagery these are identified by light to medium gray tones and coarse texture and linear shape along the river bank. Natural levees in general remain above the normal flood level and suitable for human settlement. It covers an area of 10.359sq.km in geomorphic maps (Figure 2) and (Table 2).

### *Flood Plain*

It lies between natural levee and flood basin and is lower in elevation than those of natural levee [19]. This is the largest unit in the study area. Back slope have very gently slope toward the flood basin. The deposits are composed of loose and unconsolidated medium to coarse sand, silty clay, organic clay layers. Decomposed to partially decomposed grass roots/detritious of residual crops and organic remains are common in the sediments of this unit. On the Aerial photo imagery back slopes appear as medium gray tone and blocky texture. Most parts of this unit in the study area have been converted to crop lands, which exhibit a definite geometric shape. In the study area these units are commonly observed between the Jamuna-Dhaleshwari and Lohajong River. Approximately, the unit covers 181.986 sq.km in geomorphic maps (Figure-2) and (Table 2).

### *Flood Basin*

Flood basins are featureless areas of poorly drained, flat to centrally slopping into stream depressions. Topographically flood basins are the depressed portion of the stream backslope and oval, semi-circular or irregular in shape. This unit remains under 1 to 2 meters water during the yearly monsoonal flood. Marshes have also been mapped as flood basin. The deposit consists of light gray silt, fine sand, gray to light gray organic rich clay, dark gray to blackish gray peaty clay with abundant decomposed or partially decomposed vegetal materials. On the Aerial photo flood basins appear as light grey tone, blocky texture, anastomotic drainage and irregular shape. However flood basins are sparsely distributes in low-lying landmass of the study area. The unit act as settling basins in which suspended fine grained sediments settles down from overbank flows after the coarser sediments have been deposited on levees and crevasse splays. The cover an area 7.563 sq.km in geomorphic maps (Figure 2) and (Table 2).

***Backswamp***

Backswamp usually lie behind a stream and natural levees. These are the deepest part of the flood basins having water all the year round. On aerial photo backswams appear as dark gray tone, patchy texture, irregular shape and poor drainage density. This deposit consists of dark gray clay, dark gray to blackish gray peaty clay with abundant decomposed or partially decomposed vegetal matters. Depressions/ Swamps are scattered throughout the whole city area but mostly present in the active flood plain of the Dhaleshwari and Lohajong rivers. The Backswamp covers an area of 3.709 Sq. Km in geomorphic maps (Figure 2) and (Table 2).

***Ox-bow Lake***

Ox-bow lake deposit is curved shaped cut off of meander loops with a permanent water body. The deposits are mainly consist of sand and silts veneered by clay and mud. Organic matter is present in the upper part of the deposit. On aerial photo Ox-bow lakes appear as dark gray to medium grey tone, smooth texture and curved shape. This unit is found in Jangalia, Kazipur, Sabalia, Pachkhania, Bandhabari and Pirijpur areas of the study covers an area of 1.048 Sq. Km in geomorphic maps (Figure 2) and (Table 2).

***Abandoned Channel/ Channel Scar***

Elongated and narrow depressions with or without water formed by shifting of streams course have been mapped as abandoned channels. On aerial photo abandoned channel/channel scars appear as medium gray tone and smooth texture lenticular shape. More than 20 channel scars have been identified thorough out the areas which are identified with its dark tone and linear shape on the aerial photographs. These channels are flooded in the rainy season and dry in winter and summer season. Organic remains in abandoned channels are found. The surface deposits are mainly silty clay and organic clay deposits. This area covers an area of 0. 38 Sq. Km in geomorphic maps (Figure 2) and (Table 2).

### *Active Channel*

Active channels have permanent water flow throughout the year. On Aerial photo active channels appear as dark grey tone, smooth texture and morphologic position. It is distinguished by linear and curved shape and wider in nature. Sediment deposits are mainly consisting of sand with silt and clay. The active channels provide the drainage facilities in the flood plains areas. The channel bed is composed of coarse grained sediments mostly carried by siltation or rolling as bed load. The unit covers an area of 4.429 Sq. Km in geomorphic maps (Figure 2) and (Table 2).

## Discussion

Geomorphology unit are dynamic in nature as they are affected by various human activities, including the expansion of cultivated and irrigated lands, industrialization, urbanization and others because it need to monitoring, mapping for land use planning [20]. Third World countries as Bangladesh have difficulty in meeting the high costs of controlling natural hazards through major engineering works and rational land use planning [21]. Rising demand of the city are considering low lying flood plain and backswamps areas for further development nowadays. Low lying areas, backswamps and abandoned channel deposit contain clay, silty clay, sandy clay and very fine to medium sand with organic matters. These areas would be risk for heavy foundation or infrastructure construction. Whereas, Natural levee deposits contains silt and fine sand and Flood plain deposits contains loose and unconsolidated medium to coarse sand, silty clay, organic clay layers. These deposits are comparatively better for urbanization or infrastructure construction. Bar (i.e. point & lateral bar) deposit indicates medium to dense packing of sand could be used as moderate foundation/ construction. The lack of basic knowledge about geomorphological and geological characteristics of the studied area underlies many associated hazards like erosion, silting up of culverts, flooding, cracking of buildings, etc. may occur, which will threatening people, property and infrastructure networks. The study area comprises high and low lands. High lands like levees are found along the rivers bank and remain above the flood water during rainy season. Low lands as backswamps, flood basin ox-bow Lake and abandoned channel/ scar remain water, if those areas are occupied with any infrastructure, as result the areas will be flooded and threatening for human activities. Considering the existed problems and studying the probable forthcoming geo-hazards in the areas, the engineers, planners and decision makers can take appropriate decision for applying the construction structures of the weak areas. Geomorphological maps, at a variety of scales, are required, not only for geomorphological research and praxis, but also for other sectors of environmental research and for professionals dealing with landscapes and landforms, urban planners, construction engineers, soil and forest scientists, land conservation managers, and natural hazard and geological risk manager.

## Conclusion

The approach and results discussed in this paper. Land use planning is continuous process due to natural and human causes. For future land use planning, it is necessary to understand the existing geomorphic units and extents. Remote sensing and GIS have capability to mapping geomorphic units. It provides the large view of earth surface features and has various techniques to explore the geographic features. In the studied area, geomorphic unit’s flood plain, natural levee, point bar, lateral bar, ox-bow lake, Backswamp, abundant channel and active channel are mapped by aerial photo satellite imagery using visual interpretation technique along with field check. The research area is located in Jamuna-Dhaleshwari Flood Plain is largely covered by Flood plain which are mainly composed of unconsolidated medium to fine sand with some silty and clayey sediment. Most parts of this unit in the study area have been converted to cultivated lands, which exhibit geometric shape and even textural distribution on the satellite imagery. It is observed that the low-lying units have already undergone fill-based development on field checking. In the study area natural levee and flood plain units are comparatively better for urbanization or infrastructure construction. Whereas low lying areas i.e. backswamp, ox-bow Lake and abundant channel units are worst for infrastructure construction. To assemble this necessity prior to development the areas geomorphology and subsurface geology should have consider reducing the hazards and potential risk. Now, based on mapped geomorphic units local and government authority can make decision to land use planning for human activities.


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