Chapter Four
Role of GIS and RS

4.1 Geographic Information Systems (GIS)

GIS is a valuable tool to visualize spatial data or to build decision support systems.

4.1.1 Definitions:

GIS can be defined as: a computer tool for capturing, storing, querying, analyzing and displaying spatial data from the real world for a particular set of purposes.

There are many other definitions for GIS depending on its components and functions. The United States (U.S) Federal Interagency Coordinating Committee (FICC, 1988) definition stated that “a GIS is a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modularity and display of spatially referenced data for solving complex planning and management problems” . Shoba and Ra sappan (2013) say “ GIS has capability of efficient storage, retrieval, integration, manipulation, updating, managing, changing exchanging, combining, analyzing, and presenting geographical and non-geographical information” (Christopher 1988) .

4.1.2 Overview:

Geographic information systems are an important product of the revolution of information technology, which allow the use and analysis of spatial information in conjunction with connected socio-economic information, and therefore it's an ideal basis for the planning and management of information related to various aspects of life. GIS technology can be used for scientific investigations, resources, management, asset management, environmental impact assessment, urban planning, cartography, criminology, history, sales, marketing, logistics... etc. Its applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations.

4.1.3 Components of GIS

Actually, the power and comprehensiveness of GIS stems from the strength of its components. Mainly it has five components; hardware, software, data, people, and procedures.

4.1.3.1 Hardware

GIS needs many types of hardware to satisfy some of its main functions such as data collection, storage, manipulation, and presentation. The heart of GIS is the computer which can be a Personal Computer (PC) or a workstation depending on the volume of data gathered for a given GIS project and the organization of such data. The input and output units are mainly the keyboard and the mouse for; input. A monitor for the output . Many types of devices are attached to the computer as input devices such as scanners, cameras, digitizers, and many others. Also printers and plotters of different sizes are attached to the computer as output devices. Network hardwares, such as modems, cables, hubs, bridges and other network devices, are utilized in GIS to share data, software, and hardware.

4.1.3.2 Software

Several comprehensive software systems are developed and fully support GIS applications. GIS has benefited greatly from the rapid, continuous developments in software systems. Many organizations, and companies, concerned with GIS had developed software’s to satisfy different functions of GIS such as those developed by The Environmental Systems Research Institute (ESRI) Arc view, Arc info and ArcGIS. Arc GIS is composed of many modules such as Arc Map, Arc Catalogue, Arc Toolbox, Arc Reader, Arc Globe, and Arc Scene. These modules are functioning in an integrating manner for capturing, managing, manipulating, displaying, and analyzing spatial data. There are many other GIS software’s such as IDRISI which had been developed by the Graduate School of Geography at Clark University, Geographic Resources Analysis Support System (GRASS) which had been developed by United States (U.S) Army Construction Engineering Research Laboratories (USA CERL), and Intergraph's Modular GIS Environment (MGE) in addition to many other functional systems.

4.1.3.3 Data

The efficiency of any GIS scheme depends on the quantity and the quality of data. The expected results of analysis are affected directly by the availability, accessibility, reliability, validity, integrity, and completeness of data (Carver, 1998). Data must be classified in several classes and all data of a particular level of classification, such as roads or vegetation type are grouped into layers or coverage. Layers can be combined in various ways to create new layers that are functions of individual ones. It should be borne in mind that data collection and processing is the most expensive part of GIS and constitute the major expenditure in any GIS project. There are two main types of GIS data, namely, spatial (geographical) data and non-spatial or (attributes) data.

(i) Spatial Data:

Spatial data describes the absolute, or relative, locations of geographic features. It is the graphical representation of the geographic locations in a digital form, and it can be classified into two basic data models: raster data model and vector data model. Raster data model known, also, as a grid model is a mathematical model. It is a set of grid of uniform regular cells, where the cell is called pixel. It refers to a picture element, usually rectangular or square, but it may be triangular or hexagonal. The main sources of raster data models are satellite imageries, aerial photographs and a digital image scan of existing maps. Vector data model is a representation of geographical phenomena in terms of the spatial components; consisting of points, lines, areas, surfaces and volumes. Each layer in the vector data model must be composed of only one component. The point is an object of zero dimensions called node or vertex; line is the link between two points which has one dimension called a link or an arc, while an area has two dimensions and composed of at least two arcs called a polygon or face. The geometrical relationships and connections between objects are controlled by topology that is independent of their coordinates. A topology model is based on mathematical graph theory that deals with the geometrical properties and employs nodes and links.

(ii) Attributes

Attributes are non-graphic data that describe properties of the geographic features or elements represented on the map. Attributes are stored in a table in a manner that each record or row in the table corresponds to a given geographic object on the map, whereas each property is stored in a column or a field. Each object must have an Identity (ID) or access key. The number of columns representing the properties is not limited, but is optionally selected due to the available attributes. The number of columns may be extended by joining several tables automatically using a common field. The first line or row in the attributes table contains the name of the field which must not exceed ten characters. The data of each field must be of the same type of characters and the type can be short integer, long integer, float, double, text and date. (Christopher 1988).

4.1.3.3 People

Different levels of people from different disciplines are involved to establish a GIS project or organization. People involved in a GIS team depend on the capacity of the organization and the nature of the GIS project. AGIS team may include GIS experts, who advise and solve problems for end users, cartographers, system analysts, computer specialists and people specialized in the field of the project in question e.g. geologists, agriculturists, engineers . AGIS team also include end users, who seek problem solutions and see final products only in the form of maps and reports, and GIS operators of low levels of experience who understand the functions of specific systems so as to manipulate data and data compilers, who understand the data but not the system.

4.1.3.4 Procedures

Procedures include how the data will be retrieved, input into the system, stored, managed, transformed, analyzed, and finally presented in a final output. The procedures are the steps taken to answer the questions needed to be resolved. The ability of a GIS to perform spatial analysis and answer these questions is what differentiates this type of system from any other information systems. The transformation processes include such tasks as adjusting the coordinate systems, setting a projection, correcting any digitized errors in a data set, and converting data from vector to raster or raster to vector (Carver, 1998).

4.1.4 Functionalities of GIS:

Most GIS packages provide functions and tools to enable the execution of different operations necessary for a given GIS project. There are main five functions as shown with their relationships in Figure (4.1) below.

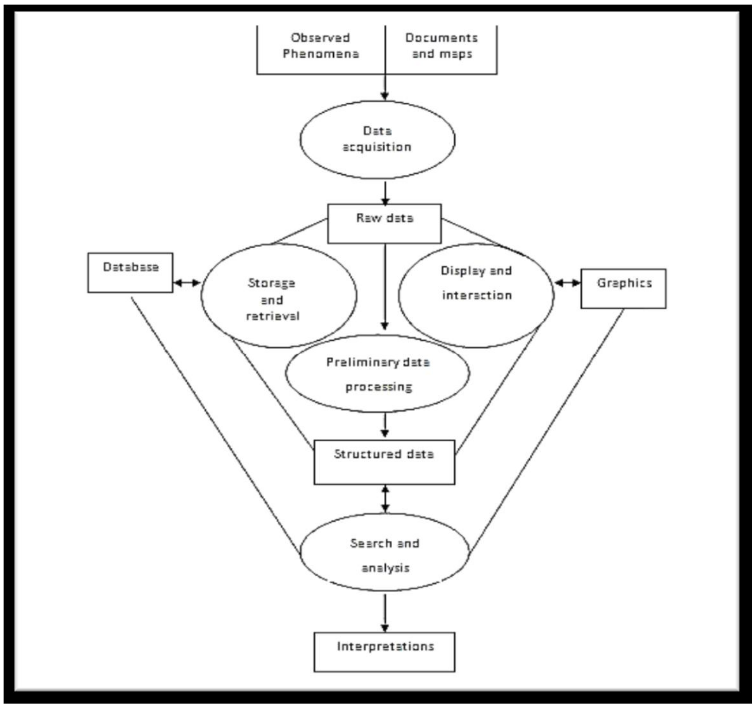

Figure (4. 1): Relationship between GIS functions (Christopher, 1988)

4.1.4.1 Data Acquisition

All data needed for a GIS project must be transformed from their original source form to the digital form to satisfy the basic requirements of GIS. Data can be obtained from primary data acquisition techniques such as direct ground survey techniques, whether in a digital form or in a hard copy form. Data in hard copy maps, which are secondary data acquisition sources, are transformed to the digital form by digitization or scanning and the resulting format depends on the employed technique. Satellite imageries and aerial photographs are important source of spatial data which can be obtained directly in digital form or scanned from hard copies. Aerial photographs provide spatial data of high accuracy which is suitable for creation and updating of large scale topographic maps while the accuracy of the spatial data obtained from remote sensing depends mainly on the ground resolution. Data acquisition is a critical, time consuming and expensive stage in many geographical information tasks.

4.1.4.1 Preliminary Data Processing

Preliminary data processing includes creating topologically structured data, classification of remotely sensed data, change of structure of data, coordinate systems and map projections transformation and conversion from raster to vector or vice versa according to the type of analysis tools. The required conversion to a raster data model from a vector data model can be done straight forward by rasterization algorithms while factorization of raster data is more complicated. Data of unknown coordinate systems can be forced by rubber sheet transformation to fit into known coordinate systems data of the same location. Data processing involves the creation of surface models by interpolation techniques to generate contour maps, Triangular Irregular Networks (TIN) or any other relief representation method. Acquiring data from different sources may cause the problem of using two or more classification or coding referring to the same phenomenon. Re-coding must be applied to solve this problem by reclassification to combine several classes to form a generalized less-detailed class.

4.1.4.2 Data Storage and Retrieval:

The manner by which the data is stored depends on the data model. The storage of vector data model consists of the spatial data or the map and the attribute tables, where every record in the attributes table corresponds to a spatial object or a feature in the map and the fields of the table are the attributes of these spatial objects. Each spatial object must have a unique identifier or access key to link the spatial object to its attributes in the table. The raster data is saved in the computer memory in the form of two-dimensional arrays in which, the coordinates of grid cells, or pixels, are implicit within the row and column ordering of the matrix. The property of this type of storage from a retrieval point of view, that each element can be referred to or addressed directly in terms of the row number and the column number.

4.1.5 Satellite Image and GIS

Satellite imagery can be used to create single, data-rich images with extracted vector features and attribute data. They can be used in mapping applications to achieve a multi-layered result for many types of analysis. Satellite images and aerial photographs have become extremely important tools for studying and managing the environment. They provide a broad view of a region, giving you the ability to "see" over that next ridge or mountain, or across a border. Many satellites acquire multispectral images. This means they capture data for a scene at several sections of the electro-magnetic spectrum, many outside of the visible range of light. These data can be used to identify vegetation type and health, soil moisture, surface geology, and other landcover. Also there is an archive of images spanning approximately 35 years, making it possible to study changes over time. ArcGIS can be used to display satellite images, along with other GIS data, to make dramatic maps and interesting background images to visually enhance your projects. The Spatial Analyst extension to ArcGIS is very good at analyzing and processing many types of raster data, such as soil or rainfall maps, but was not designed to process satellite images. This is where the Image Analysis extension to ArcGIS can be very useful. The Image Analysis extension to ArcGIS has been specifically designed to process and analyze aerial photographs and satellite images. It has tools to import industry standard satellite image formats and apply various contrast stretching techniques to visually enhance these images. By combining various bands of multispectral satellite images, using unique contrast enhancements, you can often reveal a great deal of information that is not normally visible in a scene.

Rectification tools allow you to align images to a map coordinate system so that the data can be overlaid with existing projected data. Adjacent images can then be mosaicked into a single scene. Indexes can be applied one or more layers of an image to create new data layers. Classification tools can create landcover maps, quickly identifying areas of forest cover, agricultural fields, or urban build up. This allows for the rapid identification and quantification of change over time. These new layers of data can then be saved as shapefiles for further use in your research.

4.2 Remote Sensing (RS)

4.2.1 Definitions:

Remote Sensing has many definitions Sabins and Floyd (1986) defined Remote Sensing **(**RS) as **"**collecting and interpreting information about a target, without being in physical contact with the object ".

According to (Nassri, 1999) Remote Sensing (RS) is defined as **"**the acquisition of information about an object from a distance without being physically in contact to it, by detecting and measuring changes in the reflected electromagnetic energy **".**

The definition given by (Jensen, 2000) is **"**the art and science of obtaining information about an object without being in direct physical contact with the object ". Perhaps, the most applicable and used definition is the one given by (Nassri, 1999).

4.2.2 Principles of Remote Sensing:

Detection and discrimination of objects or surface features means detecting and recording of radiant energy reflected or emitted by objects or surface material. Different objects return different amounts and kinds of energy in different bands of the electromagnetic spectrum incident upon it. This unique property depends on the material properties.

4.2.3 Stages in Remote Sensing

Any Electro Magnetic Energy (EME), seif-emitted or emitted (radiated) frame the Sean, undergoes the following stages:

1. Transmission of energy from the source to the surface of the earth, as well as absorption and scattering
2. Interaction of EMR with the earth's surface: reflection and emission.
3. Transmission of energy from the surface to the remote sensor
4. Sensor data output.
5. Data transmission, processing and analysis.

Figure (4.2) below shows these stages, including the emission source.

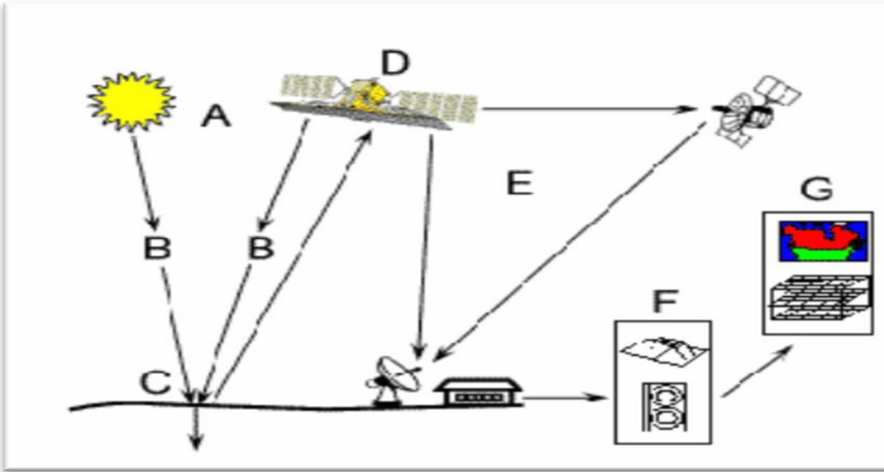

Figure (4.2): Stages in Remote Sensing (CCRS/CCT, 1999)

Energy Source or Illumination (A)

The first requirement for remote sensing is to have an energy source, which illuminates or provides electromagnetic energy to the target of interest.

Radiation and the Atmosphere (B)

As the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

Interaction with the Target(C)

Once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation

Recording of Energy by the Sensor (D)

After the energy has been scattered by, or emitted from the target, a sensor (remote - not in contact with the target) is required to collect and record the electromagnetic radiation.

Transmission, Reception, and Processing (E)

The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data is processed.

Interpretation and Analysis (F)

The processed image is interpreted, visually and/or digitally or electronically, to extract information about the, target, which was illuminate.

Application (G)

The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

4.2.4 Remote Sensing Sensors:

A sensor is a device that gathers energy (EMR or other), converts it into a signal and presents it in a simple and understandable form suitable for obtaining information about the target under investigation. These may be active or passive depending on the source of energy:

Sensors used for remote sensing can be broadly classified as those operating in Optical Infrared Region (OIR) and those operating in the Microwave Region (MR). OIR and MR sensors can further be subdivided into passive and active.

4.2.4.1 Active Sensors:

These sensors use their own source of energy. Earth surface is illuminated through energy emitted by its own source Part of its reflected energy by the surface, in the direction of the sensor, is received to gather the information.

4.2.4.2 Passive Sensors:

This type of sensors receives solar electromagnetic energy reflected from the surface or energy emitted by the surface itself. These sensors do not have their own source of energy and cannot be used at night times, except the thermal sensor, Optical Mechanical Scanner (OMS), Thematic Mapper (TM), High Resolution Visible (HRV), Linear Image Self Scanning (LISS) and Linear Imaging Self Scanning Camera-3 (LISS-3) Sensors .When they are active, or passive, could either be imaging sensors, like a camera , or Sensors which acquire images of the area and non-imaging types like non-scanning radiometers or atmospheric sounders.

4.2.5 Multi Spectral Scanners (MSS):

There are many Types of MSS Scanners these are**:** Optical Mechanical Scanner, Thematic Mapper, Linear Image Self Scanning Camera and Linear Imaging Self Scanning Camera-3

4.2.5.1 Optical Mechanical Scanners (OMS):

These scanners are found onboard Landsat series of satellites of the of United States America (USA) having bands , L1, L2,L3, L4 & L5 and provide line scan type imagery using an oscillating mirror to continuously scan the earth surface perpendicular to the spacecraft velocity**.** Six lines are scanned simultaneously in each of the four spectral bands for each mirror sweep. Spacecraft motion provides the along-track progression of the scan lines. Radiation is sensed simultaneously by an array of six detectors each of four spectral bands from 0.5 to 1.1 micrometers. The detectors' outputs are sampled, encoded and formatted into a continuous digital data.

4.2.5.2 Thematic Mapper (TM):

This type of scanners is used in Landsat series satellites; namely Landsat's 4 and 5 which have onboard a new payload called "Thematic Mapper" with 7 spectral bands and ground resolution of 30 meters. This is in addition to the MSS payload, which is identical to those carried onboard Landsat's 1 and 2 and replaces Red Blue Violet (R BV) payload. The Thematic Mapper (TM) is also an Optical Mechanical Scanner (OMS), similar to Multi Spectral Scanner (MSS); however, being a second-generation line-scanning sensor, it ensures better performance characteristics in terms of:

(i) Improved pointing accuracy and stability ,
(ii) high resolution ,
(iii) new and more number of spectral bands,
(iv) 16 days repetitive coverage ,
(v) High scanning efficiency using bi-directional scanning ,and increased quantization levels.

For achieving the bi-directional scanning, a Scan Line Corrector (SLC) is introduced between the telescope and focal plane. The (SLC) ensures parallel lines of scanning in the forward and reverse directions.

4.2.5.3 High Resolution Visible (HRV):

The French SPOT-1 spacecraft carries two nominally identical the HRV imagers, which can be operated independently or in various coupled modes. In contrast to the oscillating mirror design used in the Landsat imaging system, High Resolution Visible **(**HRV) cameras use Charge Coupled Devices (CCD) array as the sensing element for the first time in space environment. Each of the two cameras can be operated in either multispectral (20 meter resolution) mode or panchromatic (10 meter resolution) mode. The swath covered is 60 Kilometers; and the cameras can be offseted up to 27 degrees on either side of nadir. Thus any point within a width of 950 kilometers, centered on the satellite track, can be observed by a programmed camera control. SPOT-1 has a stereo coverage capability in orbit with tiltable cameras, which again provide stereo image pairs almost similar to areail photograhs of a metric camera.

4.2.5.4 Linear Image Self Scanning (LISS) Camera:

The Indian Remote Sensing (IRS) is fully designed and fabricated by the Indian Space Research Organization (ISRO) .The first version was launched on March 17th, 1988 by a Russian launcher. It has four spectral bands in the ranges of 0.45 to 0.86 µm 0.45 to 0.53 µm 0.45 to 0.59 µm, 0.62 to 0.68 µm and 0.77 to 0.86 µm in the visible and near infrared range with two different spatial resolutions of 72.5 meters . And 36.25meters from an open LISS-1 camera and two LISS-2 cameras respectively. It provides a repetitive coverage every 22 days. Like all other LANDSAT/ SPOT missions which are designed for global coverage, IRS is also in sun synchronous, polar orbit at about 900 kilometer altitude and, like spot, covers a width of 148 kilometers on ground. It uses linear array detectors Charge Coupled Devices.

4.2.5.5 Linear Imaging Self Scanning Camera-3 (LISS-3):

This camera is configured to provide imageries in three visible bands as well as in short-wave infrared band. The resolution and swath for visible bands are 23.5 meter and 142 kilometers, respectively. The detector is a 6000 element detectors the CCD based on a linear array with a pixel dimensions of 10μm by 7 μm. The detector is placed at the focus of a refractive type optical system consisting of eight lens elements, which provide a focal length of 360 mm. The processing of the analogue output video signal is similar to that of PAN chromatic Camera (PAN). For this camera, a 7-bit digitization is used which gives an intensity variation of 128 levels.

4.2.6 Remote Sensing Satellites:

There is a number of remote sensing satellites used for various, wide range, applications these are:

1. LAND SAT Series
2. MODIS, ASTER
3. SPOT Series
4. IRS series
5. IKONOS
6. LIDAR
7. RADAR
8. SRTM

The most important and mostly used is the LANSAT servies of satellites and, them fore, a rief accoeat about theses satellites is givew in the comning section.

4.2.6.1 LAND SAT Series:

NASA, with the co-operation of the U.S. Department of Interior, began a conceptual study of the feasibility of a series of Earth Resources Technology Satellites (ERTS). ERTS-1 was launched on July 23, 1972. It is the first unmanned satellite specifically designed to acquire data about earth resources on a systematic, repetitive, medium resolution, multispectral basis. It was primarily designed as an experimental system to test the feasibility of collecting earth resources data from unmanned satellites. Just prior to the launch of ERTS-2 on January 22nd 1975, NASA officially renamed the ERTS programme as "LANDSAT" programme. All subsequent satellites in the series carried the Landsat designation. So far, five Landsat satellites have been launched successfully; there have been three different types of sensors included in various combinations on these missions. There are Multispectral Scanner systems (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM). After more than two decades of success, the LANDSAT program realized its first unsuccessful mission with the launch failure of Landsat-6 on October 5, 1993. The sensor included on-board was the Enhanced Thematic Mapper (ETM). To provide continuity with Landsat -4 and -5 the ETM incorporated the same seven spectral bands and the same spatial resolutions as the TM. The ETM's major improvement over the TM was the addition of an eighth panchromatic band operating in 0.50 to 0.90 µm ranges and a spatial resolution of 15 meter. Landsat-7 includes two sensors: the Enhanced Thematic Mapper plus (ETM+) and the High Resolution Multispectral Stereo Imager (HRMSI).