Basics of Remote Sensing and GIS with Reference to its Application in Forestry

Dr. Sanjay Kumar Pandey
Department of Botany,
D. A. V. P. G. College, Gorakhpur, U.P.

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Forests play an important role in the ecological stability as well as country's economic development. As per the present National Forest Policy (1988), there is to maintain a minimum of 33% of India's geographical area under tree cover and forest. So it required to monitor of the forest cover periodically for effective planning for sustainable development. By using Remote Sensing and Geographical Information System (GIS), we can develop an information system to realize the scientific management of forest resources. GIS for forest management have becoming a very important tool for quick and easy decision making. As the importance of forestry sector is expanding, the need to develop a suitable management information system is being essential task.

Remote Sensing-

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing and applying that information. There are several types of remote sensing systems used in forestry but the most common is a passive system that senses the electromagnetic energy reflected from plants. The sun is the most common source of energy for passive systems. The sensors can be mounted on satellites, manned or unmanned aircraft, or directly on farm equipment. Objects having different surface features reflect or absorb the sun's radiation in different ways. The most important surface features are colour, structure and surface texture.

Remote Sensing satellite imagery based forest and tree cover mapping adopted by Forest Survey of India, has proved to be time and cost effective over conventional forest resource mapping. The methodology used for GIS and digital image processing as given above would efficiently employed using high resolution satellite imageries to stratify the forest resources and along with other features also provide detailed information for planning, execution and utilization of these resources for sustainable development. The information that supports forest management is stored primarily in the form of forest inventory databases within a GIS environment. A forest inventory is a survey of the location, composition, and distribution of forest resources. As one of the principal sources of forest management information, these databases support a wide range of management decisions from conservation plans to the development of long-term strategies.

Electromagnetic spectrum-

Electromagnetic radiation (or EMR) is the radiant energy released by sun by electromagnetic processes. Energy in the form of light waves travels from the sun to Earth. The behavior of EM radiation depends on its frequency. Lower frequencies have longer wavelengths, and higher frequencies have shorter wavelengths, and are associated with photons of higher energy (Figure 1). When electromagnetic energy from the sun strikes plants, three things can happen. Depending upon the wavelength of the energy and characteristics of individual plants, the energy will be reflected, absorbed, or transmitted. Reflected energy bounces off leaves and is readily identified by human eyes as the green color of plants. Interactions between reflected, absorbed, and transmitted energy can be detected by remote sensing. The differences in leaf colors, textures, shapes or even how the leaves are attached to plants, determine how much energy will be reflected, absorbed or transmitted.

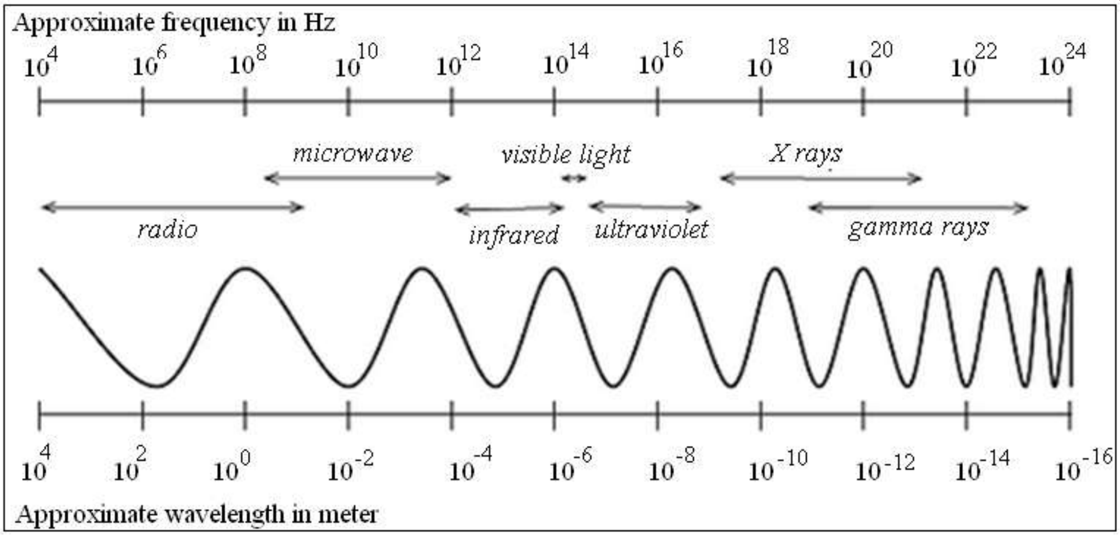

Figure 1.The electromagnetic spectrum.

Reflectance curve and NDVI-

A measurement of energy commonly used in remote sensing of the Earth is reflected energy (e.g., visible light, near-infrared, etc.) coming from land and water surfaces. The amount of energy reflected from these surfaces is usually expressed as a percentage of the amount of energy striking the objects. Reflectance is 100% if all of the light striking and object bounces off and is detected by the sensor. If none of the light returns from the surface, reflectance is said to be 0%. Interpreting the reflectance values at various wavelengths of energy can be used to assess forest health. In most cases, the reflectance value of each object for each area of the electromagnetic spectrum is somewhere between these two extremes. Across any range of wavelengths, the percent reflectance values for landscape features such as water, sand, roads, forests, etc. can be plotted and compared. Such plots are called "spectral response curves" or "spectral signatures" (Figure 2). Differences among spectral signatures are used to help classify remotely sensed images into classes of landscape features since the spectral signatures of like features have similar shapes.

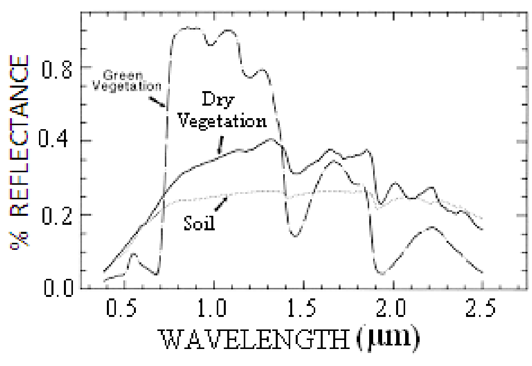

Figure 2- Typical spectral reflectance curve.

These signatures can be visualised in so called spectral reflectance curves as a function of wavelengths. Plants have a particular way to reflect the electromagnetic radiation. This unique characteristic is known as the vegetation's spectral signature. Reflectance of vegetation is very low in the blue and red regions of the electromagnetic spectrum, slightly higher in the green region and high in the near infra-red. Because of all plant pigments, most of the visible electromagnetic energy is absorbed, especially in the blue and red region. Vegetation has low reflectance in the visible region and high reflectance in the near infrared. The combination of low visible reflectance and high near-infrared reflectance is unique for most vegetation types and that is why it is known as the vegetation spectral signature. Vegetation in general has low reflectance in the visible region (what we see with our eyes), and only a small amount of green energy is not absorbed. On the other hand, it has much higher reflectance in the near infrared. The spectral reflectance curve of healthy green vegetation has a significant minimum of reflectance in the visible portion of the electromagnetic spectrum resulting from the pigments in plant leaves. Reflectance increases dramatically in the near infrared. Stressed vegetation can also be detected because stressed vegetation has a significantly lower reflectance in the infrared.

The comparison of the reflectance values at different wavelengths, called a vegetative index, is commonly used to determine plant vigor. The most common vegetative index is the normalized difference vegetative index (NDVI). NDVI compares the reflectance values of the red and NIR regions of the electromagnetic spectrum. The NDVI value of each area on an image helps identify areas of varying levels of plant vigor within fields. The NDVI is calculated from these individual measurements as follows: = IR- RED/ IR+ RED

Where, RED and IR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively.

By design, the NDVI itself thus varies between -1.0 and +1.0. It can be seen from its mathematical definition that the NDVI of an area containing a dense vegetation canopy will tend to positive values (say 0.3 to 0.8) while clouds and snow fields will be characterized by negative values of this index. Users of NDVI have tended to estimate a large number of vegetation properties from the value of this index. Typical examples include the Leaf Area Index, biomass, chlorophyll concentration in leaves, crop productivity, fractional vegetation cover, accumulated rainfall, etc.

Collection of Data and Resolution

There are several factors to consider when choosing a remote sensing system for a particular application, including spatial resolution, spectral resolution, radiometric resolution, and temporal resolution.

Spatial resolution refers to the size of the smallest object that can be detected in an image. The basic unit in an image is called a pixel. The smaller an area represented by one pixel, the higher the resolution of the image.

Spectral resolution refers to the number of bands and the wavelength width of each band. A band is a narrow portion of the electromagnetic spectrum. Shorter wavelength widths can be distinguished in higher spectral resolution images. Multi-spectral imagery can measure several wavelength bands such as visible green or NIR. Landsat, Quickbird and Spot satellites use multi-spectral sensors. Multi-spectral and hyperspectral imagery are used together to provide a more complete picture of forest conditions.

Radiometric resolution refers to the sensitivity of a remote sensor to variations in the reflectance levels. The higher the radiometric resolution of a remote sensor, the more sensitive it is to detecting small differences in reflectance values.

Temporal resolution refers to how often a remote sensing platform can provide coverage of an area. Geo-stationary satellites can provide continuous sensing while normal orbiting satellites can only provide data each time they pass over an area. Remote sensors located in neat forest can provide the most frequent temporal resolution.

Digital image interpretation and analysis-

Digital image processing is the use of computer algorithms to perform image processing on digital images. Digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. A digital image comprises of a two dimensional array of individual picture elements called **pixels** arranged in columns and rows. Each pixel represents an area on the Earth's surface. A pixel has an **intensity** value and a **location address** in the two dimensional image. The **intensity** of a pixel is digitised and recorded as a digital number. Due to the finite storage capacity, a digital number is stored with a finite number of bits (binary digits). The numbers of bit determine the **radiometric resolution** of the image. For example, an 8-bit digital number ranges from 0 to 255 (i.e. $2^8 - 1$), while the 11-bit digital number ranges from 0 to 2047. The detected intensity value needs to be scaled and quantized to fit within this range of value. There is a one-to-one correspondence between the column-row address of a pixel and the geographical coordinates (e.g. Longitude, latitude) of the imaged location. In order to be useful, the exact geographical location of each pixel on the ground must be derivable from its row and column indices, given the imaging geometry and the satellite orbit parameters.

Classification of Digital Image

Two major categories of image classification techniques include **unsupervised** (calculated by software) and **supervised** (human-guided) classification. **Unsupervised classification** is where the outcomes (groupings of pixels with common characteristics) are based on the software analysis of an image without the user providing sample classes. The computer uses techniques to determine which pixels are related and groups them into classes. The user can specify which algorism the software will use and the desired number of output classes but otherwise does not aid in the classification process. However, the user must have knowledge of the area being classified when the groupings of pixels with common characteristics produced by the computer have to be related to actual features on the ground (such as wetlands, developed areas, coniferous forests, etc.). **Supervised classification** is based on the idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together. These bounds are often set based on the spectral characteristics of the training area, plus or minus a certain increment (often based on "brightness" or strength of reflection in specific spectral bands). The user also designates the number of classes that the image is classified into. Many analysts use a combination of supervised and unsupervised classification processes to develop final output analysis and classified maps.

Component of GIS-

A working GIS integrates five key components: Hardware (hardware is the computer on which a GIS operates), Software (it provides the functions and tools needed to store, analyze, and display geographic information), Data (Vector data model by points, lines and areas and Raster data model divides the entire study area into a regular grid of cells in specific sequence), People (GIS user ranges from technical specialists who design and maintain the system to those who use it to help them perform their everyday work) and Methods (Digitizing and scanning of maps, Input image data, Direct data entry including Global Position System (GPS), Transfer data from existing sources)

Different Kinds of GIS Software-

A modern GIS software system comprises an integrated suite of software components, including end user applications, geographic tools and data access components. GIS software packages could be classified as six groups based on the functionality and type- viz. Professional GIS, Desktop GIS, Hand-held GIS, Component GIS, GIS viewer and Internet GIS

RS And GIS application in forestry-

The use of remote sensing has steadily increased, promoted in large part by better integration of imagery with GIS technology and databases, as well as implementations of the technology that better suit the information needs of forest managers.

Strategic planning and modeling: Forest management planning involves making predictions about what the future forest will look like relative to alternative management activities. This ability is crucial to nearly all aspects of management forecasting, particularly long term wood and wildlife supply. Within the limits of the inventory and model, the manager can then map what the forest will look like in 5,10, 25, or 100 years in the future.

Map production: Forest management require a wide variety of maps to assist with their daily activities. Plantation maps are most commonly used for location purposes and may contain additional useful information such as roads, rivers, compartment boundaries, planted species, and compartment size.

Fire management: Forest fires have an important influence on the vegetation cover, animals, plants, soil, stream flow, air quality, microclimate, and even general climate. Management activities include fire prevention, wildlife control, prescribed burning, and post fire recovery actions. The modeling capabilities of GIS have been quite effective in this context. Forest fire managers have used GIS for fuel mapping, weather condition mapping, and fire danger rating.

Harvest planning: Good forest management practice requires detailed planning of harvesting activities. Harvest planning activities include the identification of felling directions, extraction routes, depots and sensitive zones such as wetlands. Forest maps constitute a basic planning tool for these activities.

Resource management: The collection of forest inventory data and monitoring changes are critical to forest management activities. Yet, a remote sensing can build on these activities by incorporating models to guide, for example, timber harvesting, silviculture and fire management activities, or predict fuel wood and other resource supplies. Other priorities, such as providing for wildlife habitat, ensuring recreation opportunities and minimizing visual impacts of harvesting, are also growing in importance.

Biodiversity Assessment: Information needed for biodiversity monitoring is varied greatly. It should also be geographically based and used to predict where new populations of endangered species are present. Data for monitoring biodiversity might be available in the form of text documents, tabular data-bases, spatial data-bases (locations), image files or satellite images and should include topographic, environmental, species, administrative, socio-economic and other themes. All such data should be integrated and analyzed by GIS for assessment and monitoring purposes in order to provide information about the current environmental conditions.

Conclusions-

Forests are complex assembly of species that lend themselves well to broad level inventory through remote sensing. While forest management becoming increasingly complex, due to greater environmental and social involvement and pressures, the remote sensing and GIS is likely to play an important central role. GIS applications can strongly benefit from remote sensing and image processing technologies. However, the need for strong ground truth remains vital and it is likely that satellite positioning systems such as GPS will play an important role in augmenting traditional forest survey activities.

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