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Geomorphological and Land Use Mapping: A Case Study of Ishwardi Under Pabna District, Bangladesh

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Authors' contributions

This research work was performed by all authors. Author ARMTI gave the study design, map preparation and drafted the manuscript. Authors ZMMS, VO and MSI managed the literature searches. Authors MFA, VO and FA took part in result and discussion. All authors read and approved the final version of manuscript.

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ABSTRACT

The study presents geomorphological and land use mapping of the north western part of Ishwardi Upazila under Pabna district, Bangladesh. The objective of the research was to identify geomorphologicalunits and to prepare geomorphological and land use mapping based on remote sensing data and extensive field work. The satellite images of SPOT (Band 4) and Landsat TM-2012 were used for interpretation of geomorphological units. Land use elements are mapped using SPOT satellite images (Band 4) incorporated with field observation data.The study area consists of active

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channels, abandon channels, natural levees, flood plains, flood basins and lateral channel bars. The results revealed the need for regional and local land use policy revision employing a multi-disciplinary approach for sustainable development. The study advocates for the integration of geological factor in initial for land use planning in order to avoid damage of property and loss of lives. However, the study calls for further research work using different and longer data sets.

Keywords: Ishwardi upazila; geomorphological units; SPOT image; landsat TM; geo-information.

1. INTRODUCTION

Geomorphological maps are regarded to be graphical inventories of a landscape showing landforms and surface as well as subsurface materials. The geomorphological maps provide important information applied in land use planning, unfortunately, many developing countries such as Bangladesh lack accurate and updated maps. The formation of earth's surfaces is primarily due to hypogene or endogenous processes [1]. Landforms on the earth surface are generally expensive to map and monitor [2], partly explaining why most developing nations do not have updated geomorphological maps. According to Drăguţ and Blaschke [3], the current landform mapping and monitoring processes are based on geomorphological units in most countries. The units are preferred since they are dynamic in nature and are affected by various human activities including the expansion of cultivated lands and urbanization [3]. The global population is ever growing; this increases the level of urbanization and industrialization [4]. Geomorphological maps can serve well as a preliminary tool for land management and geomorphological and geological risk management associated with land use. According to Dramis et al. [5] and Paron and Claessens [6], the maps can as well provide baseline data for other applied sectors of environmental research such as landscape ecology or soil science. Therefore, there is need for continuous land mapping and monitoring for further land use planning [7].

Land Use/Land Cover Change (LULC) detection is an essential process in monitoring and managing natural resources and urban development. The process provides a quantitative analysis of the spatial pattern, distribution and variation of the physical and cultural landscape features [8]. The LULC pattern of a region is determined by the natural and socioeconomic factors as well as their spatio-temporal interactions [9]. Land use plan is essential to the local government authority and other planning authorities; it provides a suitable land allocation for human activities based on geomorphological survey in the study area. Morgan and McIntyre [10] studied the quaternary geology of the Bengal Basin, while a study by Islam et al. [11] focused on the geomorphology and land use mapping of northern part of Bangladesh. Sultana et al. [12] studied geomorphology and land use elements of Nawabganj Sadar, Bangladesh, revealing that geomorphological characteristics had changed abruptly due to Padma River erosion. A number of researchers have carried out studies on a regional scale in geomorphological field using remote sensing and Geographical Information Systems (GIS) techniques in Bangladesh [13-19].

The study area does not have any official statistics on land use mapping, prompting this study. The study carried out land use mapping using remote sensing data to identify geomorphological units and to prepare land use map for further socio-economic development in the region. The findings of this study are thus helpful if well utilized in planning of the study area and in future research works.

2. STUDY AREA

The areaof studyis located between longitude 89°00' E to 89°15' E and latitude 24°00' N to 24°10' N (Fig. 1). The area covers a surface area of approximately 246.9 km^2. It is bounded by Lalpur and Baraigram Upazila to the north, Kushtia Sadar and the Padma River to the south, Pabna Sadar and Atgharia Upazila to the east, Bheramara and Lalpur Upazila and Padma River to the west [20]. The area has good transport system connecting Pabna and Dhaka. The area lies in the south eastern part of the Bogra shelf zone, represented by a regional monocline gently plunging towards the southeast up to the hinge zone. The shelf is bounded by a stable Indian platform at the northwest and Shillong Massif in the north and separated from the Foredeep area of the Bengal Basin by Calcutta Mymensing Hinge Zone. The surface geology of the study area consists entirely of sedimentary formations

mainly revering in origin [19]. The surface deposit of the area is classified as recent flood plain deposits [21] (Fig. 2). The recent flood plain deposits are laid down mostly by the Ganges and Jamuna River systems and their numerous tributaries and distributaries.

The recent flood plain deposit consists of clay, silt, fine and medium grain sand that are of relatively loose and more friable in nature [22] (Fig. 3).

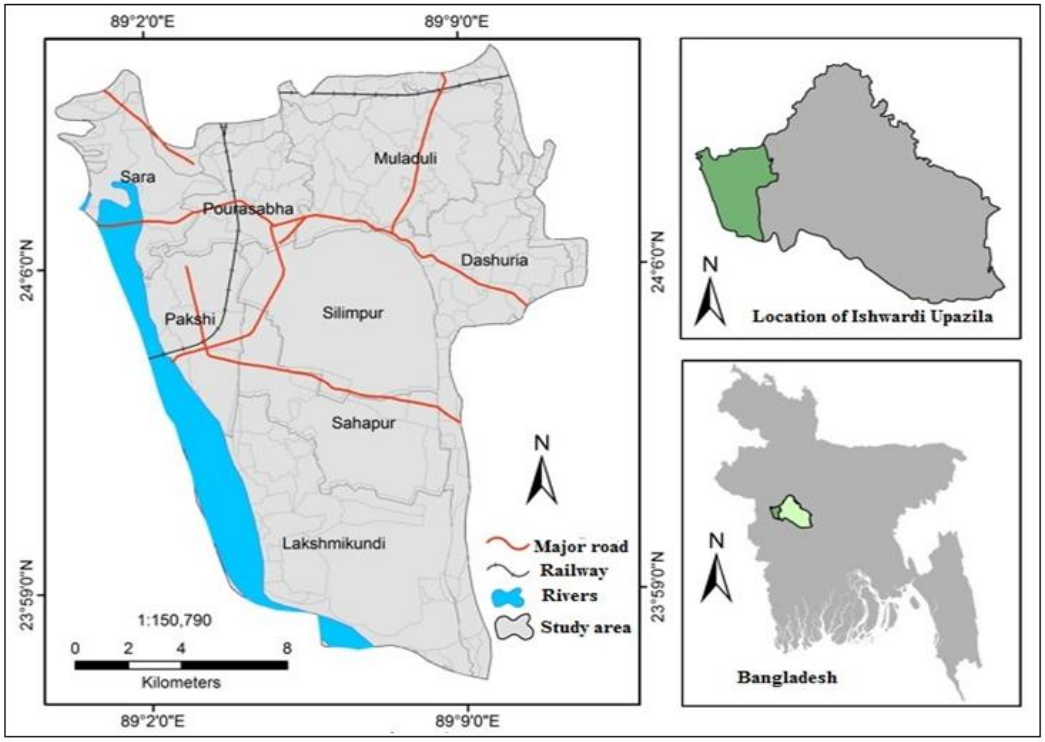

Fig. 1. Location map showing the study area

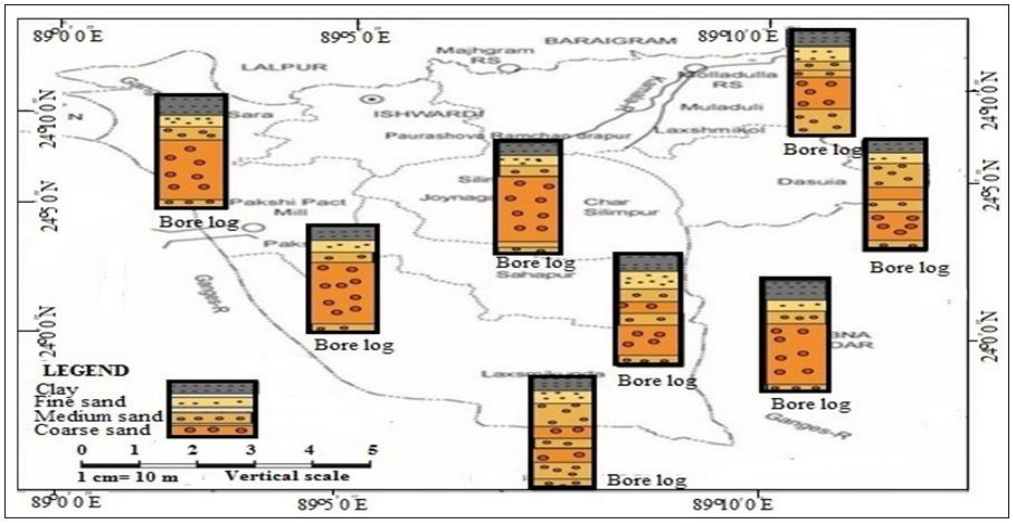

Fig. 2. Vertical cross-section of sub-surface lithology of the study area

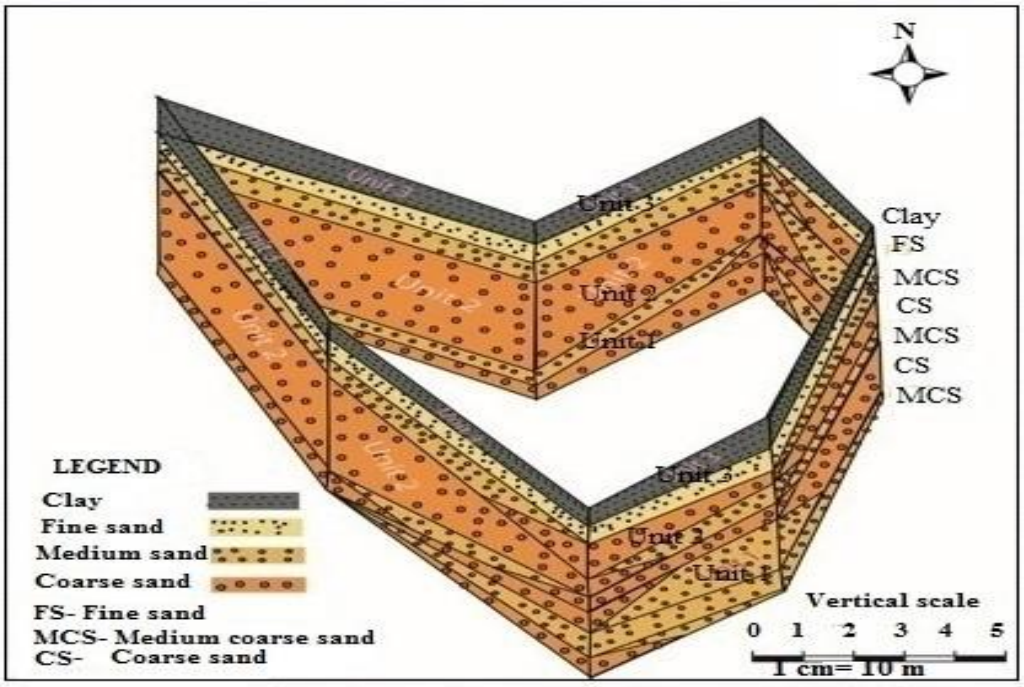

Fig. 3. Panel diagram shows the geological profile of the study area

3. DATA AND METHODS

3.1 Data

The primary data utilized in this study include two sets of satellite imageries: Landsat TM, collected from Space Remote Sensing and Research organization (SPARSO), Dhaka, and the Satellite Pour l'Observation de la Terre (SPOT) image (Band 4) of 10th September 2012 with spatial resolution of 28.5 m obtained from "Google Earth". Field work data was obtained from the study area. The Landsat TM (FCC) image of 10th September 2012 with spatial resolution 30m was used for the land use pattern map [23]. Secondary data such as base map of scale 1:50000 (2001) was collected from Local Government Engineering Department (LGED) while a topographic map with scale of 1:50,000 (1968) was sourced from Survey of Bangladesh (SoB).

3.2 Methods

The topographic map of the year 1968 was scanned and rectified using a geometrically corrected image using Arc GIS software (3.3 version). The image was geometrically corrected using a Landsat TM image of 2012 as a reference employed in this study. In addition, SPOT image (Band 4) and base maps (LGED's) were utilized to prepare a morphological map for the first step of the study. The topographic map was compiled from aerial photographs and subsequent ground truthing. The Google Earth© and Landsat TM (FCC) images depicting different land use/cover type were printed on A4 size papers and verified using field data. A number of geospatial data including municipal boundaries, road networks and geomorphological units were constructed as GIS layer from diverse sources. Analogue data was digitized with the help of topographic maps from SoB. The different geomorphological units were identified in the mapping based on image interpretation techniques, and geomorphological maps were prepared on the basis of SPOT image data (Band 4) and field data.

The LULC map was explained based on visual image interpretation and land use classification methods. Land use classification schemes were used for land use evaluation and mapping from Landsat data with spatial resolution of 30 m. ArcGIS (3.3 version) software was used to derive land use/cover mapping in a multi-temporal approach. Land use schemes were adopted to classify the land into five classes: land use element-1, land use element-2, land use element-3, land use element-4 and land use

element-5. GIS tool was applied using visual analysis, reference data and local knowledge to split and recode these land covers into their original classes. A classified land use map from satellite data was used for validation using ground truth data obtained from a variety of sources. The spatial data manipulation and error correction were performed using Arc GIS (3.3 version) software. The land use pattern map was then prepared from geomorphological map of the study area.

The flowchart presented in Fig. 4 summarizes the steps of the methodology employed in the study.

4. RESULTS

4.1 Identification of Geomorphological Units

Remote sensing data has ability of mapping geomorphological units; it is classified based on differential erosion processes [24-25]. Geomorphological units are observed on the basis of the interpretation of the image elements such as the tonal variation, texture, size, shape and association etc. Different geomorphological units are described by their distinct textural and sedimentary characteristics. Moreover, a few units lacking distinct sedimentary characters are adapted by post depositional process such as weathering and biological activities. Six geomorphological units were identified in the study area based on the morphological appearance, characteristics of slope, elevation of surface character, vegetation, drainage systems and sediment deposits.

4.1.1 Active channel

Active channels (Ac) have water flowing in them throughout the year in the Padma River. The portions of the channel are generally wet with winter base flows identified by a break in rooted vegetation or moss growth on rocks along stream margin [26]. The channels were considered by focusing on a meandering river (Figs. 5 and 6a).

4.1.2 Abandoned channel

The abandoned channel (Ab) is an elongated narrow depression with or without water. The channel is composed of clay or silty clay underlain by silty sand to fine sand deposits. Organic remains; clay and peat are common in this channel. The channel floods in the rainy season and water logging persists for more than six months almost yearly. Figs. 5 and 6b show abandoned channels found in Dasuria area of Sahapur and the southern part of the study area.

4.1.3 Natural levee

A natural levee (Nl) is a linear and irregular wedge-shaped ridge of sandy silt deposits. It is an elongated deposits parallel to the channel and developed on both sides of the river. This unit is thickest near the channel margin and narrows towards the floodplain. The slope is steep towards the channel and very gentle towards the floodplain. Along riverbank, there are silt and fine sand; they become clayey silt at the distal edge of the levee where it merges with the flood plain deposits. Figs. 5 and 6c displays a natural levee found in the side of Padma River.

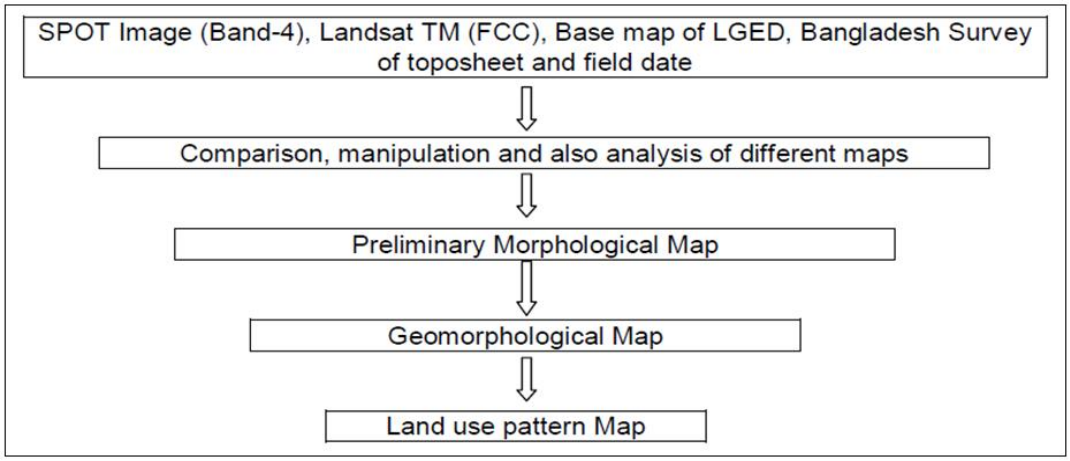

Fig. 4. Flowchart of method for the study

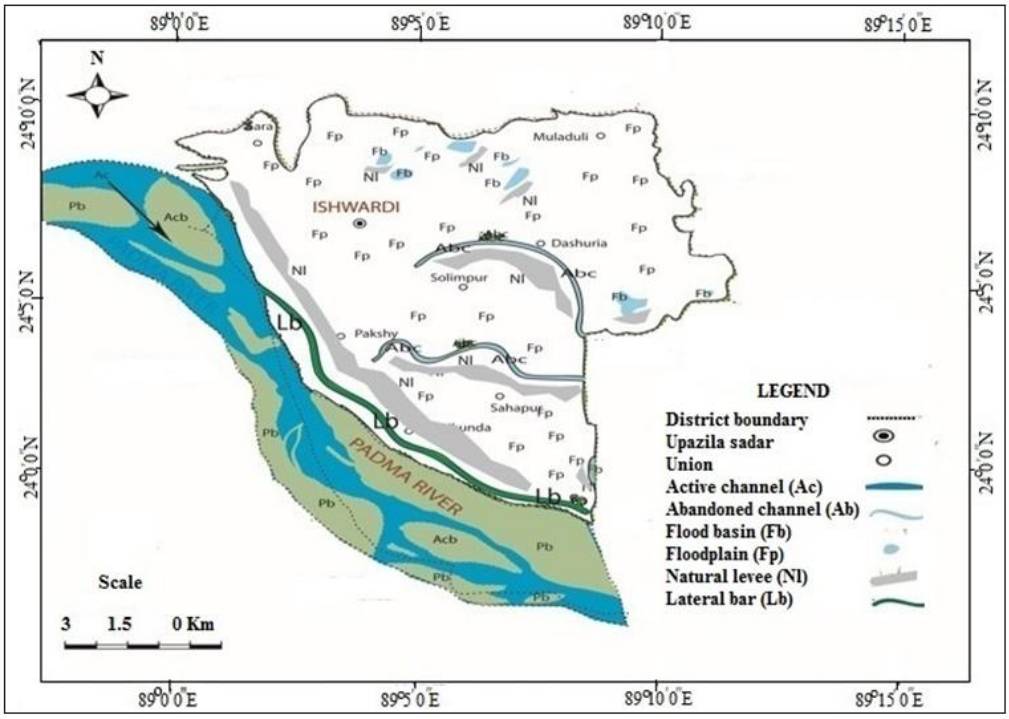

Fig. 5. Geomorphological map of the study area

4.1.4 Floodplain

A floodplain (Fp) is a strip of relatively smooth land bordering a stream and overflowed at a time with high water levels [27].This forms the largest unit in the study area. Floodplains have gentle slopes towards the flood basin which are predominantly covered by recent alluvial deposits and the soil parent material; alluvium. Floodplains are composed of gray silty and organic rich clay. Floodplains are usually used for human settlement and cultivation [28]. Figs. 5 and 6d show that decomposed to partially decomposed grass roots and organic remains are common in the sediments of this unit.

4.1.5 Flood basin

Flood basins (Fb) are poorly drained, flat to centrally slopping into stream depressions. They are oval, semi-circular or irregular depression in shape. Most of the areas are usually under water throughout the year, with a few drying up during winter season. Marshes have been mapped as flood basin. The flood basin consists of grey to light gay organic rich clay, dark gray to blackish gray peaty clay with abundant decomposed or partially decomposed vegetal matters. Several beels and marshes are found in the Pakshy, Sara and Arambaria Hat of the study area, most of which dry up during summer season. The area is located near the flood basin where human activities have the most influence on the local environment. The area has been tailored to flood basin ponds for fishery (Figs. 5 and 6f)

4.1.6 Lateral channel bar

Lateral channel bar (Lcb) is the sand bar formed within the channel, it is longitudinal and round shaped. The geomorphological character is that lateral channel bar developed between the points; one or several parallel bars have been deposited inside the Padma River. Floodplain deposit is observed behind the bars; the rivers flow into the plain, cross the bars to get into the sea. In the study area there are several active channel bars found within the Padma River (Fig. 5).

4.2 Identification of Land Use/Land Cover Map Elements

The land use was classified into five elements: element 1- 5 as suggested by Goudie [29]. Land use element-1 and element-2 are fit for human

settlement purpose and construction of roads and highways. The elements are also suitable for agricultural activities (Figs. 6e and 7). The elements are free of river bank erosion, water logging problem and flooding situation. The elements are found in the northwestern, western and in some parts of and southeastern central region of the study area. The human settlement density is high and the communication system is also good (Fig. 7).

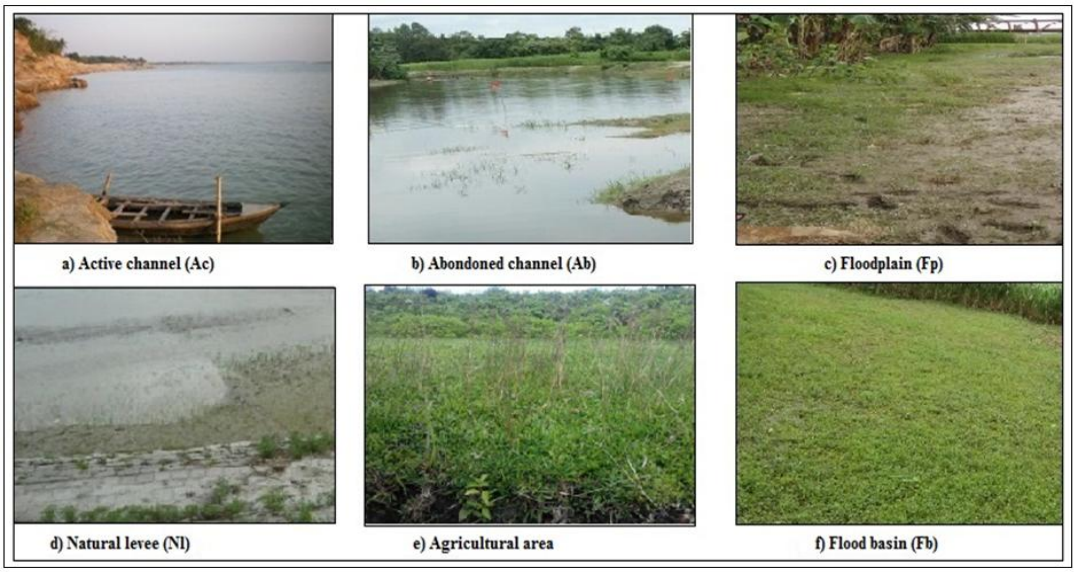

Fig. 6. Photographs show the geomorphological features of the study area (a-f)

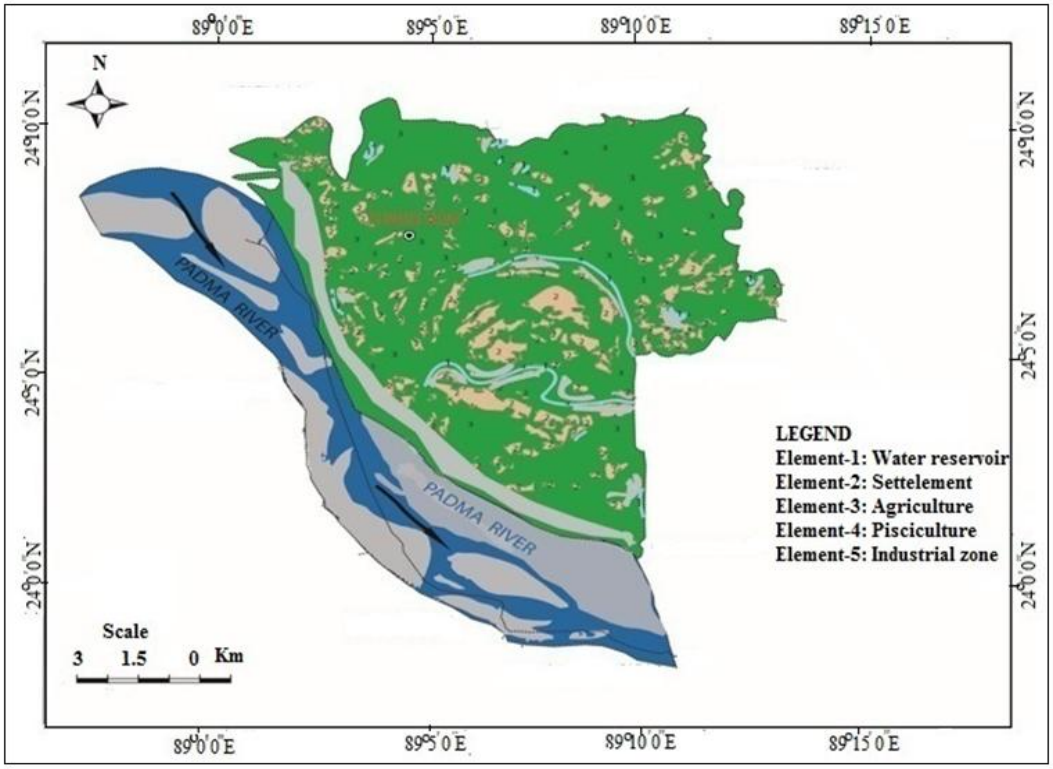

Fig. 7. Land use map of the Ishwardi Upazila under Pabna district, Bangladesh

The land use element-3 is less appropriate for human settlement purpose; the human settlement density is medium to high. The element falls in the floodplain area; has a good communication system. The element is found mainly in the central, it also covers a few other parts of the study area (Fig. 7).

Land use element-4 is not fit for human settlement and it is thus unoccupied. The element occupies the deeper part of flood basin and abandoned channel area. The element is mainly covered by almost throughout the year (Fig. 7). Land use element-5 is suitable for industrial area.

Generally, the study area has a dense transport network and thus, it is suitable for industrial development (Fig. 7).

5. DISCUSSION

Slope is one of the important geomorphological factors; it not only directly affects soil development and vegetation distribution but also controls eco-environmental patterns as well as exploitation and utilization modes. The slope of this area is about 5°–10°, composed of sedimentary rocks with low hardness, strong weathering effect and gentle slope. Active channels were identified on satellite images by their light tone, smooth texture and morphological positions. There are many active channels observed in the Padma River. Natural levees on the SPOT imagery were identified by medium to dark gray tone, coarse texture and linear shape along the river bank; this unit is mostly the vegetated area. The comparatively higher elevated area is preferred for human settlement as compared to the surrounding areas. Flood plains on the SPOT image were identified by medium gray tone and smooth texture [30]. 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 images. In the study area, these units were observed on side of the Padma River. The flood basins on the SPOT image were identified by dark gray tone, no texture and irregular shape, these are monotonous featureless areas. Most of flood basins are found in the eastern side of the Padma River of the study area. However, flood basins are sparsely distributed throughout the study area. Lateral channel bar were identified in many parts of Padma River. This result affirms the earlier findings made by different researchers using ground observation techniques [31-32].

Five (5) land use elements in the study area were identified based on the land use pattern. Land use resulted in decrease of vegetated lands, losses of wildlife and habitats, negative impact on hydrological cycle, socio-economic and environmental settings [33]. Land element-1 depicts that active channel geomorphological unit; this is used for water reservoir and agricultural purpose. Land element-2 can be used for human settlement and for the construction of roads and highways. Land element-3; flood plain, is appropriate for agricultural purposes. The older flood plains can be used for settlement and for the construction of a road network while element-4 indicates partly flood basins and partly an abandoned channel, suitable for agriculture, surface water reservoirs and fisheries land-use. The element is highly flood affected and drainage system is poor [34]. Land element-5 suggests that the area is appropriate for industrial use. Thus, the result affirms earlier observations made by Islam et al. [8] in the northern region of Bangladesh. The accuracy of the land use map was satisfactory; higher accuracy was obtained using the Landsat TM data as compared to results obtained on using the SPOT image data in the study.

6. CONCLUSION

The geomorphological map was prepared for the Ishwardi Upazila under Pabna district, Bangladesh using remote sensing data and field data. Six geomorphological units were identified from the SPOT (Band 4) and Landsat TM (FCC) images. These are active channels abandoned channels, natural levees, floodplains, flood basins and lateral channel bars. A land use map was prepared on the basis geomorphological conditions; the area was divided into five land use/land cover elements (i.e. elements 1, 2, 3, 4, 5). The land use map will provide significant guideline for the better sustainable use of the land resources in the area of study. The results reveal the need for regional and local land use policy revision employing a multi-disciplinary approach for sustainable development. The study recommends the integration of geological factor in initial for land use planning in order to avoid damage of property and loss of lives. However, there is need for further research work using different and longer data sets.

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COMPETING INTERESTS

Authors have declared that there are no competing interests.

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