



HAWASSA UNIVERSITY
WONDO GENET COLLEGE OF FORESTRY AND NATURAL
RESOURCES

TRAINING MANUAL ON:
APPLICATIONS OF GEOSPATIAL TECHNOLOGIES IN FOREST
RESOURCE ASSESSMENT



Compiled by:
Habtamu Tadesse (MSc)

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Table of Contents

List of Tables.....	ii
List of Figures	iii
1. Introduction	1
1.1. Resource assessments: forest inventories.....	2
1.2. History.....	4
2. Introduction to Remote Sensing and Basic Principles of GIS	5
2.1. Optical Remote Sensing.....	6
2.2. Components of a remote sensing system	7
2.3. The Electromagnetic (EM) Spectrum	8
2.4. Types of remote sensing systems.....	10
2.5. Image characteristics.....	11
2.6. Classifying the Data.....	12
2.7. Use of remote sensing in forestry.....	15
2.8. The Principles of GIS.....	21
2.8.1. GIS Data Structures.....	24
2.8.2. Global Positioning System (GPS)	27
2.8.3. Spatial Data Infrastructure	30
3. Practical Exercises.....	35
<i>Practical-1: Land use/cover change for assessing vegetation cover conditions of the central rift valley area of Ethiopia.....</i>	<i>35</i>
<i>Practical-2: Using GPS to supplement land cover conditions obtained from analysis of remote sensing products.....</i>	<i>44</i>

List of Tables

Table I: The advantages and disadvantages of the remote sensing approach	15
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List of Figures

Figure 1: Simple Diagram of the Electromagnetic Spectrum.	9
Figure 2: Image characteristics	12
Figure 3: Raster versus vector data structure	25
Figure 4: Vector depiction of objects in a GIS.....	25
Figure 5: Metadata file for Landsat image.....	27
Figure 6: Position of land information system from the information system framework	32

I. Introduction

Many government, state, and private forestry organizations and agencies today utilize geospatial technology such as GIS (geographic information systems), GPS (global positioning systems) and remote sensing for supporting analysis, assessment, and management of our forests. Forestry organizations and agencies have a unique and critical role in the nation's governance. They serve in public land management, private land regulation, and wildfire management. While their significance is growing due to these roles and the increasing impact of forestry on other matters of societal importance, the nation's state forestry organizations should be among the most technology users of any agency. In many countries of the world, several state foresters have indicated that geospatial technology is an invaluable resource whenever they need to understand, communicate, and make effective decisions about conditions on the ground. Forestry has long been and will likely always be a worldwide societal concern with issues that require appropriate attention by government policy makers, such as meeting the demand for forest resources while ensuring conservation and preservation. The emerging global warming and climate change situations are real problems that attract attention of the global community. These problems are believed to be combated with sustainable forest resources management and development. Geospatial technology aids foresters in the acquisition of the data that is necessary to further research, manage, and recover present and future conditions of the global forests. These technologies are applied in:

- Forest inventory (i.e. assessing the type and extent of forest resources)
- Forest harvesting (to study wood procurement problems, to assess the current competition for pulp wood and locate supply sources, geographic distribution of stand development types and changes over time to model timber harvesting,

wood supply and wildlife habitat, in design of logging roads, forest monitoring and forest land allocation)

- Forest fire modelling (using data layers of fuels, topography, weather, structures, water availability and route access)
- Forest ecology
 - Mapping forest types
 - Detection of forest changes
 - Study of forest succession
 - Assessment of stand structure
 - Assessment of physiological parameters
 - Assessment of forest productivity

1.1. Resource assessments: forest inventories

Forest resource assessment is an essential element for obtaining credible estimates of forest resources. Monitoring of the development of forest resources is crucial on deciding between the multiple possibilities that forests bear, including sustainable utilisation and biodiversity conservation. Resource assessment can be extended from traditional forest inventories to cover for instance carbon stocks, land cover changes and non-timber forest products. It is important for inventories to be well-designed and accurately implemented, because the results are used over a period of several years and erroneous information can cause significant financial or ecological losses.

The coverage of a forest resource assessment may range from small forest compartment up to national and even global assessments; and therefore, the methodologies, data needs and their application are heterogeneous. Furthermore, functional information systems enable the optimal use of forest resource assessment

results. Often forest resource assessments require the consideration of current infrastructure and possible development needs for timber harvest and other purposes. An efficient way of completing an infrastructure assessment is by combining it with the forest inventory. The forest and infrastructure assessments are a common prerequisite for harvesting and logistics planning.

It has become an important issue that a strong and close network in information and space technology, including several world leading experts and companies in building remote sensing, GIS, and information systems benefits the forestry sector.

Generally forest inventory is the systematic collection of data and forest information for assessment or analysis. An estimate of the value and possible uses of timber is an important part of the broader information required to sustain ecosystems. When taking forest inventory the following are important things to measure and note: *species, diameter at breast height (DBH), height, site quality, age, and defects*. From the data collected one can calculate the *number of trees per hectare, the basal area, the volume of trees in an area, and the value of the timber*. Inventories can be done for other reasons than just calculating the value. A forest can be cruised to visually assess timber and *determine potential fire hazards and the risk of fire*. The results of this type of inventory can be used in preventative actions and also awareness. Wildlife surveys can be undertaken in conjunction with timber inventory to determine the number and type of wildlife within a forest. The aim of the statistical forest inventory is to provide comprehensive information about the state and dynamics of forests for strategic and management planning.

1.2. History

Surveying and taking inventory of trees originated in Europe in the late 18th century out of a fear that wood (the main source of fuel) would run out. The first information was organized into maps. In the early 19th century, forest harvesters estimated the volume and dispersal of trees within smaller forests with their eyes. More diverse and larger forests were divided into smaller sections of similar type trees that were individually estimated by visual inspection. These estimates were related together to figure out the entire forest's available resources. As the 19th century progressed, so did the measurement techniques. New relationships between diameter, height, and volume were discovered and exploited. These new found relationships allowed for a more accurate assessment of wood types and yields of much larger forests. By 1891, these surveys were conducted through sample-based methods involving statistical averages and more sophisticated measuring devices were implemented. In the 20th century, the statistical method of sampling had become well established and commonly used. Further developments, such as unequal probability sampling, arose. As the 20th century progressed, an understanding of coefficients of error became clearer and the new technology of computers combined with the availability of aerial as well as satellite photography, further refined the process. **Laser scanning** both terrestrially and aerially are now used alongside more manual methods. As a result, sampling accuracy and assessment values became more accurate and allowed for modern practices to arise.

A forest inventory does not only record the tree's height, DBH and number for tree yield calculations. But it also records the conditions of the forest. So this would include: geology, site conditions, tree health and other forest factors. Aside from

field measurement techniques, geospatial technologies like GPS, remote sensing and GIS are becoming fundamental tools of forest resource assessment. Brief explanation of these emerging information systems is presented below.

2. Introduction to Remote Sensing and Basic Principles of GIS

Remote Sensing is a technology for sampling electromagnetic radiation to acquire and interpret non-immediate geospatial data from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere. Remote Sensing is the act of deriving data about the earth's surface, from above it. It is a technique of collecting data about objects without direct contact with the object under investigation. These data are simply records of reflected or emitted electromagnetic radiation from surface features. Observation and measurement of surface objects are done indirectly on photos or satellite images. Previously images were obtained through photography from aircraft for processing into maps. Now the term remote sensing is used most often specifically to satellite-mounted multispectral¹ sensors, such as the Landsat series of satellites. This is normally available in digital format from one of the satellite agencies. Some kind of RS or GIS software is required to be able to read the image, though once the basic map image has been produced, techniques other than GIS can be used to process or manipulate it.

¹ *Multispectral is the term used for recording images at various wavelengths, each as a separate layer related to a given defined image boundary. Singly or in combination they reveal much information about that portion of the earth's surface - what is on it, in it and what it is composed of. When combined and compared with adjoining images a much broader picture can be constructed of the earth's surface.*

Geographical Information Systems (GIS)² are best described as software and techniques for collecting, managing, displaying and analysing information about the earth in a digital form. GIS and RS software share many similar attributes and some software packages claim to be both RS and GIS software. They are similar fields in that they both are concerned with the digital representation of geographic phenomena and often both employ the same spatial analytical techniques to manipulate the data.

Once a remote sensing data (image) has been processed, there are a number of ways in which it can be used and manipulated, using manual and/or digital techniques.

2.1. Optical Remote Sensing

Remote sensing is simply the observation of an object from a distance. Various forms of aerial photography have been used to create maps of the earth's surface since the eighteenth century. Satellite remote sensing can be traced back to the mid- 1940's and the launch of various rockets (the Viking series) from White Sands in New Mexico, and which contained cameras on board. The first satellite sensor dedicated to the multi-spectral remote sensing of earth's surface was launched in 1972. Initially named the *Earth Resources Technology Satellites (ERTS)*, this series was renamed 'Landsat' in 1975, and is still in operation today.

Over the last three decades earth observation has become increasingly sophisticated, with a large number of countries including those in the developing world recently launching their own remote sensing satellites, such as India, Brazil, China and Pakistan. Remote sensing data has proved invaluable in a wide range of research

² A GIS is a sophisticated database management system designed to acquire, image, visualise, and display spatially referenced (geographical) forms of data.

fields, from making maps of the earth surface, to monitoring renewable and non-renewable natural resources, to urban planning. Its success is due to its unique capability to provide near real-time information of the earth's surface at a variety of scales. In addition, the continuous nature of the data acquisition, the regular revisit of the sensor to previously imaged areas of the earth, and the digital nature of the data have all added to its success and reliability.

2.2. Components of a remote sensing system

1. **Energy Source or Illumination** - the first requirement for remote sensing is to have an energy source which provides electromagnetic energy to the target of interest.
2. **Radiation and the Atmosphere** - 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.
3. **Interaction with the Target** - as the energy travels from its source to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
4. **Recording of Energy by the Sensor** - after the energy has been emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation. In order for a sensor to collect and record energy reflected or emitted from a target or surface, it must reside on a stable platform removed from the target or surface being observed. Platforms for remote sensors may be situated on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a

spacecraft or satellite outside of the Earth's atmosphere. Sensors may be placed on a ladder, scaffolding, tall building, cherry picker, crane, etc. Aerial platforms are primarily stable wing aircraft, although helicopters are occasionally used. Aircraft are often used to collect very detailed images and facilitate the collection of data over virtually any portion of the Earth's surface at any time.

5. **Transmission, Reception, and Processing** - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).
6. **Interpretation and Analysis** - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target, which was illuminated.
7. **Application** - 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.

These seven elements comprise the remote sensing process from beginning to end.

2.3. The Electromagnetic (EM) Spectrum

The basic principle underlying remote sensing is the measurement of electromagnetic energy reflected or emitted by various features on the earth's surface or in its atmosphere. The entire array of electromagnetic radiation at its various wavelengths is referred to as the EM spectrum. Wavelengths are measured in micrometers ($1 \mu\text{m} = 10^{-6} \text{ m}$).

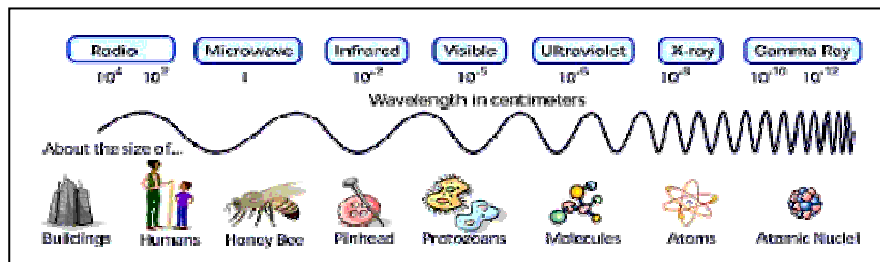


Figure 1: Simple Diagram of the Electromagnetic Spectrum.

At one end of the spectrum are radio waves and microwaves that have very long wavelengths. At the shorter end of the spectrum are x-rays and gamma rays, and in the middle is the narrow range of optical wavelengths visible to human eyes. Various sections of the spectrum are of use in remote sensing. These are primarily atmospheric ‘windows’ – bands of wavelengths where the radiation passes easily through the atmosphere to the surface of the earth. The most commonly used are visible and infrared wavelengths:

- Visible portion, consisting of blue, green and red: from 0.4 μ m to 0.7 μ m.
- Infrared portion, consisting of near, short-wave, and thermal IR: from 0.7 μ m to 14 μ m.

A satellite sensing system will be designed to ‘image’ a certain portion of the spectrum, i.e. to record the amount of radiation reflected or emitted at various wavelengths. In order to collect a sufficient amount of energy to provide a reliable measurement, satellite sensors will record the reflectance over an interval of wavelengths. These are referred to as *channels* or *wavebands*. The Advanced Very High Resolution Radiometer (AVHRR), for example images at one visible channel (0.53 – 0.73 μ m), one near infrared channel (0.73 – 1.1 μ m), two short-wave infrared channels (1.58 – 1.64 μ m and 3.5 – 3.9 μ m), and two thermal infrared channels (10.3 –

11.3 μm and 11.5 – 12.5 μm). It is therefore a *multispectral* sensor, as it images over more than one waveband of the electromagnetic spectrum.

2.4. Types of remote sensing systems

Based on their energy source, remote sensing systems can be classified as passive remote sensing systems and active remote sensing systems.

1. Passive Remote Sensing: - Makes use of sensors that detect the reflected or emitted electro-magnetic radiation from natural (external) sources. The sun provides a very convenient source of energy for remote sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re-emitted, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called passive sensors. Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded.

2. Active remote Sensing: - Makes use of sensors that detect reflected responses from objects that are irradiated from artificially generated energy sources, such as RADAR. Active sensors provide their own energy source for illumination. The sensor emits radiation, which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor. Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. Active

sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Some examples of active sensors are a laser fluoro-sensor and synthetic aperture radar (SAR).

2.5. Image characteristics

Picture Elements or Pixels: A remote sensing image is made up of an array of square *picture elements* or *pixels*. In an optical image the size of the ground area represented by a single pixel is determined by the spatial resolution of the satellite. The spatial resolution can be described simply as the smallest object that can be distinguished from its surroundings. Thus, for images produced by the AVHRR sensor, the pixel size is 1km by 1km. In comparison the Enhanced Thematic Mapper (ETM) onboard Landsat 7 has a resolution of 15m. A pixel in this case thus represents an area of 15m by 15m (or 225m²).

Based on sensor-platform characteristics, a satellite image has four basic characteristics, which we must analyse during selection of images for various applications. These are:

- **Spectral characteristics:** represent portion of the EM radiation that is used by a remote sensing device. They may refer to either spectral coverage (i.e. the entire range of EMR) or spectral resolution (part of the EM spectrum measured by the remote sensor).
- **Radiometric characteristics:** represent either the dynamic range or the radiometric resolution (the smallest differences in energy that can be measured by a remote sensing device).

- **Spatial characteristics:** deal about area. They may be explained in terms of spatial coverage (i.e. area of the earth's surface covered within a single image) or spatial resolution (the smallest unit-area measured).
- **Temporal characteristics:** these properties of images may refer to either temporal coverage (i.e. the total images stored in the archival system of a remote sensing system) or revisit time or temporal resolution (i.e. time between two successive image acquisitions over the same area). Revisit time is related to satellite orbital altitude and inclination.

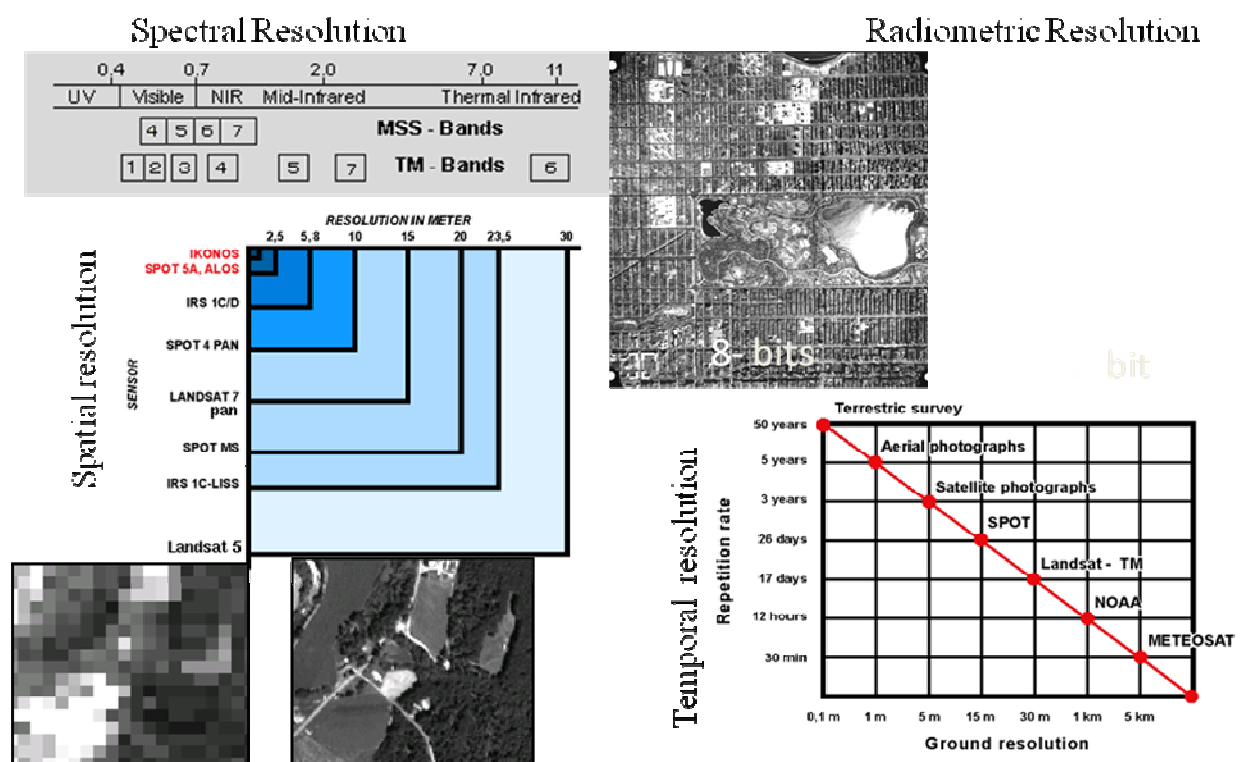


Figure 2: Image characteristics

2.6. Classifying the Data

A primary use of remote sensing data is in classifying various features within a scene into classes, thereby creating a thematic map. In a certain waveband or channel a road, for example, will reflect less energy than the surrounding vegetation, whereas

in other wavebands it will reflect or emit more. Therefore, theoretically, it should be possible to distinguish between different types of surface features based on their spectral responses or 'spectral signatures'.

The more wavebands that are used, the easier it should be to separate different features, as the more detailed their spectral signatures will be. This is the theoretical basis underlying multispectral classification procedures. Although a classification may be performed on a multi-temporal (as opposed to multispectral) dataset, this is only of relevance if distinct spectral changes are expected to take place over time, for example in agricultural seasons and crop rotation or rapidly developing or changing urban areas or in an area of continuous forest cover change.

The theory of classification allows us to perform two basic types of classification (i.e. unsupervised and/or supervised). The main difference between the two is that, during an unsupervised classification, it is the computer that develops the spectral signatures that will be used in the classification process, not the user. In addition, with an unsupervised classification, pixels are assigned to a class based on their spectral characteristics alone. During the unsupervised classification, pixels will be clustered based on the natural spectral groupings present in the dataset.

Exactly how the assignment of a pixel to a cluster takes place will depend on the software used. The most commonly used is the Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm. Pixels are assigned to classes based on their spectral distance from a class mean. This is an iterative process, with the class means shifting after each iteration. The process ends when either a maximum number of iterations have been performed, or a maximum percentage of unchanged

pixels have been reached between iterations. The various clusters created will then need to be compared to *in situ* data, in order to assign meaningful values to them.

In contrast, a supervised classification requires some prior knowledge of the classes present within the scene, in order to create a set of 'training' data from which the spectral characteristics of each class will be determined. The first stage is thus the *training* stage. This involves the identification of areas representative of each class within the image. The DN values of each area are then used to create spectral signatures for each cover type. As the classification will be based on these training sets, it is imperative that they represent the full spectral variation of each cover class.

The accuracy of the final classification is determined by the quality of these training sets, so it is important to spend some time creating these as accurately as possible. Once the training sets have been identified, the image can be classified. Numerous supervised classification algorithms exist. Some of the most common ones that are typically found in image processing software are described briefly in the following box.

Box: Types of Classifier

The *Minimum-distance-to-means* classifier is one of the simplest classification algorithms. The mean spectral value for each waveband, for each cover class is computed. The distance between the values of an unknown pixel is then compared to the mean values for each cover class. Finally, the pixel is assigned to the class to which it is closest. If the pixel value is further from all of the mean values than a user-defined distance, it is classified as 'unknown'.

In contrast, the *Parallelepiped* classifier examines the *range* of the values in each of the training sets. A parallelepiped (a rectangular area) is defined surrounding the mean value of each class – if the pixel value lies within the parallelepiped it is assigned to that class. If the pixel falls within more than one class, it is assigned to an 'overlap' class, and if it falls in none, it is assigned to 'unknown'.

Finally, the *Maximum likelihood* classifier examines both the variance and covariance of the spectral signatures for each cover class in order to classify a pixel. The probability that a pixel belongs to a certain class is calculated, with the pixel being assigned to the most likely class – or labelled 'unknown' if all the probability values are below a user-defined threshold.

Table 1: The advantages and disadvantages of the remote sensing approach

Advantages	Disadvantages
It is relatively inexpensive. The cost of software and data (which often represents a one-off cost) is less expensive than sending teams of surveyors out into the field.	There will be doubtful and uncertainties of classification related to pixel size. A full field check will be necessary to resolve ground use in these areas.
Current (within reason) data availability. One particular problem that the developing world faces is that data is old or out of date. Satellite imagery can be acquired for free from the last decade and contemporary data can be acquired fairly inexpensively	Datasets from multiple sources are sometimes difficult to georeference. Using images and maps that are drawn in different scales and projections can lead to difficulty combining them.
Provides data about large areas	The sensor performs a sweep and as such can create errors. i.e., only some of the image is directly below the sensor and so pixels toward the edge of the image may be distorted.
Provides data about inaccessible areas - or even if they're not inaccessible, at least you don't have to go there.	Objects in the image can be confused or mis-classified. For example, shadows may look like metalled roads.
Rapid production of maps is possible	To get any level of detailed, current data and to buy specialist remote sensing software can be expensive
Easy to manipulate (relatively!) with computers and derive information for map production.	In some active sensing systems (such as LiDAR) the sensor and source are moving relative to each other distortions can creep to the image. This is a form of Doppler effect (visual equivalent of a police siren changing pitch as it moves closer/further away from you).
Rapid collection of data – much more efficient than ground survey!	

2.7. Use of remote sensing in forestry

Forestry applications of remote sensing include the following:

a) Reconnaissance mapping

Objectives to be met by national forest/environment agencies include forest cover updating, depletion monitoring, and measuring biophysical properties of forest stands.

1. Forest cover type discrimination
2. Agro-forestry mapping

b) Commercial forestry

Of importance to commercial forestry companies and to resource management agencies are inventory and mapping applications that encompass collecting harvest information, updating of inventory information for timber supply, broad forest type classification, vegetation density, and biomass measurements.

1. Clear cut mapping / regeneration assessment
2. Burn delineation
3. Infrastructure mapping / operations support
4. Forest inventory
5. Biomass estimation
6. Species inventory

c) Environmental monitoring

Conservation authorities are concerned with monitoring the quantity, health, and diversity of the earth's forests. They are interested in assessing:

1. Deforestation (rainforest, mountain forest depletion, etc.)
2. Species inventory
3. Watershed protection (assessing and managing of riparian strips)
4. Coastal protection (forests at shores of water bodies like lakes and seas)
5. Forest health and vigor

Deforestation

Deforestation is the permanent destruction of forests and woodlands. It affects the quality and quantity of forest ecosystems, which are believed to be important sources of products and services to humans and other living things. It has been an

issue high on the global environmental agenda for many years; and remains a serious problem today. In the tropics and many other parts of the world, nations continue to lose their natural forests - along with valuable biodiversity, soil and water conservation, and climate regulation these ecosystems provide.

Drivers of deforestation

There are many causes of deforestation however harmless they may seem. So much damage can be done by even a single chainsaw, because behind those chainsaws are huge companies that care only about demand and profit, and forests are needed to supply this.

Commercial Exploitation

The first and most important cause of deforestation is wood extraction. Wood has always been a primary forest product for human populations and industrial interests. Since wood is an important structural component of any forest, its removal has immediate implications on forest health. Intensive harvests can lead to severe degradation, even beyond a forest's capacity to recover. When the soil has been stripped of its nutrients, farmers move further into the forests in search of new land. Shifting cultivation is one of the most unproductive uses of farmland, and a major cause of degraded land where forests cannot regrow.

Timber is one of our most precious as well as used resource. We use it to build our houses, furniture and stock our fireplaces. This heavy demand fuels the destruction of our forests at an unsustainable rate. For every tree that is logged, 27 are killed or damaged in the process (<http://www.geocities.com>).

Commercial forestry is the leading cause of deforestation. The forces of large global markets for wood and wood products drive the scale of logging activities such as

clear-cutting. The source of demand is increased consumption by the developed world, not population growth. For example, in recent years, the republic of China has shown a huge demand for wood and wood products as a result of the country's massive development achievements. Again, transportation routes have a role, opening up new areas for natural resource exploitation. Privatization of natural resource industries has led to decreased regulations regarding timber harvesting. Multinational companies for whom improvement of forest practices is not a priority often export the timber in an unprocessed state out of the country of origin.

Mining for precious resources also plays a major role. There are many forests that hold fair amounts of earth's resources, such as iron ore, copper, oil and other precious metals. Many mining methods such as strip-mining and strong-force hoses break down the earth and cause major erosion. The mining sites are large and many trees need to be demolished to make way for them. When nothing is left to be mined, there is little chance of the forest growing back because of erosion and the lack of nutrients in the soil, which was churned out during mining.

Cattle Ranching

A cattle ranching involves hundreds and thousands of cattle grazing on expansive areas in and near forests. Because the forest soil isn't adapted to these conditions, it isn't long before the area becomes unproductive. So cattle ranchers expand their grazing area, leading to more destruction. After the grazed land is left, the forest is very unlikely to grow back due to the stripping of the soil. A cattle ranching, each year in this manner, destroys an estimated 5700 square miles of rainforest alone.

Development

People destroy or degrade forests because, for them, the benefits seem to outweigh the costs. Underlying causes include such issues as poverty, unequal land ownership, women's status, education and to some extent, population. Immediate causes are often concerned with a search for land and resources, including both commercial timber and fuel wood. In many areas, rural households rely solely on fuel wood collected from the forest for their domestic energy supply (Wallmo, et. al., 1998).

The roads that are built into a forest ecosystem encourage and provide access for settling activities. In north-east India road building is often wrecking destruction on the forests. A road is cut through a hill face and the first loss is of the trees along its trace. The debris is thrown down, destroying the trees below, leaving a trail of dead or wilting trees in its wake. This debris enters the valleys, pushing up the levels of streams and rivers, causing siltation and floods (Bhasin, 1991).

Some of the causes of migration to the tropical forests are population growth and political persecution. The settlers clearing and cultivating the land do not have the knowledge and experience of indigenous peoples of the forests and are unable to utilize the land effectively or sustainably. The process of shifting cultivation is accelerated and as a result the forest doesn't have enough time to recover. Tropical rainforests are truly under the assault by humans (Anderson, 1990).

Agriculture

Mono-cultural forestry simplifies the ecosystem, leaving it vulnerable to disease and other environmental factors (EPA, 1999). In the tropical forests of the world, the clearing of land for agriculture and livestock are the primary activities resulting in deforestation. The main cause is unequal distribution of land (Anderson, 1990).

In many countries in Asia and Africa, where family farms are still prevalent, the breakdown of large joint-families is causing uneconomic divisions to existing farms. These inefficiencies, in turn, put pressure on farmers to sell their land for development, and it turns whole farming communities into new developments (Bhasin, 1991).

Poverty and Inequality

Another cause of the ecological crisis of the present is social inequality. Gender inequality is one of the more powerful forces at work, which exists in virtually all of human cultures. The natural world is often portrayed as feminine, in terms such as “Mother Nature,” “virgin forest,” “exploitation” and “rape of the valley” that are used to describe elements and uses of nature and serve to perpetuate this harmful attitude. Human society’s attitude with regard to the status of women makes an important contribution to environmental degradation and deforestation (Hui, 1997).

Although it is easy to assume a strong connection between population growth and deforestation (Preston, 1994), some research indicates that the problem is more complex. It involves non-demographic mechanisms resulting from credit and capital market failures, lack of suitable mediating institutions securing property rights, wretched poverty, uneven land distribution, consumption patterns in developed countries, greedy multinational companies, ignorance and bad management by colonist or frontier land, and so forth (Gillis and Repetto, 1988; Bilsborrow and Ogendo, 1992; Myers, 1984; Palloni, 1994).

Beliefs

One of the underlying causes of human exploitation and consumption of forests and other natural resources is human tradition and beliefs. Some community’s beliefs and

attitudes towards forest resources is a destructive nature, which contributes to loss of most forest ecosystems.

2.8. The Principles of GIS

A GIS (Geographical Information System) is a set of tools and services that allow one to collect, organize, manage, analyze, and display georeferenced information (Wing and Bettinger 2008). A GIS can be described as a computer mapping and data storage system, in which data is tied to points, lines, polygons or pixels on a computer display. Rather than just a 'dumb map', in which colours and symbols represent geographical features, the user can interact to varying levels with a GIS. For example, click the mouse on a line and discover the name of the road it represents, it's length, the last time it was surfaced, who carried out the surfacing work, when it will need surfacing again, statistics about the number of road traffic offences committed there in the last year. The possibilities are almost endless.

Additionally, a GIS can use the spatial information it contains in combination with attribute data to perform spatial analysis. For example we may want to know, how many national parks there are within a 500 kilometres radius of Addis Ababa, or how far you could get in a car along a certain route. You could ask what could I see if I look in this direction, stand at this point – or where could you see me from?

Computerized mapping and spatial analysis programs trace their roots to the Harvard University Laboratory for Computer Graphics and Spatial Analysis where in the mid-1960s one of the first GIS programs (SYMAP) was developed. GIS is closely associated and tightly integrated with various aspects of computer-aided drafting (CAD), computer-based cartography, remote sensing, and database management. Over the last three decades, a number of GIS programs have been used for natural

resource management purposes, including those developed by ESRI, Intergraph Corporation, and MapInfo. ArcGIS, an ESRI product, is perhaps the most widely used GIS program in natural resource management, although MapInfo, GRASS, Idrisi, Erdas Imagine, or other commercial or proprietary systems may also be used.

GIS is widely used in natural resource management, and recent graduates of forestry and natural resource programs are expected to be fairly proficient with this tool. Although it was 30 years ago when de Steiguer and Giles (1981) described the potential uses of GIS in forestry and natural resource management, the overall concept has not changed to a great extent. Foresters and natural resource managers are often asked to locate and map areas for timber sales, silvicultural practices, critical wildlife or aquatic habitats, wildfires, urban forests, stream systems, and other landscape features. In doing so, the structural conditions of the vegetation that reside in these areas may need to be analyzed and presented, and alternative plans of action may need to be assessed. While some management-related maps may still be hand-drawn, computerized mapping systems facilitate the rapid analysis of many natural resource management issues and allow the creation of professional maps that guide the management of natural resources.

GIS allows a forester or natural resource manager to use data with two distinctly different data structures: vector (points, lines, and polygons) and raster (grid cells). The choice of data structure employed is generally based on the information available, the purpose of the analysis, and the organizational standards within which one must work. Early in their development, GIS programs needed to be operated on specialized workstations; however, GIS programs can now be installed and used on laptops and personal computers. In fact, some hand-held devices now enable us to

use GIS outdoors in order to display, collect, and manipulate geographic data in real time. Some of the common data collection methods associated with GIS include traditional field data collection processes (i.e., measuring land and trees), scanned images, and digitized features ("heads-up" with personal computers or more traditionally with a digitizing table). Data collected with satellite-based positioning systems (i.e., GPS) or with any of a number of remote sensing devices (e.g., Landsat, Ikonos, IRS, or SPOT satellites) are also commonly used within a GIS. A wide variety of GIS data is available over the internet from both private and public sources. Some types of data that cannot easily be created by a natural resource manager, yet may be essential for natural resource management purposes, such as digital elevation models and digital orthophotographs, can be acquired from other sources or created in GIS. A small sample of the processes that can be performed with GIS include:

- Creating a thematic map. For example, a forester or natural resource manager may need to develop a timber sale map, wildlife habitat map, trail system map, wildfire map, or a general land ownership map. Several variations or versions of the map can be made quickly and can then be printed using a computerized mapping system.
- Querying a database for features of interest. For example, a wildlife biologist may be interested in understanding the location of forests that have structural conditions highly desirable for an endangered species such as the red-fox. In this case, forests with a specific density of trees, size of trees, and species of trees would be of interest. Assuming the appropriate GIS data is available, suitable habitat areas could be located by asking questions of the attribute data describing the forest.
- Defining areas within some proximity of significant features. For example, a

number of land management issues require defining and locating riparian areas or areas near streams. Given a digitized stream system database, the arcs or lines that define the streams can be buffered either fixed or variable distances to provide an approximation of the extent and amount of land within which management activities might be limited or excluded.

- Overlaying two distinctly different spatial databases to address a management issue. One example of this is in understanding the potential issues that may arise when scheduling management activities within a heavily recreated area. In this case, one might first define viewsheds from roads or buffer zones around hiking trails and then intersect these with a database of areas needing a form of silvicultural treatment. Areas of concern would be identified in the resulting overlay process which would then need to be addressed prior to implementing the treatments.

2.8.1. GIS Data Structures

Basically GIS data can be either spatial or non-spatial. The way a GIS represents spatial data is to use data structures to represent geographical object. It does so in two main ways called 'raster' and 'vector' formats.

Raster Data Structure

In a raster data structure, reality is divided into an array of square pixels – each of which has a value. For example, 1 may be road, 2 may be pasture, 3 may refer to water, etc.

The image on the left below shows a raster depiction of a house, by a river with a road serving the house and continuing on past. Each pixel has a code that represents its land type. The advantage of this is that another layer can be placed showing

property value, for example, over this map and a calculation can then be made pixel to pixel through the layers. This can be done with as many layers as needed.

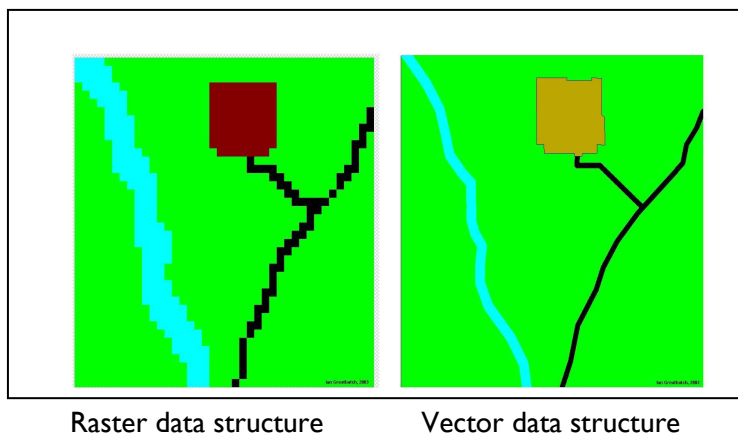


Figure 3: Raster versus vector data structure

Vector Data Structure

The most common form of GIS data structure is the vector data structure or object approach. Geographical objects are constructed of point, lines and polygons. In the view above the house is a polygon, constructed of lines that change direction at points.

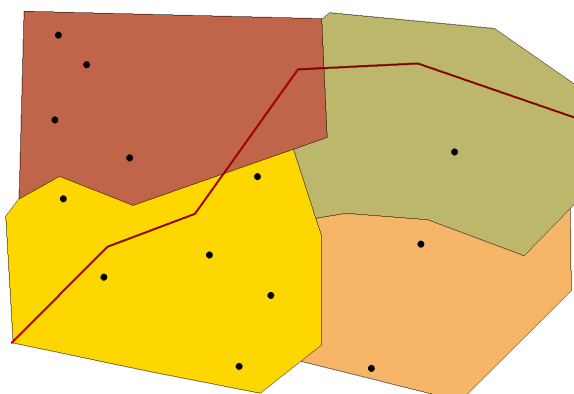


Figure 4: Vector depiction of objects in a GIS

In figure 4, a vector depiction shows the three components used together to depict geographic objects. The points could represent cities, or oil wells – any discreet

location or area that can be represented as a single point on a map, depending on the scale of the map.

The line could represent a road, a river, the route of an exploration or advance – any linear feature. The line is constructed of a series of points, known as vertices. Each vertex defines the point at which the line changes direction. In a GIS some knowledge is built into these lines, so for example the GIS can tell which direction along each line is 'forward' or 'backwards', known as the 'to' and 'from' nodes, or which district or zone is on each side of the line.

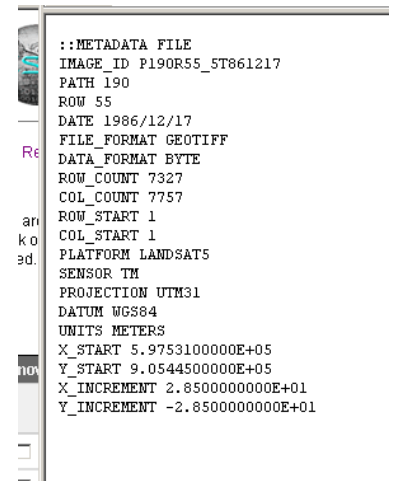
The polygonal theme – which could be districts, property parcels, electoral zone, etc - is constructed of lines (in turn defined by points) that join up to create a closed area.

Uncertainty and Metadata

The problem with the digital representation of reality in this way is that there will always be some kind of abstraction. Reality is immensely complex and maps are generally very simple models of it. A whole sub-discipline of GIS has arisen to discuss the nature of and potential solutions to the uncertainty that arises from this fact and the uncertainty associated with the data upon which GIS maps are based. The problem is that uncertainty is the only really certain thing in cartography / GIS. And the only true strategy for dealing with it is to acknowledge its existence and make some attempt to quantify the level of error or uncertainty in an image.

The best way of doing this is through metadata – roughly speaking, data about data.³

The idea is that when you create a map or an annotated image, you create a file that goes with it – the metadata file – which explains, for example, where the image / map came from, what was done to it and when. This allows anyone who uses the image after you to quantify the error or uncertainty associated with the image. Figure 5 shows a metadata file for a Landsat image from ESDI.



```

::METADATA FILE
IMAGE_ID P190R55_ST861217
PATH 190
ROW 55
DATE 1986/12/17
FILE_FORMAT GEOTIFF
DATA_FORMAT BYTE
ROW_COUNT 7327
COL_COUNT 7757
ROW_START 1
COL_START 1
PLATFORM LANDSAT5
SENSOR TM
PROJECTION UTM31
DATUM WGS84
UNITS METERS
X_START 5.9753100000E+05
Y_START 9.0544500000E+05
X_INCREMENT 2.8500000000E+01
Y_INCREMENT -2.8500000000E+01
  
```

Figure 5: Metadata file for Landsat image

However, some metadata standards can be extremely exhaustive.

2.8.2. Global Positioning System (GPS)

GPS is a global positioning system that uses satellites to pinpoint your location anywhere on the planet. Today, many people use satellite-base positioning systems for navigational and data collection purposes. Satellite-based positioning systems are commonly available in motor vehicles, boats, and airplanes and a wide variety of specialized hand-held devices are available for purchase on the open market.

How does it do that? A GPS - enabled device - such as a cell phone, car navigation system, or handheld GPS unit - determines your location by measuring the time delay between when a satellite sends a signal and when your unit receives it.

While we typically focus on the receiver that is being used to determine a position on Earth, a complete satellite-based positioning system actually consists of control

³ Metadata - a set of data that describes and gives information about other data (OED).

stations, base stations, satellites, receivers, and software. A GPS system has three basic components. All of the components must work properly for a GPS device to determine exact position of objects on the earth's surface. The first component is the space segment of GPS, which represents a constellation of about 24 satellites that are arranged in six orbits at an altitude of 20,200Km from the earth's surface and inclination of 55 degrees. Four satellites exist along each orbit. This orientation of satellites enables from 5 – 8 satellites to be available everywhere on the earth's surface at any time. Each satellite emits a coded signal containing information that allows a receiver to determine the time difference between signal emission and signal reception. With the knowledge of the satellite's position in the sky, a receiver can then trilaterate its current position if four signals can be obtained from four different satellites. These signals are constantly emitted from satellites using energy in the microwave portion of the electromagnetic spectrum. Time is measured very precisely by each satellite using atomic clocks. A *Coordinated Universal Time* (UTC), which is a close approximation to Greenwich Mean Time, is used as a standardized time reference.

The second component of GPS represents the user component, which vary in type and cost based on their accuracy. Some may be accurate enough for urban cadastre and military applications; while others may be less accurate that we may use for other applications like natural resources assessment. In general, there are three classifications of GPS receivers: recreation- or consumer-grade, mapping-grade, and survey-grade. Consumer-grade receivers are the least costly (\$100 to \$1,000 U.S. dollars) and provide the least accurate positional information. These receivers are popular among outdoor enthusiasts for navigational and informational purposes, and a wide variety is available for purchase on the open market today. Mapping-grade

receivers are moderate in price (\$1,000 to 10,000 U.S. dollars), and in some cases can provide 1 to 2 m (3.3 ft to 6.6 ft) accuracy in forested conditions (Ransom et al. 2010). These receivers are commonly used for the development of base maps and for research applications. Survey-grade receivers, as suggested by their name, are mainly used for land and water surveying purposes. These receivers are more expensive (more than \$10,000) and in most cases can provide centimetre-level accuracy. The choice of receiver to use will be a function of the applications to which they will be employed, along with other budgetary considerations.

The third component of a GPS system is the control segment of GPS. It consists of five monitoring stations (at Colorado Springs, Ascension Island, Diego Garcia, Hawaii, and Kwajalein Island) and ground antennas located in different parts of the world. Three of the stations (Ascension, Diego Garcia, and Kwajalein) are capable of transmitting data to the satellites, including new ephemerides (satellite positions as a function of time), clock corrections, and other broadcast message data while Colorado Springs serves as the master control station. The Control Segment is the sole responsibility of the department of defense of the US who undertakes construction, launching, maintenance, and virtually constant performance monitoring of all GPS satellites.

Originally GPS was invented for military purposes. With more than 24 GPS satellites in orbit around the Earth, GPS has become very popular for navigation on land, sea, and air, as well as an important tool for map making and land surveying. One important application of GPS is to provide data for GIS and, in fact, the system makes it possible to collect certain kinds of spatially referenced data that it would otherwise probably not be economically feasible to obtain. In natural resource

management, foresters use satellite-based positioning systems to delineate management areas and to collect data regarding roads, streams, and other resources. Wildlife biologists use satellite-based positioning systems to document the locations of wildlife species, their nesting points, and their critical habitat characteristics. Recreational managers use satellite-based positioning systems to map, among other things, trail systems.

Major factor we must consider when using GPS devices include season, time of the day, canopy cover, cloud covers, presence of obstacles like building roofs and electric power lines. Accuracy will vary depending on whether data is collected in open areas or in closed canopy forests, accuracy may vary when using this technology in different forest types, and accuracy may vary when using this technology during different seasons of the year.

Like all such technologies, acquiring skill in the use of GPS requires practice, and organizations which adopt the system must recognize that data accuracy will be relatively low at first but will improve over time as field crews become proficient both with the equipment and with the procedures for its correct use.

2.8.3. Spatial Data Infrastructure

“It is an infrastructure that provides a basis for spatial data discovery, evaluation and application for Macro & micro level planners, implementers, users and providers within all levels of government, the commercial sector, the non-profit sector, academia and by citizens in general.” ----- The SDI Cookbook.

Different sectors need access to coordinated geographic information.

Components of SDI

- Policies & Institutional Arrangements (governance, data privacy & security, data sharing, cost recovery)
- People (training, professional development, cooperation, outreach)
- Data (digital base map, thematic, statistical, place names)
- Technology (hardware, software, networks, databases, technical implementation plans)

We build a SDI because of the following reasons.

- Build data once and use it many times for many applications
- Integrate distributed providers of data: Cooperative governance
- “Location-based management”
- Share costs of data creation and maintenance
- Support sustainable economic, social, and environmental development

Standards may be set for the following.

- Data content
 - Common classifications
 - Common collection criteria
- Data management
 - Metadata
 - Spatial Data Transfer Standard (SDTS)
- Data transfer protocols (e.g., WMS)

Land Information System (LIS)

LIS is important to ensure sustainable development by using our land resources in a proper manner for the most profitable use that has the minimum effect on the society and the environment.

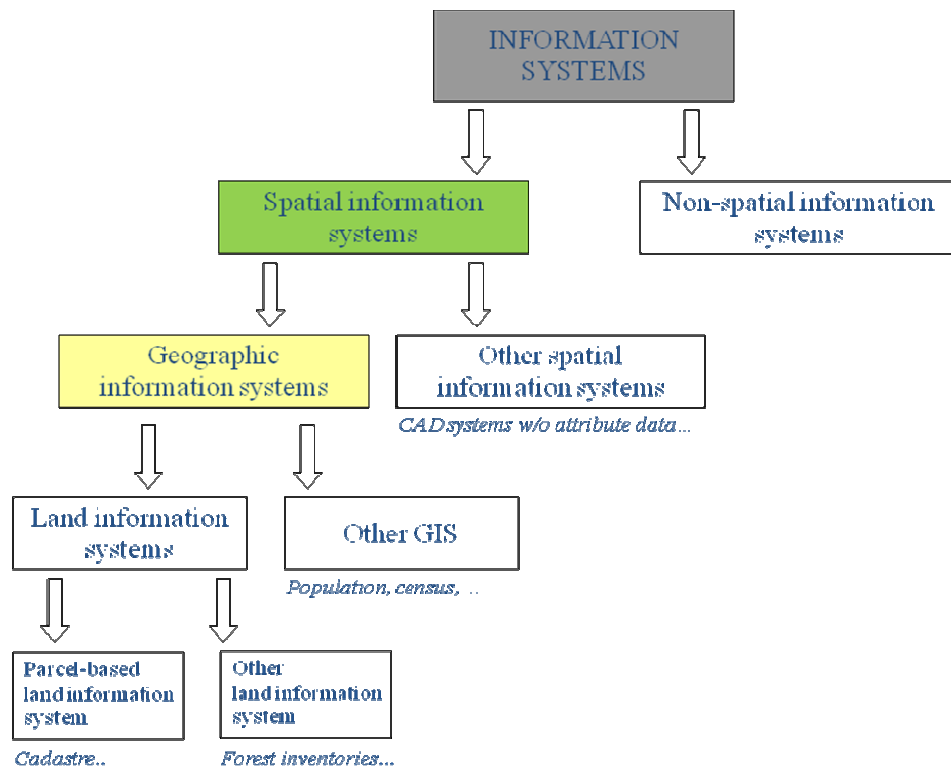


Figure 6: Position of land information system from the information system framework

Forestry data

A forest company or agency that does not have up-to-date, accurate information about its forests cannot make effective strategic decisions. This includes detailed information on forest boundaries, site quality, age classes, conditions of topography and soils and the location and condition of infrastructure. Increasingly, non-timber resource information such as recreation potential and the condition of wildlife habitat is also becoming important for strategic planning. Continuous timber inventories are of course essential, and models should also be developed for projecting growth and yield into the future so that strategy alternatives can be tested using computer simulation models.

From a strategic perspective, forestry organizations require information not only for their own forests but also for the forests of competing and client organizations, or those on which they depend for raw materials.

Market information

Private enterprises, and to some extent also government agencies, rely on markets to set the levels of demand and prices for the goods and services they provide. Information about these markets and how they are likely to change in the future is essential for strategic decision making. Forest companies and agencies should continually ask "What kinds of products and services should be provided?" The answer to this question will change as society changes. Market information and analysis is required to anticipate such possibilities.

Information related to policy and socio-economic considerations

Forestry organizations, whether in the private or public sector, are in the "business" of providing goods and services that the society values. For proper strategic planning, it is thus essential for all such organizations to utilize experts who will help identify trends in the relative values society places on these products and services, and also questions of land tenure, legal status, organizational aspects (unions, associations, etc.), demographics, decentralization, democratization, local governance, etc. In today's fast-changing world, it is becoming clear that forestry organizations that fail to assess this kind of information on a regular basis are increasingly at risk.

Tactical (medium- and short-term) planning

Most of what we normally think of as forest planning is really tactical planning (Davis and Johnson, 1987; Dykstra, 1984). Even though foresters are accustomed to thinking in terms of one or more timber rotation periods, their plans typically

concentrate on five or ten years into the immediate future, with less-detailed projections beyond that point to prevent surprises.

In its tactical plans, the forestry organization provides a tentative answer to the question "What kinds of operations will we undertake during this planning period and where will they be carried out?" For the most part, this is the type of question that makes the forestry profession attractive in the first place, and professionals spend a major part of their careers working to provide answers to it. The answers are always tentative because unseen factors such as changing markets and natural disasters may force fundamental changes in the plan. This does not negate the importance of the plan's quality. The best tactical plans, in fact, provide for such possibilities and make it easier to accommodate changes.

What kinds of information technology can contribute to better tactical planning in forestry? The easy answer is that most of the "traditional" information sources, such as maps and inventories, as well as nearly all the new crop of information systems, are focused squarely on tactical planning. However, providing a detailed, comprehensive answer is more difficult because the field is changing so rapidly and specialized knowledge is required to keep pace with it. Moreover, it is clearly necessary to figure in socio-economic considerations, not all of which lend themselves to information technology "solutions". Nevertheless, nearly all forestry organizations would probably benefit, most of them in substantial ways, from the information technologies described in the following paragraphs.

3. Practical Exercises

Practical-I: Land use/cover change for assessing vegetation cover conditions of the central rift valley area of Ethiopia.



This exercise was done using ERDAS imagine software. Landsat image of 1986 for the central rift valley of Ethiopia was classified into land cover classes of forest, crop land, woodland, barren and grass land. The remaining information classes like settlements and roads were small to be detected in this image and were put in “others” class. The technique of classifying the image into these land cover classes was performed using unsupervised classification. The procedure followed during this practical looks like.

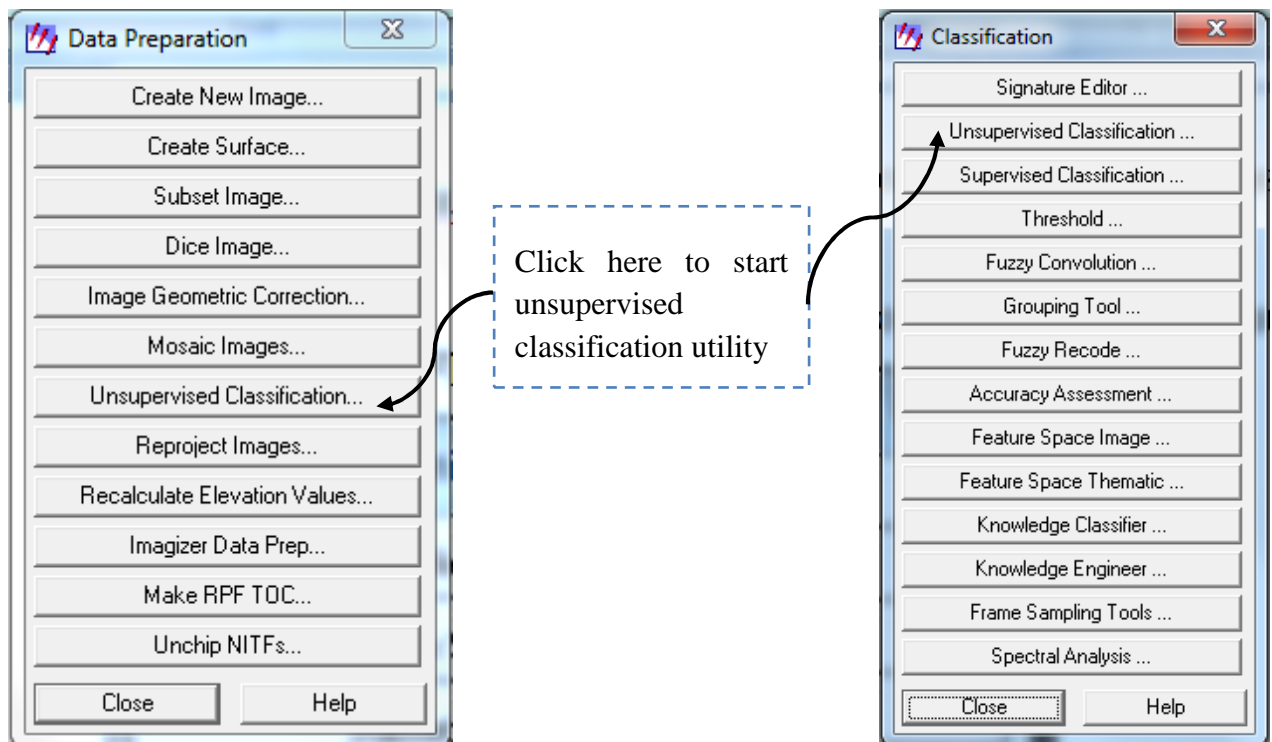
Preparing the data for classification

Any satellite image must be checked for any corrections; be it radiometric, geometric or atmospheric type. For the image used here in this exercise, all were done previously; thus, the image was free of such errors. After making sure that the satellite image is free of error, it is possible to conduct classification to convert it into information classes of interest using any method of image classification. For this exercise, unsupervised classification is applied.

Conducting unsupervised classification

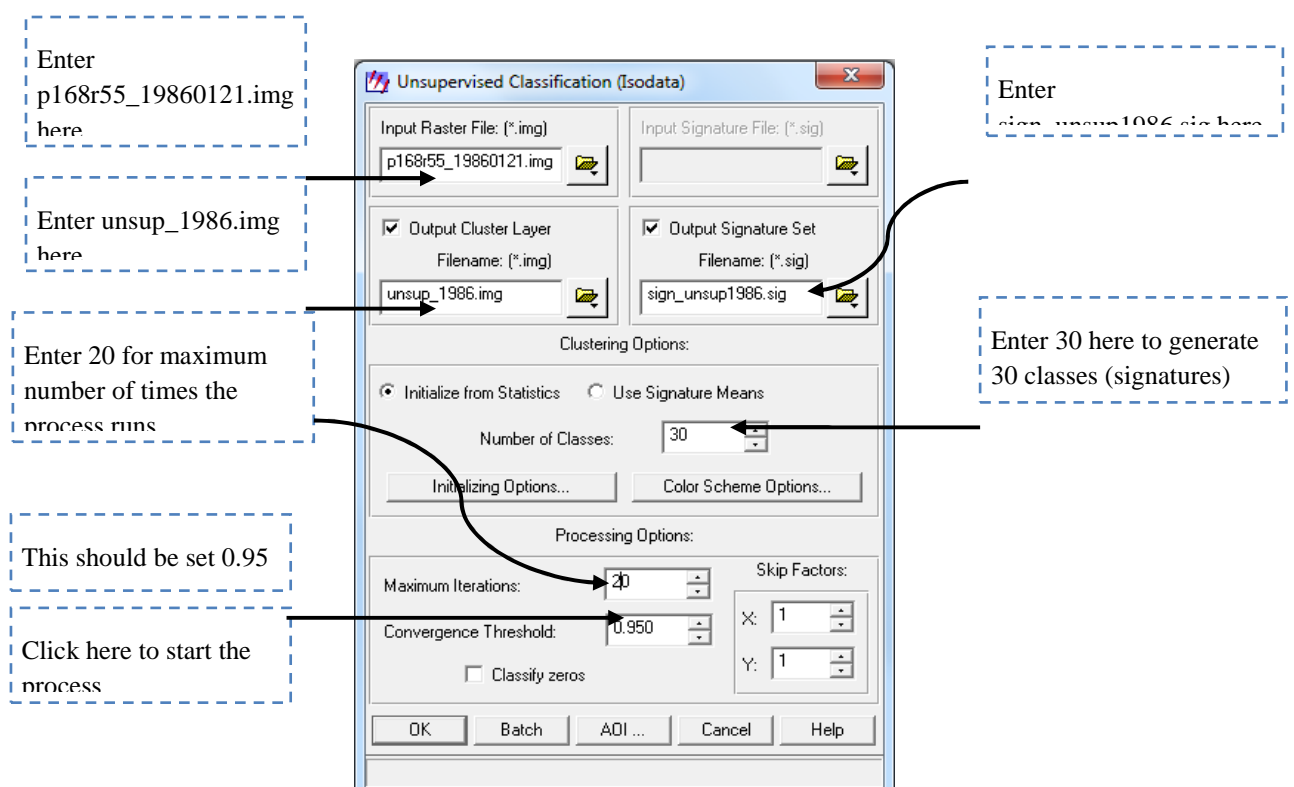
You must have ERDAS IMAGINE running.

1. Click the DataPrep icon  or the classifier icon  on the ERDAS IMAGINE icon panel.
2. The data preparation or classification menu opens.



Generate thematic raster layer

3. Select **unsupervised classification** from the **Data preparation** or **classifier** menu to perform an unsupervised classification using IsoDATA algorithm. The unsupervised classification (Isodata) dialog opens.



ISODATA Classifier

ERDAS IMAGINE uses the ISODATA (Iterative Self-Organizing Data Analysis Technique) algorithm to perform an unsupervised classification. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set. Each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration.

The ISODATA utility repeats the clustering of the image until either a maximum number of iterations have been performed, or a maximum percentage of unchanged pixel assignments has been reached between two iterations.

Performing an unsupervised classification is simpler than a supervised classification because the signatures are automatically generated by the ISODATA algorithm.

4. Click close in the **data preparation** or **classifier** menu to clear it from the screen.

5. In the unsupervised classification dialog under **input raster file**, enter **p168r55_19860121.img**. This is the image file that is classified.

6. Under **output file**, enter **unsup_1986.img** in the directory of your choice.
This is the name for output thematic raster layer.

Set the initial cluster options to define how the initial clusters are generated.

7. Under **clustering options**, enter **30** in the “number of classes” field.

Choose processing options to specify how the process is performed.

8. Enter **20** in the **Maximum Iterations** number field under **processing options**.

This is the maximum number of items that the IODATA utility reclusters the data. It prevents this utility from running too long, or from potentially getting stuck in a cycle without reaching the convergence threshold.

9. Confirm the **convergence threshold** number field is set to **0.950**.

10. Click **OK** in the unsupervised classification dialog to start the classification process. The unsupervised classification dialog closes automatically. A job status dialog displays, indicating the progress of the function.

NOTE: this process could take up to 15 minutes depending upon your hardware capabilities.

11. In the job status dialog, click **OK** when the process is 100% complete.
12. Proceed to the “evaluate classification” section to analyze the classes, so that you can identify and assign class names and colors.

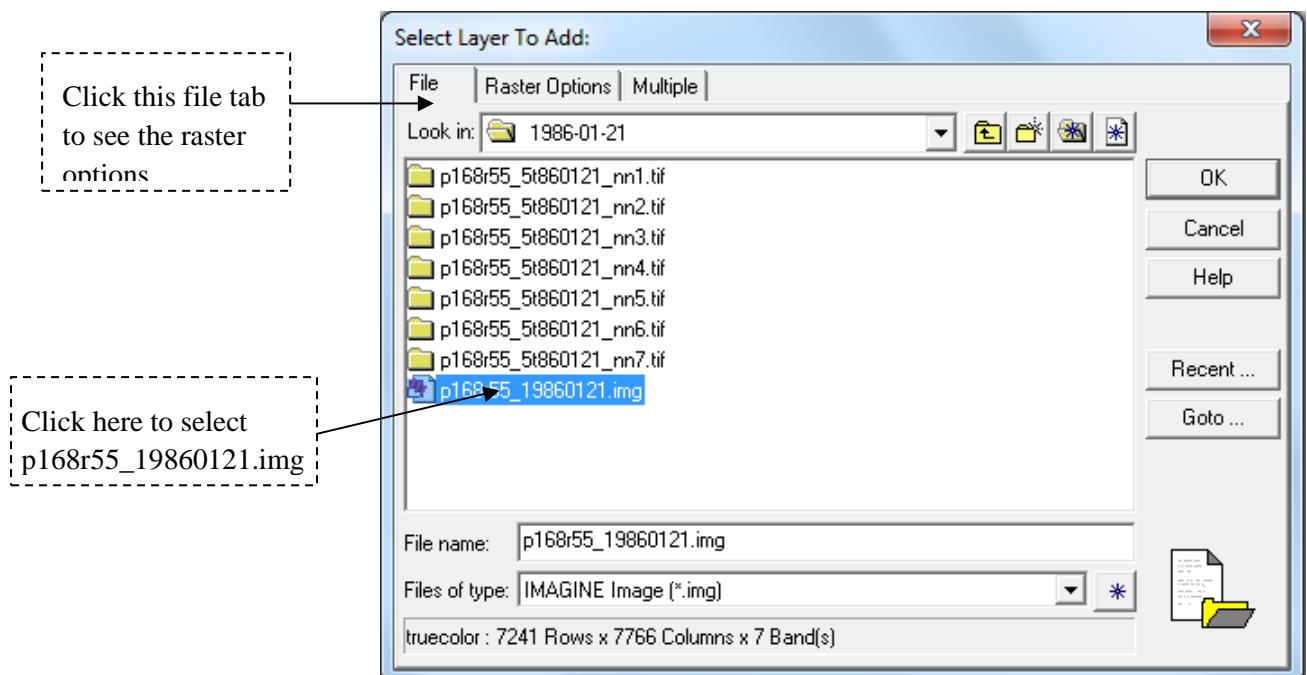
Evaluating individual classes

After a classification is performed, you can use a classification overlay or recode the classes to evaluate and test the accuracy of classification.

A. Create classification overlay

In this example, you use the attribute editor to compare the original image data with individual classes of the thematic raster layer that was created from the unsupervised classification (unsup_1986.img). This process helps identify the classes in the thematic raster layer. You may also use this process to evaluate the classes of a thematic layer that was generated from a supervised classification.

1. Select **File | Open | Raster Layer** from the viewer menu bar to display the **p168r55_19860121.img** continuous raster layer.



Convergence Threshold

The convergence threshold is the maximum percentage of pixels whose cluster assignments can go unchanged between iterations. This threshold prevents the ISODATA utility from running indefinitely.

By specifying a convergence threshold of 0.950, you are specifying that as soon as 95% or more of the pixels stay the same cluster between one iteration and the next, the utility should stop processing, in other words, as soon as 5% or fewer of the pixels change clusters between iterations, the utility stops processing.

2. In the Select Layer to Add dialog under **Filename**, select **p168r55_19860121.img**.
3. Click the Raster Options tab at the top of the “Select Layer to Add” dialog.
4. Set **Layers to Colours** at 4, 3, and 2, respectively.
5. Click **OK** in the “Select Layer To Add” dialog to display the image file.
6. Select **File | Open | Raster Layer** from the Viewer menu bar to display the thematic raster layer, **unsup_1986.img**, over the **p168r55_19860121.img** file.

The Select Layer to Add dialog opens.

7. Under **Filename**, open the directory in which you previously saved **unsup_1986.img** by entering the directory path name in the text entry field and pressing the Enter key on your keyboard.
8. Select the file **unsup_1986.img** from the list of files in the directory.

You are going to evaluate/identify the classes in this file.

9. Click the Raster Options tab at the top of the “Select Layer To Add” dialog.
10. Click **Clear Display** to turn off this checkbox.
11. Click **OK** in the “Select Layer To Add” dialog to display the image file.

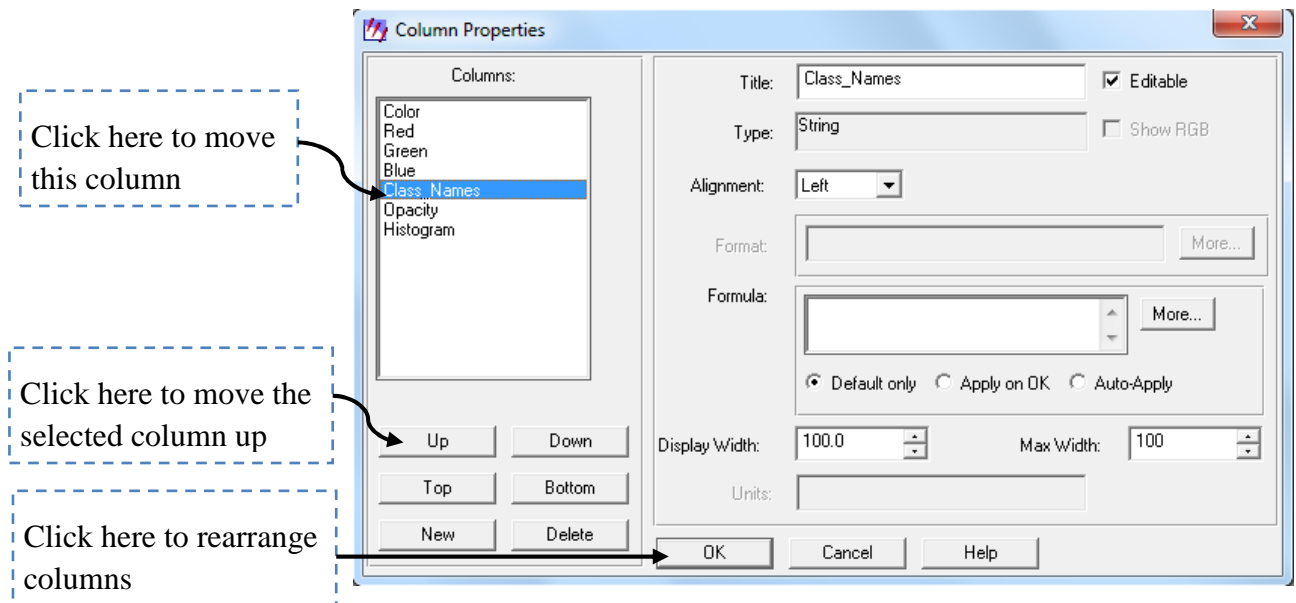
Open Raster Attribute Editor

1. Select **Raster | Attributes** from the Viewer menu bar.

The Raster Attribute Editor displays.

2. In the Raster Attribute Editor, select **Edit | Column Properties** to rearrange the columns in the Cell Array so that they are easier to view.

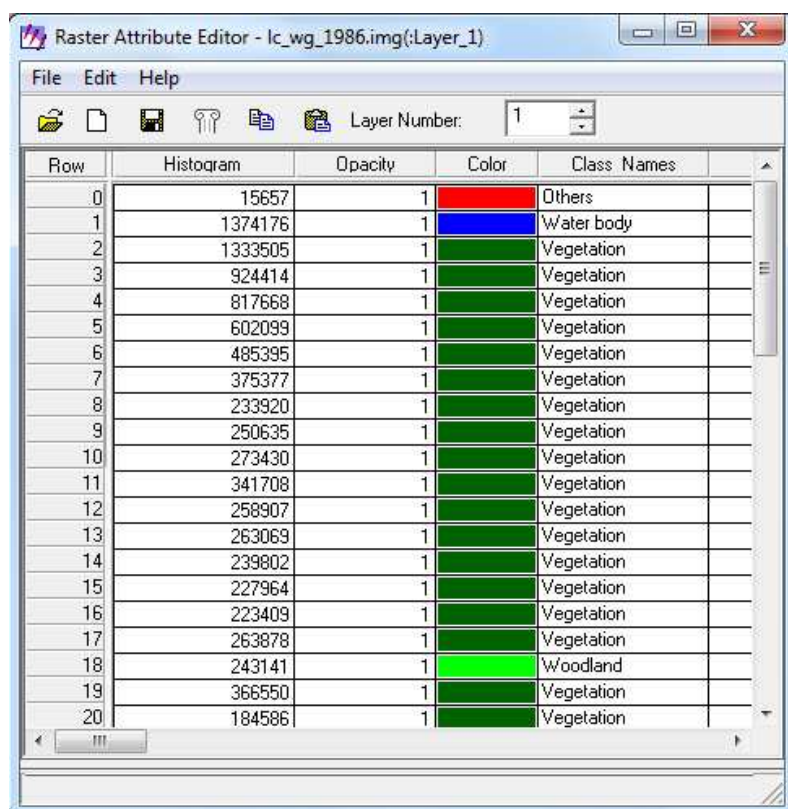
The Column Properties dialog opens.



3. In the Column Properties dialog under **Columns**, select **Opacity**, then click **Up** to move **Opacity** so that it is under **Histogram**.
4. Select **Class_Names**, then click to move **Class_Names** so that it is under **Color**.
5. Click **OK** in the Column Properties dialog to rearrange the columns in the Raster Attribute Editor.

The Column Properties dialog closes.

The data in the Raster Attribute Editor CellArray should appear similar to the following example:

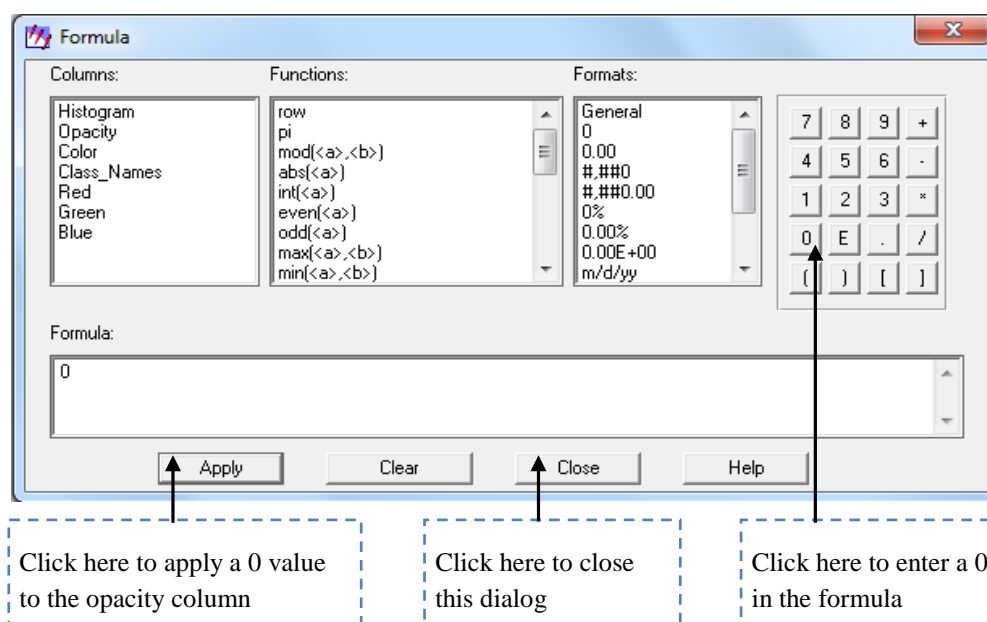


Analyze Individual Classes

Before you can begin to analyze the classes individually, you need to set the opacity for all of the classes to zero.

1. In the Raster Attribute Editor, click the word **Opacity** at the top of the **Opacity** column to select all of the classes.
2. In the Raster Attribute Editor, right-hold on the word **Opacity** at the top of the **Opacity** column and select **Formula** from the **Column Options** menu.

The Formula dialog opens.



3. In the Formula dialog, click 0 in the number pad. A **0** is placed in the **Formula** field.
4. In the Formula dialog, click **Apply** to change all of the values in the **Opacity** column to **0**, and then click **Close**.
5. In the Raster Attribute Editor, click and hold on the color patch under **Color** for **Class 1** in the CellArray and change the color to **Yellow**. This provides better visibility in the Viewer.
6. Verify the **Opacity** for **Class 1** in the CellArray is set to **1**.

This class is shown in the Viewer.

7. In the Viewer menu bar, select **Utility | Flicker** to analyze which pixels are assigned to this class.

The Viewer Flicker dialog opens.

8. Turn on the **Auto Mode** in the Viewer Flicker dialog by clicking on the checkbox.

The flashing black pixels in the **pl68r55_19860121.img** file are the pixels of this class. These areas are water.

9. In the Raster Attribute Editor, click inside the **Class_Names** column for **Class 1**. (You may need to double-click in the column.) Change this name to **Water** and then press Enter on the keyboard.
10. In the Raster Attribute Editor, click and hold on the **Color** patch for **Water** and select **Blue** from the popup list. (You may need to select the entire row for this class first.)
11. After you are finished analyzing this class, click **Cancel** in the Viewer Flicker dialog and set the **Opacity** for **Water** back to 0 in the Raster Attribute Editor. Press Enter on the keyboard.
12. Change the **Color** for **Class 2** in the CellArray to **Yellow** for better visibility in the Viewer.
13. Change the **Opacity** for **Class 2** to **1** and press Enter on the keyboard.

This class is shown in the Viewer.

14. In the Viewer menu bar, select **Utility | Flicker** to analyze which pixels are assigned to this class.

The Viewer Flicker dialog opens.

15. Turn on the **Auto Mode** in the Viewer Flicker dialog.

The flashing yellow pixels in the **p168r55_19860121.img** file should be the pixels of this class. These are forest areas.

16. In the Raster Attribute Editor, click inside the **Class_Names** column for **Class 2**. (You may need to double-click in the column.) Change this name to **Forest**, and then press Enter on the keyboard.

17. In the Raster Attribute Editor, click and hold on the **Color** patch for **Forest** and select **Pink** from the popup list. (You may need to select the entire row for this class first.)

18. After you are finished analyzing this class, click **cancel** in the Viewer Flicker dialog and set the **Opacity** for **Forest** back to **0**. Press Enter on the keyboard.

19. Repeat these steps with each class so that you can see how the pixels are assigned to each class.

You may also try selecting more than one class at a time.

20. Continue assigning names and colors for the remaining classes in the Raster Attribute Editor CellArray.

21. In the Raster Attribute Editor, select **File | Save** to save the data in the CellArray.

22. Select **File | Close** from the Raster Attribute Editor menu bar.

23. Select **File | Clear** from the Viewer menu bar.

Exporting the thematic layer to ArcGIS and preparing land cover map of the area

Practical-2: Using GPS to supplement land cover conditions obtained from analysis of remote sensing products.

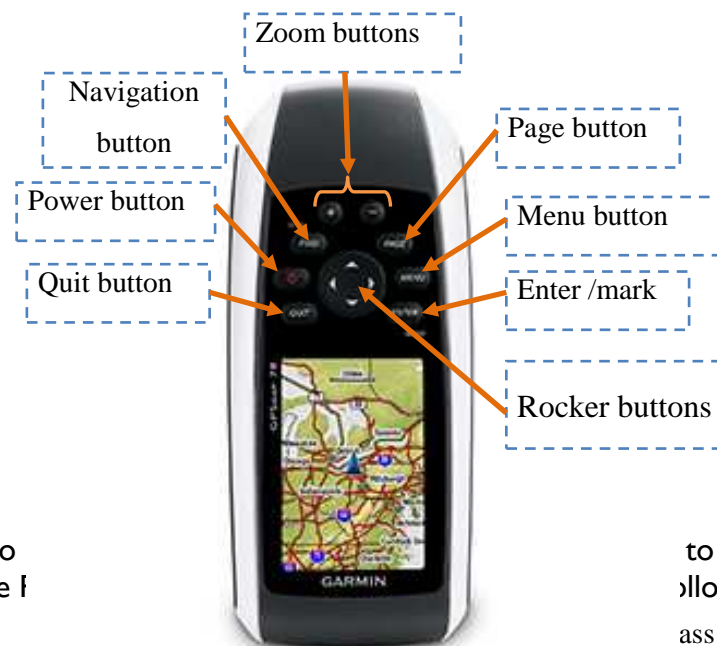
Setting up the instrument

Turn the unit on by holding down the Power button (red circle with vertical line) for two seconds.

After the welcome screen, the satellite screen will appear and it will briefly read “Acquiring Satellites” at the top. If you are out in the open, it should only take a short time to acquire enough satellites to make out your location.

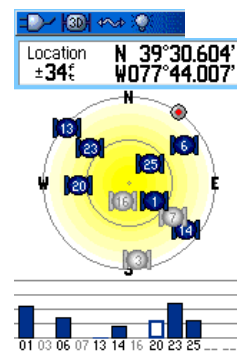
If the unit cannot get a satellite fix, an options menu with a list of solutions will appear.

Open the main menu of the receiver and look for setup, within which you find position format option. Under the position format menu, set the projection type, datum and map spheroid suiting to your local mapping and spatial data infrastructure standards.

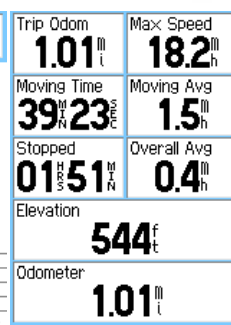


You need to
Pressing the I

Satellite



Picture 4



Picture 5



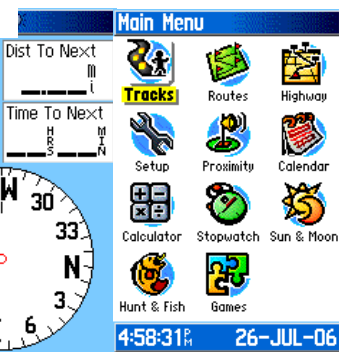
Picture 6



Picture 7

to work with it.
Following five screens:

ass Main Menu



Picture 8

- When the GPS is used on the field for the first time, the receiver needs to be initialised.
- With fresh batteries installed take the unit outside where it can get a clear 360° view of the sky. Turn it on and hold the unit with the top tilted towards the sky.
- Automatically the GPS captures satellite and it takes not more than five minutes for the unit to become operational. When it is able to navigate it will show 2D GPS Locations or 3D GPS location in the receiver's status field.
- The Setup of the GPS Receiver should also be checked before using the device on ground for example
 - Position format - hddd°mm'ss.s" (deg.min.sec) or UTM (Universal Transverse Mercator projection).
 - Map Datum-WGS84
 - Noth Reference-True

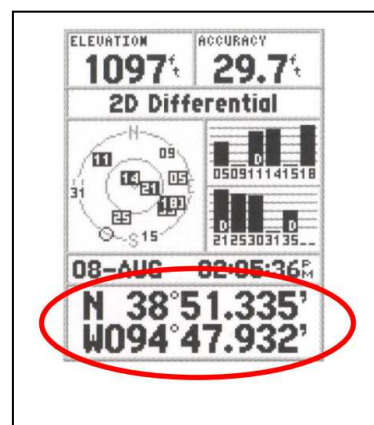
Working with Waypoints

“Waypoint” is the technical term used for a location that is obtained with the GPS. Waypoints can be saved in two ways for the required activity as follows.

A) CREATIG the waypoint using ENTER/MARK key

Procedure

1. When at a location switch on the GPS device. It will show you the GPS location (longitude and latitude values).



2. Wait till it shows the 3D mode and minimum four satellite and ensure the minimum value in accuracy field (at least less than 10m for natural resources assessment purposes).
3. To save the point press and hold the ENTER button until the Mark waypoint page is displayed



4. To save the waypoint to memory highlight the “OK” button then Press the ENTER key again to save

B) CREATIG the waypoint manually using existing coordinates

Procedure:

- Switch on the GPS. It will show you the GPS location page.
- Press and hold the ENTER button until the Mark waypoint page is displayed. The unit will capture the current location.
- Highlight the location using the “Navigation” keys. Press enter to accept the change.
- At this point you can edit the waypoint name, symbol, elevation and depth.
- Press and hold the ENTER button until the “Mark waypoint” page is displayed.

How to reach the desired location (Waypoint) which is already recorded

Procedure

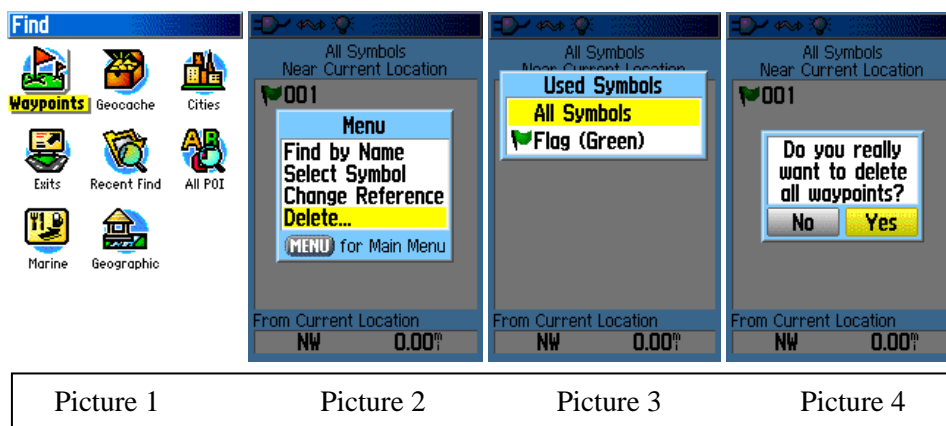
- Press the “Nav”/”goto”/”find” key
- With the “Waypoint” option highlighted, press ENTER
- Press ENTER again to select a waypoint directly from the list.
- Use the ROCKER key to scroll through the list and select a waypoint.
- When the waypoint one wants to go to is selected, press ENTER.
- Press PAGE until the “Compass Page” is displayed. Follow the direction of the arrow in the retrieving the data from the GPS

Deleting Waypoints

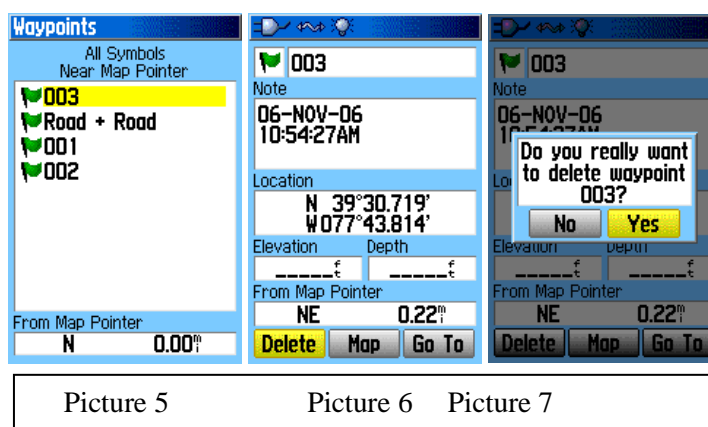
Before starting this activity, you may want to clear previous waypoints that have been saved on your GPS unit.

- Press FIND. Select **Waypoints** and press ENTER (picture 1).

- If there are waypoints listed and you want to delete them all, press MENU and select **Delete...** (picture 2).
- On the screen that appears, select **All Symbols** and press ENTER (picture 3).
- A box will now come up asking if you really want to delete all waypoints. Select **Yes** and press ENTER (picture 4).



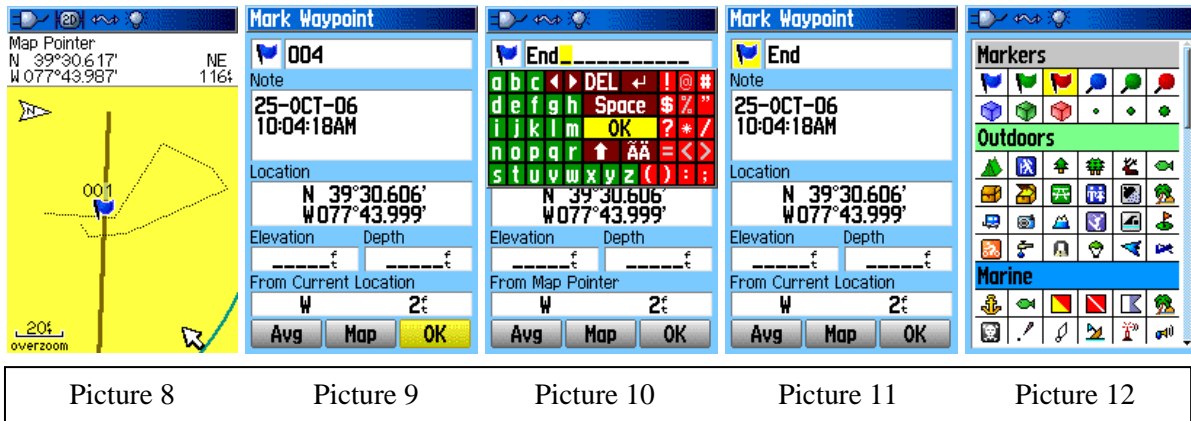
- If you only want to delete one waypoint, press FIND. Select **Waypoints** and press ENTER (pic.1).
- Highlight the waypoint you want to delete and press ENTER (picture 5).
- Highlight **Delete** and press ENTER (picture 6).
- A box will now come up asking if you really want to delete the waypoint. Select **Yes** and press ENTER (picture 7).



Creating New Waypoints

- Go to the Map screen. Zoom in all the way by pressing the IN button several times. Walk around. In the upper left corner of the screen, a compass arrow will point north (picture 8).
- Stop somewhere and create a waypoint by pressing and holding ENTER until the screen changes to show the "Mark Waypoint" screen (picture 9). This screen allows you to change the name of the waypoint and shows information about it such as when it was created and the location.
- Change the name of this waypoint by highlighting the **name box** at the top of the screen and pressing ENTER. Using the rocker and enter button, name this waypoint End. When you are finished, highlight **OK** on the letter/number screen and press ENTER (picture 10).

- You can change the symbol for any waypoint by first highlighting the flag at the top of the screen (picture 11). Press ENTER and choose the red flag symbol from the Markers screen (picture 12).
- Once you have chosen the symbol, highlight **OK** at the bottom of the screen and press ENTER. The new symbol will appear on the map where you created the waypoint.
- Walk about 30 yards away and **create another waypoint** named Start. Give this waypoint a green flag symbol. Stay at this second waypoint and begin Project B.

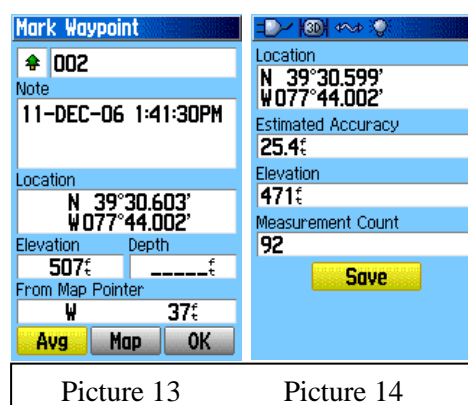


Averaging a Waypoint

To obtain a more accurate location for your waypoint, you can have the GPS receiver take several measurements at the same location. It will then average these measurements to provide a better estimate for the coordinates for your specific location.

- Create a waypoint for your current location by holding ENTER.
- Highlight **Avg** (picture 13) and press ENTER.
- A new screen will appear showing the waypoint information. At the bottom of this screen, you will see the Measurement Count number increasing about every second (picture 14). The Estimated Accuracy number should decrease as more measurements are taken.
- When you are satisfied with the estimated accuracy, highlight **Save** and press ENTER. This will save the averaged waypoint just like any other waypoint.

NOTE: Remain still as the GPS unit is taking measurements. You will have better accuracy if you are away from large objects like buildings or large trees, and if there is little or no overhead cover.



Application – You can use the waypoint function to mark and name roads, property boundaries, stream crossings, buffer areas, logging deck location, access points, tree locations (specimen trees), and high quality timber. Use the Average Waypoint function when you need a more accurate location and can remain at a marking location for a few seconds.

Downloading data: open DNR Garmin software. Turn the GPS on, connect the cable to the port at the back of the GPS, and set the map projection of your data.

Select download from the waypoint menu of the DNR Garmin window and the software will begin downloading the waypoints. You will be able to see the number of records transferred. Finally you can save the waypoints in one of the available file formats like shapefile, Dbase file, text, CSV or KML.

Transferring GPS Data Garmin GPS to ArcMap

NOTE: These instructions assume a certain degree of basic Windows operating system fluency (copying files, creating folders, opening multiple applications, etc). If you do not understand the instructions, please ask IT professional for help.

You will need a Garmin GPSmap78-PC connection cable (hooks into the back of the GPS unit and the PC).