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# Applications of Remote Sensing (RS) and Geographic Information Systems (GIS)

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## Abstract :

Remote Sensing is an extensive science, drawing from many areas for support and development. It depends greatly on the support of governments and private industries worldwide. Satellite and digital imagery play an important role in remote sensing; providing information about the land studied. Geographic Information Systems GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. It is represent and analyze the geographic features present on the Earth' surface and the events (non-spatial attributes linked to the geography under study) that taking place on it. A GIS can be viewed in three ways; these three views are critical parts of an intelligent GIS and are used at varying levels in all GIS applications. Application of remote sensing and GIS in the earth represents the topography, geology, geomorphology, digital elevation models, mining, land-use, land-cover, and change detection.

**Keywords :** Remote sensing - Geographic Information Systems – GIS Models – Satellite Digital Images - Image Processing - Image Classification.

## Introduction :

Remote sensing is the measurement or acquisition of information of an object or phenomenon, by a recording device that is not in physical contact with the object. In practice, remote sensing is the utilization at a distance (as from aircraft, spacecraft, satellite, or ship) of any device for gathering information about the environment. Is provides important coverage, mapping and classification of landcover features, such as vegetation, soil, water and forests. Satellite and digital imagery play an important role in remote sensing; providing information about the land studied. Its can provide information about global coverage (range of spatial resolutions), temporal coverage (repeat viewing), spectral information (wavelength), and angular information (different view angles) (Sabins,1994 and Drury, 1998).

It is offer four basic components to measure and record data about an area from a distance. These components include the energy source, the transmission path, the target and the satellite sensor. The energy source, electromagnetic energy, is very important. It is the crucial medium required to transmit information from the target to the sensor (Avery and Berlin, 1992 and Lillesand and Keifer, 1994).

Earth study from space is due to rapid, accurate and advanced methods. Satellites cover the large earth areas, have great spatial details at the same time, and can provide a global view within a day or few days rapidly. Remote sensors operate in all seasons (at night, and in bad weather), and provides repetitive looks at the same area (change detection). Some types of measurements made by satellite cannot be made by convential methods (Marble, *et al.*, 1983 and Mulder, 1987).

The advent of cheap and powerful computers over the last few decades has allowed for the development of innovative software applications for the storage, analysis, and display of geographic data. Many of these applications belong to a group of software known as Geographic Information Systems (GIS). Many definitions have been proposed for what constitutes a GIS. Each of these definitions conforms to the particular task that is being performed. Instead of repeating each of these definitions, I would like to broadly define GIS according to what it does (Dangermond, 1988; Carter 1989; Maguire, 1991 and Burrough, 1994).

## Types of Remote Sensing :

### A)- In respect to the type of Energy Resources :

The two broadest classes of sensors (Figure 1-a) are **Passive** (energy leading to radiation received comes from an external source, e.g., the Sun; the MSS is an example) and **Active** (energy generated from within the sensor system is beamed outward, and the fraction returned is measured; radar is an example). Sensors can be non-imaging (measures the radiation received from all points in the sensed target, integrates this, and reports the result as an electrical signal strength or some other quantitative attribute, such as radiance) or imaging (the electrons released are used to excite or ionize a substance like silver (Ag) in film or to drive an image producing device like a TV or computer monitor or a cathode ray tube or oscilloscope or a battery of electronic detectors (Avery and Berlin, 1992 and Lillesand and Keifer, 1994).

### B)- In respect to Wavelength Regions :

Remote sensing of the Earth traditionally has used reflected energy (Figure 1-b) in the visible and infrared and emitted energy in the thermal infrared and microwave regions to gather radiation that can be analyzed numerically or used to generate images whose tonal variations represent different intensities of photons associated with a range of wavelengths that are received at the sensor. Multispectral remote sensing that have a (continuous or discontinuous) range(s) of wavelength regions together (Avery and Berlin, 1992 and Lillesand and Keifer, 1994).

Images made from the varying wavelength/intensity signals coming from different parts of a scene will show variations in gray tones in black and white versions or colors (in terms of hue, saturation, and intensity in colored versions). Pictorial (image) representation of target objects and features in different spectral regions, usually using different sensors (commonly with band-pass filters) each tuned to accept and process the wave frequencies (wavelengths) that characterize a given region, will normally show significant differences in the distribution (patterns) of color or gray tones. It is this variation which gives rise to an image or picture. Each spectral band will produce an image which has a range of tones or colors characteristic of the spectral responses of the various objects in the scene; images made from different spectral bands show different tones or colors.

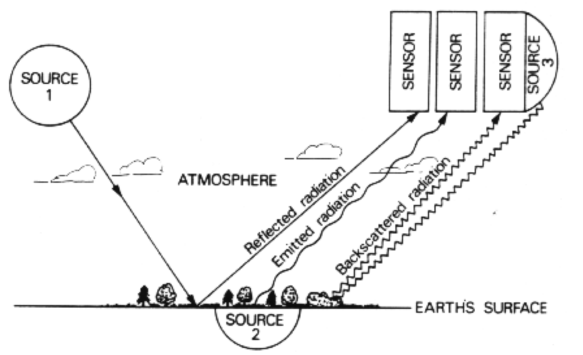



**Figure (1-a) :** Types of Remote Sensing In respect to Energy Resources

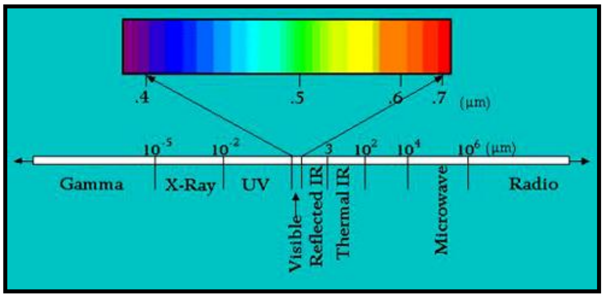



**Figure (1-b)** : Types of Remote Sensing In respect to Wavelength Regions

## Optical Remote Sensing :

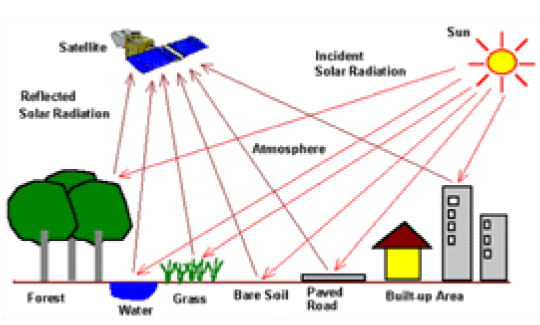
In Optical Remote Sensing (Figure 2-a), optical sensors detect solar radiation in the visible and near infrared wavelength regions (commonly abbreviated as VNIR) reflected or scattered from the earth, forming images resembling photographs taken by a camera high up in space.

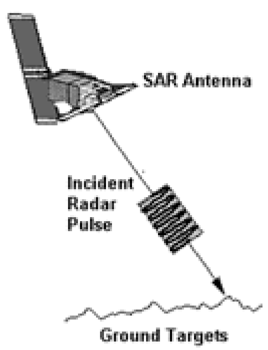
Different materials such as water, soil, trees, buildings and roads reflect visible and infrared light in different ways. They have different colours and brightness when seen under the sun. The interpretation of optical images requires the knowledge of the spectral reflectance signatures of the various materials (natural or man-made) covering the surface of the earth. There are also infrared sensors measuring the thermal infrared radiation emitted from the earth, from which the land or sea surface temperature can be derived.

## Microwave Remote Sensing :

There are some remote sensing satellites (Figure 2-b) which carry passive or active microwave sensors. The active sensors emit pulses of microwave radiation to illuminate the areas to be imaged. Images of the earth surface are formed by measuring the microwave energy scattered by the ground or sea back to the sensors. These satellites carry their own "flashlight" emitting microwaves to illuminate their targets. The images can thus be acquired day and night. Microwaves have an additional advantage as they can penetrate clouds. Images can be acquired even when there are clouds covering the earth surface.

A microwave imaging system which can produce high resolution image of the Earth is the synthetic aperture radar (SAR). The intensity in a SAR image depends on the amount of microwave backscattered by the target and received by the SAR antenna. Since the physical mechanisms responsible for this backscatter is different for microwave, compared to visible/infrared radiation, the interpretation of SAR images requires the knowledge of how microwaves interact with the targets.



| **Figure (2-a) :** Optical Remote Sensing | **Figure (2-b) :** Microwave Remote Sensing |
|---|---|

## Remote Sensing Images :

Remote sensing images are normally in the form of digital images. In order to extract useful information from the images, image processing techniques may be employed to enhance the image to help visual interpretation, and to correct or restore the image if the image has been subjected to geometric distortion, blurring or degradation by other factors. There are many image analysis techniques available and the methods used depend on the requirements of the specific problem concerned. In many cases, image segmentation and classification algorithms are used to delineate different areas in an image into thematic classes. The resulting product is a thematic map of the study area (Figure 3-a). This thematic map can be combined with other databases of the test area for further analysis and utilization.

## Image Processing and Analysis :

Many image processing and analysis techniques have been developed to aid the interpretation of remote sensing images and to extract as much information as possible from the images (Figure 3-b). The choice of specific techniques or algorithms to use depends on the goals of each individual project. In this section, we will examine some procedures commonly used in analyzing / interpreting remote sensing images (Lillesand and Keifer, 1994).

## A)- Image Pre-Processing :

Prior to data analysis, initial processing on the raw data is usually carried out to correct for any distortion due to the characteristics of the imaging system and imaging conditions. Depending on the user's requirement, some standard correction procedures may be carried out by the ground station operators before the data is delivered to the end-user. These procedures include radiometric correction to correct for uneven sensor response over the whole image and geometric correction to correct for geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing). The image may also be transformed to conform to a specific map projection system. Furthermore, if accurate geographical location of an area on the image needs to be known, ground control points (GCP's) are used to register the image to a precise map (geo-referencing) (Lillesand and Keifer, 1994).

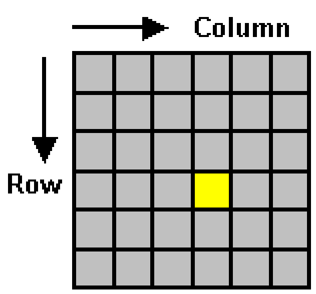



**Figure (3-a) :** Remote Sensing Images

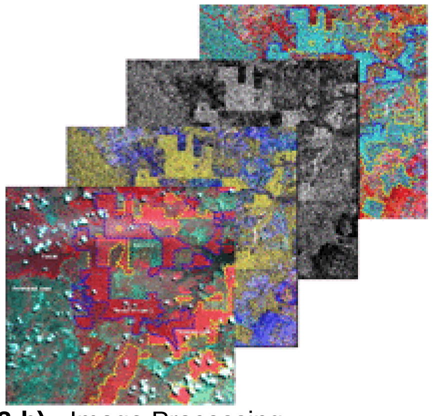


**Figure (3-b) :** Image Processing

Satellite Images may need to be geometric, radiometric, atmospheric and cosmetic (noise removal) correction. Geometric correction removes the distortions due to the Earth, the satellite, the orbit and the image projection. Radiometric correction removes the radiometric errors due to the effect of terrain. Atmospheric correction eliminates the absorption and scattering of radiation due to atmospheric effects. Cosmetic correction (noise removal) corrects the missing and disturbance in image data recorded (Lillesand and Keifer, 1994 and El-Bardan, 2004).

## B)- Image Enhancement :

In order to aid visual interpretation, visual appearance of the objects in the image can be improved by image enhancement techniques such as grey level stretching to improve the contrast and spatial filtering for enhancing the edges. An example of an enhancement procedure is shown in Figure (4) which shows the multispectral SPOT image of the same area shown in a previous section, but acquired at a later date. Radiometric and geometric corrections have been done. The image has also been transformed to conform to a certain map projection (UTM projection). This image is displayed without any further enhancement (Lillesand and Keifer, 1994).

In Figure (4) unenhanced image, a bluish tint can be seen all-over the image, producing a hazy appearance. This hazy appearance is due to scattering of sunlight by atmosphere into the field of view of the sensor. This effect also degrades the contrast between different landcovers.

It is useful to examine the image Histograms before performing any image enhancement. The x-axis of the histogram is the range of the available digital numbers, i.e. 0 to 255. The y-axis is the number of pixels in the image having a given digital number. The histograms of the three bands of this image is shown in Figures (5-a), (5-b) and (5-c).

The minimum digital number for each band is not zero. Each histogram is shifted to the right by a certain amount. This shift is due to the atmospheric scattering component adding to the actual radiation reflected from the ground. The shift is particular large for the XS1 band compared to the other two bands due to the higher contribution from Rayleigh scattering for the shorter wavelength.

The maximum digital number of each band is also not 255. The sensor's gain factor has been adjusted to anticipate any possibility of encountering a very bright object. Hence, most of the pixels in the image have digital numbers well below the maximum value of 255.

**Figure (4) :** Multispectral SPOT image of the same area with Radiometric and geometric corrections and transformed map projection (UTM projection).

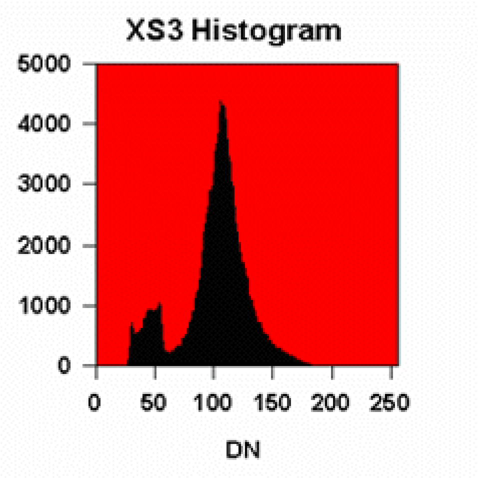



**Figure (5-a) :** Histogram of the XS3 (near infra-red) band (displayed in red).

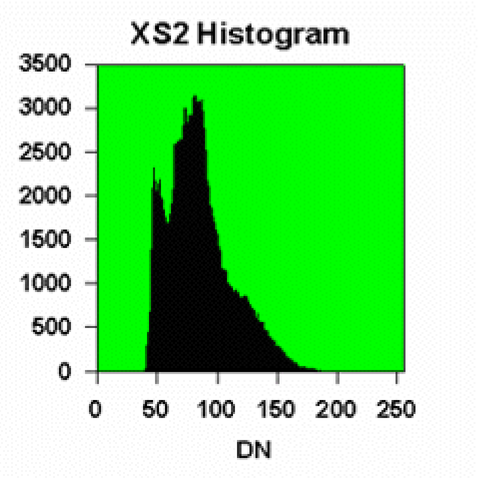



**Figure (5-b) :** Histogram of the XS2 (red) band (displayed in green).

The image can be enhanced by a simple linear grey-level stretching. In this method, a level threshold value is chosen so that all pixel values below this threshold are mapped to zero. An upper threshold value is also chosen so that all pixel values above this threshold are mapped to 255. All other pixel values are linearly interpolated to lie between 0 and 255. The lower and upper thresholds are usually chosen to be values close to the minimum and maximum pixel values of the image. The Grey-Level Transformation Table is shown in Figure (5-d).

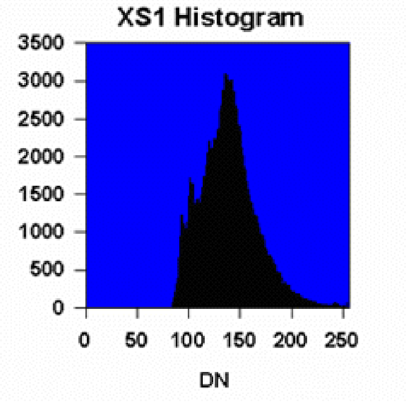



**Figure (5-c) :** Histogram of the XS1 (green) band (displayed in blue).

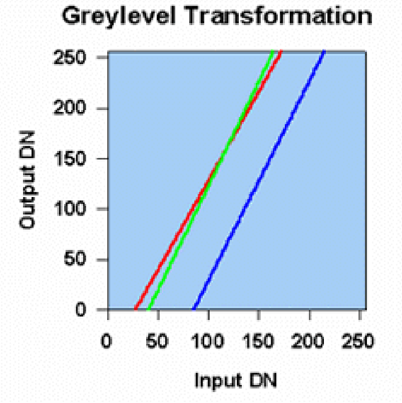



**Figure (5-d) :** Grey-Level Transformation Table for performing linear grey level stretching of the three bands of the image. Red line: XS3 band; Green line: XS2 band; Blue line: XS1 band.

The result image of applying the linear stretch is shown in Figure (6). The hazy appearance has generally been removed, except for some parts near to the top of the image. The contrast between different features has been improved.

**Figure (6)** : Multispectral SPOT image after enhancement by a simple linear grey-level stretching.

## C)- Image Classification :

Different landcover types in an image can be discriminated using some image classification algorithms using spectral features, i.e. the brightness and "colour" information contained in each pixel. The classification procedures can be "**supervised**" or "**unsupervised**" (Mulder, 1987 and Drury,1998 ).

In **supervised** classification, the spectral features of some areas of known landcover types are extracted from the image. These areas are known as the "training areas". Every pixel in the whole image is then classified as belonging to one of the classes depending on how close its spectral features are to the spectral features of the training areas.

In **unsupervised** classification, the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features. Each cluster will then be assigned a landcover type by the analyst.

Each class of landcover is referred to as a "theme" and the product of classification is known as a "thematic map".

Figures (7-a) and (7-b) shows an example of a thematic map image. This map was derived from the multispectral SPOT image of the test area shown in a previous section using an unsupervised classification algorithm.

**Figure (7-a) :** SPOT multispectral image of the test area.

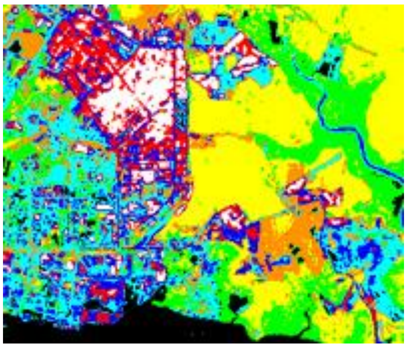


**Figure (7-b) :** Thematic map derived from the SPOT image using an unsupervised classification algorithm.

A plausible assignment of landcover types to the thematic classes is shown in Table (1). The accuracy of the thematic map derived from remote sensing images should be verified by field observation (supervised classification).

**Table (1) : Supervised classification of landcover verified by field observation**

| Class No. (Colour in Map) | Landcover Type |
|---|---|

| | |
|---|---|
| **1 (black)** | Clear water |
| **2 (green)** | Dense Forest with closed canopy |
| **3 (yellow)** | Shrubs, Less dense forest |
| **4 (orange)** | Grass |
| **5 (cyan)** | Bare soil, built-up areas |
| **6 (blue)** | Turbid water, bare soil, built-up areas |
| **7 (red)** | bare soil, built-up areas |
| **8 (white)** | bare soil, built-up areas |

The spectral features of these Landcover classes can be exhibited in two graphs shown in Figures (8-a) and (8-b). The first graph is a plot of the mean pixel values of the XS3 (near infrared) band versus the XS2 (red) band for each class. The second graph is a plot of the mean pixel values of the XS2 (red) versus XS1 bands. The standard deviations of the pixel values for each class are also shown.

In the scatterplot of the class means in the XS3 and XS2 bands, the data points for the non-vegetated landcover classes generally lie on a straight line passing through the origin. This line is called the "soil line". The vegetated landcover classes lie above the soil line due to the higher reflectance in the near infrared region (XS3 band) relative to the visible region.

In the XS2 (visible red) versus XS1 (visible green) scatterplot, all the data points generally lie on a straight line. This plot shows that the two visible bands are very highly correlated. The vegetated areas and clear water are generally dark while the other nonvegetated landcover classes have varying brightness in the visible bands.

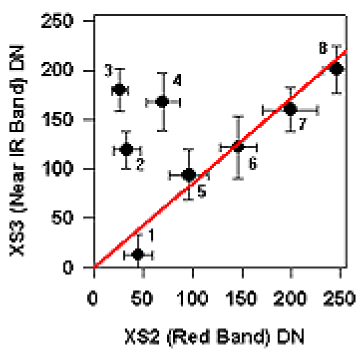



**Figure (8-a) :** Scatter Plot of the mean pixel values of the XS3 (near infrared) versus the XS2 (red) bands for each landcover class

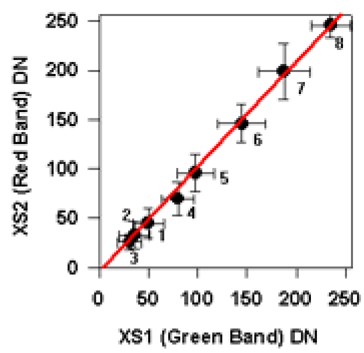



**Figure (8-b) :** Scatter Plot of the mean pixel values of the XS2 (red) versus XS1 bands for each landcover class

## Relating Information from Different Sources :

Remote sensing data may be acquired through a variety of devices depending upon the object or phenomena being observed. Most remote sensing techniques make use of emitted or reflected electromagnetic radiation of the object of interest in a certain frequency domain (infrared, visible light, microwaves). This is possible due to the fact that the examined objects (lithology, geology, topography, plants, houses, water surfaces, environment, and air masses) reflect or emit radiation in different wavelengths and in different intensities according to their current condition. It has many applications in mapping land-use and cover, agriculture, soils mapping, forestry, city planning, archaeological investigations, military observation, and geomorphological surveying, among other uses. For example, foresters use aerial photographs for preparing forest cover maps, locating possible access roads, and measuring quantities of trees harvested. Specialized photography using color infrared film has also been used to detect disease and insect damage in forest trees.Some remote sensing systems use sound waves in a similar way, while others measure variations in gravitational or magnetic fields depending on the type of geosciences observed and recorded (Obermeyer and Pinto, 1994 and Chan and Williamson, 1996b).

The power of a GIS comes from the ability to relate different information in a spatial context and to reach a conclusion about this relationship. Most of the information we have about our world contains a location reference (longitude, latitude, and elevation), placing that information at some point on the globe. A GIS, therefore, can reveal important new information that leads to better decision-making.

Many computer databases that can be directly entered into a GIS are being produced by Federal, State, tribal, and local governments, private companies, academia, and nonprofit organizations. Different kinds of data in map form can be entered into a GIS (Figures 9-a, 9-b, 9-c, 9-d, 9-e, and 9-f).

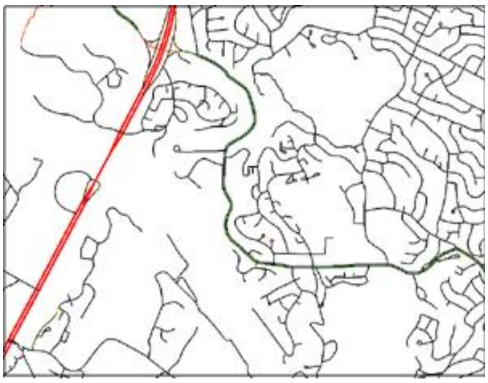


**Figure (9-a) :** Digital line graph (DLG) data of roads.

**Figure (9-b) :** Digital line graph (DLG) data of rivers.

**Figure (9-c) :** Digital line graph (DLG) data of contour lines (Hypsography)

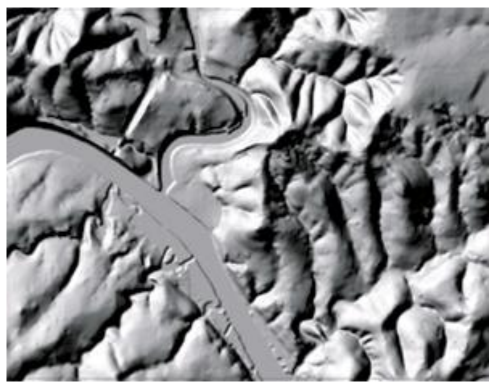


**Figure (9-d) :** Digital Elevation Model (DEM)

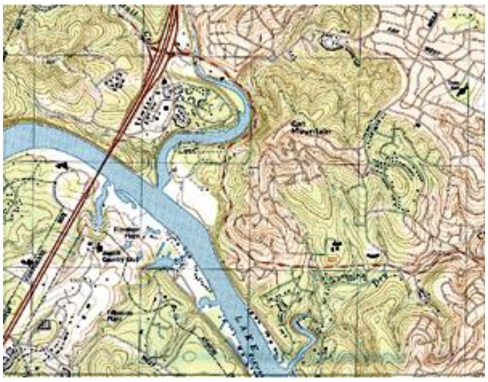


**Figure (9-e) :** Digital Raster Graphic (DRG).

**Figure (9-f) :** Digital Orthophoto Quadrangle (DOQ).

A GIS can also convert existing digital information, which may not yet be in map form, into forms it can recognize and use. For example, digital satellite images can be analyzed to produce a map of digital information about land use and land cover (Figures 10-a and 10-b). Likewise, census or hydrologic tabular data can be converted to a map-like form and serve as layers of thematic information in a GIS (Figures 11-a and 11-b).

**Figure (10-a) :** Land cover information derived from Landsat 7 satellite image.

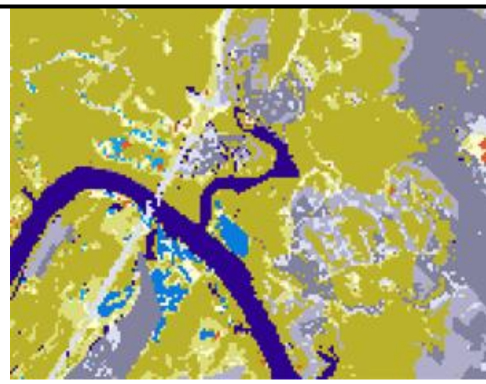


**Figure (10-b) :** Classes of Land uses / Land cover derived from Figure (14-a)

**Figure (11-a) :** Part of a census data file.

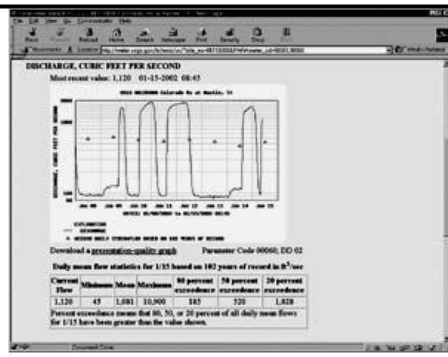


**Figure (11-b) :** Hydrologic data Chart.

## GIS Data Capture :

Various techniques can be capturing the information; maps can be digitized by hand-tracing with a computer mouse on the screen or on a digitizing tablet to collect the coordinates of features. Electronic scanners can be also convert maps to digits. Coordinates from Global Positioning System (GPS) receivers can also be uploaded into a GIS (Obermeyer and Pinto, 1994 and Chan and Williamson, 1996b).

A GIS can be used to emphasize the spatial relationships among the objects being mapped. While a computer-aided mapping system may represent a road simply as a line, a GIS may also recognize that road as the boundary between wetland and urban development between two census statistical areas.

Data capture-putting the information into the system-involves identifying the objects on the map, their absolute location on the Earth's surface, and their spatial relationships. Software tools that automatically extract features from satellite images or aerial photographs are gradually replacing what has traditionally been a time-consuming capture process. Objects are identified in a series of attribute tables-the "information" part of a GIS. Spatial relationships, such as whether features intersect or whether they are adjacent, are the key to all GIS-based analysis.

## GIS Data Integration :

A GIS makes it possible to link, or integrate, information that is difficult to associate through any other means. Thus, a GIS can use combinations of mapped variables to build and analyze new variables (Figure 12) (Parent and Church, 1987).

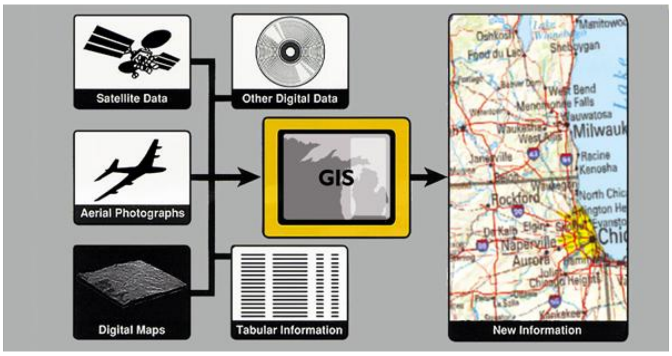



**Figure (12) : Data integration in different forms through a GIS.**

## GIS Data Structures :

GIS must be able to convert data from one structure to another. Satellite image data that have been interpreted by a computer to produce a land use map can be "read into" the GIS in raster format. Raster data files consist of rows of uniform cells coded according to data values. An example is land cover classification (Figure 13-a). Raster files can be manipulated quickly by the computer, but they are often less detailed and may be less visually appealing than vector data files, which can approximate the appearance of more traditional hand-drafted maps. Vector digital data have been captured as points, lines (a series of point coordinates), or areas (shapes bounded by lines) (Figure 13-b). An example of data typically held in a vector file would be the property boundaries for a particular housing subdivision.

Data restructuring can be performed by a GIS to convert data between different formats. For example, a GIS can be used to convert a satellite image map to a vector structure by generating lines around all cells with the same classification, while determining the spatial relationships of the cell, such as adjacency or inclusion (Figure 19) (Parent and Church, 1987 and El-Bardan, 2004).

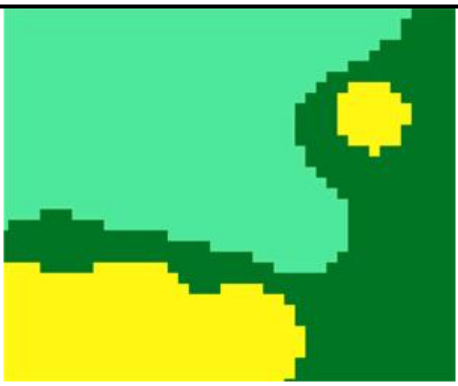


**Figure (13-a) :** Magnified view of the GIS Raster format.

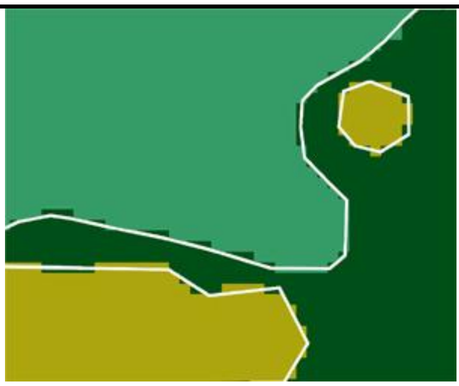


**Figure (13-b) :** Magnified view of the GIS Vector format.

## GIS Data Modeling :

GIS data models represent the linkage between the real world geographical data and computer representation. Raster type (continuous space) is a set of cells located by coordinate is used, each cell is independently addressed with the value of an attribute, each cell contains a single value and every location corresponds to a cell; require a huge volume of data (simple, easier, faster). Vector type (discrete space), line or points represented by x, y coordinates to identify locations, connecting set of line segments forms area objects, require less storage space, estimation of area/perimeter is accurate and editing is faster and convenient.

It is impossible to collect data over every square meter of the Earth's surface. Therefore, samples must be taken at discrete locations. A GIS can be used to depict two- and three-dimensional characteristics of the Earth's surface, subsurface, and atmosphere from points where samples have been collected (Dueker, 1987; Dangermond, 1988 and Chan and Williamson,1996b).

### Contour Maps Model :

Two- and three-dimensional contour maps created from the measurement points.

### GIS Information Retrieval Model :

GIS can "point" at a location, object, or area on the screen and retrieve recorded information about it from off-screen files.

### GIS Topologic Model :

GIS can recognize and analyze the spatial relationships among mapped phenomena. Conditions of adjacency (what is next to what), containment (what is enclosed by what), and proximity (how close something is to something else) can be determined with a GIS.

### GIS Network Model :

Linear network is important to know in which direction the Lineaments, and Drainage Systems.

### GIS Overlay Model :

Different GIS rank layers used to produce a new map layer or overlay that ranks according to their relative sensitivity.

## GIS Data Output :

A critical component of a GIS is its ability to produce graphics on the screen or on paper to convey the results of analyses to the people who make decisions about resources. Wall maps, Internet-ready maps, interactive maps, and other graphics can be generated, allowing the decision makers to visualize and thereby understand the results of analyses or simulations of potential events (Figures 14-a and 14-b) (Parent and Church, 1987; Dangermond, 1988 and Obermeyer and Pinto,1994).

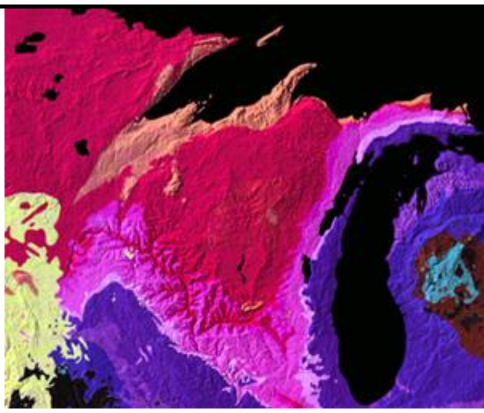


**Figure (14-a)** : Landforms and geology map.

**Figure (14-b) :** Human-built and physical features.

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