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Current Status of Geological Remote Sensing in Bangladesh: A Review

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Abstract

Geological application of remote sensing in Bangladesh has been reviewed from published literatures with an objective of evaluating its present status and potentiality of future use. Application of remote sensing started in Bangladesh with the use of aerial photographs in the middle of the last century, and satellite remote sensing started since the beginning of Landsat era in early 1970s. Data from different sensors are being used in geological mapping, mineral exploration, neotectonic studies, coastal geological mapping etc. and is also used in the fields of urban geology, environmental geology and natural hazard assessment which give valuable results. Both visual image interpretation and digital image processing techniques are being applied for data analysis. The review result clearly shows its effective use in various geological applications and ascertains its potential utilization to meet the challenges of the country in the 21st century. But the future successful and wide use of remote sensing will largely depend on trained and knowledgeable manpower and availability of these data at low cost.

Keywords

Bangladesh, Remote Sensing, Geology, Natural Hazards, Neotectonics.

Introduction

Bangladesh, with an area of about 1,47,570 square kilometers, is one of the most densely populated countries of the world. This huge population needs food, shelter, communication, safety from natural hazard etc. Moreover additional pressure is expecting from global warming and sea level rise due to climate change. Reliable geological information is essential for resource exploration and management, floodplain management, development planning, urbanization, environmental restoration, coastal zone monitoring and management, natural hazard assessment etc. Remote sensing can play vital role to study the geology.

Application of remote sensing in Bangladesh geology started during the middle of 1950s. Until the availability of satellite remote sensing data aerial photographs were used for geological mapping, which is still continuing. Scientists of the country have been working with aerial photography, Landsat (MSS, TM, ETM+), SPOT, IRS, Radarsat, JERS-1, Lidar, CORONA, RapidEye, Pleiades data in different fields of geology.

In the following pages history and current status of application of remote sensing in geology of Bangladesh have been reviewed with brief descriptions and results, and future prospect. The objective of this work is to give an idea to the users and especially the young researchers about the present status and strength of the remote sensing technology and its potential future use in geology and related-fields in Bangladesh.

The paper has been prepared on the basis of published sources and websites. All the references have been cited at the end of all mentions. Obviously, this is not a complete inventory of works.

It may be mentioned here that optimum utilization of remote sensing technology depends on clear understanding of the interaction among electromagnetic spectrum, atmosphere and terrain characteristics. As an aid, a brief on geology and climate of the country have been given below. The country is covered with Tertiary folded sedimentary rocks (12%), Pleistocene soil (8%) and Holocene alluvial sediments (80%), and situated in a tectonically active region. The sediments, consisting mainly of unconsolidated sand, silt and clay in varying amounts, come from different geological environments and deposit in different geomorphological conditions (Brammer, 1996).

The country has a tropical monsoon climate (Reimann, 1993). Mean annual rainfall is 1250 mm in the centre-west, more than 2500 mm in the north-west and near the coast, and exceeds 5000 mm in the north-east (Brammer, 1996). Mean temperature is about 25°C, and mean temperatures range from 18°C to 30°C in winter and summer respectively. Wind is generally light but it goes 50-100 km/hr or more during pre-monsoon or cyclones. Wind direction is mainly between SW and SE during pre-monsoon and monsoon, and NW and NE during post-monsoon and dry seasons. Evaporation is about 50-75, 100-175 and 100-125 mm/month in winter, pre-monsoon and monsoon respectively.

Geological and Geomorphological Mapping

A geological reconnaissance in part of Bangladesh and India was made during 1955-56 on an area exceeding 1,80,000 square kilometres covered with Quaternary deposits (Morgan and McIntire, 1959). This classic study was based on interpretation of aerial photographs coupled with as much field work as was possible. They defined the geomorphic and stratigraphic framework of the Bengal delta and demonstrated the neotectonic activity influencing the course of rivers on the delta. Geologists of the country started using aerial photographs for geological mapping and delineating natural resources as early as 1961-62 (Alam and Quaraishi, 1985) to prepare maps in the folded sedimentary rock terrain of the SE part of Bangladesh. In a later date the floodplain of the Jamuna-Brahmaputra river was mapped on the basis of examination, in detail, of several sets of aerial photo-mosaics (scale 1:50,000) to determine the sediment dynamics, geomorphology and tectonics of the Bengal delta (Coleman, 1969).

Use of satellite remote sensing data in geological purposes started with the preparation of geomorphological map on the eastern part of Bangladesh with the help of Landsat-1 and 2 imagery at the scale of 1:1 million (Bakr, 1977). The image interpretation was supported by field work during 1973-76. The objectives of the work were to identify Quaternary geomorphic surfaces and the accompanying deposits, the past and present drainage, and analyze the nature of geomorphic evolution of the area. The imagery furnished useful information on tonal variation and texture, and aided in classification of mappable units. In this work archeological evidences have been efficiently used to solve Holocene geological problem.

In early 1980s geological mapping were done in an area adjacent south of the Shillong Plateau (Islam and Alam, 1992) and in the SE part of the country using aerial photographs at the scale of 1: 30,000 (Khan *et al.,* 1998). The aerial photographs were found to be useful for geological mapping. The later work identified few environmental problems in the area. Field surveys were carried at different times during 1984-85 to prepare geomorphological and geological maps of the coastal parts in the SW region of Bangladesh with the help of aerial photographs (1:30,000) and Landsat images (Azeem and Khalequzzaman, 1994). They classified the terrain into different land facets for obtaining maximum benefits from landuse.

During late 1980s Geological Survey of Bangladesh took a large geological mapping programme in different geological environments in 1988-1990 periods (Alam *et al.,* 1990; Khan *et al.,* 1990; Huq *et al.,* 1991; Huq *et al.,* 2003; Alam *et al.,* 2008) to map Pleistocene and Holocene deposits. Remote sensing data gave the opportunity to reinterpret the images in many cases. Geological map of the NW part of Bangladesh was prepared to understand the Tista fan geology (Khan *et al.,* 1990). They also identified a number of lineaments and many of them are structurally controlled. Geology of another area in the NW part of Bangladesh was studied using aerial photographs and Landsat imagery (Huq *et al.,* 1991). The area is covered with Pleistocene soil and Holocene sediments. They identified a lineament, which was not identified by earlier workers, from Landsat image and discussed nicely about the Holocene tectonics of the area. Geology of an area in the NE part of Bangladesh was studied where Tertiary folded rocks, Pleistocene soil and Holocene sediments are exposed (Huq *et al.,* 2003). Besides the surficial mapping they also discussed about tectonic geomorphology of the area produced by the ongoing tectonic activities. In this study aerial photographs and Landsat TM images were used. The middle part of the country was mapped where aerial photographs (scale 1:30,000 and 1:50,000 taken in 1975 and 1983 respectively), Landsat MSS Band 5 and 7, and TM FCC imagery were also used (Alam *et al.,* 2008). Field studies were done to record field descriptions and analyses of the sediments and to interpret this information in the light of what is known of the tectonic setting and Quaternary history of the complex delta of the Jamuna (Brahmaputra) River. Photographs were used to describe surface expression, sedimentological characteristics, drainage, and geomorphic relationships whereas Landsat images were used for the interpretation of lineaments and geologic structures. The area is occupied by Pleistocene soil and Holocene sediments.

Alam and Islam (2011) identified four geomorphic terraces on the Brahmaputra Floodplain in the northern part of Bangladesh (Figure 1) from the SPOT Panchromatic data (scales 1:50,000 and 1:100,000) using standard visual image interpretation techniques. These terraces show unique image characteristics, geomorphic features, and topography. Later, the results of the interpretation were compared with ground truth like topographic data and sediment properties of the area, and other information of the region. With the help of remote sensing data Akter *et al.* (2012) studied geomorphology of the Mymensingh terrace.

In a reconnaissance study, the geomorphology and geology of the coastal plain of Bangladesh, based on qualitative and quantitative interpretation of hardcopy SPOT Pan, Landsat MSS and TM data, and field data, were described (Khan, 2001). Here three distinct geomorphic domain of the entire coast, viz. deltaic, estuarine and intradeltaic or coastal plains, have been identified. Based on the interpretation of SPOT and Landsat TM band 4 imagery at the scale of 1:50,000 with field data a broad overview of geomorphological elements of the eastern coastal zone of Bangladesh and their relationship were given by Hasan and Hasan (2002).

Hatiya, an off-shore island and a mouth bar in the Meghna estuary, and Barguna district were geologically mapped with the help of Landsat imagery and aerial photographs, and subsequent field work. The first work show the changes in the size and shape of the island with time from 1778 to 1985, bank erosion, cyclone and storm surge susceptibility of the area (Khan, 2003). The later work also shows river bank and coastal erosion, storm surge susceptibility, and the coast line changes during a period of 1770-1984 in the area (Sengupta and Khan, 1996).

A geological mapping project covering the entire coastal area of Bangladesh was implemented by the Geological Survey of Bangladesh during 2006-2011. This vast coastal zone is rich in natural resources like forest, land, mineral sand, natural gas etc. and home of about 30% population. Multidate aerial photographs, SPOT Panchromatic, Landsat and IRS-1D LISS data have successfully been used to prepare geological, geomorphological and hazard maps. Interpretation of these data gave the opportunity to extract huge amount of information, especially on changes in coast line, sediment dynamics showing areas of erosion and deposition and also mineral resources (Alam, 2011; Majlis *et al.,* 2013). Figure 2 shows the coastal zone on IRS-1D LISS image.

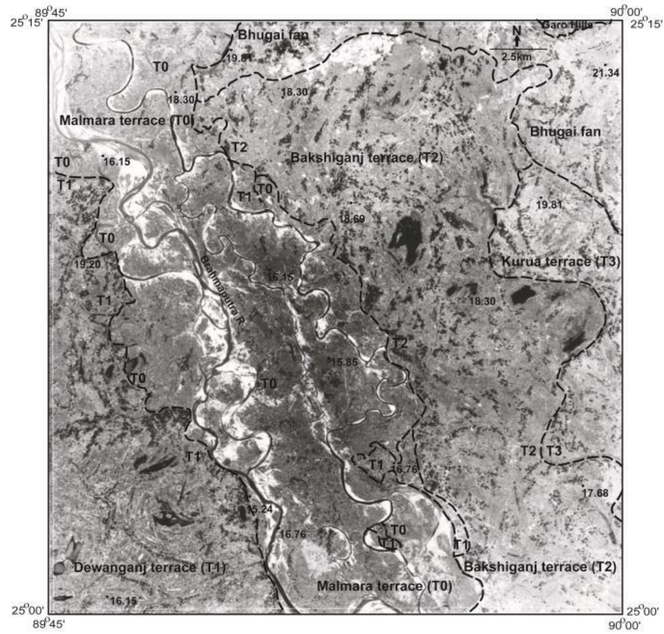

Figure 1: SPOT Panchromatic image showing different geomorphic terraces and figures are spot heights in metres (Alam and Islam, 2011).

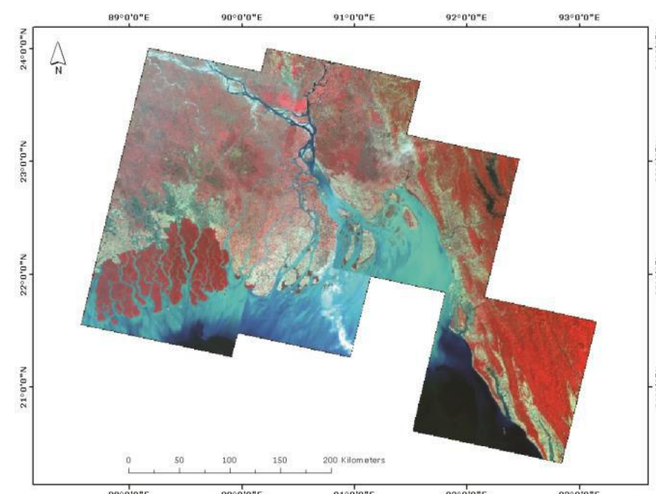

Figure 2: Coastal zone of Bangladesh on IRS-1D LISS image acquired on 15 February 2005.

Neotectonic Study

Bangladesh is located in a tectonically active region of the world. Studies on the neotectonics have been carried out to understand the style, pattern and behavior of the activities. Technique of neotectonic studies in soft sediment-covered area is quite different from that in folded sedimentary terrain. A number of researches have been done by many authors (Alam, 1995; Alam, 2001b; Rashid *et al.,* 2014;

Kamal *et al.,* 2000; Kamal *et al.,* 2005; Biswas and Grasemann, 2005; Alam, 2006a). A neotectonic study, in the NW part of Bangladesh, shows that the lineament is distinctly identifiable on Landsat MSS image whereas it is not easily identifiable on aerial photographs (Alam, 1995). The geomorphology and neotectonic activities along some suspected young faults in different parts of Bangladesh using Landsat image, aerial photograph and topographic maps were studied, and an evaluation of their nature was made (Alam, 2001b). Anomalous behaviour of drainage network on the floodplain was identified Kamal et al., 2000; Kamal *et al.,* 2005), which they interpreted to be the result of neotectonic activity. Geomorphic investigation based on remote sensing (Landsat TM and ETM+) techniques and 3D visualization support a general interpretation of the Dauki Fault as a north dipping, high angle reverse fault that facilitated the exhumation of the Shillong Plateau (Biswas and Grasemann, 2005). A detailed work on the use of different remote sensing data (Aerial Photograph; Landsat MSS, TM and ETM+; SPOT Pan and Radarsat SAR) with temporal variation for neotectonic study (Figure 3) in a terrain covered with soft sediments was carried out (Alam, 2006a). This work got many successful results on the potentiality of using remote sensing data for such a study. Ahsan *et al.* (2015) created high resolution digital elevation model (DEM) of the Raghunandan Hills of Habiganj district using stereopair Pleiades Pan images (Figure 4) to study the active faults.

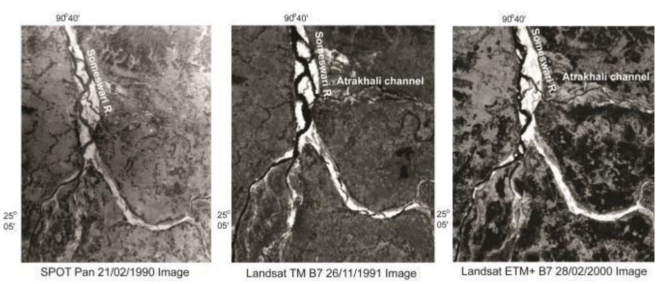

Figure 3: Widening of main channel and rejuvenation of other channel during 1990-2000 period due to neotectonic activity (Modified from Alam, 2006a).

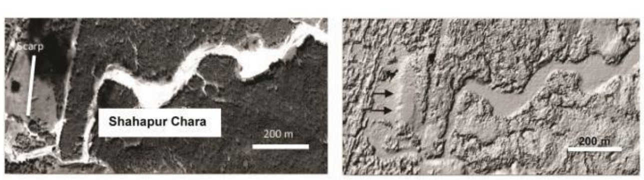

Figure 4: Pleiades Panchromatic Image (50 cm resolution) of the middle part of the Raghunandan Hills, Habiganj district (left) and high resolution DEM constructed from stereo image pairs (right). White line and black arrows show the fault scarp (Ahsan *et al.,* 2015).

Natural Hazard Study

Several studies show that there is relationship between geology and occurrence of natural hazards in Bangladesh. Remote sensing data have been used for natural hazard identification and assessment (Coates *et al.,* 1991; Coates *et al.,* 1992; Asaduzzaman, 1994; Khan, 1995; Alam, 1997b; Alam, 2006b). Study on flood hazard assessment covering entire Bangladesh and on Dhaka area in detail using SPOT images and GIS was done (Asaduzzaman, 1994), where he concluded that SPOT images were found to be useful for such study. Hardcopy SPOT Panchromatic images at the scale of 1: 30,000 have been found to be suitable for landcover mapping as input for the cyclone surge modeling (Khan, 1995) in the coastal parts of Bangladesh. In another study geologic hazard (flood, channel migration, earthquake-related affects, subsidence, river bank erosion, siltation) maps were prepared on the mid-northern part of the country using mainly Landsat and SPOT images (Alam, 2006b). In this study qualitative and experienced-based assessments were done which gave good results.

A study was carried out using time series MODIS satellite data covering 1995-2005 period in a GIS to understand past flood occurrence and location with the intention of flood risk reduction and preparedness (Choudhury *et al.,* 2006). They were successful to identify high-risk flood prone areas.

River bank erosion is great problem in Bangladesh that creates huge loss of properties and suffering to the people. Identifying the causes of unstable behaviour of the rivers is of great interest to river scientists, engineers and planners in attempting better management of the resources. Research was conducted to find out the causes using time series satellite images since 1973 and other relevant maps and data leading to develop a conceptual model to explain the observed processes (Shamsuzzaman *et al.,* 2009; Sarker, 2003).

From stereo-paired satellite images of CORONA (resolution: 7.5 m) and ALOS (resolution: 2.5 m) active fault traces were detected under a paleo-seismological study to identify seismic events along the Dauki fault at Jaflong, Sylhet, Bangladesh (Morino *et al.,* 2014).

Interferometric Synthetic Aperture Radar (InSAR) covering the 2007-2011 period where Advanced Land Observing Satellite Phased-Array L-band SAR scenes were used to study the land subsidence rates (Figure 5) and its variability, and land subsidence of 0 to >10mm/yr has been seen in Dhaka (Higgins *et al.,* 2014).

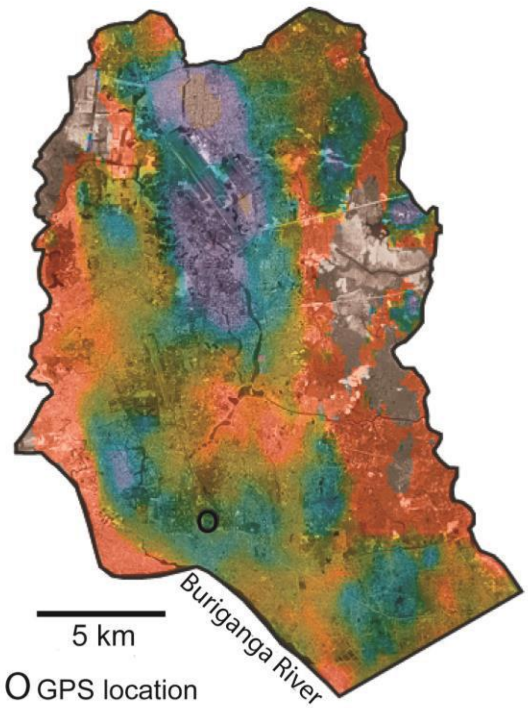

Figure 5: InSAR-derived average annual subsidence rates in the city of Dhaka (Modified from Higgins *et al.,* 2014).

Urban Geology and Planning

Bangladesh is one of the most densely populated countries of the world with a density of population 1021 per square kilometer (Bangladesh Bureau of Statistics, 2014). Population of urban areas is increasing rapidly, whereas land resources are very limited. So, for sustainable development proper planning is urgently needed. A geological mapping programme for Dhaka City, with an intention to be used for urban planning, was carried out during the end of 1980s (UN ESCAP, 1999). The work was done using aerial photographs and satellite imagery and it also covered the study of geomorphology, engineering properties of the material and artificially filled areas. A report accompanying a geomorphic map prepared from aerial photographs on Keraniganj Upazila of Greater Dhaka City was published by UN ESCAP in its atlas of urban geology series with the objective to determine the importance of geology for land-use planning in tropical deltas (Khan *et al.,* 1991). In a research work, attempt was taken to evaluate landscape for urban planning near Dhaka with the help of different remote sensing data (hardcopy SPOT Pan, digital ADEOS, Landsat TM, IRS-1D Pan, Quickbird) preparing geomorphological, drainage and landuse maps. Result of image analysis with integration of field data they gave a zonation showing suitability for urban expansion (Rahman *et al.,* 2008). In a recent work digital aerial photographs and high-resolution Lidar data (acquired in February 2009) have been used to derive hazard maps in support of risk assessment for urban planning at Purbachal area of Dhaka (GSB and BGR, 2009). This study was carried out to assess the drainage, identify the loose-fill area and predict the post-development flood flow, land settlement potential causing water logging, and overall hydrodynamic change due to modification of land in an area where urban development process is going on now in Greater Dhaka.

Environmental Geology

Most of the geological mapping reports contain a brief description about the environmental condition of the area studied. Geomorphological changes occurred in the SW coastal part of Bangladesh due to poldering effects were compared using a series of aerial photographs taken in 1960s, 1970s, and 1980s, and tried to determine the geological and other causes of water logging and drainage problems (Ali, 1999). These changes caused environmental degradation and crop failure in the area. Monitoring of surface water bodies was done using Landsat TM and ETM+ images in the Tista river (Mia *et al.,* 2014).

Geoarcheology

Bangladesh has a very rich cultural heritage documented from the discovery of many archaeological sites dating since 4th BC. Human habitations since the earliest times favoured the following four landforms—alluvial, coastal, eolian and other terrestrial landforms. For archaeological researches (Figure 6) in Bangladesh, different landform features have been identified with the help of remote sensing (Sen, 2012; Sen *et al.,* 2014). Geomorphology of Mahasthangarh and surrounding area was studied with the help of satellite imagery for archaeological excavations under Bangladesh-France jointly during early 1990s. Geological evidence for disappeared habitation sites can be identified from remote sensing (Ferentinos *et al.,* 2015).

Figure 6: Spatial distribution of Goal Bhita and occurrences (Modified from Sen *et al.,* 2014).

River Morphological Change Detection

Changes in Jamuna river morphology (Figure 7) using time series remote sensing data in a GIS was studied to quantify and map morphological changes (CEGIS, 2010).

Future Applications

In Bangladesh, basement rock lies at shallow depth in the northwestern part of the country. Geological exploration indicates that the pre-Cambrian basement is highly fractured and jointed. It is inferred that metallic mineralization could occur along these fractures. A study with the help of SPOT Panchromatic image interpretation from NW part of Bangladesh show anomalous geomorphic features (Sarker *et al.,* 2009), which may have relationship with the structure of basement complex. Results of digital image processing of different bands combining with geomorphic information may help in the identification of such mineralized zones. Moreover, each kind of imagery has its own benefits and drawbacks, which provide great potential to fully exploit increasingly sophisticated multisource data through data fusion. For example, MODIS imagery has significant advantage in temporal resolution (one day) but is very poor in spatial resolution (250, 500 or 1,000 m) for certain applications, whereas Landsat TM imagery performed very well in spatial resolution (30 m) but with 16-day revisit (Wang *et al.,* 2010).

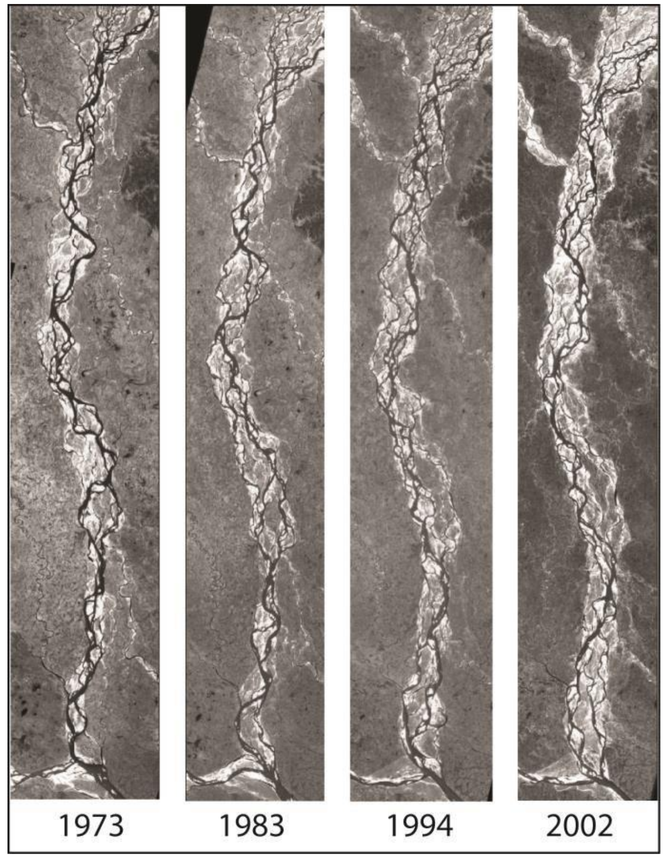

Figure 7: Changes in Jamuna River morphology during 1973-2002 period (Modified from CEGIS, 2010).

Space borne radar remote sensing can be a potential field for archaeological research in Bangladesh with the development of Synthetic Aperture Radar (SAR) in terms of multi-band, multi-polarization and high-resolution data. Success of use of remote sensing in archaeology depends on selection of appropriate imagery which is again depend on landscape type(s) and potential features to be extracted (Parcak, 2009).

Delta building processes, coastal change, landuse change should be monitored with the help of remote sensing data periodically for sustainable coastal zone management. Hyperspectral remote sensing data may be helpful for the identification of saline water intruded zone from the environmental condition and in monitoring the intrusion process. Oceanographic studies viz. physical parameters of the oceanic conditions including chlorophyll concentration in ocean biomass can be studied and monitored using remote sensing data. Hyperspectral data have the ability to collect ample spectral information across a continuous spectrum generally with 100 or more contiguous spectral bands. Hundreds of spectral bands with 10-20 nm spectral bandwidths offer new possibilities to detect subtle differences between objects of interest. Remote sensing can more intensely be used in earthquake and seismological studies.

Important environmental issues of Bangladesh are air pollution, pollution from municipal waste, industrial and oil pollution in the coastal region. These pollutions can be monitored and protective and mitigative measures may be taken. Environmental impact of development projects can be studied using this technology and the knowledge can be applied to such projects in future. Environmental impact of the underground coal and hardrock mines in the northwestern part of the country can be monitored using different remote sensing data. Melting of Himalayan ice due to global warming is predicted that will cause more erosion in upper part and sedimentation in the down-stream part. Study and monitoring these effects will help taking proper steps towards adaptation or mitigation. Dynamics of mangrove forests can be monitored using hyperspectral remote sensing.

Conclusions and Recommendations

Remote sensing techniques have been found to be very effective in various fields of geology. Although the high cost of remote sensing data and related hardware and software hinders research works and applications in many developing countries. Besides the optical and infer-red region of the electromagnetic spectrum other potential range could be in the thermal infrared and microwave region. The technology could be of much beneficial for Bangladesh in resource exploration, exploitation and management. Pressure from huge population on a small piece of land for food, shelter, urban and other development activities can be reduced through proper planning and management which depends on reliable and timely information. More research should be carried out in order to understand the interactions between the electromagnetic energy and terrain characteristics. This is true in case of Bangladesh because it has a unique combination of soft Holocene sediment covered alluvial-deltaic country in an active tectonic region with anthropogenic influence from its huge population. Moreover, its position is in a tropical humid climatic zone. To obtain maximum benefit using the RS tool we have to understand the interactions among these. With the development in data acquisition capability, and in image processing software, trained and skilled users with up-to-date knowledge will help in successful application of remote sensing.

In addition to the academic courses in different universities arrangement of short training courses are recommended which will help in reducing deficiency in qualified manpower in this sector. Moreover, its application will get wider spectrum if the remote sensing data are available at low cost.

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