Table of Contents

List of Figures

Appendix: Remote Sensing Technology…………………..

Abstract:

The growing availability of remote sensing technology is helping us observe, study and learn about our world in ways we could only imagine a generation ago. In the rapidly growing of GIS technology guides to deep understanding for historical, conceptual and practical uses of remote sensing. Since of this powerful technology supports plenty of fields, therefore this paper invaluable for GIS managers to become more knowledgeable users of remote sensing products and services and to manage the development of innovative solutions suited to the needs and goals of their organizations.

Remote sensing is a potentially powerful complement to GIS technology. Skilled analysts can, in many instances, employ remote sensing to provide current information on, among other things, land use and land cover, water resources, terrain elevation, biophysical characteristics of the earth's surface and landscape change. Organizations seeking to integrate remote sensing into the GIS processing stream should begin by carefully assessing the potential of the technology for meeting data requirements.

This paper will go briefly through remote sensing benefits, history, technology and its instruments. And will also be covered the GIS and remote sensing integration and their applications. The Remote Sensing Technology discussed in details in the appendix.

1. Introduction:

1.1. General:

When we explaining the synergy between GIS and remote sensing, we build a bridge between the image world and the geospatial vector world. This multilayer integration of raster and vector data within the GIS environment is important as we move forward. Now the remote sensing data is one of the major drives accelerating GIS diffusion and effectiveness.

My term paper will provide the basic information we need to integrate remote sensing information into our unique application of GIS, because today most of GIS technology depend on a steady flow of images acquired from vantage points high above the earth to inventory, assess and manage resources from the local to the global scale. Analysis of this imagery is the discipline known as remote sensing.

In this paper I will go briefly through remote sensing benefits, history, technology and its instruments. And will also be covered the GIS and remote sensing integration and their applications through summarized case studies in many fields such as; forestry, geology, meteorology, oceanography and climatology.

1.2. Remote Sensing Benefits:

Remote sensing that the science, technology and obtaining information about objects from a distance, takes us well beyond the limits of human capabilities. It allows us to collect information over regions too costly, too dangerous or too remote for human observers to directly assess. Remotely sensed data takes many forms, including aerial photography, digital satellite imagery and radar.

Remote sensing offers important advantages over other methods of data collection that have led to its use in a wide range of applications. Aerial photography and digital imagery are used to produce maps of the earth's land and seafloor topography, natural resources and urban infrastructure in status rapidly and repeatedly over large areas and at low cost. Rapid availability of remote sensing imagery has also proved valuable in assessing disaster events and in assessing, planning and monitoring emergency response activities. Additionally, remote sensing data serves as a valuable historical record that allows changes in land cover, biophysical processes and human activities to be monitored and analyzed over time. Also remote sensing technology can record wavelengths the human eye cannot see, such as infrared, to detect phenomena otherwise not visible, such as heat or radioactivity. The image in figure 1 clearly shows the pattern of the Gulf Stream, the warm water current that flows east toward northern Europe (shown here as yellow, orange and red with red being warmest). The commercial availability of satellite imagery with spatial resolutions finer than one meter led to present vegetation, geology, soils, hydrogeology, transportation network and settlement patterns together showing their spatial relationship, (Figure 2) shows type of satellite images useful in observing the geology of an area, as well as assessing other resources.

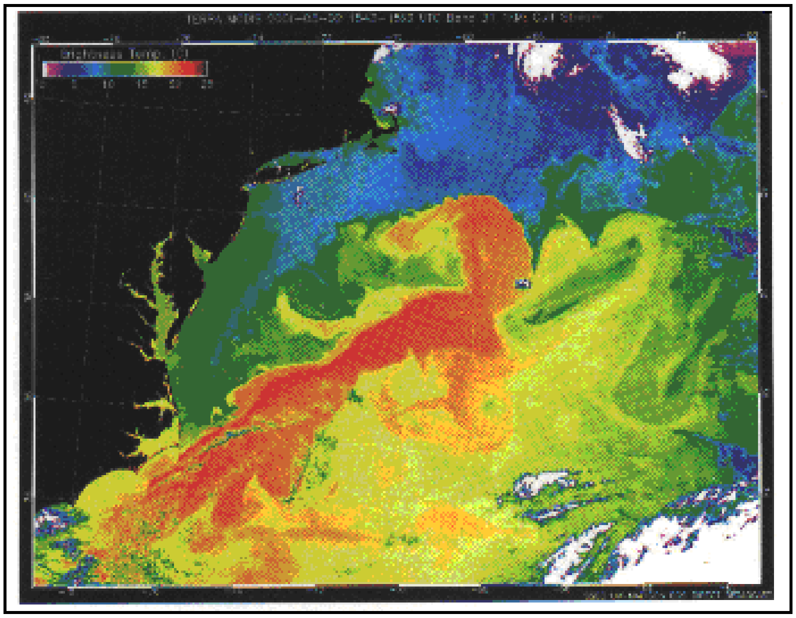


Figure 1 Thermal infrared image for Gulf Stream, E-N USA.
(Source: University of Wisconsin-Madison Space Science and Engineering Center)

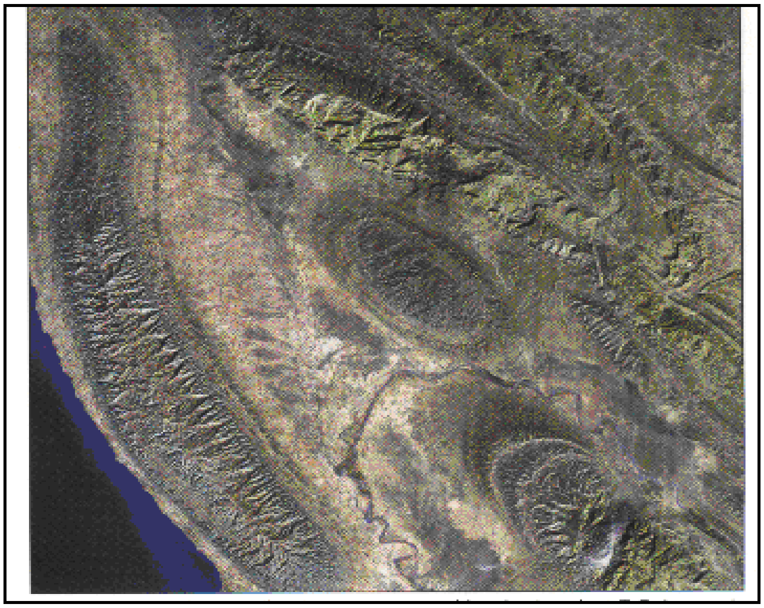


Figure 2 satellite image for Mand River and the small town of Konari nestled in the Zagros Mtn. of W. Iran. (Source: USGS EROS Data Center Satellite Systems Branch)

1.3. GIS and Remote Sensing:

Remote sensing is included within the broader field of "geomatics" which are the group of technologies and disciplines that collect, store and analyze geospatial information. Geomatics also includes such disciplines as geographic information science, surveying and cartography. Many applications implemented using GIS depend on datasets derived from remotely sensed imagery or make use of the imagery directly as a background in graphic displays, the digital remotely sensed data can be directly imported into a GIS and the photographic image can also be used if they are scanned and rectified to create GIS digital imagery. Improved GIS tools and software packages will make the integration of remote sensing information and GIS possible and easy, (Figures 3, 4).

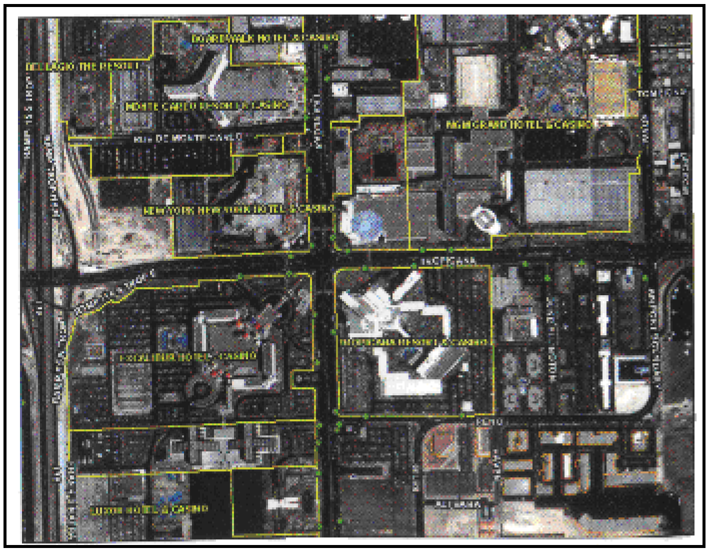


Figure 3 vector data displayed over an orthoimage background in a GIS. (Source: ESRI and DigitalGlobe)

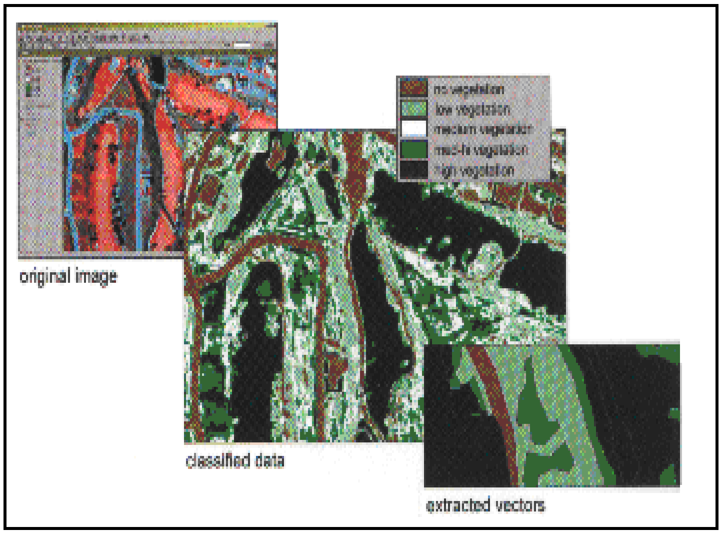


Figure 4 Transfer of remote sensing derived data to a vector GIS. (Source: Positive System, Inc.)

1.4. Brief history of GIS and Remote Sensing:

Remote sensing technology has been used for more than a century. Beginning as photography acquired from tethered balloons and later from aircraft and spacecraft, since the remote sensing has proven to be a versatile and valuable source of diverse geographic information should be focused on its history. Concerning Remote Sensing literature, there are many monographs and professional publications on the technology and its applications. The "Manual of Remote Sensing" is considered authoritative handbook on this technology, also the "Photogrammetric Engineering and Remote Sensing" and the "International Journal of Remote Sensing" are the two most famous professional and academic journals in this field. The following part presents the major events of remote sensing and GIS developments with refer to those references:

1858 – 1918: Aerial photography – from curiosity to practical use.

1918 – 1939: Development of nonmilitary applications.

1939 – 1945: World War II – the military imperative.

1946 – 1971: Continued remote sensing advancement and the introduction of GIS. In 1969 was also the year "Design with Nature" by Ian McHarg was first published, illustrated the technique of using clear plastic map overlays to visually integrate resource datasets the author used for land use planning.

The demand for GIS technology was met by several companies were found in 1969 such as; (ESRI) and Intergraph Corporation (M&S Computing, Inc.) Remote sensing and GIS are complementary technologies, the remotely sensed imagery is a rich source of geospatial data and GIS is a powerful tool used to manage, analyze and display geospatial data. Integrating these technologies has been a challenge.

1972 – 1986: Introduction of satellite – based earth observation.

1986 – 1999: Global competition, increased commercialization and the World Wide Web.

1999 – The present: Commercial availability of very high resolution imagery.

2. Objectives:

The growing availability of remote sensing technology is helping us observe, study and learn about our world in ways we could only imagine a generation ago. Rapidly growing in GIS technology guides to deep understanding for historical, conceptual and practical uses of remote sensing. Since of this powerful technology supports plenty of fields, therefore this paper invaluable for GIS managers to become more knowledgeable users of remote sensing products and services and to manage the development of innovative solutions suited to the needs and goals of their organizations.

This paper starts with general benefits of GIS and Remote Sensing integration technology, history, Overview of key remote sensing and GIS applications and an extensive bibliography with some of case studies, Invaluable for GIS users to become more knowledgeable users of remote sensing technology.

Furthermore, Remote Sensing basics, outlines the characteristics of remotely sensed data, Confronts the challenges of interpreting, managing and storing the ever-increasing range of remotely sensed data available today, covered in the appendix.

3. Methodology:

Despite the wide use of remotely sensed images, GIS users are often unfamiliar with remote sensing techniques and the capabilities of the technology. This paper provides an introduction to remote sensing history, technology, and applications tailored to the needs of GIS managers and practitioners. However, to understand how remotely sensed data can be used; some basic information about what the data represents and the methods used to analyze it is needed. The appendix provide a background to the technology, the fundamental principles on which remote sensing is based, and the instruments developed to detect and record earth observation imagery, as well as to present the principles of visual interpretation and computer-based image analysis methods, which are used for extracting information from imagery in conjunction with other data sources.

My purpose in writing this paper was to collect practical information on remote sensing that would be of value to those who use the data and those who need an appreciation of the capabilities of the technology, This information obtained from the specialized remote sensing and GIS bibliographies which are available from a wide range of service providers that can be found on the Web sites of professional associations in the remote sensing, GIS and geomatics field. Also the professional magazine, text books was used in this purpose. Some of case studies' provided information was obtained from so many published articles, some of those reviewed in the following section.

4. Literature Review:

This term paper prepared based on specialized remote sensing and GIS bibliographies which are available from a wide range of service providers that can be found on the Web sites of professional associations in the remote sensing, GIS and geomatics field. Also the professional magazine, text books was used in this purpose. Some of case studies' provided information was obtained from so many published articles, some of those reviewed in the following section.

(Franklin 2001) emphasized, remote sensing and GIS are complementary technologies that when combined, enable improved monitoring, mapping and management of forest resources. (Wulder, Franklin 2003) and (Michael A. Wulder, Ronald J. Hall, Steven E. Franklin 1999) done a project of Remote sensing and GIS data integration in forestry applications. (Wulder, Franklin 2003) tested Polygon decomposition. In forestry application also (Waring, Running 1998) assigned that, the types of attributes attached to individual mapping units or polygons might include stand species composition, density, height, and age and leaf index. (James D. Hipple et al. 1995) conducted the study of remote sensing in urban infrastructure and business geographic project North America. (Scott Madry 1998) studied remote sensing and GIS in archaeology.

5. GIS and remote sensing integration (Case Studies):

GIS and Remote sensing technology have been applied to a range of applications, in this paper some of those applications were selected to illustrate how the remote sensing serves the GIS technology when data integrated such as; agriculture, forestry, geology, archaeology, military, geospatial intelligence analysis, urban infrastructure and business geographics, meteorology, oceanography and climatology.

5.1. Agriculture:

Remote sensing data is most commonly used to management of food supplies in agricultural production, and assessment of worldwide supply and demand. These analyses will systematically include data on climate, location and environmental quality issues. Specialized image analysis software is used to process the remotely sensed data and then the derived information used within GIS to perform integrated analyses. As an example, so many projects carried out in this field such as; Global Information and Early Warning System (GIEWS) of the United Nations Food and Agriculture Organization (FAO), and also in 1989 Crop Condition Assessment Program of Statistics Canada (CCAP), Figure 5 shows the final results carried out from this project.

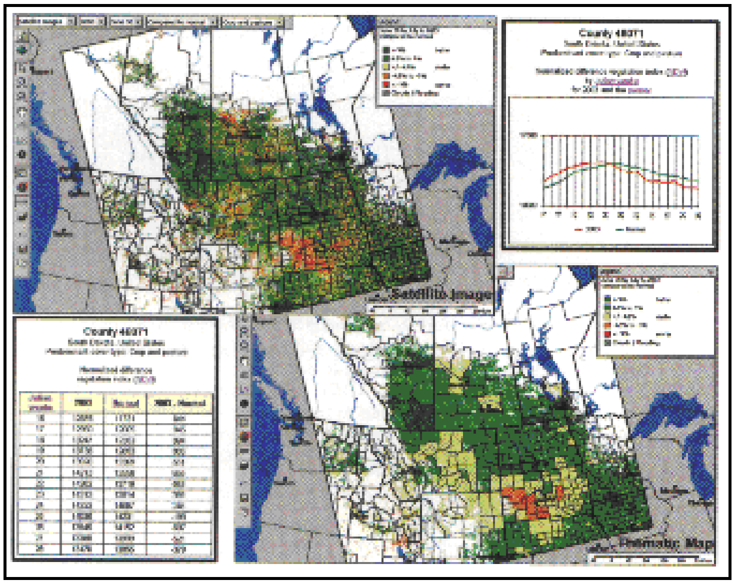
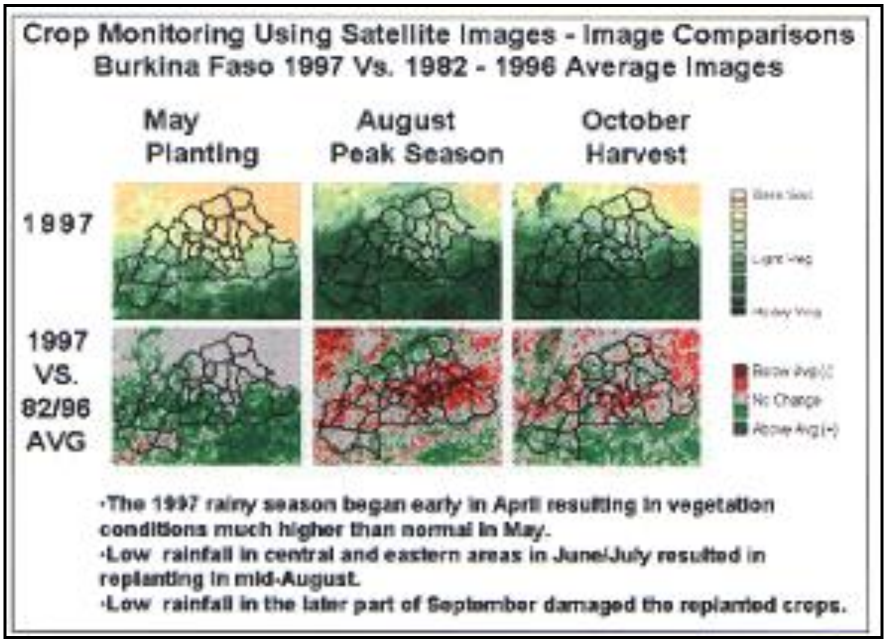


Figure 5 Products available from the Crop Condition Assessment Program. (Source: Statistics Canada)

Figure 6 illustrates the use of NDVI images to monitor crop conditions during 1997 in Burkina Faso, a country in the famine-prone Sahel of West Africa. Cloud-free composite imagery is generated from the daily imagery for a 10-day period. The 10 images are registered, and for each pixel, the NDVI values for the 10 days compared. The pixel with the highest NDVI value (lowest cloud level) is used to produce the composite image. Since clouds appear much brighter than vegetation in both the red and near-infrared bands, pixels depicting clouds are easily identified and not used. To facilitate interpretation, the NDVI values in the images are subdivided into 12 ranges that are color-coded from yellow for low values (indicating bare soil) to dark green for high NDVI values (indicating well-developed healthy vegetation). It is these classified NDVI images that are used by the crop analysts.

The upper row of three images in figure 6 shows the classified NDVI images at the beginning, middle, and end of the growing season (May, August, and October). The bottom row of images shows the difference between the 1997 NDVI values and the 15-year average from 1982 to 1996. The difference image is color-coded by dividing the NDVI difference values into five ranges from red (bellow average) to green (above average). Viewing these images together, the relationship of growing conditions to crop development can be evaluated.


Crop Monitoring Using Satellite Images - Image Comparisons
Burkina Faso 1997 Vs. 1982 - 1996 Average Images

- The 1997 rainy season began early in April resulting in vegetation conditions much higher than normal in May.
- Low rainfall in central and eastern areas in June/July resulted in replanting in mid-August.
- Low rainfall in the later part of September damaged the replanted crops.

Figure 6 Crop condition monitoring by the GIEWS program. (Source: GIEWS and United Nations Food and Agriculture Organization)

5.2. Forestry:

The use of remote sensing by forest managers has increased, and by better integration of imagery with GIS technology and databases as well as implementations of technology that better suit the information needs of forest managers (Wulder and Franklin 2003). The most important forest information obtained form remotely sensed data can be broadly classified in the following categories; detailed forest inventory data (e.g., within-stand attributes), broad area monitoring of forest health and natural disturbances, assessment of forest structure in support of forest management. One of the Case studies done by (Ronald J. Hall) under title GIS, remote sensing and jack pine budworm defoliation in North America, the data used for this study consisted of color and color-infrared aerial photographs, digital forest inventory and site quality data residing in GIS databases, and field observation. Figure 7 shows the final result of that study.

The objective of managing forests sustainably for multiple timber and nontimber values has required the collection of more detailed tree and stand data, as well as additional data such as gap size and distribution. Detailed within-stand forest inventory information can be obtained from high-spatial-resolution remote sensing data such as large-scale aerial photography and airborne digital imagery. Two methods of obtaining this information are polygon decomposition (Wulder and Franklin 2001) and individual tree crown recognition (Hill and Leckie 1999). Integrate of remote sensing and GIS analyses that support insect damage monitoring and mitigation include; detecting and mapping insect outbreak and damage areas, characterizing patterns of distribution relative to mapped stand attributes, modeling and predicting outbreak patterns through risk and hazard rating systems, and providing data to GIS-based pest management decision support systems

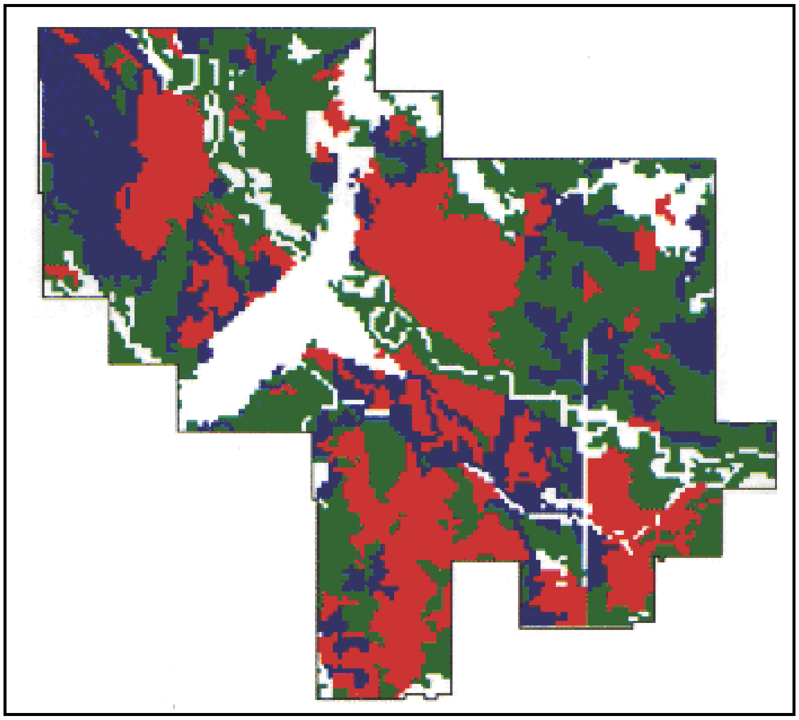


Figure 7 Hazard rating map produced from GIS depicting forest stands that were rated as light (blue), moderate (green) and high (red) hazard to damage from jack pine budworm defoliation (Source: R.Hall.© Natural Resources Canada).

5.3. Geology:

Since the satellite imaging systems born in 1972 was a technological advance of considerable interest to the earth scientists, satellite images gave geologist a unique opportunity to observe the complex interaction of large-scale geological structures that make up earth's landscape (Figure 8). Further, digital satellite data could be manipulated and enhanced in order to accentuate the surface expressions of certain geological features. Today the availability of integration of satellite imagery with traditional exploration datasets and how GIS can be used to integrate multiple datasets to refine interpretation, the diagram in figure 9 illustrates that effective development of new exploration concepts involves the integration of multiple datasets, including seismic, potential field and satellite remote sensing data, as well as structural maps and magnetic models.

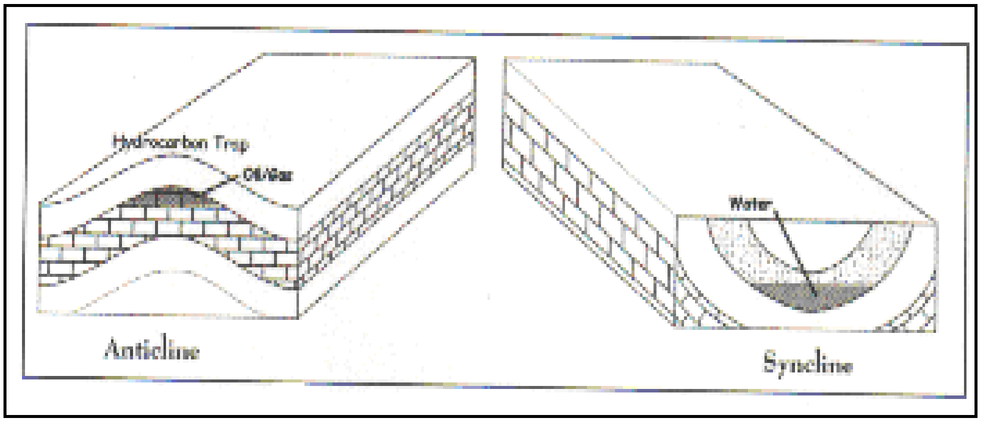


Figure 8 Fold structures, anticlines host hydrocarbon, water accumulates within synclines (Source: Image Interpretation Technologies. Calgary, Alberta)

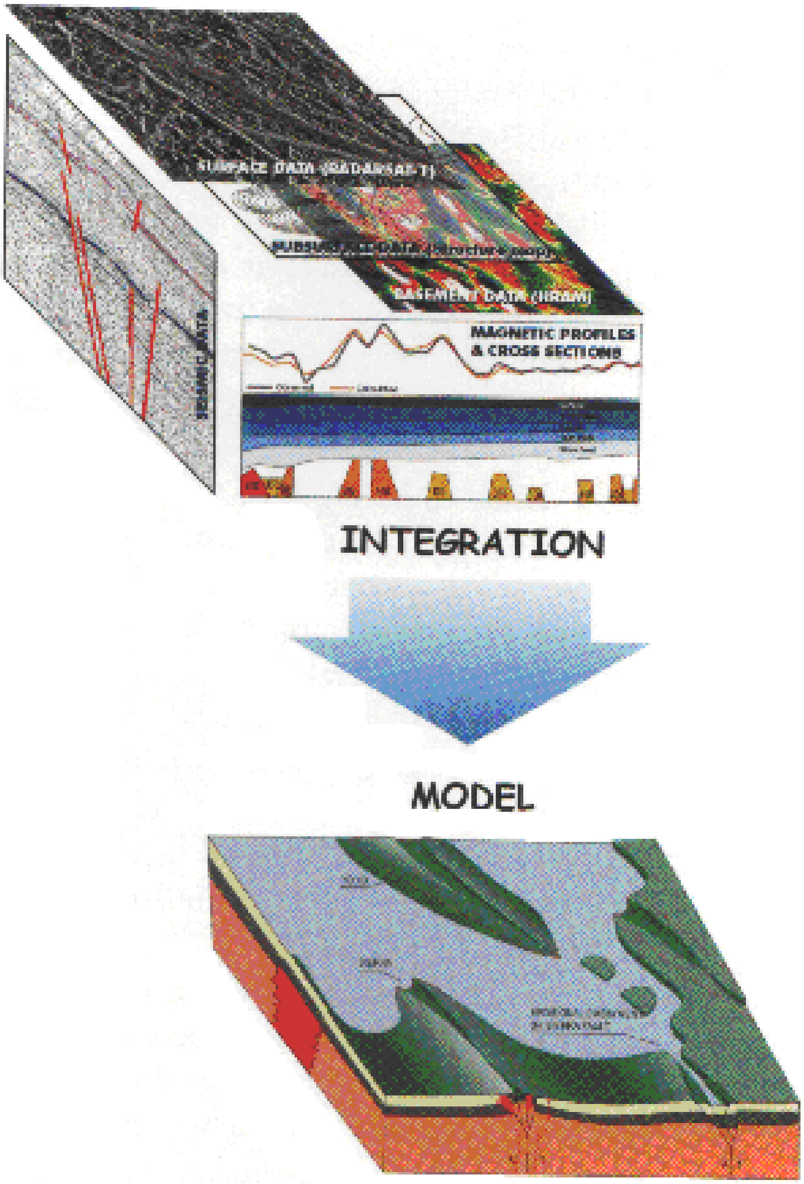


Figure 9 Data integration and development of an exploration concept (Source: Image Interpretation Technologies. Calgary, Alberta).

Integrated geological study of the Gabon Sedimentary Basin one of the case studies carried out in this application (Figure 10).high-resolution aeromagnetic (HRAM) data, Radarsat-1 imagery, and regional seismic data were used to investigate the hydrocarbon potential of deep-seated structures in the Dianongo Trough area of Gabon. The objectives of the study were to improve the understanding of the area's structural style and to relate structures to potential hydrocarbon accumulations. The HRAM data was collected using a fixed-wing airplane over an area 45 km wide and 140 km long. The survey was flown with N-S transverse lines at 600 m line spacing with control lines flown approximately perpendicular at 1800 m line separation. The position of aircraft was maintained using a differential GPS navigation system. A mosaic of the Radarsat-1 imagery was first used to map and evaluate the surface expression of basement structures in the Dianongo Trough, as well as to analyze the exposed basement structures east of the trough. The analysis of the radar imagery identified the dominant faults and fractures system present in the area and the presence of a profound topographic escarpment near the western edge of the exposed basement, which forms the eastern margin of the trough.

The cost of the whole study was approximately $ 240,000 CAD. The most expensive portion of the project was the collection of the HRAM data.

The client for this project received a series of images and maps that illustrated the results of the integrated geological study in both hard-copy and digital formats.

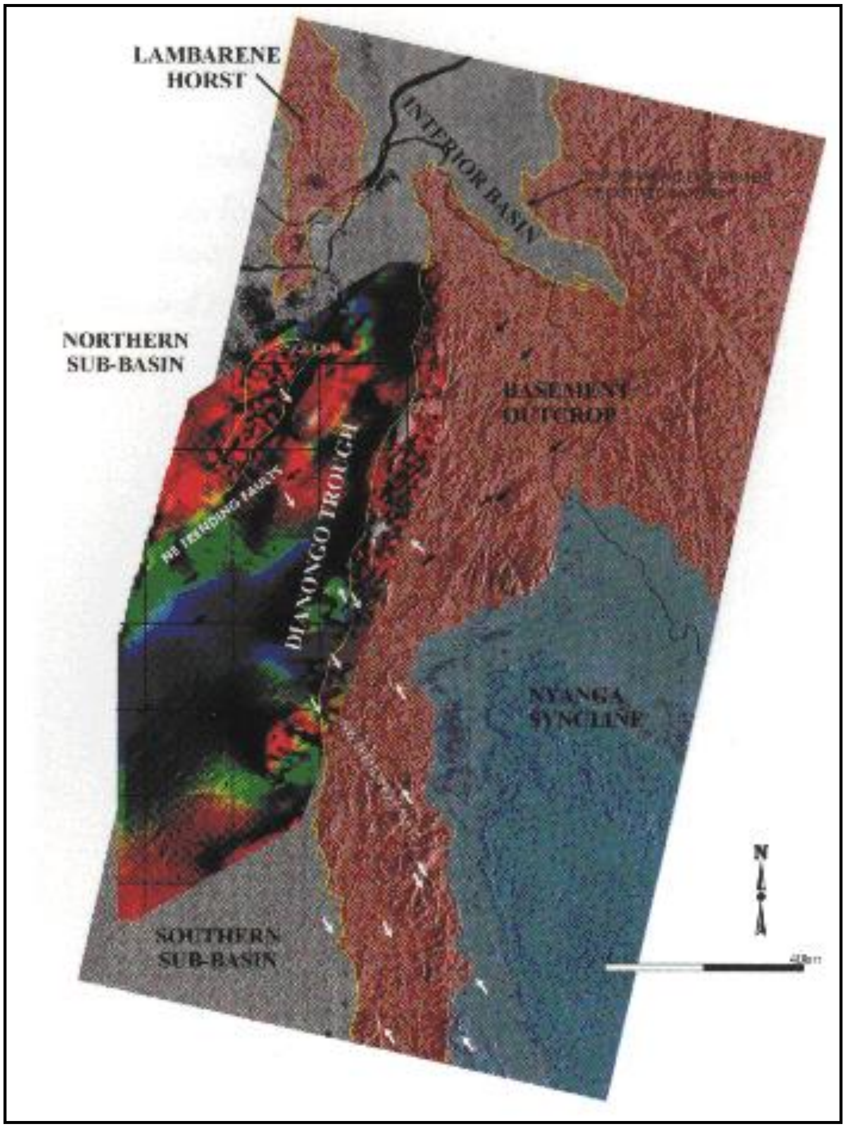


Figure 10 HRAM and Radarsat-1 data integration over the Dianongo Trough, Gabon (Source: Image Interpretation Technologies. Calgary, Alberta).

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6. Discussion and Analysis:

Earth observing sensor packages on aircraft and spacecraft and advanced image processing technologies provide researchers, resource management and policy makes personnel with powerful tools for producing and analyzing spatial, spectral and temporal information. (GIS) provide researchers, resource managers, and decision makers with a tool for effective storage, manipulation and analysis of remotely sensed, other spatial, non-spatial data and information, for scientific, commercial, management, and policy oriented problem solving. As such, these technologies may be used to facilitate measurement, mapping, monitoring, modeling, and management see (figure 11) for a wide range of users.

GIS not only facilitate the use of many types of data, GIS also permit data to be updated readily. Indeed, the synergism between remotely sensed data for updating spatial data/information, and the use of GIS for improving the information extraction potential of remotely sensed data, is a major advantage of the merging of these two powerful technologies. (GIS):

- facilitate access to a variety of data and information,
- facilitate the creation, updating and modification of maps,
- improve our ability to model important science research questions and operational resource management tasks,

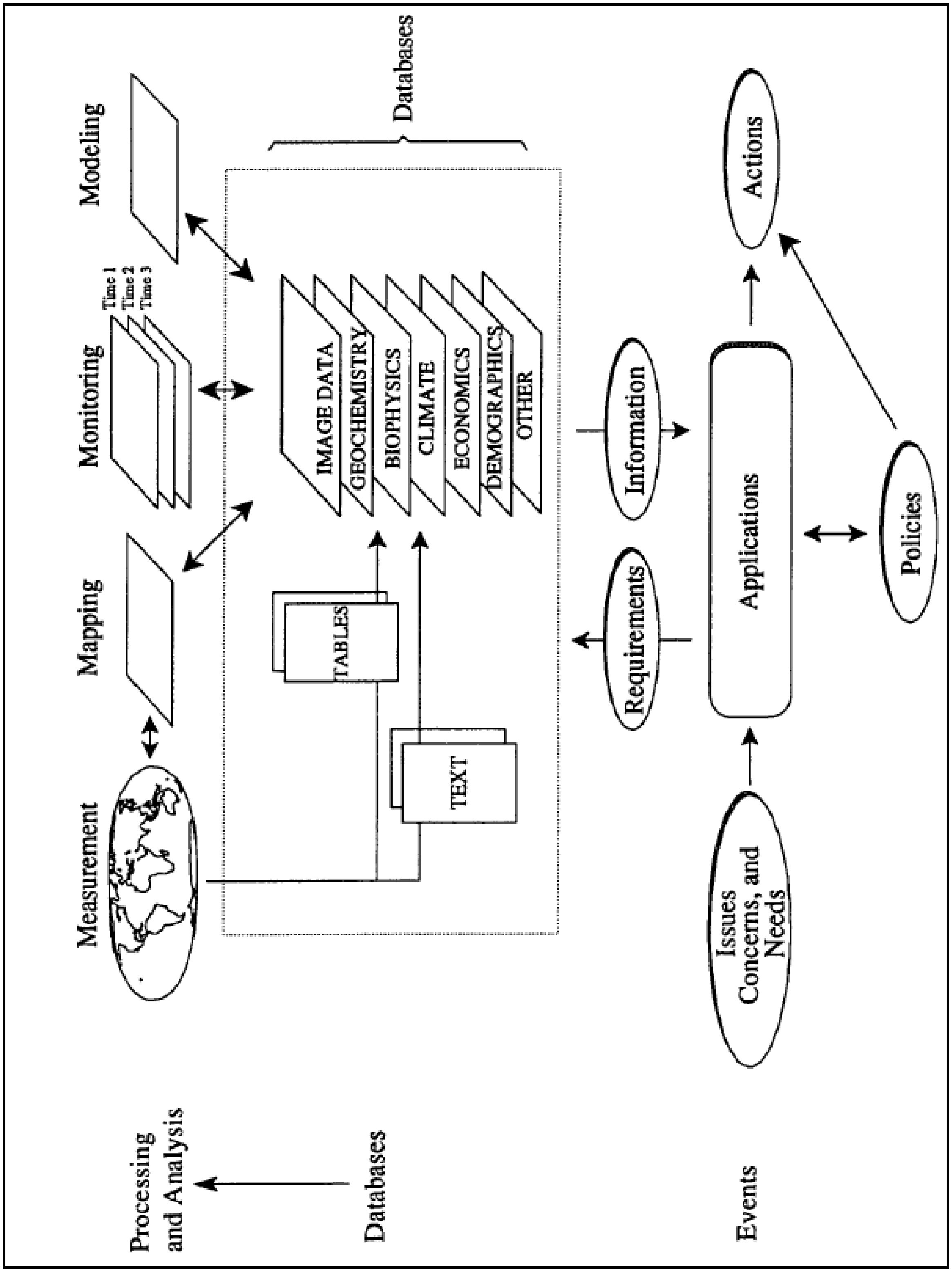

Figure 11 GIS depicted as a decision support system (Source: Image Interpretation Technologies. Calgary, Alberta).

- enhance graphic display of complex phenomena, and thus, our understanding, and
- Provide tools for enhancing decision making.

7. Conclusion and Recommendations:

There is an increasing awareness of the importance of the integration of remote sensing and GIS technologies as shown by the themes of a number of recent workshops and conferences both within the United States and abroad. The trend toward more emphasis on the application of integrated geographic information systems (IGIS, defined here as systems which can process remotely sensed imagery as well as raster and vector data sets in a consistent fashion) stems in part from:

- improvements in the quality and quantity of remotely sensed data available,
- improvements in computer hardware and software,
- increasing population and competition for natural resources,
- decreasing resource availability and environmental quality,
- recognition of the global nature of problems,
- an increase in the number of public and private organizations working on local, national, regional and international problems,
- the creation of larger and larger data bases to provide information in various scales.

These important trends are definitely indications of broader changes that are developing in society in general. They make it imperative for us as researchers to not only improve remote sensing and GIS technology but to widen our focus in order to examine a greater range of science, management, and public policy related issues which can be impacted by an improved synergism these two technologies between both GIS and remote sensing have moved well beyond the novelty stage. These two powerful technologies are being merged.

Researchers in many fields have realized that the synergism created by this merger has the potential for a significant increase in information extraction and analysis for both applied and research operations. Nevertheless, if this potential is to be realized, if we are to use these tools to move to higher levels of understanding, there are a great many steps to be taken.

Acknowledgments:

Acknowledgment is due to King Fahd University of Petroleum and Minerals (KFUPM) for support of this research.

I wish to express my appreciation to City and Regional Planning Department (CRP) for offer this GIS course and provide the exercise training in their GIS work station unit.

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References:

ASPRS.1983. Manual *of remote sensing*. 2nd ed. 2 vols. Falls Church, Va.: American Society of Photogrametry.

Colwell, R.N., ed.1983. *Manual of remote sensing*. Falls Church, Va.: American Society of Photogrametry.

Campbll, J.B.1996. *Introduction to remote sensing*. 2nd de. New York: The Guilford Press.

Campbll, J.B.2002. *Introduction to remote sensing*. 3rd de. New York: The Guilford Press.

Foresman, T.1998. *The history of geographic information systems: Prospective from the pioneers*. Upper saddle River, N.J.: Prentice Hall.

Estes, J.E., and J. Hemphil.2003.Some important dates in the chronological history of aerial photography and remote sensing.

www.geog.ucsb.edu/~jeff/115a/remotesensinghistory.html

The Remote Sensing Tutorial.

Rst.gsfc.nasa.gov/Front/overview.html

1993. The national aerial photography program as a geographic information system resource. *Photogrammetric Engineering and Remote sensing* 59(1):61-66.

The Federation of American Scientists.

www.fas.org

NASA's Visible Earth Image Gallery.

Visibleearth.nasa.gov

Jensen, J. R.1996. *Introductory digital image processing: A remote sensing perspective*. 2nd ed. Upper Saddle River, N.J.: Simon and Schuster.

Lillesand, T. M., and R. W. Kiefer.2000. *Remote sensing and image interpretation*. New York John Wiley and Sons, Inc.

USGS Video Mapping of Coral Reefs.

Coralreefs.wr.usgs.gov

Mather, P. M.1999. *Computer processing of remotely- sensed images*. 2nd ed. New York: John Wiley and Sons, Inc.

Goetz, A. Hyperspectral imaging. University of Colorado at Boulder.

Cires.colorado.edu/steffen/classes/geog6181/goetz/definition.html

ITC.ITC online database of satellites and sensors. International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands.

www.itc.nl/reserch/products/sensordb/searchsat.aspx

Toutin, T., andP.Cheng.2002. QuickBird: Amilestone for high-resolution mapping. *Earth Observation Magazine* 11(4):14-18.

ess.nrcan.gc.ca/esic/ccrspub/index_e.php

Canada Center for Remote Sensing Tutorial on Radar and Stereoscopy.

www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/stereosc/stereo_e.htm

Sabins, F.F.1997. *Remote sensing: Principles and interpretations*. 3rd ed. New York: W.H. Freeman.

Global seafloor topography from satellite altimetry. NOAA.

www.ngdc.noaa.gov/mgg/announcements/announce_predit.html

Blondel, P., and B. J. Murton.1997. Handbook of seafloor sonar imagery. New York: John Wiley and Sons, Inc.

World Data Center for Remotely Sensed Land Data (USGS).

Edc.usgs.gov/wdcguid.html

Agri ImaGis.

www.satshot.com

United National Food and Agriculture Organization (FAO). Global Information and Early Warning (GIEWS) Program.

www.fao.org/giews/english/index.html

Franklin, S. E.2001. *Remote sensing for sustainable forest management*. Boca Raton, Florida: CRC Press.

Remote Sensing Course Online from CTI Center for Geography, Geology, and Meteorology, university of Leicester.

www.geog.le.ac.uk/cti/online/rsonline.html

ESRI: Quik Intro to GIS, ArcView GIS, and ArcInfo.

www.esri.com/industries/k-12/basicgis.html

The Geography Network

www.geographynetwork.com

Canada Center for Remote Sensing (CCRS)

www.ccrs.nrcan.gc.ca/ccrs/homepg.p

Appendix

Remote Sensing Technology

1. Remote Sensing Technology:

1.1. Remote Sensing Basics:

Remote sensing information is based on the analysis of energy received from the features being evaluated, imaging systems such as; an aerial camera and photographic film, systematically record the energy received from an area of the earth's surface and produce a detailed picture of the scene. In order to fully take advantage of remote sensing capabilities, the GIS manager should understand how the remote sensing process works. In context the following part explains how remote sensing system acquire information about the earth features and use that information to produce the data products used in GIS and remote sensing applications.

1.2. The Remote Sensing Process:

Remote sensing system derive information about a feature by analyzing the energy reflected or emitted from it, this process shows in (Figures 1, 2). (a)The source of the energy reflected by the object may be the sun or the remote sensing system itself. (b)The energy illuminating the scene must travel through the atmosphere. (c)The energy reflected, transmitted from the object or absorbed, and then passes through atmosphere. (d)To be detected

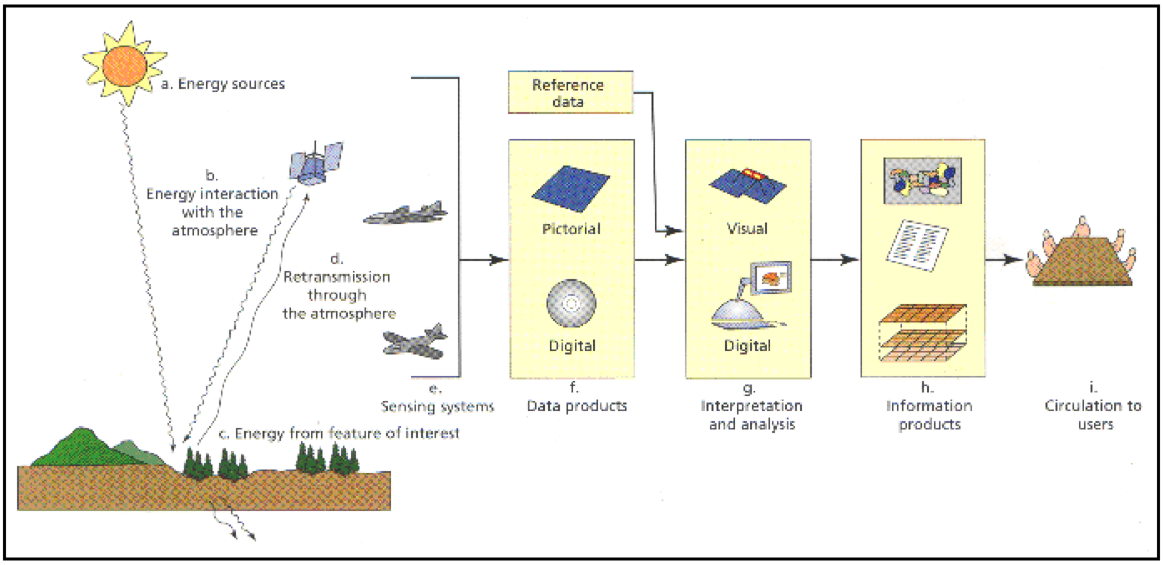

Figure 1 the remote sensing process (Source: Remote Sensing and image interpretation, 2nd.ed.)

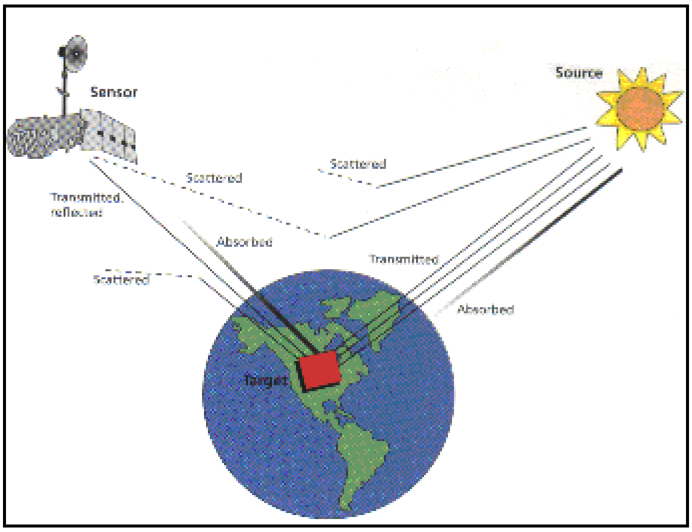

Figure 2 Electromagnetic energy is transmitted, absorbed and scattered by the earth's atmosphere (Source: Remote Sensing and image interpretation, 2nd.ed.)

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by sensor system by using film (photography),electronic detectors (scanner, digital camera) or antennae (radar), and record it as a physical image or as digital data that can be used to generate an image. The recorded data is then processed to generate data products for display or further analysis. This supporting data, as well as analysis results, are commonly stored within a GIS which can offer image-processing capabilities as well.

The information products from remote sensing and GIS may include maps, tabular summaries, images, multimedia presentations and Web sites. They also may be in hard copy or digital format or as data files for input to other information systems such as a GIS.

1.3. Characteristics of remotely sensed imagery:

Differences in the spatial, spectral, radiometric and temporal resolution of remotely sensed imagery affect their suitability for a specific application and the methods used to analyze the data. In addition, accurate georefrencing of the imagery is important to ensure that the information derived from the imagery is accurately registered with any other geospatial data with which it will be used. The growing capability of GIS to make use of remotely sensed imagery has provided GIS users with direct access to this data, both as backgrounds over which to display other geospatial information and as a source of information to update existing data, assess changes at a location over time and other applications, (Figure 3).

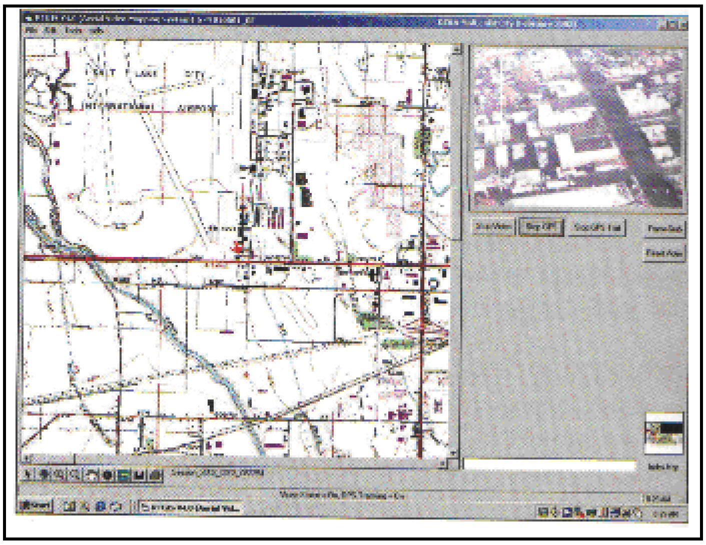

Figure 3 real-time videography integrated with a GIS (Source: BlueGlen Technology, Ltd.)

1.4. Remote sensing sensors systems:

Remote sensing has five types of sensors systems to imagery considered more effective and advance technology, they are; frame-capture sensors and scanning system, satellite-based sensors, active sensors and sonar. The sensors systems will be discussed in this paper represent the remote sensing image source most widely used in GIS.

1.4.1. Frame-capture sensors:

Remote sensing systems that operate in the visible (0.4-0.9µm) portions of the electromagnetic spectrum, they can be grouped into frame-capture and scanning systems. Frame-capture systems such as; Photographic cameras, digital cameras, videography collect images as separate scenes recorded at on instant in time. To record an image of an area, a series of images are captured with overlapping coverage (Figures 4, 5). And create one large image of the area called an "image mosaic" recorded on film as digital images or analog.

1.4.2. Line scanners:

The line scanners operate over a much wider wavelength from about (0.3-0.14μm) and can simultaneously collect data in a greater number of wavelength bonds.

1.4.3. Satellite-based sensors:

This technique operating in the visible and infrared wavelengths, and the availability of continuously collected, complete remote sensing image coverage of the global dramatically changed earth resource inventory and management. Activities ranging from weather forecasting to forestry and from crop monitoring to mineral exploration depend on this flow of data; (Figures 6, 7).

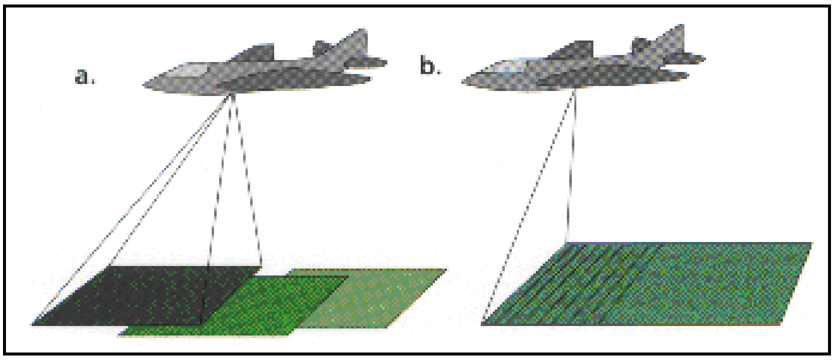

Figure 4 Frame-based and scanning imaging sensors (Source: NASA, JPL, and NIMA)

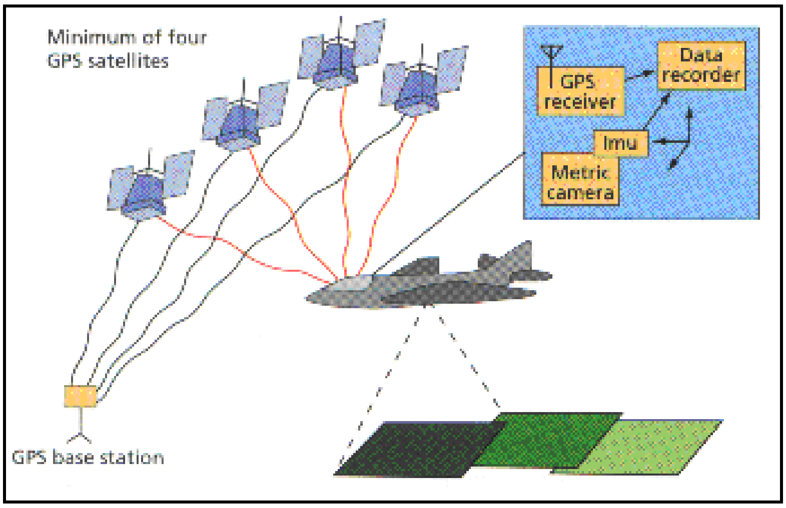

Figure 5 illustration of supporting technology for airborne remote sensing sensors
(Source: NASA, JPL, and NIMA)

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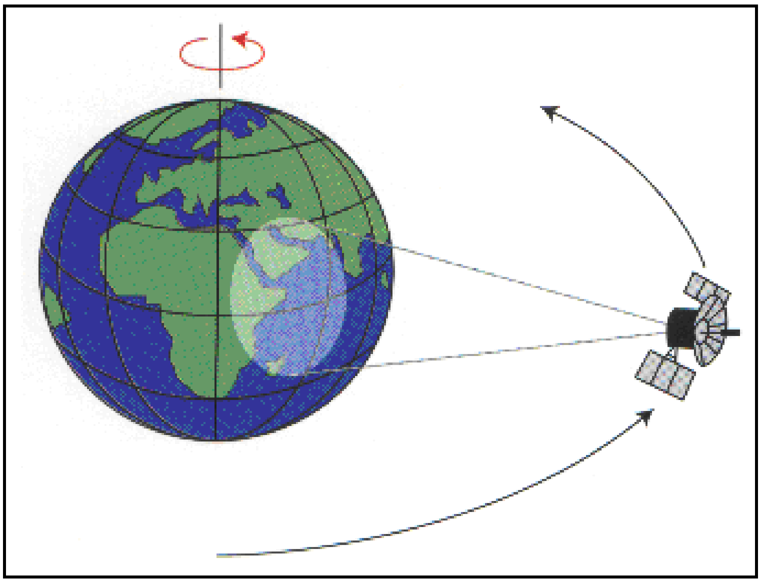

Figure 6 Geosynchronous orbits (Source: © National Resources Canada)

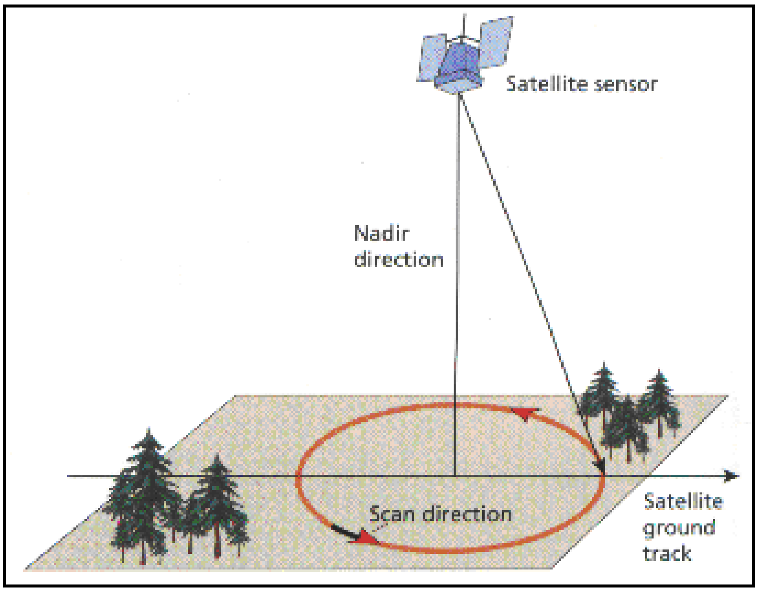

Figure 7 Principles of conical scanning (Source: © National Resources Canada)

1.4.4. Active sensors:

Radar, lidar and sonar remote sensing systems actively illuminate a scene with an energy source and detect the reflected return signals. Radar uses microwave energy (1-100cm), while lidar use lasers operating at much shorter wavelengths in the visible or infrared; (Figure 8). The active sensors have a wide applications such as; engineering and construction, topographic mapping, urban infrastructure mapping, wildland resource management, hydrographic applications, emergency response, image rectification and 3D visualization.

1.4.5. Sonar:

Sonar systems uses sound (acoustic energy) is a form of active remote sensing. Sonar technology is the major remote sensing data sources for imaging and measurement of water depths too deep or with turbidity levels too high for sensors dependent on bottom reflection of visible light, such as lidar. Sonic imaging and classification technologies are being used to map the geology, material composition and habitat of costal and deep ocean regions. In the effort to better manage costal recourses, planners are using geographic and land information systems (GIS/LIS) to plan future land development, assess costal and offshore recourses, mitigate pollution and monitor environmental change within the costal zone over time.

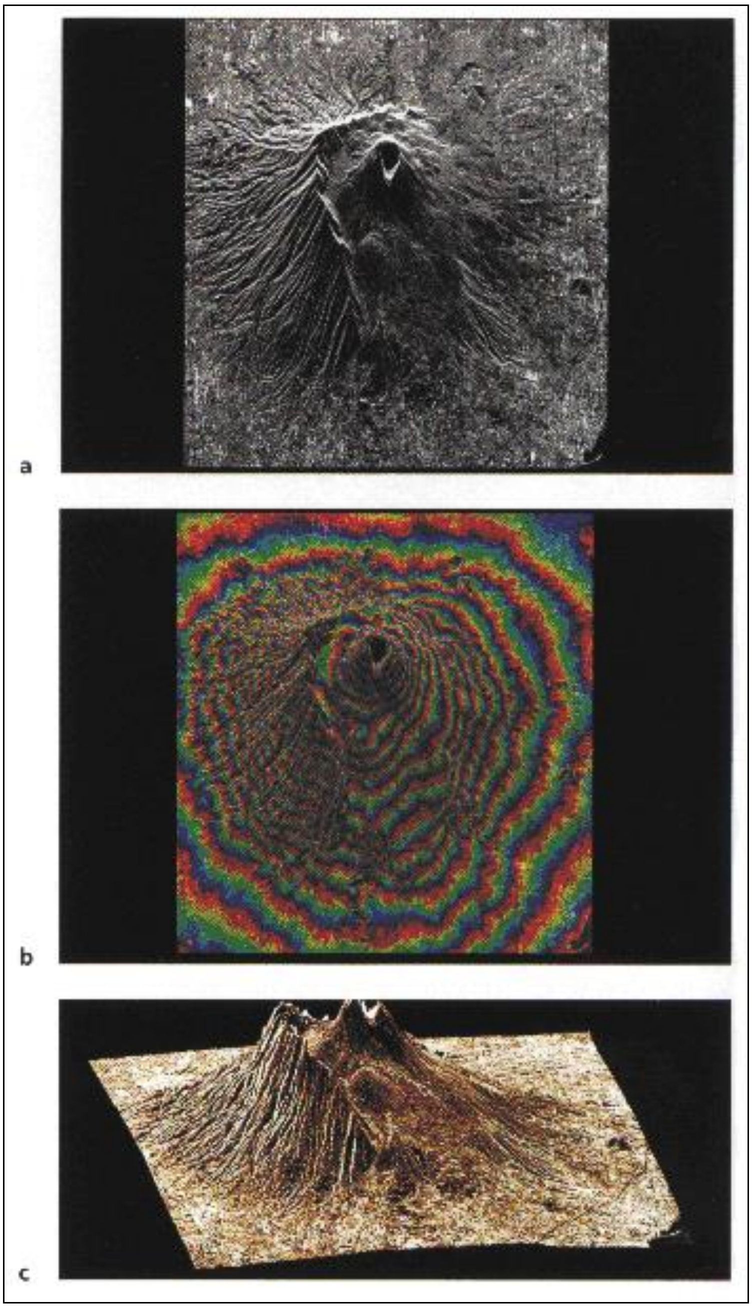

Figure 8 Radar interferometry of Mt. Vesuvius interferometric analysis of an ERS-1 satellite radar image pair (Source: © European Space Agency)

1.5. Visual interpretation of aerial imagery:

Visual interpretation plays an important role in GIS development and application. Until recently, the expression visual interpretation conveyed a very clear meaning, the interpretation of aerial photography, transparencies or paper prints, by a photo interpreter. Image interpretation can provide information not easily obtained from other sources like spatially detailed and taxonomically explicit information which are the more interest in GIS; (Figures 9, 10, 11) shows some remote sensing images interpretations.

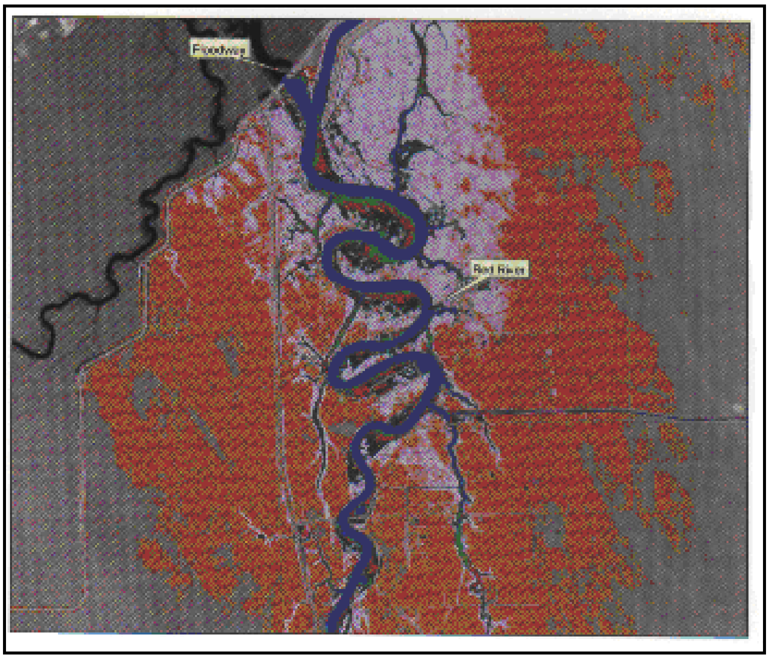

Figure 9 Flood risk mapping, digital elevation models generated from lidar data (Source: Mosaic Mapping System, Inc.TerraPoint USA, Inc)

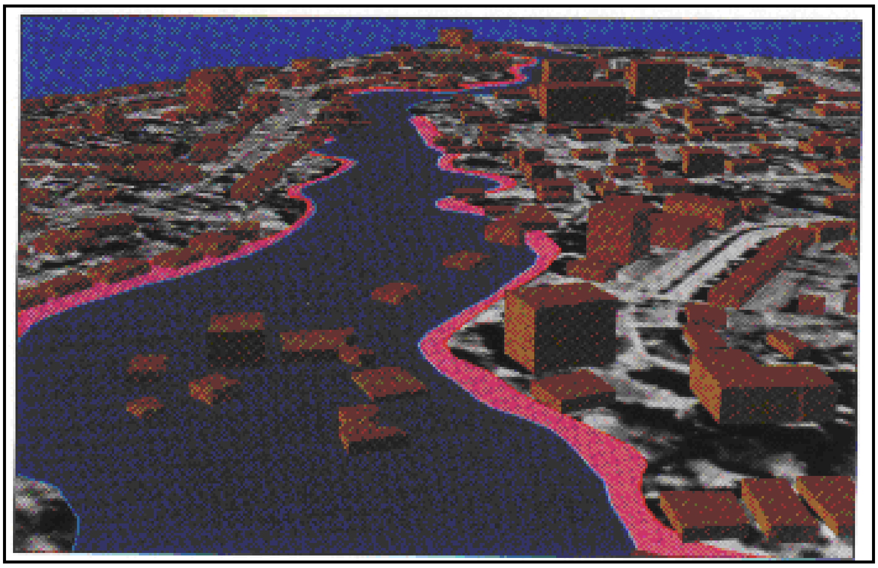

Figure 10 Flood simulations. Lidar data was used to generate a bald earth surface (Source: Earthdata Holdings, Inc)

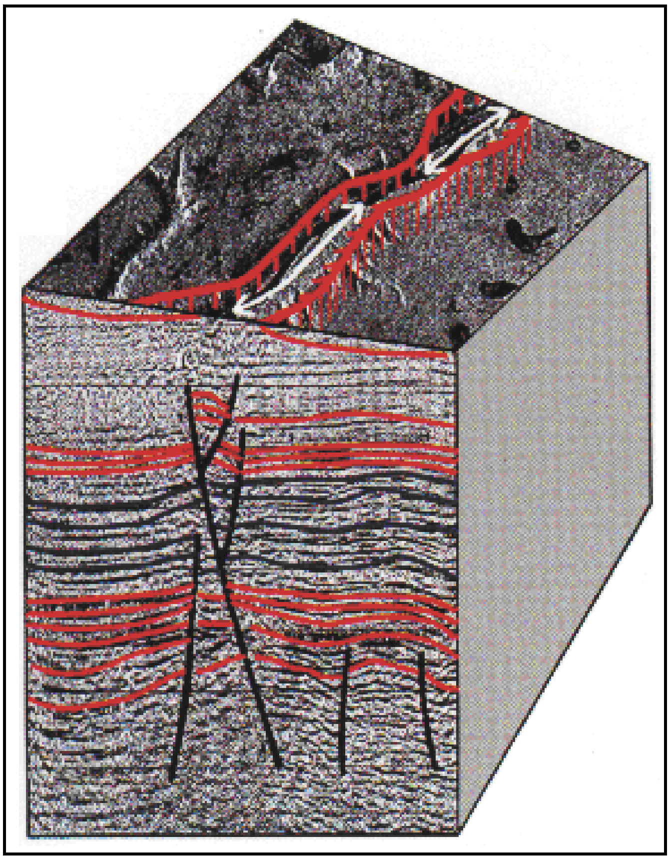

Figure 11 Seismic surveys record the time and strength of sound waves reflected from different rock strata (Source: Image Interpretation Technologies, Calgary, Alberta)

1.6. Digital image analysis:

Digital image analysis is a set of specialized techniques and computer processing tools used to enhance the visual appearance of and extract information from remotely sensed imagery. Remote sensing analysis depends heavily on the use of other spatial datasets such as digital elevation models and various information sources derived from field observations. Most of these data sources can be stored and managed within a GIS environment. The development of more effective methods of data transfer has facilitated the sharing of information between GIS and image analysis systems; (Figure 12) shows an example of this digital analysis.

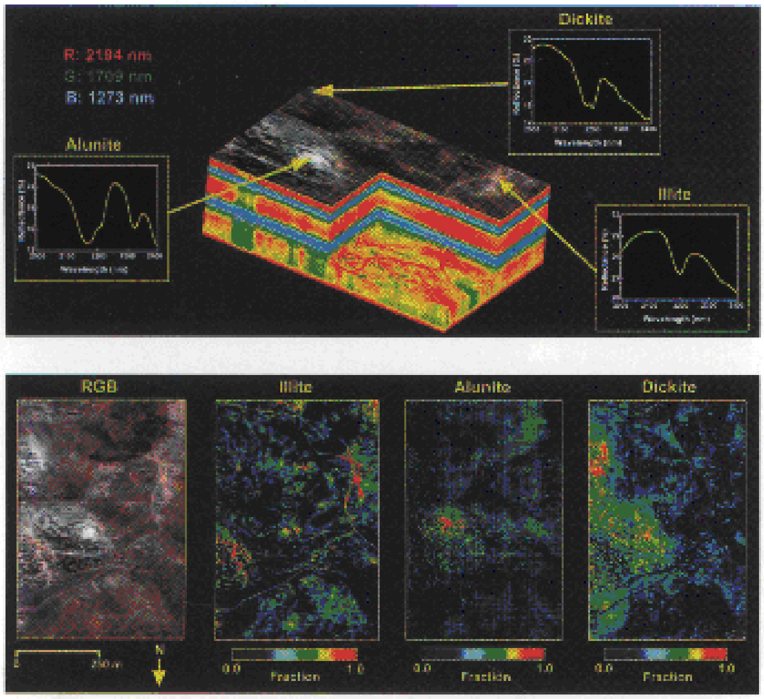

Figure 12 Hyperspectral remote sensing for mineral identification (Source: Intermap Technologies, Inc. Englewood, Colo)