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GIS And Remote Sensing Applications In Natural Resources Management

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Abstract: ***This paper presents an overview of the GIS and remote sensing applications in natural resources management and the information were taken from secondary sources. The first national Agro-Ecological Zone (AEZ) database was prepared in the period from 1980 to 1987. The database contains information on the country's land resources including physiography, soils, climate, hydrology, cropping systems, and crop suitability. In eighties, natural resources modeling systems were based on static GIS overlays. With the advent of more powerful desktop computer systems and more powerful software tools, it has become possible to develop more flexible and dynamic modeling tools. At the start of the new development efforts in 1997, an overall system design was established to allow for a dynamic analysis and modeling capability. The AEZ database constituted the foundation for a new effort to develop a comprehensive multi-scale GIS-based Land Resources Information System (LRIS) including additional databases and procedures, such as socioeconomic and demographic data influencing agricultural production. The technology used to establish the LRIS includes Arc View GIS; the Arc View Spatial Analyst and Dialog Designer extensions and Avenue; Arc View GIS software's programming language as well as multi-criteria analysis tools. The land resources inventory (LRI) application, for the classification and mapping of soil characteristics from the LRI database, allowed the users to specify the study area, the data to be classified, and the number of classes to create. Space Research and Remote Sensing Organization (SPARRSO) has an Advanced Meteorological Satellite Ground Station (AMSGS) for receiving real time high and low resolution data/imagery from meteorological satellites like NOAA of USA and GMS(Geostationary Meteorological Satellite) of Japan. These data are being used for day to day weather forecasting and agro-climatic environmental monitoring, as well as water resource studies. The SPARRSO uses sophisticated digital image processing systems with ERDAS software for analyzing both meteorological and resource satellite data. GIS facilities include Mainframe ARC/INFO, ERIM GIS (Raster) and IDRISI (Raster). The SPARRSO applies space and remote sensing technology to survey the natural resources and monitor the environment and natural hazards in the country. Centre for Environmental and Geographic Information System (CEGIS) is supporting the management of natural resources for sustainable socio-economic development using integrated environmental analysis, geographic information systems, remote sensing, and information technology. It conducts activities to provide solutions to challenges related to natural resources management in sectors like water, agriculture, fisheries, environment, transportation and engineering.***

Keywords: GIS, remote sensing, natural resources, management

I. INTRODUCTION

A geographic information system (GIS) captures, stores, analyses, manages, and presents data, which is linked to locations or having spatial distribution. It is a computer-based system that provides four sets of capabilities to handle geo-reference data. These are:

- ✓ data capture: graphic data (digitized, converted from existing data) and attribute data (keyed-in, loaded from existing data files)
- ✓ data storage and manipulation: file management and editing
- ✓ data analysis: database query, spatial analysis and modeling
- ✓ data display: maps and reports

GIS is run on all spectrums of computer systems ranging from personal computers (PCs) to multi-user supercomputers, and are available in a wide variety of software languages. A

number of tools are essential for effective GIS establishment such as computer, digitizer, GPS (Global Positioning System), plotter, network, CD-ROM drive, printer and software which links all of the equipment to run properly.

GIS provides a valuable tool for information analysis, automated mapping and data integration. The powerful GIS software, tools in problem-oriented systems, provides direct and easy access to large volumes of data. It supports their interactive analysis and helps to display and interpret results in a format directly understandable and useful for decision-making processes. A GIS can manage different data types occupying the same geographic space. The major advantage of GIS is that it can read and analyse different layers of spatial information in the form of maps and satellite images easily and allows identifying the spatial relationships. The objective of GIS is to help and assert in decision making processes for the management and effective conservation of natural resources.

Remote sensing (RS) technology has been developed well ahead of GIS technology. RS acquires information about material objects from measurements made at a distance, without coming into physical contact with the object. Usually an aircraft or satellite does the process. Remote sensing technology may be divided into three phases: (i) data collection from a sensor mounted on a platform eg. a satellite; (ii) data handling; (iii) data interpretation which end up in generating some thematic maps of the investigated surfaces. A remote sensing system using electromagnetic radiation has four components - a source, interactions with the earth's surface, interaction with the atmosphere and a sensor. The source of electromagnetic radiation may be natural, like the sun's reflected light or the earth's emitted heat, or man-made microwave radar. Earth's surface interaction, that is the amount and characteristics of radiation emitted or reflected from the earth's surface, is dependent upon the characteristics of the objects. Electromagnetic energy passing through the atmosphere is distorted and scattered, treated as atmospheric interaction, and the electromagnetic radiation that has interacted with the atmosphere and the surface of the earth is recorded by a sensor, such as a radiometer or camera.

Aerial photography is the earliest method of remote sensing and even in today's age of satellites and electronic scanners it remains the most widely used remote sensing method. Aerial photo means sensing the image of earth's surface through cameras fitted in an aeroplane or balloon.. Satellite remote sensing is a modern innovation. Remote sensing satellites have been designed according to the application such as the study of earth's resources, meteorology, communication or military purposes. The most commonly used earth's resource satellites are - Landsat series of USA, SPOT satellite series of France, and IRS series of India. These bear different types of scanners, viz, Multispectral Scanner (MSS), Thematic Mapper (TM), Panchromatic (PAN) scanner, High-Resolution Visible (HRV) scanner, Linear Imaging and Self Scanning (LISS) system, Wide Field Scanner (WiFS), etc. NOAA, NIMBUS, GOES Meteos are the most commonly used meteorological satellites.

Remote sensing data can be digitized and analyzed by GIS tools to give precise outputs in different formats. The principal areas for application of GIS and RS are land-use planning and management, management of natural resources (land, water, agriculture and fishery); forestry and wildlife management, soil degradation studies and enumeration area mapping, environmental impact studies, natural hazard mapping, disaster forecasting and management, mineral exploration, etc. The application of GIS and RS is rapidly expanding worldwide for planning and management of natural as well as man-made resources. The present study was undertaken to explore the applications of GIS and RS in natural resource management.

II. METHODOLOGY

This study is based on secondary data and information mostly downloaded from internet. The information materials from internet include research papers, reports, workshop outputs, and information published in the websites of the related organizations. The information on the applications of GIS and RS in natural resource management were collected, sorted, compiled, and presented in this study. GIS/RS applications in meteorology, climate change, disaster management, urban planning, health and transport are also included.

III. ORGANIZATIONS HAVING GIS/RS INSTALLATIONS

The history of remote sensing technology in Bangladesh dates back to 1968 when the first Automatic Picture Transmission (APT) station was set up on the premises of the Atomic Energy Centre, Dhaka, for receiving real time weather pictures directly from meteorological satellites. The Space and Atmospheric Research Centre (SARC) was created at the Bangladesh Atomic Energy Commission in 1972 and APT ground station was absorbed within SARC. With NASA's launch of the Earth Resource Technology Satellite (ERTS-1), was one of 35 Principal Investigator Programs worldwide. Subsequently ERTS was renamed as Bangladesh Landsat Program (BLP). A major activity of BLP included the generation of the first land cover map of the entire country using Landsat MSS data of 1979. During this period, GMS and NOAA ground receiving stations were installed. The Space Research and Remote Sensing Organisation (SPARRSO) was established in 1980 by merging SARC and BLP [4]. Between 1980 and 1983, a LANDSAT/SPOT ground receiving station along with a VIPS digital image processing system was set up under French support. In 1983, under the UN/ESCAP Regional Remote Sensing Program, SPARRSO became the national focal point for space and remote sensing activities. Under the Agro-Climatic Environmental Monitoring Project (ACEMP) sponsored by USAID in the early eighties, SPARRSO acquired complete digital image processing system including the necessary hardware and software. Scientists and engineers were trained in hardware, software maintenance and image processing techniques.

The use of GIS application started in 1991 by Irrigation Support Project for Asia and the Near East (ISPAN) for the

Flood Action Plan-19 project. Under this project the Environment and Geographic Information System (EGIS) was equipped with GIS installations.

At the beginning, most of the GIS installations were donor supported and operated by foreign experts with limited local personnel. Now the situation has changed, a number of government and non-government organizations have installed GIS and are operated by local expert. The exact number of GIS installations could not be ascertained due to lack of information available. However, the following organizations have been identified to have GIS/RS installations.

Govt Organizations having GIS and Remote Sensing Installations

- ✓ Space Research and Remote Sensing Organisation (SPARRSO) [http://www.sparrso.gov.bd/]
- ✓ Bangladesh Meteorological Department (BMD) [http://www.bmd.gov.bd/]
- ✓ Geological Survey of Bangladesh (GSB) [http://www.gsb.gov.bd/]

Private Organizations having GIS Installations

- ✓ Development Design Consultants (DDC)
- ✓ Geographical Solutions Research Centre Ltd. (GSRC)
- ✓ Natural Resources Programmes (NRP)
- ✓ CIPROCO Computers Ltd.
- ✓ GEOSERV Ltd.

The literatures show that GIS and RS technologies are applied for a wide range of areas in various sectors. The Table 1 represents some common fields and areas of GIS/RS applications by the government and private organizations.

Major Fields	Areas of GIS/RS Applications
Land Resources	Land use planning, land inventories, land survey, land use and land cover mapping
Agricultural Resources	Agricultural planning and management, National Agro-Ecological Zone (AEZ) database, soil resources database, soil survey, soil data analysis, characterization of soil, soil erosion assessment and prediction, climate change impact on agriculture
Forest Resources	Planning and management, forest inventory, afforestation, climate change impact on forests
Water Resources	Water resources management, watershed analysis, fisheries resources development planning, river bank erosion and accretion, monitoring morphological changes and hydrology of rivers, navigation and dredging, Construction and maintenance of embankments, flood forecasting and management, water pollution.
Protection and conservation	Habitat and ecosystem, wetlands, wildlife, protected areas, National parks and World heritage sites, ecotourism development
Weather	Monitoring and recording of weather data - rainfall, temperature, humidity, etc.; weather forecasting and warning
Environment	Monitoring, modelling and management of land degradation; weather and climate modelling, prediction and forecasting; river and coastal erosion modelling; flood management
Climate change	Climate change studies/research, climate change impact assessment, vulnerability assessment, adaptation to climate change
Disasters	Disaster management, disaster forecasting, disaster risk management, cyclone recovery and restoration, cyclone shelter management, assessment and monitoring of damage, flood risk and vulnerability assessment
Health	Spatial distribution of different diseases in relation to environmental factors – dengue, malaria and diarrhoea diseases, arsenic contamination in drinking water, GIS mapping of anthrax and avian influenza outbreaks
Social studies	Demographic studies and development analysis, population census, demographic database
Transport	Planning and management, rural road development (planning, project preparation, construction, monitoring and maintenance), road network mapping
Regional/Local planning	Development of plans, maintenance, management; infrastructure development programme, land registration
Urban planning	GIS maps of urban areas, cities and municipalities, infrastructure development planning, industrial development planning

Table 1: Major Fields and Areas of GIS/RS Applications

A. SPACE RESEARCH AND REMOTE SENSING ORGANIZATION (SPARSSO)

The SPARRSO is a multi-sectoral research and development agency, which is mandated for remote sensing data acquisition and interpretation. Its major objective is to apply remote sensing technology to surveying the natural resources and monitoring the environment and natural hazards in the country. It operates and maintains satellite ground receiving stations, conducts research and develops capabilities for both visual and digital interpretation of satellite and airborne data for applications in various sectors, e.g. forest cover mapping and monitoring, land use and land cover mapping, mapping of water resources, agriculture, fisheries studies, coastal zones and marine environment studies, geology, meteorology and climatology. It also provides data and services to the government and non-government organizations engaged in development and policy-making activities.

SPARRSO performs routine monitoring activities concerned with meteorology and climatology. The Advanced

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Meteorological Satellite Ground Station (AMSGS) receives data from Japanese Geostationary Meteorological Satellite (GMS-5) and NOAA series of polar orbiting satellites. The data from GMS-5 is acquired on an hourly basis and used to study the large-scale atmospheric processes and the dynamic features of the weather in the entire region covered by the satellite. The NOAA AVHRR data is collected on a 6 hourly basis. The weather monitoring data and forecasts are disseminated to different user agencies, e.g. the Bangladesh Meteorology Department, Disaster Management Bureau and the media for disaster preparedness. The catastrophic cyclones of 1970, 1985, 1991 and 1994 were monitored in near real time using GMS and APT and NOAA AVHRR data.

In the early 1970s and 1980s Landsat MSS data were used for land use and land cover mapping and hydro-geomorphological interpretation. Afterwards IRS-1C PAN data (the highest resolution within the earth's resources satellites, 5.8m ground resolution) were used for research. Now a major facility is the Advanced Meteorological Satellite Ground Station (AMSGS) for receiving real time high and low resolution data/imagery from meteorological satellites like NOAA of USA and Geostationary Meteorological Satellite (GMS) of Japan. These data are being used for day to day weather forecasting and, agro-climatic environmental monitoring, as well as water resource studies. SPARRSO has acquired sophisticated digital image processing systems for analyzing both meteorological and resource satellite data. The digital images are processed with ERDAS software. GIS facilities include softwares - Mainframe ARC/INFO, ERIM GIS (Raster), IDRISI (Raster). Apart from the GMS and NOAA ground receiving stations, SPARRSO facilities include Microvax 3400 Computers, Pentium III PCs, ERDAS Imagine, and PC ARC/INFO. It has a well equipped photographic laboratory, photogrammetric equipment and groundtruthing equipment. The SPARRSO has technical capabilities, trained manpower and allied facilities for receiving, processing, analyzing, archiving and utilizing aerial photographs and satellite data.

B. METEOROLOGICAL DEPARTMENT (MD)

The MD is the authorized Government organisation for all meteorological activities in the country. It maintains a network of surface and upper air observatories, radar (5 radar stations) and satellite stations, agro-meteorological observatories, geomagnetic and seismological observatories and meteorological telecommunication system. The MD performs the following functions:

- ✓ observe different meteorological parameters both for surface and upper air
- ✓ prepare and analyse all weather charts and to make interpretation
- ✓ provide weather forecasts and to issue warnings for severe weather phenomena such as tropical cyclones, tornadoes, tidal surges, heavy rainfall, flood, etc.
- ✓ maintain surveillance of weather radars for probing impending tropical cyclones, nor'westers and tornadoes.
- ✓ exchange meteorological data, forecasts and warnings
- ✓ receive round the clock satellite imageries (IR and VIS images) for timely use in operational meteorology.
- ✓ extract, maintain quality control, process, archive and publish climatic data
- ✓ provide daily climate information: Rainfall, temperature, relative humidity, rainy day, sunshine hours.
- ✓ provide weekly Agromet Forecast
- ✓ provide special Weather Bulletin / Warning Message
- ✓ provide Earthquake Info and Warning

C. GEOLOGICAL SURVEY (GS)

The GS, established in 1972, is a government organization engaged in geological mapping and geo-scientific activities. GS is attached to the Ministry of Energy and Mineral Resources. The department has a computer cell with RS and GIS facilities.

D. AGRICULTURAL RESEARCH COUNCIL (ARC)

The Agricultural Research Council (ARC) is an autonomous organization under the Ministry of Agriculture. It was established in 1973 with the aim of coordinating systematic agricultural research in the country. It is the apex body of National Agricultural Research System (NARS). The mission of the ARC is to strengthen and mobilize research capabilities of the institutes of the NARS, universities, private sectors and other stakeholders in partnership in the generation of appropriate technologies and information for the development of agriculture sector.

During the period from 1980 to 1987 ARC created non-spatial AEZ Land Resources Database and Crop Suitability Database. The first national Agro-Ecological Zone (AEZ) database was created by computerizing landform, soil, inundation and climatic information generated by different organizations of the country. Soil, landform and inundation information was generated by SRDI through reconnaissance soil survey carried out between 1963 and 1974. Climatic data on rainfall, dry-bulb and wet-bulb temperature, relative humidity, wind speed, sunshine/solar radiation, and cloud cover were collected from 30 Climatic stations of MD and 203 rainfall stations of Water Development Board (WDB). These data were available on daily basis for a period ranging from 20 to more than 50 years. Location map of climatic stations of MD and rainfall stations of WDB has also been created. Crop Suitability Database contains suitability potentials of 48 crops under rainfed and irrigated conditions.

In 1996 ARC initiated a project on Utilization of Agro-ecological Zones Database and Installation of GIS for Agricultural Development with support from UNDP and FAO. The main objective was to create a National Agricultural Land Information System Database in GIS environment to fulfil the agricultural planning and research needs. The project had a GIS setup with ARC/INFO, ArcView and IDRISI as the key GIS software. An important activity was to convert the Land Resources Inventory (LRI) and non-spatial AEZ database into spatial GIS/AEZ database. GIS based crop or cropping pattern suitability database has been developed based on the improved models and data. A GIS based decision support system (DSS) has been developed using cropping pattern suitability and socio-economic factors to assist in agricultural planning and

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research.

E. BUREAU OF STATISTICS (BS)

The BS was created by the Government in August 1974 as the national statistical organization responsible for collecting, compiling and disseminating statistical data relating to a wide variety of sectors. It carries out population census every decade as well as agricultural census, household surveys for sample sites and maintains and updates the national database including all sectoral information by administrative units in digital form. The BS has established automated cartographic section with GIS and RS support. As a pioneer partner of Digital Bangladesh, the BS has established three ICT Labs and high powered servers in 2009 to strengthen its working capability and connecting its divisional and regional field offices under the computer network system. GIS Software used by BS include ArcInfo, ArcView and ERDAS Imagine.

F. CENTRE FOR ENVIRONMENTAL AND GEOGRAPHIC INFORMATION SERVICES (CEGIS)

A range of environmental and GIS projects initiated in 1991 under the Flood Action Plan (FAP) were ultimately integrated into a single Environment and GIS Support (EGIS) Project for Water Sector Planning in 1995. It was a project under the Ministry of Water Resources funded by the Government of the Netherlands. In the year 2002, EGIS was renamed as the Centre for Environmental and Geographic Information Services (CEGIS), an independent institute under a Board of Trustees. CEGIS services are available to both the public and private sectors and include consultancy, research and development, and training.

The EGIS was a pioneer organisation in the development of GIS. Over the last decade, EGIS has developed capabilities in terms of expertise, hardware and software for digital image processing, GIS analysis, building digital spatial databases, GIS modelling, differential GPS surveys and metadatabases. EGIS also collected data sources from high-resolution optical images (European ERS-1, ERS-2, Canadian RADERSAT-1 SAR images) which are used for planning and management. The EGIS/CGIS computer base consists of Windows NT 4 servers, Pentium II PCs running under Windows NT4 Workstations, Digital Dec Alpha Workstations with UNIX along with plotters, printers and digitizers. The GIS and image processing software include ARC/INFO NT, PC ARC/INFO, ArcView, ArcView Spatial Analyst and ERDAS Imagine. The EGIS/CGIS completed many GIS/RS application projects during the period from 1993 to 2012.

G. DIRECTORATE OF LAND RECORDS AND SURVEYS (DLRS)

The Ministry of Land (MoL) is entrusted with the land management since 1950. The important objectives of MoL are management and settlement of the Government owned lands (*khas* lands), *sairat mahals* (*jalmahal*, shirmp *mahal*, etc.), vested properties and abandoned properties. Other important tasks are collection of land development tax, conducting land survey, keeping and updating land records and acquisition and requisition of land.

The DLRS is mandated to carryout periodical cadastral survey and settlement operations for preparing, updating and publishing land records including maps and ownership records. Land related data published by DLRS are Record of Rights (cadastral maps and record of ownership rights, land use, etc.), *Thana* (sub district) administrative maps and data on agriculture and livestock. DLRS has started the huge task of updating cadastral maps and land ownership records with improved accuracy. In the late nineties, it has initiated a number of projects at a pilot level to perform digital cadastral surveys and mapping using modern ground survey technologies such as survey-grade dual frequency GPS receivers, Total Stations, photogrammetry and GIS technology. The vision set-forth under the modernization efforts is to build up a comprehensive Land Information System (LIS) for Bangladesh where information on every piece of land will be available digitally for public and departmental use.

H. FOREST DEPARTMENT (FD)/MINISTRY OF ENVIRONMENT AND FOREST (MOEF)

The Forest Department initiated the Resource Information Management System (RIMS) during 1984-85 under the auspices of IDA funded Second Forestry Project. The main objective of the RIMS was to produce reports and maps relevant to all aspects of the management plan, silvicultural prescriptions and to provide information on present and predicted yields from relevant operations. This was designed as an aid to intensive forest resource management through management plans and perspective planning in forestry. The FD has installed GIS set up in 1995 and executed Forest Resource Management Project with the assistance of World Bank. The main activities include forest plantation planning as well as to provide professional and technical services in the field of GIS and associated technologies. The department prepared forest plantation maps for specific site matching.

I. INSTITUTE OF WATER MODELLING (IWM)

The Surface Water Modelling Centre (SWMC) was formed as a Trust organisation in 1997, which was renamed as Institute of Water Modelling (IWM) Trust with effect from 1st August 2002.

The SWMC used GIS as a data processing, modelling and planning tool and succeeded in monitoring optimum operation of Karnafuli Hydro Power Station, arsenic contamination of groundwater and crop damage assessment. The SWMC also developed GIS based Interactive Information System (IIS), which combines GIS-based topographic maps and field information of channels, structures, roads, embankments and homesteads, stored in a Rational Database Management System (RDMS). The IWM provides world-class services in the field of water modelling, computational hydraulics and allied sciences for improved integrated water resources management. The applications of IWM modelling tools cover a wide range of water related areas such as flood control, flood

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forecasting, irrigation and drainage, river morphology, salinity and sediment transport, coastal hydraulics, port, coast and estuary management, environmental impact assessment, bridge hydraulics and related infrastructure development.

J. LOCAL GOVERNMENT ENGINEERING DEPARTMENT (LGED)

The LGED works under the Ministry of Local Government and its prime mandate is to provide technical support to local government bodies for planning and implementation of development programs for cost effective and sustainable infrastructures in the rural, urban and water sectors throughout the country. The LGED prepared planning maps with local level information of rural infrastructure in the early 80's. It established a GIS set-up in it's headquarter in early nineties with a view to facilitate development of nationwide spatial database for rural infrastructure and to enhance institutional capability for planning and monitoring of rural development programs. GIS unit is equipped with a large number of GIS instrument such as GPS, DGPS, Digitizer and Total Station along with GIS/RS softwares - ArcView 3.2, ArcGIS 9.2 and 9.3, ERDAS IMAGINE 9.2 and MultispecW32.

The LGED maintains the GIS database and maps which enable the local stakeholders to take part in the process of planning and decision making. The GIS Unit of LGED has completed digitization of *Upazila* (sub-district) Base Maps at 1:50000 scale in early 90s for the whole country which comprises of various layers including administrative boundaries, physical infrastructure, educational institutions, settlement pattern and other agriculture and socio-economic infrastructures. The basic spatial data were captured for *Upazila* Base Map with the help of 1961's topographic maps of SoB, old *thana* maps (1942) of DLRS, aerial photograph of SoB (1983-84), SPOT Satellite Image of 1989-90, data of GPS survey groundtruthing with the help of *Upazila* level technical staff.

K. ROADS AND HIGHWAYS DEPARTMENT (RHD)

This Department is under the Ministry of Communication. The RHD is responsible for the management of the national, regional and district level road network of about 21,000 km and about 18,258 bridges [16]. In 1995, RHD under an Institutional Development Components (IDC) Project sponsored by Overseas Development Agency (ODA) completed GIS mapping programs to create national transport network. In 1996 the project successfully built a comprehensive geographical database for the road and rail sectors. GIS tools are being used effectively for planning, monitoring, construction and maintenance of the road system. An advanced online management system accommodating multi access data users are also established.

L. SOIL RESOURCES DEVELOPMENT INSTITUTE (SRDI)

The SRDI is a government organization under the administrative control of Ministry of Agriculture. It renders supports for preparing *Thana* Land and Soil Utilisation Guides including a soil database, soil fertility and land use monitoring, salinity monitoring and preparation of soil and land use related maps. All these activities of mapping and monitoring systems are GIS related. The GIS unit of SRDI analyzes land and soil resources data using GIS technology for production of digitized maps as per requirement of the stakeholders. The ARC and CEGIS are digitizing maps for various uses based on the LRI information using GIS technology. For this purpose, various cartographic base maps produced by SRDI were linked to the LRI database to produce national level crop suitability map, land inundation map, land use map, nutrient deficiency map, flood prone map, drought area map etc. By integration of RS with GIS, both SRDI and CEGIS are giving services to the stakeholders by producing relevant maps and information using satellite images.

There are two research centres under SRDI, which are doing specific research works. These are Soil Conservation and Watershed Management Centre (SCWMC) at Bandarban of Chittagong Hill Tracts for conducting research in hilly areas about soil erosion and soil conservation and Salinity Management and Research Centre (SMRC) at Botiaghata, Khulna to select crop/cropping pattern suitable for coastal areas, to conduct research and to indentify location specific agricultural technology.

M. WATER RESOURCES PLANNING ORGANIZATION (WARPO)

The WARPO prepared and updated National Water Resources Database (NWRD) for the National Water Policy adopted by the Government. The database is designed with SQL (Structured Query Language) in back-end and GIS based graphical user interfaces in front-end.

GIS based flood-forecast models (MIKE-11) have been developed in Bangladesh. This is a valuable tool for determining flood control and drainage structure operation rules, and providing inputs to flood preparedness programs. At the implementation stage, MIKE-11 is useful for a range of needs from scheduling flood prone construction works to a flood preparedness training aid.

The Embassy of the Netherlands engaged CEGIS to develop a GIS-based Ground Control Point (GCP) database and data bank software for WARPO. A standard methodology has been explored to collect highly accurate GCPs from the field through DGPS survey using 6m resolution IRS and LANDSAT images of 2000 and onward. A national level archive of GCPs based on 6m resolution IRS images and DGPS survey has been established and a automated software called GCP Databank is developed for future geo-referencing of RS and GIS data layers. Recently several alleviation schemes have been proposed to get rid off water logging problems of Dhaka City and a pilot hydrodynamic drainage model using GIS technology is made for low-lying parts of the city. Similarly, Digital Elevation Model (DEM) and SWMC's MOUSE model have also been installed to evaluate the various alleviation schemes.

Some private organizations are listed in Table 2, who has developed GIS/RS facilities to provide various types of

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consultancy services and made significant contributions in GIS/RS based research and services.

Private Organization	GIS/RS Services
Natural Resources Planners Ltd.	GIS services to CARE Bangladesh, Mapping HIV/AIDS
[http://www.nrpbd.com /index.php]	prevention and care activities in Bangladesh and GIS database, GPS survey and editing DGPS data of *Thana* Road coverage
Development Design Consultants Ltd. (DDC) [http://www.ddclbd.com/]	Survey, soil and material testing, database management, project management and monitoring
Arc Bangladesh Ltd. http://www.arcbangladesh.com/	Geospatial Solutions and Services, Information System And Software Development, Data Processing and Database Management, Surveys and Data Capture, Other Consulting Services
SoftWorks Bangladesh [www.softworksbd.com/]	Problem oriented GIS Maps, GIS Map of Anthrax Outbreak in Bangladesh
Geoplan Bangladesh [www.geoplanbd.com/]	GPS related products, GPS/GIS Map Services

Table 2: Important Private Organizations Providing GIS/RS services

IV. EDUCATION AND TRAINING ON GIS/RS

GIS and RS technologies are used for assessing complex systems and their application requires trained personnel. Some universities have set GIS/RS labs for conducting research and for providing education and training. Some other organizations are providing training on GIS and RS.

- ✓ Department of Geology, Dhaka University, has established a remote sensing laboratory initially with an ERDAS Imagine based system in 1999 in order to offer courses on remote sensing for the Masters students. Masters thesis students and faculty members use this facility to carry out research on geological problems.
- ✓ Department of Geography and Environment, Dhaka University, started its GIS laboratory in 1993. Remote sensing and GIS courses are offered at undergraduate and graduate level. Short certificate training courses are offered in PC ARC/INFO. On going research includes land use change and bio-ecological mapping. Facilities include PC ARC/INFO, ArcView with Extensions, IDRISI and ILWIS software.
- ✓ Department of Geography and Environmental Studies, Rajshahi University, set up its remote sensing and GIS facility in 1993. Courses are offered to graduate, Masters and Ph.D level. Research is carried out on land use change, environmental impact studies and urban planning. The facilities include IDRISI for Windows, PC ARC/INFO, ArcView, Cartalinx and Popmap.
- ✓ Department of Geography and Environment, Jahangirnagar University, offers courses for undergraduate and graduate students in remote sensing and GIS. It also offers short training course on GIS and RS. The GIS and RS laboratory is equipped with PC ARC/INFO, ERDAS Imagine software with sufficient hardware support.
- ✓ Department of Water Resources Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka introduced a course on remote sensing and GIS in 1998 for Masters Students. Research activities include studies on river morphology and hydrological parameter estimation. Laboratory facilities include PC ARC/INFO, ArcView with extensions and the necessary hardware support.
- ✓ Institute of Water and Flood Management (IWFM) in Bangladesh University of Engineering and Technology (BUET) is providing higher education and doing GIS and RS based research on water resources and flood management.
- ✓ Training courses are offered by EGIS in ARC/INFO and ArcView to both public and private sectors. EGIS professionals undergo periodic training in GIS and image processing software to keep abreast with technological development.
- ✓ With technical assistance from International Center for Integrated Mountain Development (ICIMOD) based in Nepal, LGED has organized six international training courses on GIS through which, a total of 60 professionals have been trained.

V. NATIONAL AND INTERNATIONAL COOPERATION

The SPARRSO works closely with the UN/ESCAP Regional Remote Sensing Programme (RRSP) for environmentally sound and sustainable development in Asia and the Pacific. It is a member of the Asian Association on Remote Sensing (AARS) and the Inter-Islamic Network on Space Science and Technology under Organization of Islamic Countries (OIC). It has developed close collaboration with NASA/NOAA of USA, CNES of France and NASDA of Japan. It is a founding member of the Asian Association of Remote Sensing and actively participates in the activities of AP-MCSTA (Asia-Pacific Multilateral Cooperation in Space Technology and Application) and APRSAF (Asia-Pacific Regional Space Agency Forum). SPARRSO is also a member of the International Astronautical Federation.

The CEGIS works in collaboration with the agencies in the country which are the major spatial information providers and/or users, e.g. SPARRSO, SOB, BARC, BBS, LGED for having a better exchange of ideas and expertise for a more harmonious development. [Huque, 2000] CEGIS also works in cooperation with international agencies such as RADARSAT International, Canada; Space Imaging, USA; National Remote Sensing Agency (NRSA), India; Asian

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Institute of Technology (AIT), Thailand and ITC and National Aerospace Laboratory (NLR) of The Netherlands.

The SOB works in cooperation with national organizations like SPARRSO, BBS, DLRS and international organizations like Japan International Cooperation Agency (JICA), IGN of France, ITC of The Netherlands and Ordinance Survey of England.

Over the years IWM has established close linkages with different national and international institutions. DHI Water and Environment of Denmark has been a close partner in the technology transfer. Similar linkages were also established with the Bangladesh University of Engineering and Technology (BUET), Asian Institute of Technology (AIT), Thailand, HR Wallingford, UK and Delft Hydraulics of the Netherlands.

VI. CONCLUSION

Country faces hundreds of problems in management of natural as well as man-made resources. So the applications of GIS/RS tools have become inevitable. International development partners are encouraging GIS/RS applications in all spheres of resource management. Most of the government organizations, engaged in natural resource management, have developed GIS/RS facilities. Realizing the gradual increase in demand of GIS/RS services, private entrepreneurships with GIS/RS professionals are being developed.

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