CHAPTER - 23

Use of Geo-spatial Technology as an Evolving Technology of 21st Century for Natural Resource Management in Different Regions of India

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INTRODUCTION

The evolution of National Natural Resource Management System (NNRMS) towards fully harnessing the potentials of space remote sensing and the development of the series of Indian Remote Sensing Satellites, besides establishment of necessary ground based data establishment of necessary ground based data reception processing and dissemination systems as well as remote sensing facilities at National Remote Sensing Centre (NRSC), Space Applications Centre (SAC) and Regional Remote Sensing Service Centers (RRSSCs) for efficient and effective analysis of remotely sensed data are the major steps accomplished in pursuit of this goal. With the establishment of Remote Sensing Applications Centers in several States under many Governmental organizations, remote sensing today has come to stay as an integral part of the national development efforts in the vital sectors of agriculture, hydrology, geology, forestry, oceanography, mineral resources and disaster management like drought, flood, cyclone, earthquake, landslides crop pests, forest fires etc., thus touching every facet of national development. Today, India has acquired a strong self-reliant base to harness the full potential of this technology and as a result, the national objective of achieving sustainable development at micro level is being addressed through the integration of remotely sensed data with other relevant collateral information to arrive at locale specific, environment friendly, economically viable and culturally acceptable treatment packages (Rao, 1991 and Jayaraman, *el at.* 1993).

The remarkable developments in space technology during the past three decades have established their immense potential for the optimum utilization of this technology especially in the field of agriculture for taking up many application project in various sectors. Indian remote Sensing Satellites, IRS-IA launched in March 1988 and IRS IB launched in August 1991 are provided good quality data with a combined repetitively of 11 days. Full-fledged operation remote sensing programme, which only a few nations could achieve around the generation, Indian Remote Sensing programme is now well poised to reach even greater heights through the development of second generation of Remote Sensing Satellite series, viz., IRS-IC and IRS-ID with better capabilities. Krishna Rao *et al.* (1997) estimated the chilli crop acreage by digital analysis of IRS IC LISS III data covering five mandals of Guntur district of Andhra Pradesh. Presently IRS P6, Cartosat I and Cartosat II provide high resolution information. Under the umbrella of National Natural Resources Management System (NNRMS), several new application areas were achieved with the active involvement of user agencies. IRS data is being used on an operational basis for several applications such as agriculture crop acreage and yield estimation, draught monitoring and assessment flood mapping, landuse and land cover mapping, wasteland management, urban planning, mineral prospecting, forest resources survey and management, soil mapping, water resources management, fisheries potential forecasting, coastal zone management environment impact assessment etc.

Remote Sensing Technique

Remote Sensing is an extensive science, drawing from many areas for support and development. Remote sensing is an interesting and exploratory science, as it provides images of areas in a fast and cost-efficient manner, and attempts to demonstrate the "what is happening right now" in a study area. While air photos and fieldwork remain critical as sources of information, the cost and time to carry out these methods sometimes may not be feasible for the study. Satellite and digital imagery acquired recently, provide more overall detail to assist the researcher in the classification process. Literature reviews and map interpretation are methods that can also be used for interpretation processes. The benefits of remote sensing continue to arise. It can be used to access hard to reach areas for fieldwork, and provides a more detailed, permanent and objective survey that offers a different perspective. Air photos are still favored and easily accessible sources of information for classification. It depends greatly on the support of governments and private industries worldwide. Satellite and digital imagery play an important role in remote sensing; providing information about the land studied.

Remote Sensing Systems offer four basic components to measure and record data about an area from a distance. These components include the energy source, the transmission path, the target and the satellite sensor(Fig.1). The energy source, electromagnetic energy, is the crucial medium required to transmit information from the target to the sensor. Remote sensing provides important coverage, mapping and classification of land use/ land cover features, such as vegetation, soil, water, forests and manmade activities etc.

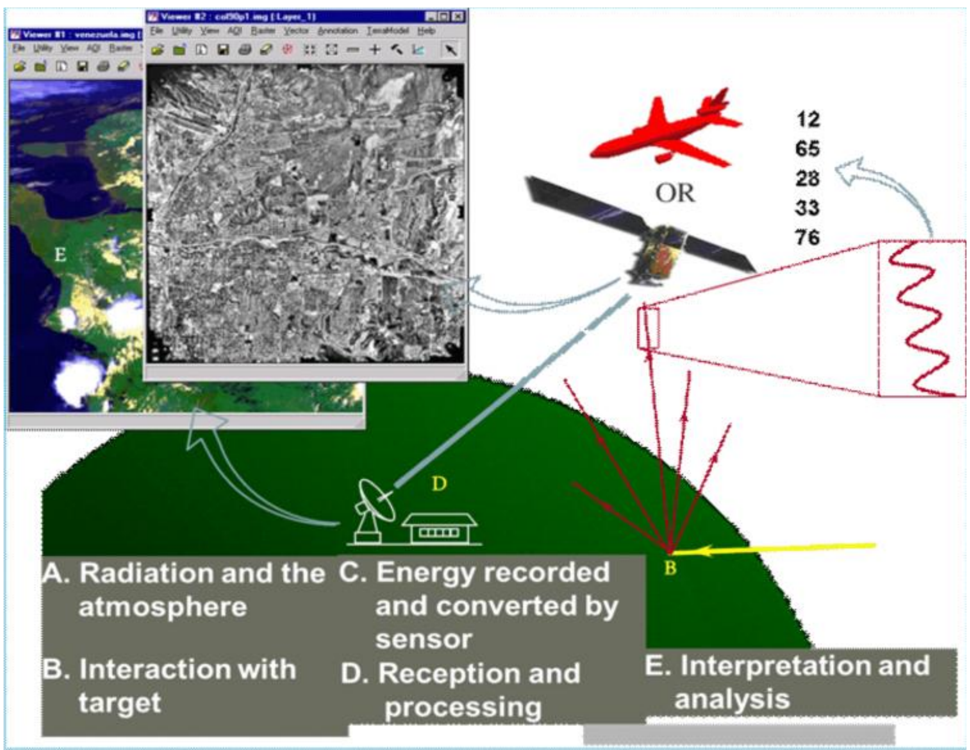

Fig. 1 : Mechanism of Remote Sensing

Bands Used in Remote Sensing: Emission of EMR (Electo-Magnetic Radiation) from gases is due to atoms and molecules in the gas. Atoms consist of a positively charged nucleus surrounded by orbiting electrons, which have discrete energy states. Transition of electrons from one energy state to the other leads to emission of radiation at discrete wavelengths. The resulting spectrum is called line spectrum. Molecules possess rotational and vibrational energy states. Transition between which leads to emission of radiation in a band spectrum. The wavelengths, which are emitted by atoms/molecules, are also the ones, which are absorbed by them. Emission from solids and liquids occurs when they are heated and results in a continuous spectrum. This is called thermal emission and it is an important source of EMR from the viewpoint of remote sensing (Fig. 2).

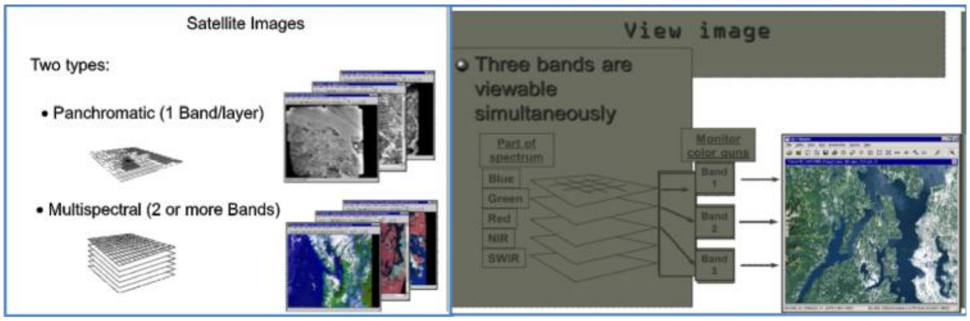

Fig. 2 : Band use in Satellite Remote Sensing technology

The **Electro-Magnetic Radiation (EMR)**, which is reflected or emitted from an object, is the usual source of Remote Sensing data. However, any medium, such as gravity or magnetic fields, can be used in remote sensing. Remote Sensing Technology makes use of the wide range Electro-Magnetic Spectrum (EMS) from a very short wave “Gamma Ray” to a very long ‘Radio Wave’. Wavelength regions of electro-magnetic radiation have different names ranging from Gamma ray, X-ray, Ultraviolet (UV), visible light, Infrared (IR) to Radio Wave, in order from the shorter wavelengths.

The optical wavelength region, an important region for remote sensing applications, is further subdivided as follows:

Table 1: Wavelength regions of electro-magnetic radiation

Name	Wavelength (mm)
Optical wavelength	0.30-15.0
Reflective	0.38-3.00
1. Visible	1. 0.38-0.72
2. Near IR	2. 0.72-1.30
3. Middle IR	3. 1.30-3.00
Far IR (Thermal, Emissive)	7.00-15.0

Microwave region (1mm to 1m) is another portion of EM spectrum that is frequently used to gather valuable remote sensing information. The sunlight transmission through the atmosphere is effected by absorption and scattering of atmospheric molecules and aerosols. This reduction of the sunlight’s intensity called extinction.

Energy Interactions, Spectral Reflectance and Color Readability in Satellite Imagery: All matter is composed of atoms and molecules with particular compositions. Therefore, matter will emit or absorb electro-magnetic radiation on a particular wavelength with respect to the inner state. All matter reflects, absorbs, penetrates and emits Electro-magnetic radiation in a unique way. Electro-magnetic radiation through the atmosphere to and from matters on the earth's surface are reflected, scattered, diffracted, refracted, absorbed, transmitted and dispersed. For example, the reason why a leaf looks green is that the chlorophyll absorbs blue and red spectra and reflects the green. The unique characteristics of matter are called spectral characteristics (Fig. 3).

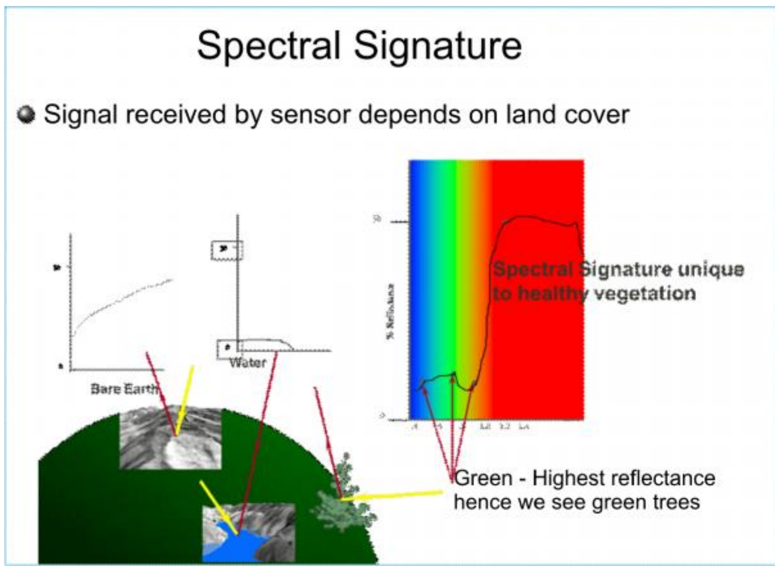

Fig. 3 : Spectral Signature of different landuse/land cover

An Ideal Remote Sensing System: Having introduced some basic concepts, we now have the necessary elements to conceptualize an ideal remote sensing system. In doing so, we can then appreciate some of the problems encountered in the design and application of the various real remote-sensing systems examined in subsequent chapters.

The basic components of an ideal remote-sensing system are as follows.

- A uniform energy source. This source will provide energy over all wavelengths, at a constant, known, high level of output, irrespective of time and place.
- A non-interfering atmosphere. This will be an atmosphere that will not modify the energy from the source in any manner, whether that energy is on its way to earth's surface or coming from it. Again, ideally

this will hold irrespective of wavelength, time, place, and sensing altitude involved.

- A series of unique energy/matter interaction at the earth's surface. These interactions will generate reflected and/or emitted signals that are not only selective in respect to wavelengths, but also are known, invariant, and unique to each and every earth surface feature type and subtype of interest.
- A super sensor. This will be a sensor, highly sensitive to all wavelengths, yielding spatially detailed data on the absolute brightness (or radiance) from a scene (a function of wavelength), throughout the spectrum. This super sensor will be simple and reliable, require, virtually no power or space, and be accurate and economical to operate.
- A real-time data handling system. In this system, the instant the radiance versus wavelength response over a terrain element is generated, it will be processed into an interpretable format and recognized as being unique to the particular terrain element from which it comes. This processing will be performed nearly instantaneously (real time), providing timely information. Because of the consistent nature of the energy/matter interactions, there will be no need for reference data in the analytical procedure. The derived data will provide insight into the physical-chemical-biological state of each feature of interest.
- Multiple data users. These people will have comprehensive knowledge of both their respective disciplines and of remote-sensing data acquisition and analysis techniques. The same set of data will become various forms of information for different users, because of their vast knowledge about the particular earth resources being used.

Unfortunately, an ideal remote-sensing system, as described above, does not exist. Real remote-sensing systems fall short of the ideal at virtually every point in the sequence outlined.

Remote Sensing Satellites: A satellite with remote sensors to observe the earth is called a remote-sensing satellite, or earth observation satellite. Remote Sensing Satellites are characterized by their altitude, orbit and sensor.

TRIOS Series (1960-1965): The Television and Infrared Observation Satellites.

NOAA It is the first generation of National Oceanic and Atmospheric Administration satellites and was as the first operation operational remote sensing satellite system. The third generation NOAA satellites are also successfully used for vegetation monitoring, apart from meteorological monitoring. It is equipped with Advanced Very High Resolution Radiometer (AVHRR) sensors, and is established at an altitude of 850 km.

GMS(Geo-synchronous meteorological satellite): It is established at an altitude of 36,000 km, and its main purpose is meteorological observations.

Landsat is established at an altitude of 700 km is a polar orbit and is used mainly for land area observation.

Other remote sensing satellite series in operations are: SPOT, MOS, JERS, ESR, RADARSAT, IRS etc.

Indian Remote Sensing Programme

The Indian Remote Sensing Satellite (IRS-A), the first in the operational series of Indian Remote Sensing Satellites has been functioning satisfactorily for more than 20 years but still continues to provide quality data. The second satellite in the IRS series, IRS-IB, launched is performing very well. These two satellites have become the mainstay of the National Natural Resources Management System (NNRMS) IRS-1A/1B provides imagery from the two cameras, linear Imaging Self Scanners, LISS-I with both the resolution 72.5m and LISS-IIA and LISS-IIB both with a resolution of 36.25m. IRS-1A and 1B together provide imagery with a combined repetivity of 11 days. While IRS-IA has so far provided more than 5, 00,000 scenes, IRS-1B has provided more than 2,00,000 scenes. The successful implementation of the operational IRS-IA 1B system in the country. The second generation remote sensing satellites IRS-IC and ID taking in to account the technology development scenario and user requirements during the nineties. The Indian Remote Sensing (IRS) Satellites viz., IRS 1A, 1B, 1C, 1D, P4, P6, Cartosat I and Cartosat II etc. is being widely used.

Scope of IRS Mission

Sustainable development of natural resources relies on maintaining the fragile balance between productivity functions and conservation practices through precise identification and systematic monitoring of problem area in various resources and developmental sectors. The process of sustainable development packages evolving from such an integrated effort will be economically acceptable and environmentally friendly. Towards this, Department of space had initiated pilot studies in 21 perennially drought affected districts of the country to generate locale specific action plans. These pilot studies carried out has demonstrated the efficacy of using remote sensing based approach for optimal utilization of land and water resources towards combating drought on a long term basis. Based on the results obtained form these pilot studies, Department of Space has launched a major, unique programme on Integrated Mission for Sustainable Development. This mission, as of now, covers a total of 157 problem districts of the country, covering nearly 45% of India's geographical area which are perennially affected and tribal areas. Nationwide crop yield forecast is now possible and is being regularly practiced since last decade.

The integration of the various thematic maps and attributes data, and further analysis for identified alternatives for development are carried out using geographic information system to identify set of coherent micro-level land units which are unique in terms of their resources potential and problems. Specific developmental plans for these units are arrived at in consultation with and close coordination between space scientists, experts from various central/state developmental departments, agricultural universities/research institutions, district level officials and local farmers, so as to ensure the technical feasibility and cultural acceptability of such action plans. Further, methodology has been developed to overlay the land capability map over the cadastral maps to provide information at the field levels. Various elements of such action plans are prioritized and categorized as those relating to land and water resources and others. Sensitivity of each element of the action plan would also be studied to see visible regress over the coming years, once they are implemented. The parameters such as, vegetation index, forest cover, land use, agricultural production, ground water table, soil erosion, etc., would be identified for bench marking the impact of such an implementation. The action plans are being implemented by the district authorities for these watersheds. The initial feedback on the implementation of action plans in the watersheds of Anantapur has been encouraging as shown by increased ground water levels through water harvesting structures and related activities. The supports for implementation is derived from ongoing developmental programmes such as Drought Prone Area Development Programme (DPAP), Desert Development Programme (DDP), Integrated Wasteland Development Programme (IWDP), National Watersheds Development Project for Rain-fed Areas (NWDPRA), Hill Area Development Programme (HADP), etc. It is also proposed to use satellite data for monitoring of the impact of these action plans.

Further, in view of the advantages of the integrated approach wherein local specific action plans will be generated with cadastral overlays, Ministry of Rural Development has suggested taking up of 92 selected blocks from among the IMSD districts, on an urgent basis in a time frame of 18 months. Ministry of Rural Development provided funds for implementation of these action plans through pooling of resources from the various ongoing schemes for rural development.

National (Natural) Resources Information System (NRIS)

A National Natural Resources Information System (NRIS) for the country has been evolved to aid decision makers at various levels. A number of pilot scale studies on various themes viz., wasteland development, land capability classes, district level planning, regional mineral targeting, etc., were carried out towards implementation of NRIS. Several geographic information packages have also been developed indigenously to cater to computer based decision support systems. More particularly crop wise forecast of production at regional to national level.

Training and Education in Remote Sensing

With the increased awareness and utilization of remote sensing in India, need for adequate number of trained manpower for harnessing the benefits of remote sensing technology has steeply gone up. Adequate efforts are being made to increase the present throughput of trained manpower in various themes in collaboration with central/state/academic institution by way of augmenting the existing training infrastructure. Regular training courses are being conducted by several training institutions such as Indian Institute of Remote Sensing (IIRS, Dehradun), Centre of Studies for Resources Engineering (IIT, Bombay), Institute of Remote Sensing (Anna University, Madras), Survey of India, ecological Survey of India Training Institute, Forest Survey of India and Indian Agricultural Research Institute (IARI, Delhi). Besides these regular courses, on the job training is being provided by National Remote Sensing centre (NRSC, Hyderabad) and Space Applications Centre (SAC, Ahmedabad) for specific themes and training in digital analysis and GIS by RRSSCs. Efforts are also on to introduce remote sensing evening school and college curriculum. Many universities have introduced remote sensing in their post-graduate courses as a full-fledged degree course or a part of a core subject.

International Collaboration

India has many collaborative programme with several countries in promoting active cooperation in remote sensing. For example, the ESCAP/UNDP Regional Remote Sensing Programme (RRSP), under the execution of the ESCAP, is playing a crucial role in promoting active cooperation in remote sensing among member counties of Asia-Pacific region, by bringing together experts from different areas who can share their experiences, disseminating information on available experts where needed. The Shares (Sharing of Experience) program initiated by India is also continuing to provide assistance to candidates from developing countries for participation in remote sensing training courses in India. The data reception/processing courses in India. The data reception/processing facility at Norman, USA has been recently established, to receive data from India Remote Sensing Satellite (IRS) as part of arrangements between EOSAT, USA and Department of Space/Antrix/NRSC, India, IRS-P6, Cartosat I & II data are also being acquired at this station.

Geographic Information System (GIS)

The year 1962 saw the development of the world's first true operational GIS in Ottawa, Ontario, Canada by the federal Department of Forestry and Rural Development. Developed by Dr. Roger Tomlinson, it was called the "Canada Geographic Information System" (CGIS) and was used to store, analyze, and manipulate data collected for the Canada Land Inventory (CLI). CGIS was the world's first "system" and was an improvement over "mapping" applications as it provided capabilities for overlay, measurement, and digitizing/scanning. It supported a national coordinate system that spanned the continent, coded lines as "arcs" having a true embedded topology, and it stored the attribute and locational information in separate files. As a result of this, Tomlinson has become known as the "father of GIS," particularly for his use of overlays in promoting the spatial analysis of convergent geographic data. CGIS lasted into the 1990s and built the largest digital land resource database in Canada. It was developed as a mainframe based system in support of federal and provincial resource planning and management. Its strength was continent-wide analysis of complex data sets. The CGIS was never available in a commercial form. By the early 1980s, M&S Computing (later Intergraph), Environmental Systems Research Institute (ESRI) and CARIS emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures. By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to export the concept of viewing GIS data over the Internet, requiring data format and transfer standards. More recently, there is a growing number of free, open source GIS packages which run on a range of operating systems and can be customized to perform specific tasks.

GIS can be defined as a data management system designed to input, store, retrieve, manipulate, analyze, and display spatial data for the purposes of research and decision-making (De Mers, 1997). Use of geographic information systems (GIS), a collection of computer hardware and software used to analyze and display geographically referenced information (Table 2), can facilitate this planning process. Spatial data layers like soil type, slope, and land cover can be used to develop suitability assessments that can identify optimal locations for agroforestry practices to solve landowner and community concerns. By selecting data with the appropriate spatial resolution, this assessment process can be used at any scale for planning agroforestry practices. The most significant benefit of using GIS-guided suitability assessments is the ability to combine different assessments to determine locations where multiple objectives can be achieved.

In a GIS, a database is associated with map features, and data values are geographically referenced, so resource managers can spatially represent information such as soil types or plant communities. Since land use and a diversity of related disciplines (i.e., agriculture, forestry, rural planning, and conservation) all deal with spatial characteristics of landscapes (Lacher 1998), GIS has gained considerable use in land use planning and natural-resource management, providing a spatial framework to aid in the decision-making process (Zeiler 1999).

Table 2: Major categories of computer-based spatial information technologies.

Category	Description
Databases	Organizes and facilitates the management and querying of large quantities of data and information
Geographical Information Systems (GIS)	Brings in a geographic or spatial component to a database; manages, manipulates and analyzes spatial data
Computer-Based Models	Mathematical computer models that represent real world processes and predict outcomes based on input scenarios
Knowledge-Based or Expert Systems	Adopts 'Artificial Intelligence' in the form of organizing, manipulating and obtaining solutions using knowledge in the form qualitative statements, expert rules (i.e. rules of thumb) and a computer language representation system for storing and manipulating knowledge.
Hybrid Systems	Integrates two or more of the above computer-based technologies (e.g. (GIS, KBS and Models) for more versatile, efficient and comprehensive DSTs.

Geo-databases

A database with extensions for storing, querying, and manipulating geographic information and spatial data.

GIS software

GIS Software can be accessed, transferred, transformed, overlaid, processed and displayed using numerous software applications. Within industry commercial offerings from companies such as ESRI and Map-info dominate, offering an entire suite of tools. Government and military departments often use custom software, open source products, such as GRASS, or more specialized products that meet a well-defined need. Although free tools exist to view GIS datasets, public access to geographic information is dominated by online resources such as Google Earth and interactive web mapping.

Basics of ArcGIS/ ArcInfo Workstation

ArcGIS is a desktop mapping program produced by ESRI (Environmental Systems Research Institute, Inc.) that allows you to create your own maps from scratch starting with geographic data in electronic form. There are several interrelated component programs, the basic ones being *ArcCatalog, ArcMap*, and *ArcToolbox*. These three components comprise what is now known as ArcGIS Desktop, or ArcView. When other advanced components are added, it comprises ArcGIS Workstation, or ArcInfo. It is a complex program. Users need to be familiar with Microsoft Windows and must be willing to spend time to learn how to use ArcGIS.

ArcCatalog

ArcCatalog allows the user to easily access and manage geographic data that is stored in folders on local disks or relational databases that are available on the user's network. Data can be copied, moved, deleted, and quickly viewed before it is added to a map. In addition, metadata can be either read or created using this ArcGIS application.

ArcMap

ArcMap allows the user to display and query maps, create quality hardcopy maps and perform many spatial analysis tasks. ArcMap provides an easy transition from viewing a map to editing its spatial features.

ArcToolbox

ArcToolbox provides an environment for performing geo-processing operations (i.e., operations that involve alteration or information extraction). Tools step the user through the many geo-processing tasks. ArcToolbox is embedded in both ArcCatalog and ArcMap.

Data Retrieval

Data collection and preparation is one of the most expensive and time-consuming aspects of creating a GIS facility. There are many governmental and commercial data sources that provide digital and tabular data sets as well as analogue data including maps, aerial photographs, and satellite imagery.

ArcGIS Supported Data Formats

ArcGIS allows the user to work with an extensive array of data sources. These are ArcIMS feature services, ArcIMS map services, ArcInfocoverages, DGN (through v8). DWG (through v2004), DXF, Geodatabases, Geography Network connections, OLE DB Tables, PC ARC/INFO coverage.

Raster Formats

ARC Digitized Raster Graphics (ADRG) (*.img or *.ovr and *.lgg), ArcSDERasters, Band Interleaved by Line (ESRI BIL) (*.bil and *.hdr, *.clr, *.stx), Band Interleaved by Pixel (ESRI BIP) (*.bip and *.hdr, *.clr, *.stx), Band Sequential (ESRI BSQ) (*.bsq and *.hdr, *.clr, *.stx), Bitmap (BMP), Device Independent Bitmap (DIB) format, or MicrosoftWindows Bitmap (*.bmp) ,Compressed ARC Digitized Raster Graphics (CADRG) ,Controlled Image Base (CIB),Digital Geographic Information Exchange Standard (DIGEST) Arc Standard Raster Product (ASRP), UTM/UPS Standard Raster Product (USRP) (*.img and *.gen, *.ger, *.sou, *.qal, *.thf), Digital Terrain Elevation Data (DTED) Level 0, 1 and 2 (*.dt0, *.dt1, *.dt2),ER Mapper (*.ers) ,ERDAS 7.5 GIS (*.gis and *.trl) ,ERDAS 7.5 LAN (*.lan and *.trl) ,ERDAS IMAGINE (*.img),ERDAS RAW (*.raw), ESRI GRID (*.clr),ESRI GRID Stack ,ESRI GRID Stack File (*.stk), ESRI SDE Raster, Graphics Interchange Format (GIF) (*.gif) , Intergraph Raster Files (*.cit and *.cot), JPEG File interchange Format, JIFF (*.jpg, *.jpeg, *jpe), JPEG 2000 (.jp2), Multiresolution Seamless Image Database (MrSID) (*.sid; generations 2 and 3; Note that the export command Raster to MrSID outputs in MrSID generation 2 format), National Image Transfer Format (NITF) (*.ntf), Portable Network Graphics (*.png). Tagged Image File Format (TIFF) (*.tif, *.tiff, *.tff) , SDC (Smart Data Compression), SDE layers, Shapefiles, Text Files (.TXT), and VPF. Additional Data Types Supported via Importers in ArcInfo are ADS, DFAD, DIME, DLG, ETAK, GIRAS, IGDS, IGES, MOSS, S-57, SDTS (Point, Raster, and Vector), SLF, TIGER (through v2000) and Sun Raster.

Data Sources

A data source is any geographic data that may be used as input to or output from a geo-processing tool. Supported data sources include:

1. Geo-database feature datasets
2. Geo-database feature classes
3. Shapefile datasets
4. Coverage datasets
5. Coverage feature classes
6. CAD feature datasets
7. CAD feature classes
8. SDC datasets
9. SDC feature classes
10. VPF datasets
11. VPF feature classes
12. Raster datasets
13. Raster dataset bands
14. Raster catalogs
15. TIN datasets
16. Layers
17. Layer files
18. Tables
19. Table views

Viewing Data in ArcCatalog

Once the user has successfully acquired GIS data in one of the aforementioned supported formats, it can be previewed using the ArcCatalog application. If the data format is listed under the above heading "ArcGIS Supported Data Types," it can be simply viewed without the need to actually import using an import utility. If the data format is listed under any of the other headings (above), the data will first need to be imported. The ArcCatalog application window includes the catalog display that allows you to preview data, either spatially or tabularly, a catalog tree for browsing the data, and several toolbars (Fig.4).

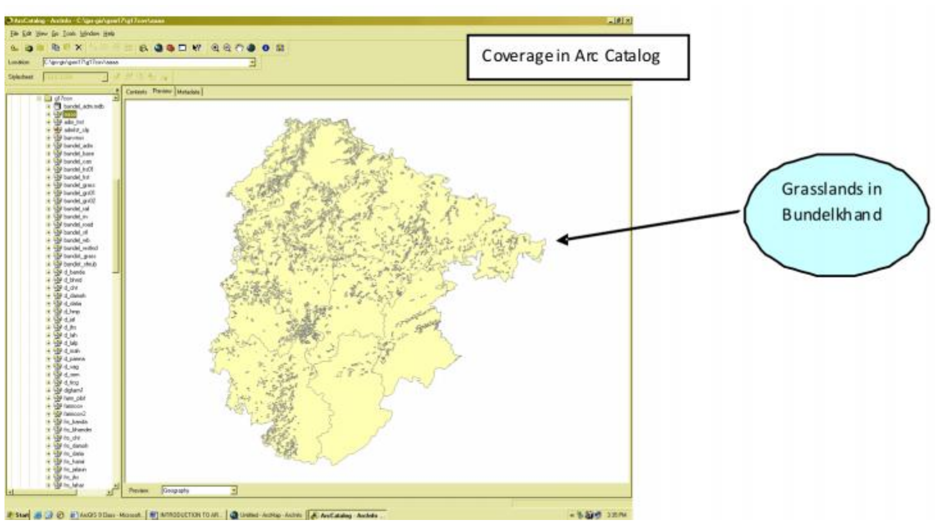

Fig. 4 : Screenshot of ArcCatelog

Viewing Data in ArcMap

The ArcMap application window consists of a map display for viewing spatial data, a table of contents for listing the layers shown in the display and a variety of toolbars for working with data. When ArcMap opens, the ArcMap dialog appears on top of the application window. To open a data layer, the user can specify, whether or not they want to start using ArcMap with a new empty map, a template, or an existing map (Fig. 5).

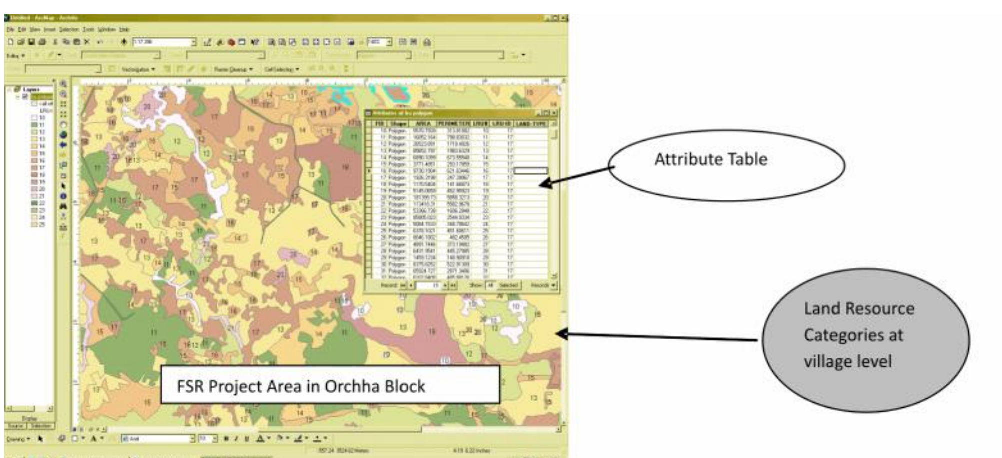

Fig. 5 : Screenshot of ArcMap

Using ArcToolbox

ArcToolbox is the application that provides an environment for performing geographic information system (GIS) analysis. ArcToolbox allows the user to perform a variety of geoprocessing tasks including data conversion. Geoprocessing tools are organized into toolboxes and toolsets within ArcToolbox. The toolbox is organized into toolsets that provide solutions for different types of tasks (Fig. 6).

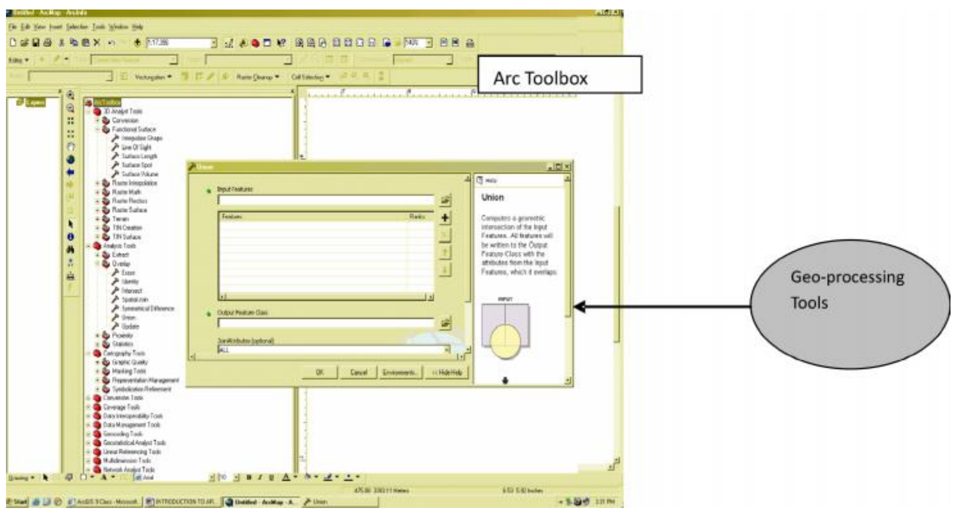

Fig. 6 : Screenshot of ArcToolbox

The eleven toolsets may be seen listed in the graphic immediately below. Four of the more frequently used are briefly described.

1. **Analysis Tools**: This toolset is designed to allow users to perform analysis of vector data including feature and attribute extractions, geographic overlays, create buffers, calculate statistics on attribute data, and perform proximity analysis. If the user wants to solve a spatial or statistical problem in the vector environment, this toolset should be used.

2. **Conversion Tools**: This toolset contains the tools needed to convert data between various formats. The tools are organized into smaller toolsets that pertain to the type of conversion being performed. Most commonly used data formats are supported. The user can convert raster to other formats, prepare and convert features to a native computer-aided design (CAD) format, convert: feature classes to coverage format; tables to dBase format; features and CAD files to geo-database feature classes; data to raster; and convert features to

shapefiles. This toolset should be used whenever a user needs to change from one type of dataset to another.

3. **Data Management Tools:** This toolset allows the user to manage and maintain feature classes, datasets, layers, and raster data structures. Database join operations, topology building, projections and transformations operations, workspace management, and much more. If the user needs to modify the characteristics of a particular dataset they can do so using this toolset.

4. **Spatial Analyst Tools**: This toolset is designed to allow users to perform cell-based (raster) analysis including a variety of neighborhood, overlay, reclass, map algebra, extractions, density, distance, cost surface functions, and more. If the user wants to solve a spatial or statistical problem in the raster environment, this toolset should be used.

Global Positioning Systems (GPS)

GPS is a means for inputting spatial data with real world coordinates into a GIS and has become an important tool for researchers locating and recording information in the field. Remote sensing involves using spatial data from photographic and satellite images, and software tools to analyze and interpret these data.

GPS based ground survey /route line mapping: Intensive ground-truthing and field observation were carried out to generate the geo-spatial information and route mapping (Fig.7).

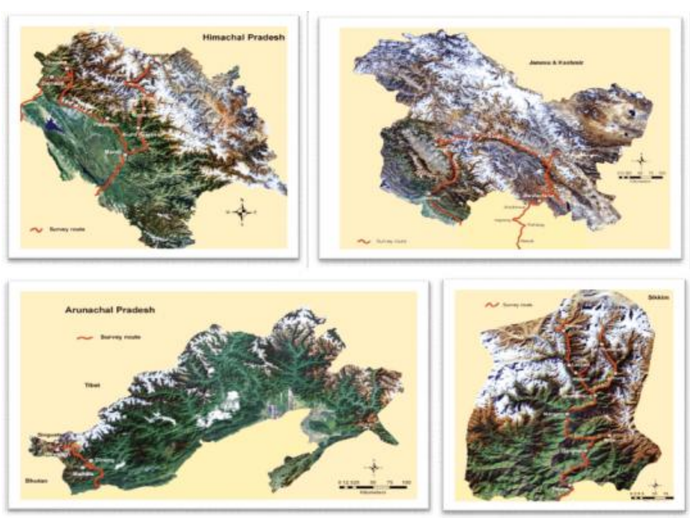

Fig. 7 : Route-line Mapping through GPS of different State

Application of Geo-spatial technologyin Grassland Management

Vast areas mostly under natural vegetation dominated by grasses, which are unfenced, unfertilized and non-irrigated, where animals (wild and domestic) grazed are called grassland/rangeland. The grassland vegetation consists of a number of perennial and annual grasses mixed with legumes and forbs. The availability of grasslands area can be assessed more precisely with the help of satellite remote sensing and GIS tools(Fig.8).

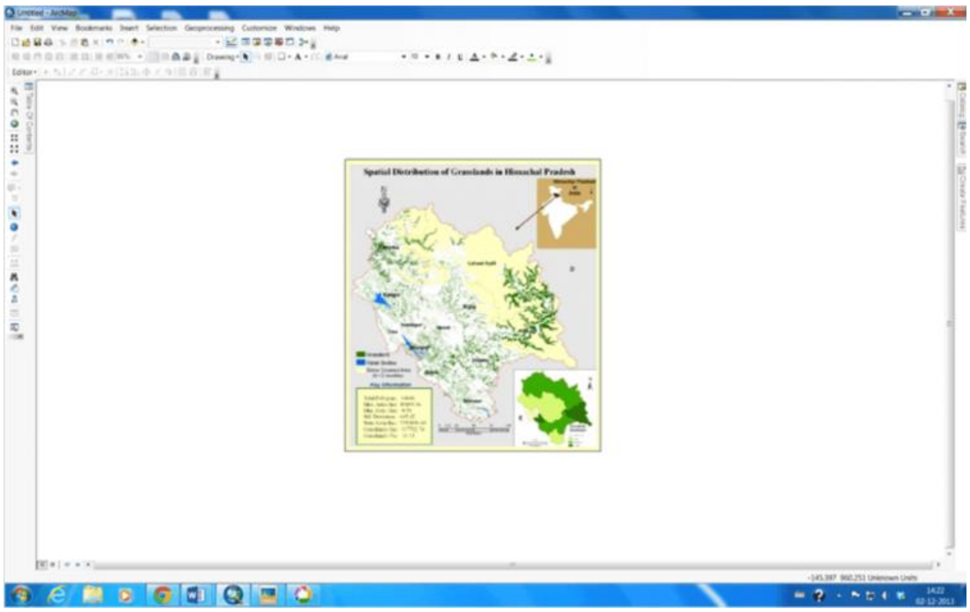

Fig. 8 : Spatial Distribution of Grasslands of Himachal Pradesh- a screenshot of ArcMap 10.1

Himachal Pradesh: The area under grassland in the state constituted only 16.53% (917702.73 ha) of the total area as against 33.34% reported by Directorate of Economics and Statistics, Government of Himachal Pradesh. Grasslands occupied 15.38, 21.56, 17.99 and 15.32 percent area of geo-climatic zone 1 (Low hill sub tropical), 2 (Mid hill sub humid), 3 (Mid hill temperate wet) and 4 (High hill temperate) respectively. Again, according to the hill zone classification, grasslands covered 15.35, 19.51 and 15.23 percent area of low, mid and high hills, respectively.

Jammu and Kashmir: The state of Jammu and Kashmir was targeted for identification, characterization and mapping of grasslands. In this investigation total 21 scenes of IRS P6 LISS-3 bands 2, 3, 4 &5 were used for grasslands identification and mappingFig. 9. The total geographical area of Jammu & Kashmir was 222236 sq. km. Within the state illegally Pakistan has occupied about 34.8% area where another 17.26% area by China. The relief ranges from

500 m. in Jammu to >6000 m. in Ladakh region. The study reveals that about 9595 sq. km(4.32%) area is under productive grasslands and where as other grazinglands including scrubs and other unpalatable grasslands were 10455 sq. km(9.81%) of the total geographical area. The area under grasslands in Jammu, Kashmir and Ladakh were 3.53, 13.22 and 5.76 percent respectively together contributing about 6756.5 sq. kmor 6.34%. Where as in POK it was 2.16% and in China occupied area it was 3.04 percent.

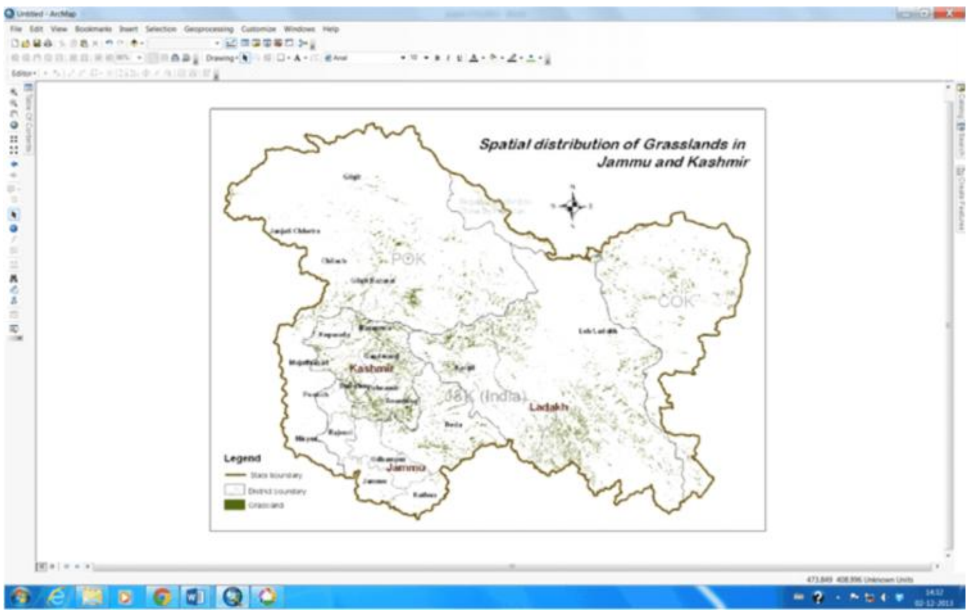

Fig. 9 : Spatial Distribution of Grasslands of J & K- a screenshot of ArcMap 10.1

Sikkim: In this investigation IRS P6 LISS-3 bands 2, 3, 4 &5 were used for grasslands identification and mapping(Fig. 10). The study reveals that about 14.13 % area is under pasture lands of total geographical area of Sikkim.

Bundelkhand: Based on the intensive field survey, study of IRSP6 imagery and geo-spatial analysis geo-referenced information on grassland have been generated at district level.IRSP6 data was used for the identification and analysis of grasslands using ERDAS Imagine software. ArcGIS- ArcInfo workstation was used for the geo-spatial analysis (Fig.11). And Geographical Information System (GPS) was used for intensive ground truthing and sample survey. The study reveals that the area under grasslands was estimated as 3.54% of the total geographical area of Bundelkhand region (about 7160250 ha).

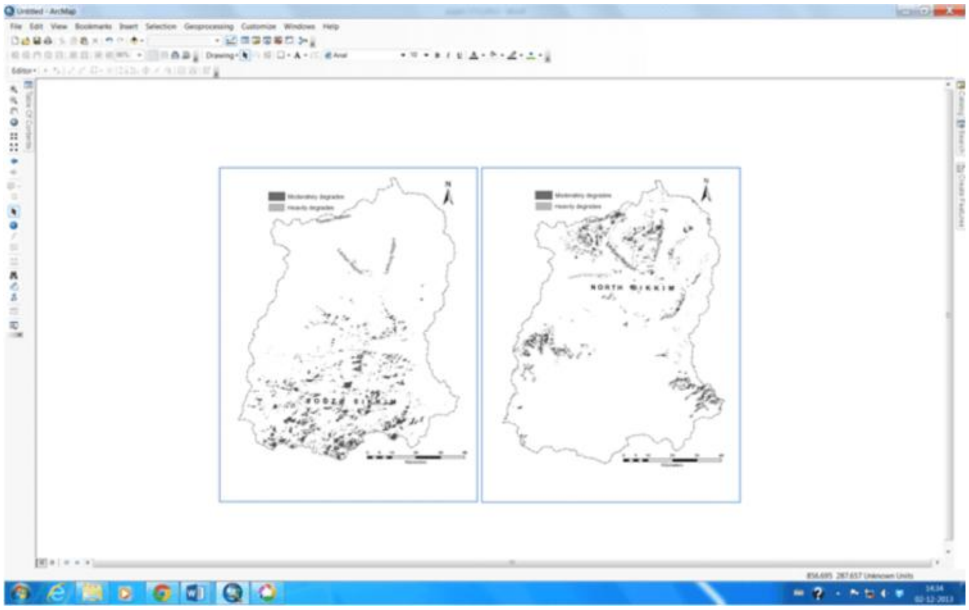

Fig. 10 : Spatial Distribution of Grasslands of Sikkim- a screenshot of ArcMap 10.1

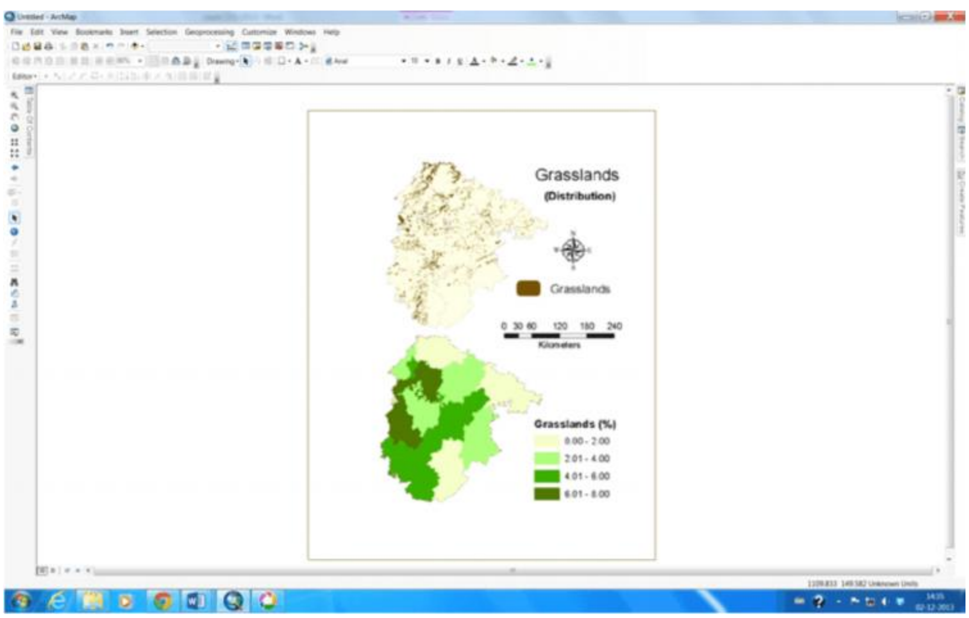

Fig. 11 : Spatial distribution of Grasslands of Bundelkhand Region - a screenshot of ArcMap 10.1

Application of Geo-spatial Technology in Forage Resource Study

The availability of forage from rangelands can be assessed more precisely with the help of satellite remote sensing and GIS tools. The present study reveals that forage production from the rangelands of the Bundelkhand region was approximately 2.57 m t DM/ year. Based on the intensive field survey, study of IRSP6 imagery and geo-spatial analysis geo-referenced information on range forages have been generated at district level. It covers 7160250 haarea located between $23^0 8'$-$26^0 31'$N latitude and $78^0 11'$-$81^0 31'$E longitude. SOI toposheets number 54K, L, J, P, O; 63 A, B, C, D, H, G; 55I and 65M were used for the generation of base map. IRSP6 data dated October 2004 was used for the identification and analysis of grazinglands using ERDAS Imagine (ver. 9.3) software. ArcGIS- ArcInfo workstation (ver.10.1) was used for the geo-spatial analysis. The study reveals that about 1.99 m ha land (27.88%) classified as grazinglands including the forest lands. It was found maximum (55.62%) in Panna district where as minimum (4.55%) in Banda district.

Application of Geo-spatial Technology in Crop Yield Estimation

In many countries Crop yield estimation are based on conventional techniques of data collection for crop and yield estimation based on ground-based field visits and report. Such reports are costly, time consuming and large errors due to incomplete ground observation which leading to poor crop yield assessment and crop area estimation (Reynolds *et al*, 2000). Many empirical models have been developed to try and estimate yield before harvesting. With the development of satellites, remote sensing images provide access to spatial information at global scale; of features and phenomena on earth on an almost real-time basis. They have the potential not only in identifying crop classes but also estimating crop yield and can identify and provide information on spatial variability as well as permit more efficiency in field scouting (Schuler, 2002). Remote sensing could be used for crop growth monitoring and yield estimation. For example, the traditional approach of crop estimation in India involves complete enumeration for estimating crop acreage and sample surveys based on crop cutting experiments for estimating crop yield. Remote sensing technology application for agriculture (Agro-RS) was introduced to China in the late 1970s. Twenty years on, there more than 200 scientists and technicians throughout China works on resources survey, agro-ecological assessment, sown areas, crop condition and disaster monitoring, and yield estimation using remote sensing by Ministry of Agriculture. They have participated in national key projects of Agro-RS, international exchanges, resources and crop monitoring. In 1999, The Center for Remote sensing application of the Ministry of Agriculture organized sub-centers all over China to monitor sown area and production of winter wheat, corn and cotton using satellite remote sensing at national scale. The monitoring results are now a part of the official resources of agricultural information system of the Ministry.

The crop acreage and corresponding yield estimate data are used to obtain production estimates (Singh *et al*, 2002). Final production estimates based on the sampling method become available after the crops are actually harvested. Although the approach is fairly comprehensive and reliable, there is a need to reduce the cost and also to improve upon the accuracy and timeless of crop production statistics. To achieve timely and accurate information on the status of crops and crop yield, there is need to have an up-to-date crop monitoring system that provides accurate information on yield estimates way before the harvesting period. The earlier and more reliable information are the greater the value (Reynolds *et al*, 2000). Remote sensing data has the potential and the capacity to achieve this.

In the present study IRS P6 LISS III (Row 98, Path 53) data dated February 2008 was selected. After the geometric and radiometric correction and histogram enhancement the image was classified using Erdas Imagine Professional s/w ver. 9.3. It was modified on the basis of the information gathered during the ground truthing and field data verification. Finally information on wheat yield production was generated in ArcGIS ArcInfo Workstation ver10.1 and presented in Fig.12. The study reveals that the total area under a single crop (Wheat) is

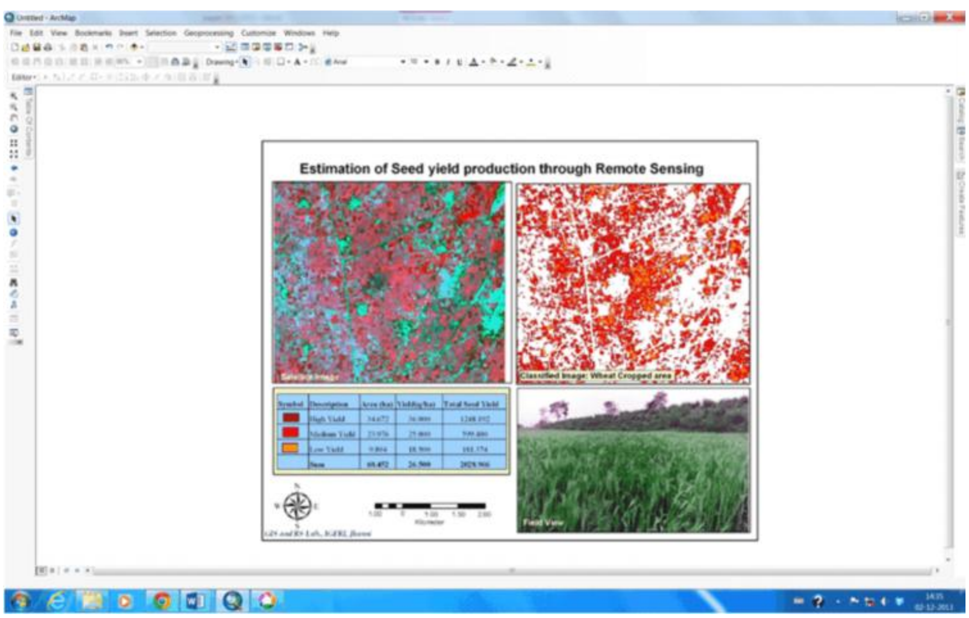

Fig. 12 : Estimation of Seed Yield Production - a screenshot of ArcMap 10.1

about 43% (ha) of the total geographical area. Based on crop health (plant vigor) it was classed as high yielding crop (34.67ha), medium yielding crop (23.97ha) and low yielding crop (9.80 ha). Again based on ground sample data the seed yield was estimated under Arc GIS environment. The total seed yield was estimated as 202.89 ton. This technique can be applied for the estimation of seed production for any crop at regional to nation level with suitable modification.

Application of Geo-Spatial Technology for Biomass Estimation

Biomass is an important element in the carbon cycle, specifically in carbon sequestration which is useful to help in quantifying the pools and fluxes of greenhouse gasses (GHG) from the terrestrial biosphere to the atmosphere associated with land-use and land cover changes. Development and applications of appropriate biomass estimation methods for precise assessment of above ground biomass is important for national development planning as well as for scientific studies of ecosystem productivity, carbon budgets etc. Mathematical modeling to forecast growth/production of different components of forage and fodder crops is an essential tool to predict the performance of the system. Prominent among the methods of forecasting are based on models that utilize data on crop biometrical characters, weather parameters, farmer's eye estimates, agro meteorological conditions and remotely sensed crop reflectance observations etc. has modeled the performance of *Acacia tortilis – Cenchrus ciliaris* silvopastoral system spread over three sites. Modeling growth and yield of multipurpose tree species have been tried in F/FRED project of Winrock International. But developing a biomass equation requires harvesting of trees and measurement of sample trees for their biomass which is quite a tedious, time consuming task and normally tree felling is not permitted. To overcome this problem an alternative is Geomatics (GIS/RS/GPS) based biomass assessment technique which does not require harvesting of trees. Locally developed biomass equations give better estimation compare to existing regional or global biomass equations. Vegetation Indices developed using RS parameters can be used to build above-ground biomass and further can be a useful tool to asses carbon sequestration. On the basis of RS parameters biomass equations can be developed and validated through the use of geo-spatial tools (Fig. 13). The sampled information can be precisely and accurately up-scaled to regional or national level.

Similar type of work of estimating tree above ground biomass through statistical modelling using Remotely sensed parameters captured by Geomatic tools was undertaken at Indian Grassland and Fodder Research Institute in which project predictive equations for biomass production from some shrub and multipurpose trees were developed on the basis of several species available at IGFRI, Jhansi Central Research Farm which will be able to provide objective crop forecasts with reasonable precisions well in advance before harvests for taking timely decisions.

Research Approach

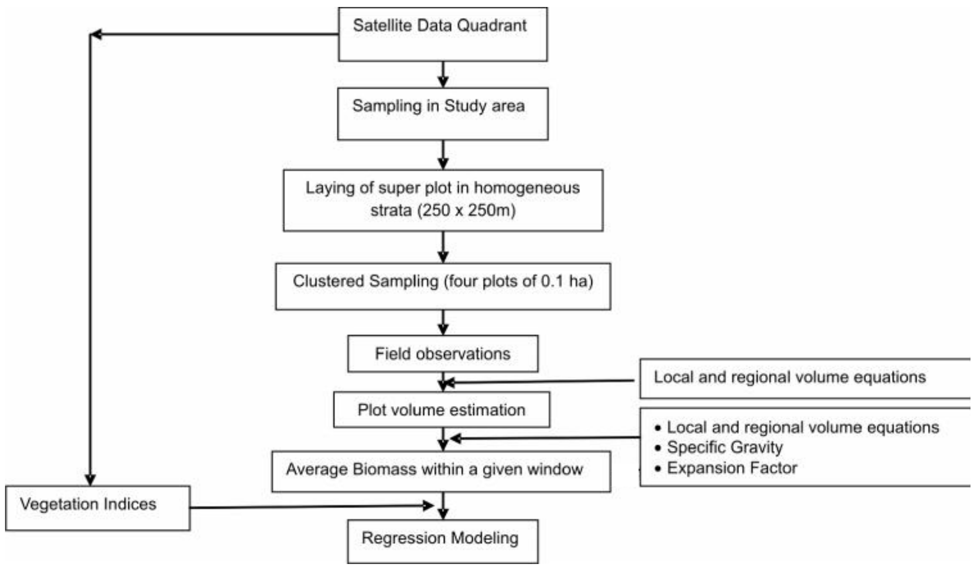

Fig. 13 : Broad steps of biomass estimation

The database used for this study purpose contains information on Altitude, Soil type, Crown density, Stand ht., CBH, Dia, Tree-Height , Ht-1st-forking, dbh, Radius, and Basal area of all these species along with remotely sensed parameters like Normalized Difference Vegetative Index (NDVI). Based on these biometric values total wood biomass of particular tree species can be calculated using the volume equations given in the State of Forest Report 2005, forest survey of India , Ministry of Environment & Forests, Dehradun. The sampling of tree data was done by selecting total 20 zonal sites i.e. quadrants, then 100 sites per quadrant i.e. total 2500 plots (each of 250m x 25m size) selected and finally 4 sample plots from each sites cumulating 10000 permanent sample plots were used. The dbh range of sample trees was 3.00 cm to 35.00 cm which constitutes the predominant diameter range of the region.

Study sites and data collection: In the present study Data was collected on different biometric or physiological characters of several tree and shrub species, grown at different sample sites representing the Central Highland physiographic zone of Madhya Pradesh and Uttar Pradesh, which are identified inNational Carbon Project (NCP) for Vegetation Carbon Pool Assessment (VCP) under ISRO Geosphere Biosphere Program (IGBP) as one of the 20 Zonal sites of 350 x 350km more or less equivalent to one quadrant of AWiFS scene.

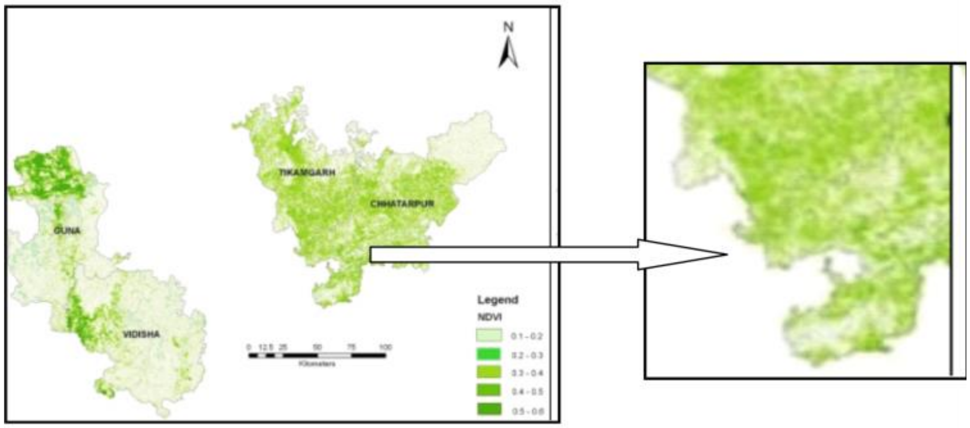

Fig. 14 : Data collection from different District of MP part of Bundelkhand Region

Sample tree selection:For collection of tree data in total 20 zonal sites i.e. quadrants were first selected then 100 sites per quadrant i.e. total 2500 plots (each of 250m x 250m size) selected and finally 4 sample plots from each sites cumulating 10000 permanent sample plots were used. The following diagram shows the final sample plot (Fig. 15).

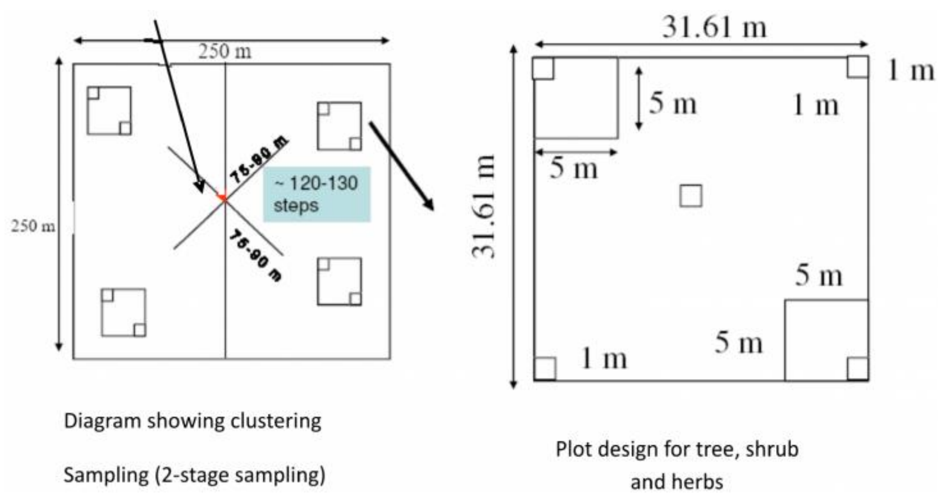

Fig. 15 : Sample of tree selection each of 250m x 250m in size

First of all the data that was collected, arranged and classified to study different descriptive statistics, distribution of the data for its suitability to build biomass models. The database consists of data on different physiological parameters like CBH (Collar Dia. At Breast Height), Diameter, Tree Height, Height at First Forking, DBH (Diameter at Breast Height), Basal Area etc. of 7 trees and shrub species grown in 8 districts (Datia, Guna, Tikamgarh, Shivpuri, Hamirpur, Jhansi, Lalitpur and Mahoba) of U.P and M.P of India. Figure 16.shows frequency of different species corresponding to their different DBH classes.Table 3.contains the species selected, DBH, CBH, Basal Area range and No. of trees.

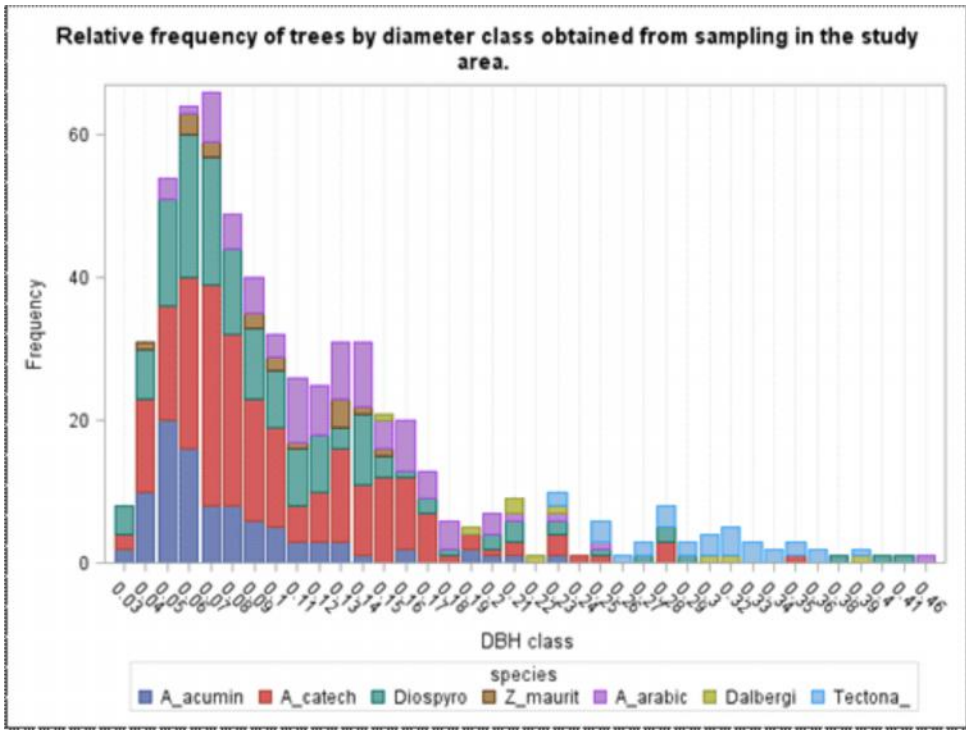

Fig. 16 : Relative frequency of trees

Table 3: No. of sample trees by species and diameter range:

Sl. No.	Tree/Shrub Species	DBH Range(m)	CBH Range(cm)	Basal Area Range(m)	No. of Trees
1	*Anogeissusacuminata*	0.032 - 0.228	10.1 - 71.5	0.008 - 0.406	92
2	*Acacia Arabica*	0.049 - 0.455	15.7 – 143.0	0.019 - 1.627	83
3	*Acacia Catechu*	0.033 - 0.345	10.6 - 108.5	0.008 - 0.936	220
4	*Dalbergiasissoo*	0.154 - 0.386	48.5 - 121.5	0.187 - 1.174	9
5	*Diospyrosmelanoxylon*	0.032 - 0.409	10.2 - 128.6	0.008 - 1.316	145
6	*Tectonagrandis*	0.229 - 0.387	—-	0.414 - 1.176	30
7	*Zizyphusmauritiana*	0.040 - 0.145	12.6 - 45.7	0.012 - 0.166	17

The descriptive statistics of the data were calculated as follows:

Table 4: Tree sample analysis of different tree spacies

Botanical Name	N Obs	Variable	Mean	Std. Dev.	Minimum	Maximum	Coeff. of Variation
A. acuminata	92	CBH(cm)	24.56543	13.04545	10.1	71.5	53.1049
		Dia(cm)	7.819427	4.152499	3.214933	22.759176	53.1049
		Tree-Height (mts)	2.810652	1.441602	0	7.23	51.29067
		dbh(D) m	0.078194	0.041525	0.032149	0.2275918	53.1049
		Basal area	0.061418	0.075788	0.008118	0.4068203	123.3982
		Frequency	411.5	26.70206	366	457	6.488957
A. arabica	83	CBH(cm)	41.25783	17.42643	15.7	143	42.23788
		Dia(cm)	13.13279	5.54701	4.997469	45.518352	42.23788
		Tree-Height (mts)	3.39759	1.089302	1.7	6.7	32.06103
		dbh(D) m	0.131328	0.05547	0.049975	0.4551835	42.23788
		Basal area	0.159333	0.187097	0.019615	1.6272811	117.4253
		Frequency	499	24.10394	458	540	4.830449
A. catechu	220	CBH(cm)	31.68636	16.4838	10.6	108.5	52.02173
		Dia(cm)	10.22788	5.287854	3.374088	34.536652	51.70037
		Tree-Height (mts)	3.455455	0.798753	1.5	5.5	23.11572
		dbh(D) m	0.102279	0.052879	0.033741	0.3453665	51.70037
		Basal area	0.104021	0.121675	0.008941	0.9368067	116.9714
		Frequency	110.5	63.6527	1	220	57.60426
Dalbergiasissoo	9	CBH(cm)	77.62889	23.31788	48.5	121.5	30.03763
		Dia(cm)	24.71006	7.422318	15.43804	38.674684	30.03763
		Tree-Height (mts)	9.844444	2.932197	7.5	16.5	29.78529

Contd.

		dbh(D) m	0.247101	0.074223	0.15438	0.3867468	30.03763
		Basal area	0.518014	0.319457	0.187186	1.1747435	61.66955
		Frequency	545	2.738613	541	549	0.502498
Diospyrosme lanoxylon Tectonagrandis	14530	CBH(cm)	32.16966	20.96043	10.2	128.6	65.15591
		Dia(cm)	10.42082	6.903927	3.246764	40.934686	66.25131
		Tree-Height (mts)	5.388966	3.813538	0	14.6	70.76568
		dbh(D) m	0.104208	0.069039	0.032468	0.4093469	66.25131
		Basal area	0.122466	0.204563	0.008279	1.3160502	167.0367
		Frequency	293	42.00198	221	365	14.33515
		Tree-Height (mts)	10.40033	1.643651	4.9	12.7	15.80383
		dbh(D) m	0.301906	0.04155	0.229852	0.3870015	13.76262
		Basal area	0.728973	0.197799	0.41494	1.176291	27.13398
		Frequency	581.5	8.803408	567	596	1.513914
Z. mauritiana	17	CBH(cm)	30.77647	10.55619	12.6	45.7	34.29955
		Dia(cm)	9.796463	3.360143	4.010708	14.546774	34.29955
		Tree-Height (mts)	4.752941	1.305813	2.5	7.5	27.47378
		dbh(D) m	0.097965	0.033601	0.040107	0.1454677	34.29955
		Basal area	0.083721	0.05147	0.012634	0.1661969	61.47764
		Frequency	558	5.049753	550	566	0.904974

The scatter plot of sample tree wood volume against DBH (Figure 17) demonstrated a good association between these two variables.

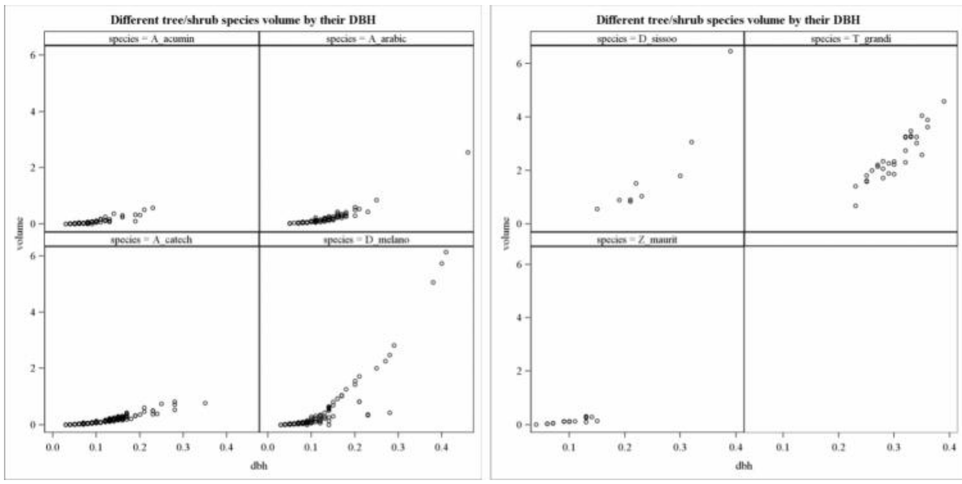

Fig. 17 : The scatter plot of sample tree wood volume against DBH

Most commonly used non linear functions for fitting relationship between wood volume and dbhwere tried for all the species and the best fitted one was of the type

$$\text{wood volume} = a^* (\text{dbh})^b$$

In the present analysis the modified Gauss-Newton method has been used. The following Figure 3 demonstrates the samples of all the 7 tree and shrub species with a good list square fit by the power modelbetween wood volume and DBH. The best fit can be observed from a good R^2 (coefficient of determination)value obtained from the power model. As, for non linear models the R^2 alone is not enough to judge the fit of the model, so The residual diagnostics was also performed to assess the goodness of fitof the model. The predicted volume against dbh, it closely matches the observed ones. Observed Vs predicted value plot and autocorrelation plot of residuals also shows the close association. Autoregressive procedure is performed here also to identify the presence of autocorrelation. The first order Durbin-Watson test is not significant which signifies that the error terms are independent.

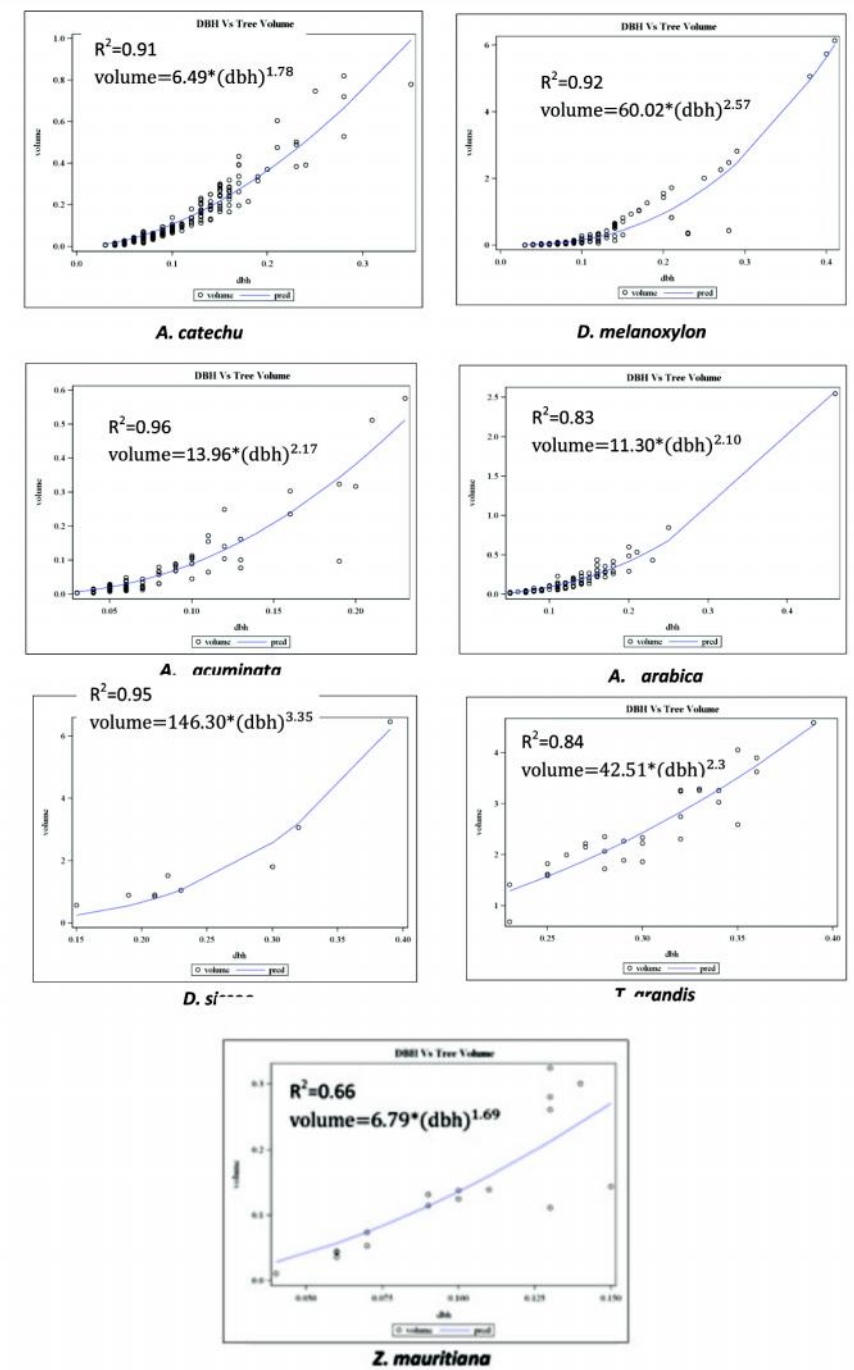

Fig. 18 : The scatter plot of sample DBH Vs Tree Volume

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