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Synergistic Use of Passive and Active Remote System Imagery: Review on Bangladesh Perspective

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Authors' contributions

This work was carried out in collaboration between both authors. Author SCS designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author MAP managed the literature searches and, analyses of the study performed through final editing. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Background: Remote sensing data are widely used in different sectors in all over the world. Remote sensing data are two types; one is active while another is passive remotely sensed data. In Bangladesh recently remote sensing data are widely used in different filed of applications while the application of remote sensing has started in the early 1970s. However, its uses are limited because lack of expertise and required financial support to obtain updated information and logistics support. The major users are SPARRSO (Bangladesh Space Research and Remote Sensing Organization), LGED (Local Government Engineering Department), Universities and CEGIS (Center for Environmental and Geographic Information Services). The main objective of this paper is to explore the different uses of remote sensing data in different applications of Bangladesh.
Methodology: Study was done by accumulation of secondary published data through desk based literature review.
Results: Remote sensing data have mainly used in the environmental application, river dynamics,

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flood monitoring, coastal zone monitoring, wetland monitoring, agricultural monitoring, forestry and urban applications. In these above applications are mainly used Landsat, SPOT, IRS-LISS, Ikonos and Radarsat remote sensing data. At present the researches with remote sensing data are emerging slowly within two major organizations such as SPARRSO and CEGIS while the universities are lagging behind.

Conclusion: This study has revealed that if the government of Bangladesh will take the initiative to provide logistics support, remote sensing data applications area will be increased in near future which would be helpful to develop different infrastructural plan.

Keywords: Remote sensing; Active and Passive system; Landsat; SPOT, IRS.

1. INTRODUCTION

1.1 Importance of Remote Sensing

The conventional techniques are used for the identification, delineation, quantification and monitoring of terrestrial phenomena (including natural resources) and analysis of their properties are very time consuming, costly and unbiased free. However, the use of remote sensing offers an effective alternative means in such case.

The advantage of remote sensing is possible provides synoptic view with large area coverage. The remote sensing data is very useful for multiple applications because this data is a digital data and are readily available on computer compatible modes and in standardized formats. Being digital the remotely sensed data may be directly input into geo-based information system and incorporated into host of other data from wide sources thus facilitates feature classification and discrimination within a very short time.

1.2 Nature of Remote Sensing

Remote sensing is the science of deriving information about the earth’s terrestrial environment from image acquired at a distance using a platform (e.g. aircraft, satellite) based sensors [1]. It usually relies upon measurement of natural and man-made electromagnetic energy, reflected or emitted or scattered from the features of interest. Until 1970’s, black and white aerial photography was the principal form of remote sensing available to Geographers. Since then an array of remote sensing techniques have been developed and becoming available to public use. Some of these include true-colour photography, infrared (IR), black and white and false-colour photography (NIR imagery), IR line scan and radar imagery. Major development in remote sensing came in the 1960s, when a series of important development occurred in rather rapid sequence. The first satellite (TIROS-1) was launched in April 1960. Since then a number of remote sensing sensors were released to civilian use from military research and application [2,3]. There are two major types of sensing system: Passive and active based on sensing device used. The passive imaging system may be again divided into direct system (for example, black and white, true colour and false colour photography) and indirect system (for example, IR line scan).

Passive system records energy, emitted or reflected, but it does not produce or transmit energy of its own. In short, it is a system that detects or measures radiation emitted by the target. For instance, major passive sensors commonly used in spacecraft are MSS, TM, ETM and SPOT. On the other hand, a remote sensing system that transmits its own electromagnetic emanations at an object (s) and then records the energy reflected back to the sensor is active. In short, it is a system with the capability to transmit, repeat, or re-transmit electromagnetic information. For example, some active sensors are commonly used in spacecraft are SAR, Radar Altimeter, Scatter meters [4].

1.3 Aim and Objectives

Despite many successful remote sensing applications in many fields of research, there are few instances of synergistic use of passive and active remotely sensed data. In this paper an attempt has been made to explore how these two types of data are used in various scientific disciplines. The main objectives of the paper are to investigate focus on optical (i.e. Landsat and SPOT) and radar (i.e. Radarsat and ERS) satellites and their sensors and discuss the synergistic application of images on the basis of sensing mechanisms; present some examples on the applications and performance of satellite data on Bangladesh.

Study was done by accumulation of secondary published data and satellites images through desk based literature review.

2. MAJOR OPERATIONAL REMOTE SENSING SATELLITES

2.1 Passive Systems

2.1.1 Landsat (Optical Remote Sensing) satellites

NASA was launched on July 23, 1972 the first series of satellites designed to provide repetitive global coverage of the Earth's land masses, known as the Earth Resources Technology Satellite- A (ERTS-A). The second in this series of Earth resources satellites (designated ERTS-B) was launched on January 22, 1975. It was renamed Landsat 2 by NASA, which also renamed ERTS-1 to Landsat-1. Three additional Landsat were launched in 1978, 1982 and 1984 (Landsat 3, 4, and 5 respectively). Landsat 6 was launched in October, 1993 but failed to obtain orbit. Each successive satellite system had improved sensor and communications capabilities. Landsat 4 and 5 had both the MSS and the TM sensors. The MSS sensor (Landsat 1, 2, 3, 4, 5) and TM (4 and 5) sensors primarily detect reflected radiation from the Earth's surface in the visible and near-infrared wavelengths, but TM sensors provide more radiometric information than the MSS sensors. Sixteen detectors for the visible and mid-infrared wavelength in the TM sensor provide 16 scan lines on each active scan. In 1992, the US Congress authorised the procurement, launch and operation of a new Landsat satellite [4]. This new system Landsat 7 mission successfully placed into orbit on April 15, 1999 [5]. The primary new features on Landsat 7 enhanced TM plus (ETM+) are: A panchromatic band with 15 m resolution; On board full aperture, 5% absolute radiometric calibration and a thermal IR channel with 60 m resolution. The Landsat 7 ETM+ sensor offers several enhancements over the Landsat 4, 5 Thematic Mapper (TM) sensors, including increased spectral information content, improved geodetic accuracy, reduced noise, reliable calibration, the addition of a panchromatic band, and improved spatial resolution of the thermal band [5]. Recently NASA and USGS have launched Landsat 8 satellite program on February 11, 2013. Landsat 8 providing moderate-resolution imagery, from 15 meters to 100 meters, of Earth's land surface and polar regions, Landsat 8 will operate in the visible, near-infrared, short wave infrared, and thermal infrared spectrums. Landsat 8 will capture approximately 400 scenes a day, an increase from the 250 scenes a day on Landsat 7. The OLI and TIRS sensors will see improved signal to noise (SNR) radiometric performance, enabling 12-bit quantization of data allowing for more bits for better land-cover characterization. The Thematic Mapper (TM) records seven spectral bands and the Enhanced Thematic Mapper Plus (ETM+) records eight spectral bands here one is panchromatic band. These spectral bands have been carefully tailored to record radiation of interest to specific scientific investigations as described in Table 1.

2.1.2 SPOT (System Probatorie d'Observation de la Terre) satellites

The SPOT Image Company was incorporated in 1982 to market produce and distribute world-wide, data returned by the SPOT series of Earth observation satellites. SPOT has been operational since February 1986 and is guaranteed to remain so for the next 15 years. SPOT 1 has been followed by SPOT 2 in January 1990. SPOT 3 was launched in September 1993. SPOT 4 with improved capabilities (middle infrared band) is under construction and SPOT 5 will be a satellite of completely new design with improved ground resolution and continuous stereoscopy. A single scene covers a geographic area 60 km 60 km. Two alternative modes of imaging are Panchromatic and Multispectral are shown in Table 2.

The HRV can be operated in either of two modes (Tables 2 and 3). In the panchromatic mode the sensor is sensitive across a broad spectral band from 0.51 to 0.73 mm. In the other mode, the multispectral configuration, the HRV instrument senses three spectral regions (Band 1 to Band 3).

Many operational applications in a variety of domains ranging from Earth sciences to economic planning and decision making benefits from SPOT data; vegetation, agriculture, forestry, soils, geology, erosion, oil and mineral exploration, water resources, urban and regional planning, civil engineering, development projects, or environmental monitoring. Here, some of the broad filed of applications are briefly discussed in Table 4 [6].

Table 1. Landsat TM and ETM+ Bands and their objectives

Band	Objectives
Band 1	Coastal water mapping/ bathymetric mapping along coastal areas, soil vegetation differentiation, forest type (e.g. deciduous/coniferous) differentiation;
Band 2	Green reflectance by healthy vegetation;
Band 3	Chlorophyll absorption for plant species differentiation;
Band 4	Water body delineation; water-land interfaces detection; near IR reflectance in healthy green vegetation (biomass survey);
Band 5	Vegetation moisture measurement; snow cloud differentiation; discrimination between rock and mineral types;
Band 6	Hydrothermal mapping; and
Band 7	Plant heat stress measurement; soil moisture and vegetation studies.
Band 8	This band can be merged with the 30m data from ETM+ bands 1 to 5 and 7 to produced “pan-sharpened” color images. Panchromatic, Black and white visible spectrum; data providing fine geometric details.

Sources: [44,45,46,47,48]

Table 2. Two alternative modes in SPOT satellite

Band type	Description
Panchromatic	Black and white, with a ground resolution of 10 meters which makes SPOT data the most advanced system in terms of image resolution as features as small as 10 meters in size on the ground are detected. This complies with mapping at scales up to 1:50,000; and
Multispectral	Colour, with 20 meter ground resolution acquired simultaneously in bands: green, red and near infrared.

Table 3. SPOT bands and their objectives

Band	Objectives
Band 1	Sharp vegetation response peak;
Band2	Chlorophyll absorption rate vary between species;
Band 3	Strong reflectance by healthy vegetation; and
Band 4	Panchromatic, Black and white visible spectrum; data providing fine geometric details.

2.2 Active System

2.2.1 Radarsat

The application of imaging radar for remote sensing is fairly new and considered as an important tool only for the last one and half decades, through the success of optical satellite images from space is well recognized. The wavelengths of electromagnetic radiation most commonly used for remote sensing of Earth are the spectrum of visible light, a wide spectrum of radio wavelengths and several infrared wavelengths. When radar (which employs radio waves) is selected from these possible choices, the decision is usually based on radar’s independence of solar illumination and weather conditions. However, the advantages of this technique have been focused upon by [7,8]:

- Independence of the sun as a source of illumination,
- Capability to penetrate clouds e.g.,
- Ice clouds that are dense enough to completely obscure the ground but have almost no effect at any microwave length.
- Water clouds have a significant effect only when the wave length gets below 2 cm and the effect is really string only for below 1 cm.
- Rain has a greater effect than clouds. The effect is negligible below about 4 cm and becomes important only for wave lengths of the order of about 2 cm when the rain in extremely intense.
- Capability to penetrate more deeply into vegetation than optical waves can, e.g.,
- The extent of penetration into vegetation depends upon the moisture content and density of the vegetation as well as upon the wave length of the microwaves. Thus,

the shorter wavelengths yield information about the lower layers and the ground beneath.

- Capability to penetrate significantly into the ground, e.g.,
- For dry soil the penetration depth at lower microwave frequencies is substantial while for wet soil the higher microwave frequencies penetrate only a centimeter or so. Nevertheless, this penetration is higher than that obtainable with visible and infrared radiation.

Radarsat is an advanced observation satellite project developed by Canada to monitor environmental change and to support resource sustainability. Radarsat was launched in November 1995. Radarsat, with planned lifetime of five years, is equipped with SAR. Using a single frequency, C-Band, the Radarsat SAR has the unique ability to shape and steer its radar beam over a 500 km range. Users have access to a variety of beam selections that can image swathes from 35 km to 500 km wide with resolution from 10 meters to 100 meters respectively. Incidence angles range from less than 20° to more than 50°. Radarsat can provide complete global coverage with the flexibility to support specific requirements. Radarsat can provide daily coverage of the Arctic and achieve complete coverage at equatorial latitudes every six days using a 500 km wide swath. Radarsat uses a sun-synchronous orbit; user can repeatedly view a scene at the same local time.

Table 4. Some applications of SAR image

Fields	**Applications**
Flood monitoring and hazard assessment	SAR data is particularly useful for flood monitoring because it helps to assess the effects of flood damage, predict the extent of flood waters and analyze the environmental impact of water diversion projects.
Cartography	SAR is an effective tool to map rugged or flat terrain where clouds and poor light conditions have so far limited the usefulness of other surveying techniques. It map the Earth stereoscopically to develop three-dimensional digital elevation models, these can be used monitoring erosion in high-relief areas.
Landuse	SAR imagery makes easier to map land use changes particularly the expansion on decline of urban areas and farmland.
Geology	Mapping features such as faults, folds and lineaments can supply information on ground water distribution, economic mineral deposits, and oil and gas potential. The seismic and fault data acquired by SAR assist studies on the nature and causes of earthquakes.
Crop production forecasting	Using SAR data, agricultural planners can examine and asses crop characteristics to forecast crop yields.
Forestry	Using SAR data, maps of clear cuts in boreal and tropical forests can be created to asses' environmental impact and measure the success of replanting operations.
Coastal surveillance (erosion)	SAR data is a rich source of information about the world's coastal areas. It can detect changes in coastal erosion, monitor aquaculture activities, map intertidal seaweed distribution and detect shipping and fishing operations in near shores.
Environmental Monitoring	Monitoring environmentally sensitive areas will represent a major application of SAR data, especially when combined with historical satellite data.
Coastal and open Ocean	Regardless of clouds, fog or darkness SAR can accurately measure changes in ocean waves and winds. This information is useful to offshore exploration and ocean research operation and locating potentially productive fishing area.
Sea ice monitoring	SAR data have the ability to map sea ice distribution and to identify ice types, particularly for large polar areas enveloped in darkness for long periods.
Geographical Information systems	Many professionals in these disciplines already use GIS to integrate and analyses large amounts of data from a variety of sources.

Moreover, Radarsat's dawn-dusk orbit places the satellite's solar arrays in almost continuous sunlight. Radarsat can downlink data to ground stations at different times from other remote sensing satellites, most of which use a mid-morning orbit [9].

2.2.2 ERS (European Remote-Sensing Satellites)

ERS-1 was launched in July 17, 1991, followed by identical satellite ERS-2, launched in April 1995. The largest of these are the active microwave instrument, which in SAR imaging mode is generating the familiar detailed 100100 km scenes of regions over which the satellite flies and which determine, over the oceans, wind speed and direction together with wave height, length and direction. The second active instrument is the radar altimeter, which measures with extreme precision the distance between the satellite and sea or ice surfaces and mean wave height [10,11,12]. ERS-1 and ERS-2, from August 16th, 1995 to May 16th, 1996, ERS-1 and ERS-2 were operated simultaneously. This was the first time ever that 2 identical SARs were operating in tandem. The orbits of those two satellites were carefully phased to provide a 1-day revisit interval; this enables collection of interferometric SAR image pairs which may be used for the generation of a global *Digital Terrain Model* (DTM) set as well as for many other novel applications such as interferometric difference. These are mainly useful for agriculture, hydrology and oceanographic research. The potential of *SAR* interferometry (INSAR) and deferential INSAR for geo-hazard risk assessment arising from earthquakes, volcanic eruptions, landslides and glacial surges are also explored.

Aside from their traditional meteorological and military applications, radar has been used extensively for mapping geological/ archaeological structures (particularly in those parts of the world where cloud cover presents a serious problem to optical sensors) vegetation mapping; discrimination of sea-ice types; measuring ocean wind speed and directions; mapping soil moisture content; mapping snow water content land use evaluations etc [7]. Some applications of non-imaging radars have been given in Table 5.

Based on the issues mentioned above, the indication is that both optical and radar satellites could be utilized for a wide range of applications in Bangladesh. In the next section, an attempt has been made to list some of those probable applications with brief highlights.

3. DISCUSSION

3.1 Synergistic Applications: A Perspective Example from Bangladesh

The pioneering remote sensing application started in the early 1970s with the work of Hile Haor Wetlands of Mouluvi Bazar, Bangladesh based on Landsat MSS [13]. Since then, remote sensing data have been used for a wide range of application in Bangladesh, although in limited institutions, partly due to lack of expertise and required financial support to obtain updated image and logistics. The major user agencies are SPARRSO, LGED, Universities and Some NGOs (Non-Governmental

Table 5. Non-imaging modes of ERS and applications of the active remotely sensed data reviewed

Non-imaging modes	Objectives
AMI (Active Microwave Instrument) Wave mode	Providing information about the length and direction of the ocean wave.
AMI Wind Scatterometer Mode	Providing data for climatology, oceanography, glaciology, land processes, operational meteorology etc.
RA (Radar Altimeter): Ocean and Ice Mode	Providing measurements leading to the determination of altitude, significant wave height, ocean surface wind speed and ice surface topography.
ATSR (Along Track Scanning Radiometer)	Providing data for sea surface temperature, cloud-top temperature.
GOME (Global Ozone Monitoring Experiment, ERS-2 only)	Providing data for Ozone, trace gases and aerosols in the stratosphere and troposphere.

Organization)/Research Organizations including CEGIS (former ISPAN). Documentation of the completed works with remote sensing may be divided into several thematic aspects including environmental, urban/infrastructure, agricultural, forestry and geological. In the following section, selected examples related to remote sensing work are furnished under different themes:

3.1.1 Environmental applications

One of the most popular applications of remote sensing data was the environmental sector wherein flood monitoring, cyclone, water logging, river monitoring, coastal change detection, salinity, drought stress are most important issues covered. These issues were researched under different institutions as part of government and NGO initiatives. For instance, CEGIS have been using SPOT and Landsat TM, ETM satellite data for years for river course monitoring, flood monitoring, and river morphological applications in order to provide field data to the WARPO (Water Resources Planning Organization) and to other Government agencies like LGED, SPARRSO, SRDI (Soil Resource Development Institute), BARC (Bangladesh Rural Advancement Committee), SOB (Survey of Bangladesh), GSB (Geological Survey of Bangladesh). One of the limitations of the RS applications is that a few systematic efforts have been directed towards socializing the utility of remote sensing data. These are lacks in national coordination in prioritizing issues of remote sensing based research themes in environment and duplication of researches are common and often data access to outsiders are very limited.

3.1.2 Flood monitoring

Flood is one of the recurring natural disasters in Bangladesh. As it occurs during wet monsoon, the sky in most cases remains cloudy, thereby, operational optical remote sensing data in most cases were found not usable. Therefore radar remote sensing and meteorological data are being used in Bangladesh because of dense cloud-cover during the monsoon flooding period. SAR has proven to be the most reliable tool for mapping and monitoring the dynamics of the flooding process. Recently CEGIS has initiated using Radarsat Imagery for flood monitoring during wet seasons Fig. 1 is an example of real time Radarsat data use for flood monitoring in Bangladesh. Mapping flood and damage extent has also been done by SPARRSO and others since 1988 using NOAA-AVHR meteorological satellite data [14]. NOAA data being 1 km spatial resolution are less useful for discriminating land water interface during wet monsoon. However, using its advantages of repetitive coverage (1 hour interval) and phonological information, flood extent may be reasonably identified at a generalized scale, which is valuable during flood [15]. Existing available research work based on Landsat and SPOT suggests that even with their improved spatial resolution, spectral discrimination between clear water and floodwater is often difficult. As a result inundation and flooding are not separable to the extent that helps in identifying boundary or extent of flood. The damage extent due to flood however is relatively easier to demarcate with the remote sensing imagery provided phonological data are supplemented.

3.1.3 River bank erosion

Bank erosion is recognized as one of the most important environmental hazard in Bangladesh, taking away valuable agricultural land and settlements, thus affecting crop production and rendering people homeless. Spatial extent of bank erosion is one of the key aspects for planning, management and engineering need in developing appropriate measures of the problem. River bank line and bank erosion relatively easier in detection, identification, and monitoring with remote sensing data and can easily by vectorized in GIS format. Therefore, Remote sensing data are readily applied in river monitoring including course shifting, bank erosion and management related activities in Bangladesh (Fig. 2) [16,17,18].

3.1.4 River morphology

River related data includes river basin, bank line, processes like erosion and siltation, river stage; all these are spatial in nature. Therefore, remote sensing data are capable to provide critical information related to spatial changes, particularly tracing past historical changes occurred in a river basin. The history of applications of remote sensing in river morphological analyses dates back from 1985-86 with Landsat MSS data [16]. Remote sensing in the form of aerial photographs have been routinely used for documentation of the historical river courses in order to select stable sites for the construction of bridges and flood protection embankments in the middle eighties [19]. However, aerial photograph being restricted, limited to 10 years interval and limited to dry season only; potential users instead prefer high resolution satellite images. Satellite images like SPOT and Landsat TM are being used for identifying the bank line shifting tendency and erosion and siltation behavior (Fig. 2). Demarcating historical bank lines using archival remote sensing data are important for the international trans-boundary rivers between Bangladesh and India. River stage monitoring with real time remote sensing data particularly in international rivers during flood period are now a reality [17].

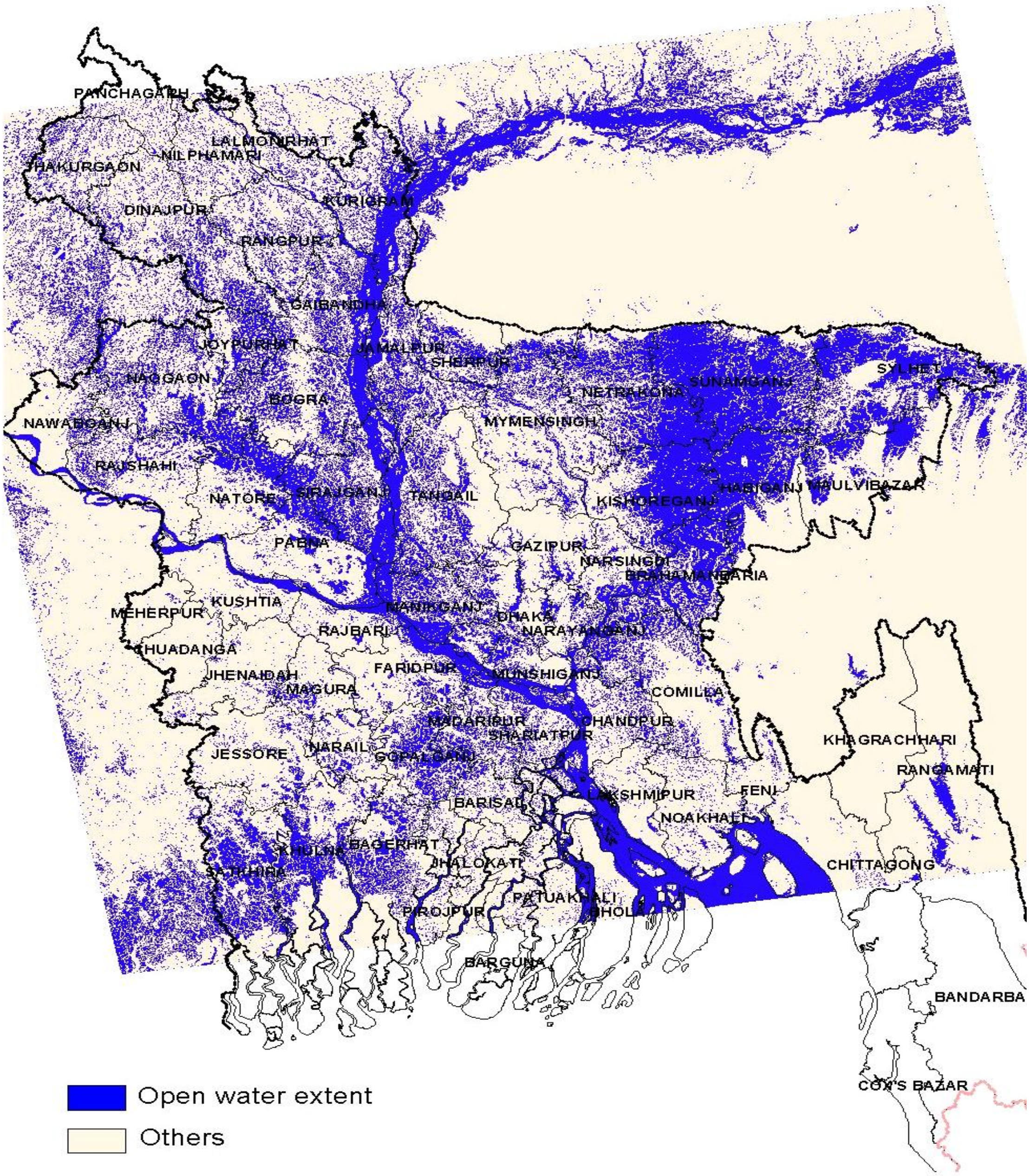

Fig. 1. Open water extent is derived from RADARSAT ScanSAR Wide Beam image with ground resolution of 100 m X 100 m. (Radarsat image 23 July, 2004)

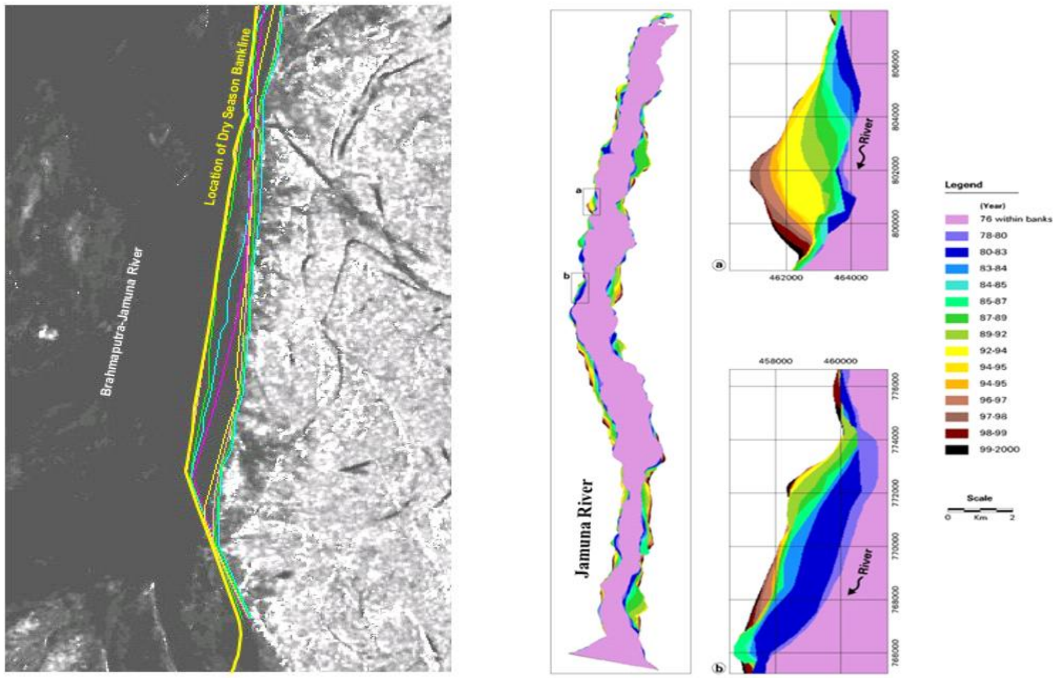

Fig. 2. River course shifting map and River bank erosion map developed by satellite image

3.1.5 Coastal zone monitoring

Bangladesh being endowed with more than 7 hundred coast line, coastal zone is vitally important for the country. About 30 percent of the total populations are living in the coastal belt of Bangladesh. Identification of coastal resources, stability of coastal islands, vulnerable coastal shorelines, submerges islands and estuaries are important coastal habitats which are being used for shrimp farming, salt manufacturing, agriculture and host of other purposes. Therefore, remote sensing technology was found useful for coastal zone monitoring and its management. A wide range of remote sensing data has been used for coastal application [20]. Meghna estuary (Fig. 3), changes in coastal land formation [20], coastal land reclamation [21], deforestation of Mangrove [22] and Feni dam impact studies [23], are some of the important examples [20,24,17,14,15,25]. Estuarine bio-geomorphology, ecology, land degradation due to shrimp farming, salt manufacturing and water logging, coastal change detection and historical land formation are some of the recent issues covered using high-resolution remote sensing data, particularly IRS-LISS, SPOT, Landsat TM and IKONOS [18]. The coastal area is susceptible to severe tropical every year. Meteorological satellite data (NOAA and GMS) has given reliable new tool to gather vital real time information related to cyclone formation and development and follow its track in an hour interval and are routinely used in Bangladesh [26].

3.1.6 Drought stress

Remote sensing and GIS technique is increasingly being regarded as a useful drought detection technique, as evidenced by its use across many parts of the world, e.g. Gujarat, India [27,28], Western and Central Kansas, USA [29], Batticaloa District, Srilanka [30] and Borkhar District, Iran [31]. Drought indicates low moisture content in the soils, easily appreciable through remote sensing technology using thermal infrared sensors/micro-wave remote sensing. However, NOAA-AVHRR data have been successfully used in semi-desert Shahelian belt in the early 1980s using a vegetation indicator derived from NDVI (Normalized Difference in Vegetation Index). The method has been replicated in Bangladesh to identify the drought stress areas with limited success, partly due to the coarser resolution of NOAA data and mixed nature of vegetation complex in Bangladesh. The thermal infrared data were also applied in the Barind-tract in the north-western part of Bangladesh for mapping and monitoring drought prone areas. But again, the result was not satisfactory due to time lag of data collection and image acquiring [14]. However, very recently CEGIS in collaboration with WARPO has initiated a project called Drought Assessment Framework (DRAS), where satellite data are expected to pay a key role [18] and agricultural drought risk areas were identified based on NDVI by using surface reflectance with 250m resolution from MODIS satellite during 2000-2008 [28].

3.1.7 Wetland monitoring

Wetland is recognized as one of the most critical resources in Bangladesh. Apart from external threat (diversion of river flow), internally it is now under threat and fast disappearing due to conversion to agricultural land, reclamation for settlement expansion both urban and rural, and developing industrial sites, brickfields and other uses. Poldering coastal areas, construction of cross dams and river embankments have also altered the very nature of the wetlands in large parts of Bangladesh. Given this context, nature, occurrence and state of wetlands are some of the critical issues wherein remote sensing data may be of great value. Basin wise wetland monitoring with remote sensing have been attempted [32]. However, there is a need for developing a national data base on wetlands and a national wetland atlas and provision for wetland monitoring as a priority. In all these cases, remote sensing is capable of playing a vital role; organization like WARPO and/or SPARRSO may be entrusted with such responsibility.

3.1.8 Urban applications

Urban land use and land cover information on a regular basis are crucially important for map updating and planning for development initiatives. High resolution SPOT (panchromatic) image, IKONOS, Quick Bird are found to be extremely useful in urban land cover mapping and sequential cover changes detection at a scale up to 1:5000 which are essential for detail urban planning. Landsat ETM and IRS data are also proved to be of value for analyzing land use mapping but at coarser scale 1:25000. Even at this scale, some applications like identification and mapping of urban wetland extents [33], trend of wetland filling [34], location of urban waste disposal sites, and extent of urban surface drainage congestion sites are important. However, overlying with SPOT panchromatic band both ETM and IRS LISS images would provide a powerful tool for better feature discrimination. One of the limitations of the SPOT, IKONOS and Quick Bird images are their prohibitive cost; which will certainly hinder its wider application in Bangladesh at least for the time being.

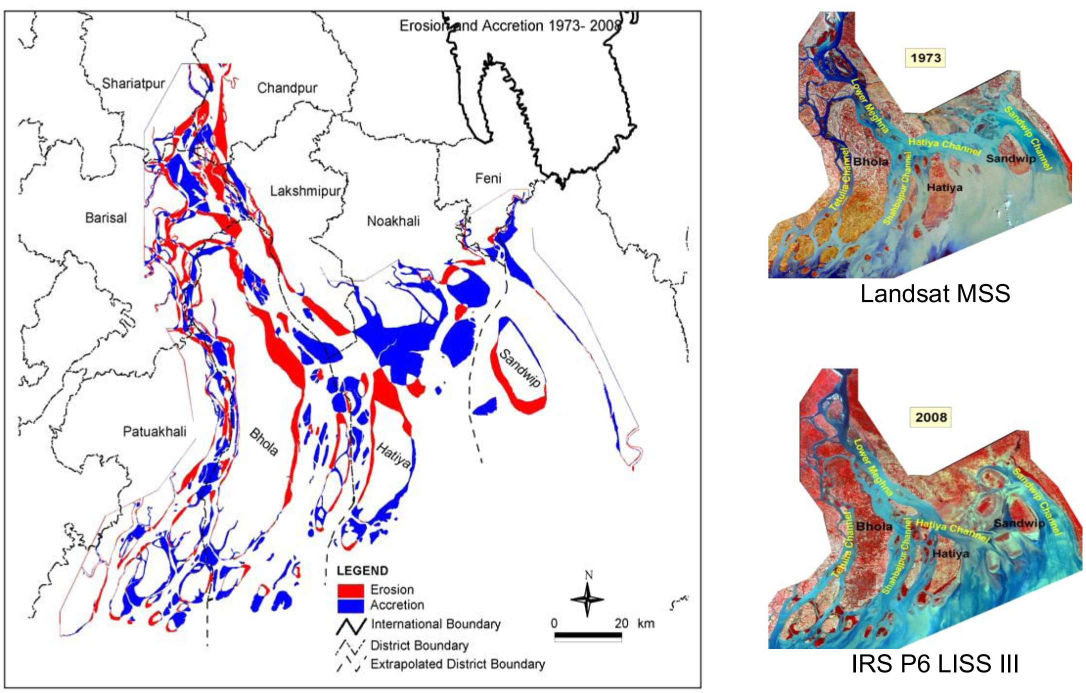

Fig. 3. Meghna Estuarine coastal erosion and accretion 1973-2008

3.1.9 Agricultural sectors

Agricultural applications of remote sensing in Bangladesh mainly focused on mapping shrimp farm area [35,36,17] and estimation of Boro paddy area. The NOAA-AVHRR data has been used to monitor the extension of Boro rice area in Bangladesh. The NOAA-AVHRR data showed good performance for Boro rice acreage estimation at country level and regional level [37]. Other crop inventorying through remote sensing has been attempted sporadically [14] but has not progressed much. Reliable estimation of crop area and crop yield through remote sensing data would require close collaboration between agriculture scientists and remote sensing specialists with access to real time remote sensing data and ancillary filed data, particularly crop phenology and ground condition. Small plot sizes, diverse cropping practice within a small patch and large time lag between image acquisition and procurement to the end user are some of the practical limitations that hinder the growth of this field of research in Bangladesh.

3.1.10 Forestry applications

Unlike agriculture, remote sensing data found wider applications in forestry sector of Bangladesh. For instance, forest area mapping, identification of actual forest cover extent, preparation of forest working plan, identification of vulnerable sites of forest encroachment, mapping extent Jhum cultivation sites, and identification of new plantation sites, particularly along the coastal belts are quite important [38]. For timber volume estimation, forester's still prefer infrared colour aerial photograph then satellite remote sensing. However, some attempt has been made to use Landsat TM and SPOT data on this purpose [39] but the forest area could not be identified properly from NOAA-AVHRR data, only the mangrove forest area has been identified slightly due to its lower canopy temperature with respect to its adjoining areas [37].

3.1.11 Land transformation study

Historical remote sensing data can help to understand the micro-complexity in physical landscape and cultural factors at local scale involving with land transformation over a period of time. Bangladesh has a wide range of remotely sensed data since 1950s including Aerial Photography (B/W and Colour Infrared, e.g. 1953, 1974, 1990, 1999 and so on) at 1:30,000 scale, recently declassified US Spy Satellite negative films of CORONA Programme between 1960 and 1974 up to 2 meter resolution (7.5 microns), and the currently available commercial satellite imagery at sub-meter accuracy. All these imagery are compatible with each other in order to detect land transformation in detail thus fulfils the synergistic applications. One of the most pioneering works has been carried out on Savar Upazila illustrating a significant and visible land transformation have been occurred over a last half century from a completely river dependent country side to a modern road network orientation [40].

4. CONCLUSION

The primary advantage of Landsat data over Radarsat/ERS data is its multispectral nature while the Landsat TM instrument acquires information in 7 (for HRV 3) spectral bands, Radarsat/ERS acquires data only in specific microwave Band-C. Multispectral information (visible, near infrared, short wave infrared and long wave infrared) is useful to distinguish, for example, types of vegetation and the condition of vegetation [41] and SPOTs improved spatial resolution allows most ground features to be mapped for planning at a scale of 1:50,000 and in some cases 1:25,000. On the other hand, the major advantages of active sensors are to transmit and receive signals through clouds, haze, smoke and darkness and obtain images of the Earth in all weather, in contrast to optical sensors. However, each radar image is composed of many elements of varying brightness. Unlike passive remote sensing system, active systems illuminate the land with radiation of known and carefully controlled properties.

Finally, it should be mentioned that the information available from radar imaging sensors is different from that available in optical sensors. Therefore, sensors operating in this case complement each other. For example, the colour observed in the visible and near-infrared region is determined primarily by molecular-resonance in the surface layer of the vegetation or soil, where as the 'colour' in the microwave region is a result of geometric and bulk-dielectric properties of the surface or volume studied. Thus, the synergistic use of active and passive microwaves and of visible and infrared radiation allows a study of the geometric bulk-dielectric and molecular-resonance properties of the surface and either one alone is less effective than the combination of the two in delineating all the properties one may wish to sense remotely [7,42,43].

Nevertheless, more advanced and specific knowledge about both forms of remotely sensed data can be obtained through continuous co-operation and research among the scientists from pertinent disciplines. Therefore, it is imperative to encourage interdisciplinary research in this field both in the developed and developing countries. To take advantage of GIS and Satellite data based technology, developing countries like Bangladesh should come forward to develop their own manpower and be able to use this technology in its broadest field of synergistic applications in a bigger way.

The perspective examples of synergistic remote sensing applications referred in Bangladesh context demonstrates that the utility of remote as whole have gained a foot hold already. It also indicates that the research with remote sensing data is emerging slowly within two major research organizations viz., SPARRSO and CEGIS at the moment. Clearly the Universities are lagging behind in this respect. The sub themes of remote sensing are gaining ground in terms of its utility in close collaboration with other disciplines. Therefore, Government of Bangladesh and Institutional support in the form of research grants, training and logistics are required to optimize the benefit of high resolution remote sensing data in near future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cook RU, Harris. Remote sensing of the terrestrial environment-principles and progress. Transaction IBG. UK. 1975;1-19.
2. Campbell JB. Introduction to Remote Sensing. USA: The Guiford Press; 1987.
3. Cracknell AP, Hayes LWB. Introduction to Remote Sensing. UK: Taylor & Francis Ltd; 1991.
4. Colwell RN. Manual of Remote Sensing-Theory, Instrument and Techniques, 2nd Edition. USA: American Society of Photogrametry; 1983.
5. Masek JG, Honzak M, Goward SN, Liu P, Pak E. Landsat-7 ETM+ as an observatory for land cover Initial radiometric and geometric comparisons with Landsat-5 Thematic Mapper. Remote Sensing of Environment. 2001;78:118-130.
6. NRSC, SPOT Users Guide, UK: National Remote Sensing Centre; 1987.
7. Ulaby FT, Moore RK, Fung AK. Microwave remote sensing-active and passive: microwave remote sensing-fundamentals and radiometry. USA: Addision-Wasley Publishing Co. 1981;1.
8. Pravdo SH, Huneycutt B, Holt BM, Held DN. Seasat synthetic-aperture radar: data user's manual. USA: NASA/JPL; 1983.
9. Krammer HJ. Observation of the earth and its environment-survey mission and sensors, 2nd Edition. Germany: Spring-Verlag; 1994.
10. FPCO (Flood Plan Coordination Organization), Satellite-based radar for flood monitoring in Bangladesh. Geographic Information Systems (FAP-19), Dhaka: Ministry of Water Resources USAID; 1995.
11. Emiliani L. ESA earth observation programmes and plans for the future, Askne J. Sensors and Environmental Applications of Remote Sensing. Sweden: A.A. Balkema; 1995.
12. Dochossois G. Status and future plans for ERS-1. Alan T.D., (editor) Satellite Microwave Remote Sensing. England John Wiley & Sons; 1983.
13. Chowdhury MI. Optimization of Benefits from the Haors of Sylhet and Mymensingh-an analysis of Landsat data. Dept. of Geography, Jahangirnagar University, Bangladesh. 1977;99.
14. SPARRSO, Remote sensing and monitoring component for mangrove a forestation programme of second forestry project. Dhaka, Bangladesh. 1993;17.
15. Shamsuddin SD, Alam MS. Interpretation of temporal changes of the coast line along the active delta of Bangladesh using remote sensing: A reassessment. Jahangirnagar Rev. 1985-86;1990:10(2).
16. Elahi KM. Riverbank erosion, Flood and population displacement Bangladesh, Jahangirnagar University, Bangladesh. River bank erosion impact study; 1991.
17. CEGIS, Drought Assessment Model. The CEGIS Technical Note 01. Dhaka; 2002.
18. CEGIS, Tidal river management: a sustainable solution to drainage congestion in the coastal region of Bangladesh. Khulna-Jessore Drainage

Rehabilitation Project. The CEGIS newsletter. 2003; 2.
19. JICA, Greater Dhaka protection project (study in Dhaka Metropolitan area) of Bangladesh Flood Action Plan no 8 A. Final report; 1991.
20. Pramanik MAH, Ali A, Quadir DA, Rahman A, Shahid MA, Hossain MD. Conference Report Regional seminar on the application of remote sensing techniques to coastal zone management and environmental monitoring, Dhaka, Bangladesh. Int. J. Remote Sensing. 1987;8(4):659-673.
21. BWDB, Land Reclamation Project Report, Govt. of Bangladesh; 1988.
22. Alam MS, Shamsuddin SD, Skider A. Application of remote sensing for monitoring shrimp culture development in a coastal mangrove ecosystem in Bangladesh. Proc. ASPRS and ACSM annual convention. Denver, Colarado, USA; 1990.
23. Alam MS, Hossain D. Impact of river damming on coastal geomorphology: A case study on Feni river dam, Bangladesh. J. Remote Sensing and Environment. 1998;2:87-101.
24. MES, Technical note 023. Meghna Study. Dhaka, Bangladesh; 1999.
25. Alam MS, Rashid MS. Remote sensing for coastal landform and land cover mapping in Bangladesh. In Atkins PJ, Alam MS. (eds.): Information technology, Resources and Development in Bangladesh, Department of Geography, University of Durham, England. 1996;100.
26. Choudhury AMFA. Monitoring of Tropical cyclone of May 1997 that Hit Bangladesh using data from GMS-5 satellite. J. Remote Sensing of Environment. 1998;2:51-69.
27. Chopra P. Drought risk assessment using remote sensing and GIS, A case study in Gujarat. M.Sc. Thesis. Dept. of Geo-information Science and Earth Observation, ITC, Netherland; 2006.
28. Murad H, Islam AKMS. Drought assessment using remote sensing and GIS in North-West Region of Bangladesh. 3rd International Conference on Water & Flood Management (ICWFM); 2011.
29. Park S, Feddema JJ, Egbert LS. Impacts of hydrologic soil properties on drought detection with MODIS thermal data. Remote Sensing of Environment. 2004;89.:53-62.
30. Partheepan K, Dayawansa NDK. A GIS and remote sensing modeling approach for drought risk assessment in Batticaloa District, Srilanka. Paper-14, Third South Asia Water Research Conference: Innovative Modeling and Approaches for IWRM. Dhaka, Bangladesh; 2008.
31. Moktari MH. Agricultural drought impact assessment using remote sensing: a case study Borkhar District-Iran. M.Sc. Thesis. Dept. of Geo-information Science and Earth Observation, ITC, Netherland; 2005.
32. Alam MS, Saifuzzaman M. Environmental changes in coastal wetlands: A river basin approach. Proc. 10th Bangladesh National Geographical Conference. Camilla; 2002.
33. Reza ANMG. Transformation of the western part of the Dhaka city wetlands (1963-2000). Unpublished M.Sc. Thesis, Dept. of Geography and Environment, Jahangirnagar University, Savar, Bangladesh; 2000.
34. Saifuzzaman M, Alam MS, Rashid MS. Remote sensing application for assessing Dhaka urban wetland filling: 1993-2003. *Proc.* 48th Bangladesh Geographical Conference, Dhaka, Bangladesh; 2003.
35. Shahid MA, Pramanik MAH, Jabbar MA, Ali S. Remote sensing application to study coastal shrimp farming areas in Bangladesh. Geocarto-International, 1992;7(2):5-13.
36. Shahid MA. Remote sensing and GIS for suitable shrimp farming area selection in Bangladesh. J. Remote sensing of Environment. 1997;1:27-41.
37. Salam MA, Rahman H. Application of Remote Sensing and Geographic Information System (GIS) Techniques for Monitoring of Boro Rice Area Expansion in Bangladesh. Asian Journal of Geoinformatics. 2014;14(2):11-17.
38. Sanyal N. Use of multi-temporal Landsat images for the monitoring of changes of the mangrove forest in Maheshkahli, South-east coast of Bangladesh. International Institute for Geo-information Science and earth observation, Enschede, The Netherlands. 2003;56.
39. Islam MJ, Alam MS, Elahi KM. Remote sensing for change detection in the Sunderbans, Bangladesh. Geocarto International. 1997;12(3):91-100. DOI: 10.1080/10106049709354601.
40. Rashid MS. A Study of Land Transformation in Savar Upazila, Bangladesh, 1951-2001: An Integrated

GIS Approach using Remote Sensing, Census, Map and Field Data. PhD Thesis, Department of Geography, Durham University, UK; 2003.

41. Shefner E. Landsat Images, USA: NASA; 1996.
42. Ulaby FT, Moore RK, Fung AK. Microwave Remote Sensing-Active and Passive: Radar Remote Sensing and Surface Scattering and Emission Theory, USA: Addision-Wasley Publishing Co. 1982;2.
43. Ulaby FT, Moore RK, Fung AK. Microwave Remote Sensing-Active and Passive: From Theory to Application, USA: Arctech House, Inc. 1986;3.
44. Carey RM, Pritchard J. Flooding in Bangladesh-1988 (Images on: NOAA-9 Sept 19 and NOAA-11 Nov 14), Photogrammetric Engineering and Remote Sensing. 1989;974.
45. Available:http://geo.arc.nasa.gov/esd/esdstaff/landsat [Accessed Feb. 4.2014]
46. Curren PJ. Principles of Remote Sensing, England: Longman Group Limited; 1985.
47. Cracknell AP, Hayes LWB. Introduction to Remote Sensing, UK: Taylor & Francis Ltd; 1991.
48. Lillesand TM, Keifer RW. Remote Sensing and Image Interpretation, 2nd edition, USA: John Wiley and Sons; 1987.

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