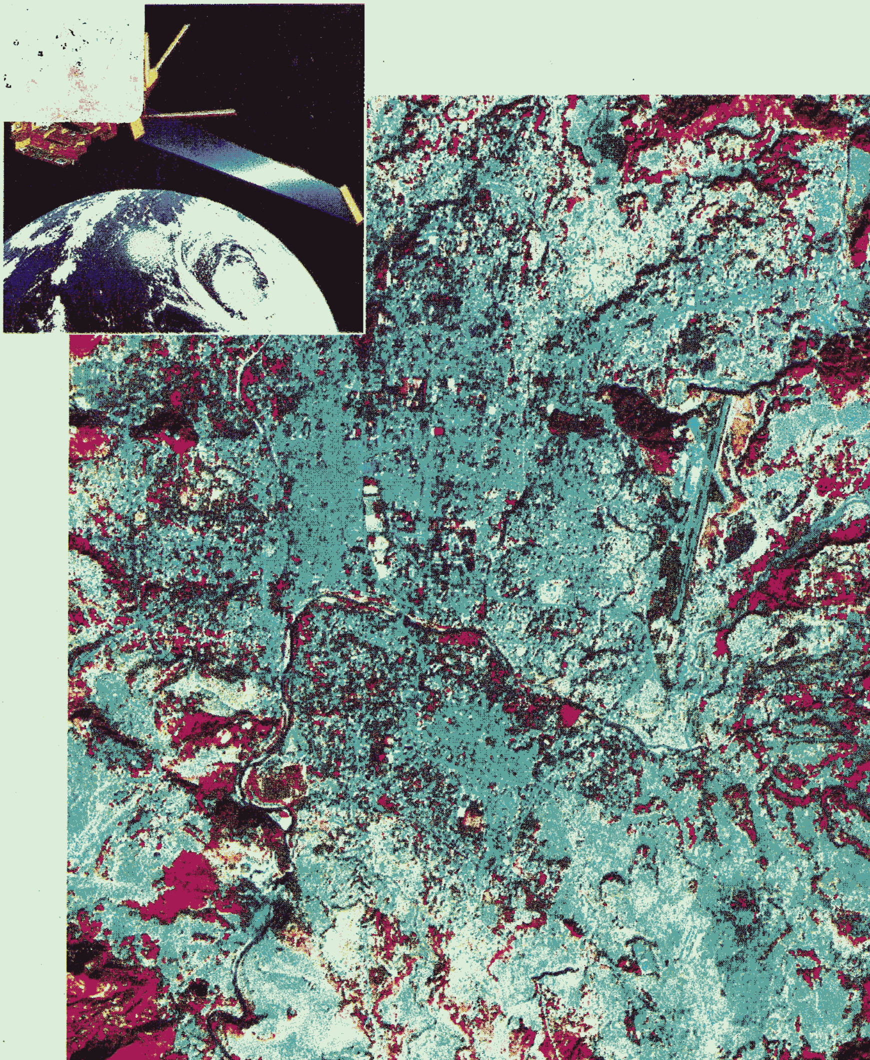
Application of Satellite Remote Sensing in Forest Resource Management in Nepal



Department of Forest Research and Survey
Ministry of Forests and Soil Conservation,
Babarmahal, Kathmandu, Nepal

Application of Satellite Remote Sensing in Forest Resource Management in Nepal

Prepared by

Dr. Swoyambhu Man Amatya
Mr. Rajendra B. Joshi
Mr. Sahas Man Shrestha
Mr. Siva Sharma Paudel
Mr. Gyani Babu Juwa and
Mr. Rishi Ram Sharma

Department of Forest Research and Survey
Ministry of Forests and Soil Conservation,
Babarmahal, Kathmandu, Nepal
June, 2000

Published by

Department of Forest Research and Survey
Ministry of Forests and Soil Conservation
Babarmahal, Kathmandu, NEPAL
Tel : 222601, 220482
Email: foresc@wlink.com.np

Date of Publication
June 2000
500 Copies

Cover page: ADEOS (AVNIR) False Colour Image of Kathmandu Valley (Image of December 5, 1996) and ADEOS Satellite on Inset

Layout, Designed and Printed at
P.U. Printers
Battisputali, Kathmandu
Tel: 480452

PREFACE

This report focuses on the application of satellite remote sensing in forest resources management of Nepal. The Chapter 1 deals with concept of Satellite Remote Sensing Technique while Chapter 2 deals with Application of Remote Sening in Forest Resource Management.

Remote sensing is one of the important tools in forest resource management. Recently, while carrying out the National Forest Inventory of Nepal, satellite remote sensing data were extensively used. Now- a-days high-resolution remote sensing data are also available and thus management of natural resource at local level is also possible.

Forestry professional unfamiliar with remote sensing techniques may find vocabulary difficult. The aim of the document is partly to describe the current state of the science, hence the use of remote sensing nomenclature was unavoidable. Nonetheless, it is not intended as an introductory remote sensing textbook but to provide a simple understanding of the science.

This is the first document of this kind, especially in forestry discipline. Despite the careful editing and compilation, there could be several errors and omissions and we would like to take the responsibility of such errors and omissions.

Finally, we would also like to take this opportunity to thank our colleagues who supported to bring out the document. Special thanks are to the support staffs Ms. Anu Rajbhandari, Ms. Sangita Shakya and Ms. Junu Shrestha for their effort in providing figures and pictures obtained from the satellite data.

The Authors

Phone - 220067
223862
Fax - (977-1) 223868

His Majesty's Government
MINISTRY OF FORESTS AND SOIL CONSERVATION

Singh Durbar
Kathmandu, Nepal

Ref.

26 June, 2000

FOREWORD

In Nepal, forest resource assessments have been carried regularly since 1960. In this regard National Level Forest Inventory (NFI) also falls into this category. One of the objectives of NFI is to develop strategic planning sources for developing the national forests of Nepal.

Recently, remote sensing has become increasingly important in the assessment of forest resources of the country. A national level forest inventory was also carried out based on satellite data. Satellite images from Landsat MSS of 1977 were used to estimate the national forest coverage.

This book illustrates the concept and application of remote sensing and its techniques used in analyzing the forest resources of the country. As far as I know, this is the first book of its kind prepared by Dr. Swoyambhu Man Amatya, Deputy Director General and his colleagues of the Department of Forest Research and Survey. I believe, this book will be an added asset in this field. I would like to congratulate Dr. Amatya and his team in bringing out this book.

(Mr. Rabi B. Bista)
Secretary
Ministry of Forests and Soil Conservation

Table of Contents

Terms Used in Satellite Remote Sensing Technology

ADEOS	Advanced Earth Observation Satellite
AVNIR	Advanced Near Infrared
CCT	Computer Compatible Tape
CD-ROM	Compact Disk-Read Only Memory
DEM	Digital Elevation Model
ERDAS	Earth Resource Data Analysis System
ERS	European Remote-sensing Satellite
GIS	Geographical Information System
ILWIS	Integrated Land and Water Information System
IRS	Indian Remote Sensing Satellite
JERS	Japan Earth Resource satellite
Landsat	Land Resource Satellite
LISS	Linear Imaging Scanner System
LRMP	Land Resources Mapping Project
MSS	Multi Spectral Scanner
NFI	National Forest Inventory
NRSC	National Remote Sensing Centre
RADAR	Radio Detection and Ranging
SPOT	Systeme Probatoire d'Observation de la Terra
TM	Thematic Mapper

Chapter 1

Satellite Remote Sensing Technique

Remote sensing is the acquisition of data about an object or scene by a sensor that is far from the object. Aerial photography, satellite imagery, and radar are all forms of remotely sensed data. Usually, remotely sensed data refer to data of the earth surface collected from sensors on satellite or aircraft.

Before using remote sensing data, clear understanding of data use, data processing, tools and techniques, and its limitation, are necessary. Since Nepal does not have its own receiving station, available remote sensing data should be searched through internet or other communication media to suit for use in the country. The nearest, receiving station, which covers Nepal, is located in Hyderabad, India. Bangkok station of Thailand only covers Eastern Nepal. India has own remote sensing satellites called IRS.

Electromagnetic radiation reflected or emitted from an object is the usual source of remote sensing data. A device to detect the electromagnetic radiation reflected or emitted from an object is called "remote sensor" or "sensor". A vehicle to carry the sensor is called "platform". Aircraft or satellites are used as platforms.

The sensors on remote sensing platforms usually record reflected or emitted electromagnetic radiation. Electromagnetic radiation is energy transmitted through space in the form of electric and magnetic waves. Remote sensors are made up of detectors that record specific wavelengths of the electromagnetic spectrum.

All matters reflect, absorb, penetrate and emit electro-magnetic radiation in a unique way. For example, the reason why a leaf looks green is that the chlorophyll absorbs blue and red spectra and reflects the green spectrum. The unique characteristics of matters are called spectral characteristics.

1.1 Spectral Response of Land Covers

All type of land cover or objects-rock type, water bodies, vegetation, soil etc. absorb a portion of the electromagnetic spectrum, giving a distinguishable "signature" of electromagnetic radiation. A signature is a unique value recorded in a digital number for a given object. An object from the earth surface can be identified by looking the response (reflected or emitted energy) with the specific range of electromagnetic spectrum.

Figure 1 shows three curves of spectral reflectance for typical land covers; vegetation, soil, and water. As seen in the figure, vegetation has a very high reflectance in the near infrared region. Soil has rather higher values for all most all spectral region. Water has almost no reflectance in the infrared region.

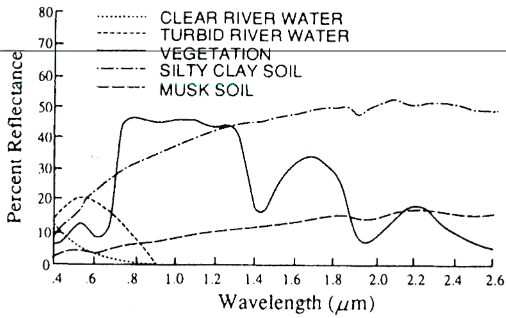


Figure 1. Spectral reflectance of vegetation, soil and water

Based on the response with the reflected or emitted energy in reflectance spectra different vegetation types and condition can be identified. Vegetation, attacked by disease can be distinguished by comparing the spectral curve of a healthy to unhealthy vegetation. The yield forecasting can also be done. Figure 2 shows a comparison of spectral reflectance among different forest types.

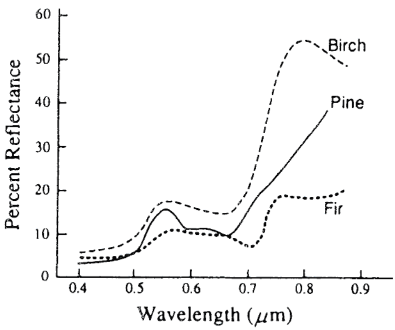


Figure 2. Spectral reflectance of different forest types

1.2 Remote Sensing Satellites and Sensors

There are about a dozen of remote sensing satellites launched by various nations in space. Some of them are- Landsat (USA), SPOT (France), IRS (India), ADEOS (Japan), ERS (EU), JERS (Japan), etc. Within a satellite, different sensors acquired the data in different bands and resolution. Some important sensors are MSS (Landsat), TM (Landsat), AVNIR (ADEOS), LISS (IRS) etc.

Remote sensing satellites are characterised by altitude, orbit, and sensors. Most of the remote sensing satellites operates at an altitude of around 900-km from the earth surface. They have sun-synchronous orbit. This means satellites always pass above a particular ground position at the same local time. Other satellites, called geo-synchronous satellites operate at the altitude of 36,000 km from the earth surface. Communication satellites are geo-synchronous satellites. These satellites are always moving above the same geographical position. Their orbits are parallel to the earth orbit. Contrary to the satellite, aircraft usually flies few thousand meters above the ground surface.

1.3 Radar Satellites

There are two types of remote sensing system: active type and passive type. In passive type, sensors record or detect incoming energy from a ground object without sending its own energy source. Satellites like Landsat, Spot, IRS etc. are passive types. They record reflected energy, originally coming from the sun or emitted energy from a ground object. In active type, sensor records reflected energy, originally sent from the satellite. Microwave energy is usually used in active type. All the radar satellites such as Radarsat, ERS, JERS are of this category.

In passive type, sensor cannot detect the ground object, which is underneath the cloud. But in active type, sensor can record or detect reflected energy coming from ground object penetrating cloud. In some cases, sub-surface information can be obtained from the use of active remote sensing system. Radar data is especially useful for flood monitoring.

1.4 Image Data

In general term, an image is a digital picture or representation of an object. Remotely sensed image data are digital representation of the earth's surface. Image data are stored in data files, also called image file, on computer compatible magnetic tapes (CCT), computer disks, CD-ROM, or other media. The image data consists only of numbers. These representation forms image when they are displayed on a screen or printed in hardcopy. Each number in an image file is referred to as pixel. The term pixel is abbreviated from picture element. A pixel is the smallest part of a picture with a single value. In remotely sensed data, each pixel represents an area of the earth at a specific location. The data value assigned to that pixel is the record of reflected light or emitted heat from the earth's surface at that location.

Satellite image represents radiation conditions of the surface of a certain area. Topography of terrain, slope and aspects generates variations to radiation. For example, having same forest type but on a different side (aspect) of the mountain different radiation values to the pixels of an image can be obtained. Shadow in the satellite image, caused by the topography of an area, distorts the radiation values. Therefore, the real radiation of the surface is difficult to identify.

Image data may include several bands of information. Each band is a set of data values for a specific portion of the electromagnetic spectrum of reflected light or emitted heat. This means same object on the earth surface can be recorded by different sensor of different electromagnetic spectrum. This is why Landsat TM has seven band data, MSS has four band data, SPOT has three-band data etc. Figure 3 shows pixels and bands in a typical raster image.

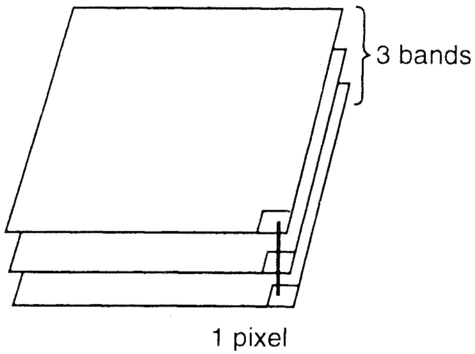


Figure 3. Pixels and Bands in a Raster Image

1.5 Co-ordinate Systems

The location of a pixel in a file either displayed only or printed as an image can be expressed using a co-ordinate system. In two-dimensional co-ordinate systems, location is organised in a grid of columns and rows. Each location on the grid is expressed as a pair of co-ordinate known as X and Y. The X co-ordinate specifies the column of the grid, and the Y co-ordinate specifies the row. Image data organised into such a grid are known as ***raster data***.

There are two basic co-ordinate systems used in image data.

- File co-ordinates: This indicates the location of a pixel within the image (data file). Usually upper left co-ordinate is assigned (1,1), which means the co-ordinate of upper left pixel is x=1 and y=1 or row =1 and column =1. This co-ordinate system is independent with the geographical co-ordinate system.

- Map co-ordinates: This indicates the location of a pixel in a map. The position of a pixel in map co-ordinate system can be expressed by different values depending on the types of projection system. The most common one is latitude and longitude co-ordinate system.

1.6 Resolution

'Resolution' is a broad term commonly used to describe:

- the number of pixels displayed on a display device, or

- the area on the ground that a pixel represent in an image file.

These broad definitions are inadequate when describing remotely sensed data. In remote sensing, distinct types of resolution can be considered:

- ***Spectral resolution*** is known as the specific wavelength intervals that a sensor can store. Each band of the image represents the radiation of the specific wavelength of the ground surface. This is called spectral resolution. In the land resource satellites, the spectral resolution has been selected so that different features of the surface of the ground can be recorded as clearly as possible, for example, one band is sensitive for biomass, another is sensitive for water, etc.

- ***Spatial resolution*** is known as the area on the ground represented by each pixel. A satellite image is composed of raster data. It means that the image is built by square grids, which is called pixel. Each square has its own radiation value. Pixel size on the ground is called spatial resolution of the image. If the spatial resolution is 30 m x 30 m, features smaller than 30 m x 30 m cannot be identified separately on the image. Landsat TM has spatial resolution of 30m x 30m, SPOT panchromatic has 10m x 10m, and multispectral has 20m x 20m.

- ***Radiometric resolution*** is known as the number of possible data file values in each band. It is generally expressed in bits (7 bits, 8 bits). If the radiometric resolution has 8 bit data ($2^8 = 256$ levels), satellites can record or detect 256 different levels of an object.

- ***Temporal resolution*** is known as how often a sensor obtains imagery of a particular area. This is also called revisit cycle. Usually on the interval of two week's time, satellite revisit the same trajectory path.

1.7 Data Format

Ground receiving stations directly receive remote sensing data when a satellite passes over the ground station. Multi-band or multi-spectral image data are represented by a combination of spatial position (pixel number and line number) and band. The data format for a multi-band image is classified into the following three type.

- **BSQ format** (Band sequential) image data (pixel number and line number) of each band are separately arranged (see figure 4).

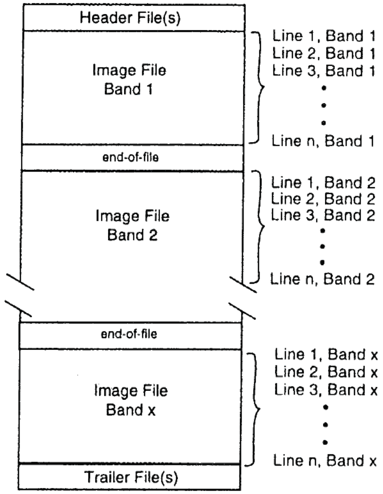


Figure 4. A typical structure of band sequential (BSQ) format

BIL format (band interleaved by line) line data are arranged in the order of band number and repeated with respect to line number (see figure 5).

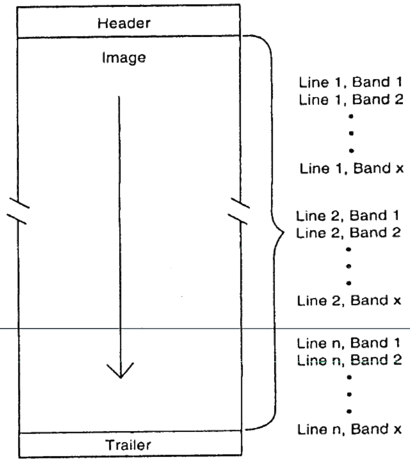


Figure 5. A typical structure of band interleaved (BIL) format

- **BIP format** (band interleaved by pixel) a set of multi-band data with respect to each pixel arranged spatially by pixel number and line number. The sequence of BIP format is:

  Pixel 1, Band 1
  Pixel 1, Band 2
  Pixel 1, Band 3
  .
  .
  .
  Pixel 2, Band 1
  Pixel 2, Band 2
  Pixel 2, Band 3
  .
  .
  .

An image scene is composed of multiple files, each of which is composed of multiple record. Data other than image data in the files are called auxiliary data. The auxiliary data involves description of file, dimension of image data, format, platform, sensor, satellite position data etc.

Remote sensing data involves many artificial variations or errors resulting from sensitivity of detector, atmospheric condition, alignment of detectors and so on. To remove the system errors or variation the image data should be calibrated with the ground truth data. Calibration is defined as the correction of the observed data, or relationship, into physically meaningful data, or relationship, by using a reference. Calibration can be classified into two types: ground calibration and on-board calibration.

1.8 Image Interpretation or Classification

Satellite image analysis can be carried out in two ways: visually or numerically. Visual interpretation does not presume any computerised facilities. It is purely subjective interpretation by human interpreter. Conventional visual interpretation (dichotomous keys) e.g. colour, size, texture, tone etc are used in the analysis. Numerical interpretation is based on the use of the computers and other electrical facilities.

Land resource satellites (Landsat, SPOT, IRS, etc.) record the images used in forestry applications. The image are recorded by the sensor of the satellite and received by the ground station. The images are in numerical form. Only the computer handles them.

The basic differences between visual and numerical analysis is that with numerical analysis, large areas can be classified much faster than with numerical analysis using computer. Computers give a similar result for similar areas, but the visual interpretation is sensitive to human subjectivity and there could be errors. On the other hand, a computer does not think like a human brain. The computer can make Very severe omission, for example, when unsupervised classification is carried out, tea plantation could be classified as forest. Perhaps, by a visual classification, the analyst would be able to tell the difference between forest and tea plantations.

1.9 Visual Interpretation

A numerical image has many bands. When producing a hardcopy, not all original information can be utilised. At a time, only three bands can be utilised for hard copy production. Someone has to decide which bands will be used and which will be rejected for printing purpose. Landsat Thematic Mapper has seven bands. Depending upon the band selection during printing, different false colour composite images can be formed. For example, by assigning band 4 in red, band 3 in green and band 2 in blue colour plates, a standard false colour image can be obtained (figure 6). In the standard false colour image, red colour associates with vegetation. Same image but choosing different band combination for printing, band 7 (red), band 4 (green) and band 1 (blue), is shown in figure 7. In figure 7, green colour is strongly associated with vegetation or forest.

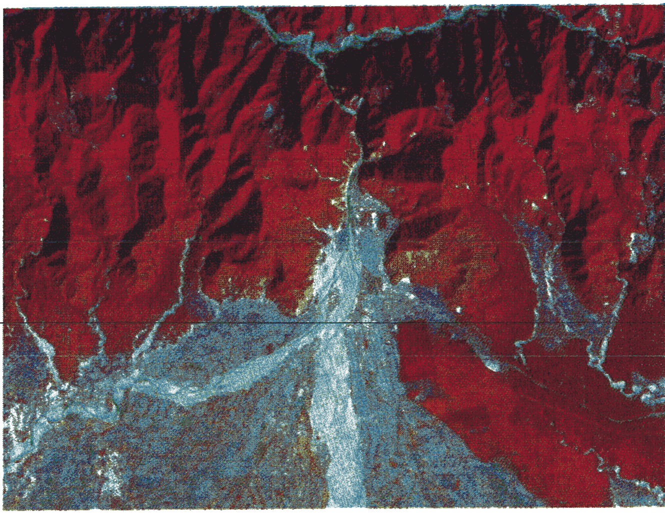


Figure 6. A standard false colour image of Butwal area (showing Tinau river), band 4 (red), band 3 (green) and band 2 (blue)

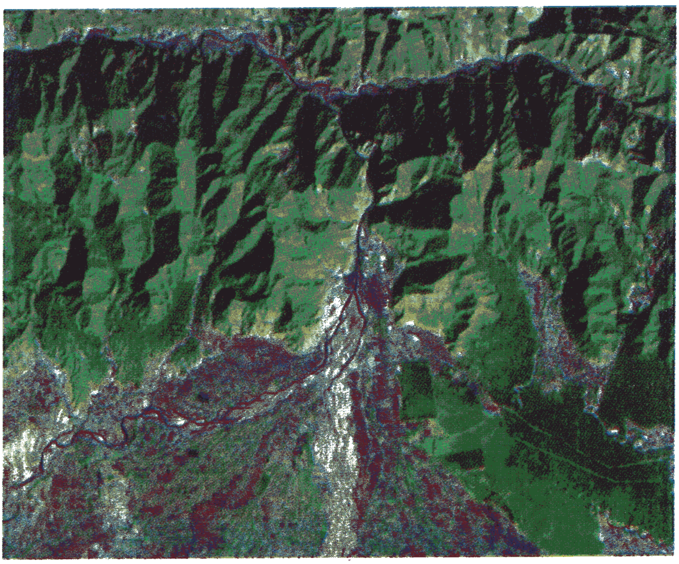


Figure 7. Same image of the area (as in figure 6), but with different colour combination, band 7 (red), band 4 (green) and band 1 (blue)

Interpretation of the visual hardcopy can be done manually only. Necessary and desired features on the hardcopy are delineated manually. Information drawn on the output can be transformed later in the digital format. For interpreting a data, clear understanding of spectral response of different objects is needed. Satellite image hardcopy does not have significant distortion due to very high altitude. Satellite images are recorded at 700 - 900 km altitude, but air photos are always taken under 8 kilometres altitude.

Classification is the process of sorting pixels into a finite number of individual classes, based on their radiation values. Class limits can be decided by a computer or by an analyst. Accordingly, classification is called unsupervised or supervised classification.

Vegetation has typical response with electromagnetic spectrum. In general, vegetation has higher digital number in infrared band. Actual phenomena and reason of showing the different behaviours in different bandwidths has linkages with atomic structure and energy level of electromagnetic spectrum.

Human eye can not differentiate more than a dozen of different grey level of a same colour. This is also one of the limitations of visual interpretation. On the other hand, computer system, can differentiate as many different level (256 level in case of 8 bit data) as available.

1.10 Unsupervised Classification

Unsupervised classification can be used when the analyst does not have much information about the area to be classified. Then the classification software is allowed to sort pixels according to their values.

Therefore computers are allowed to make difficult decisions but it may encounter errors, hence in some cases, information of the classes can be difficult to interpret after classification.

In unsupervised classification, which is based on statistical features of the image, the analyst can specify some parameters only. For example exact information on boundaries, are generated only on the basis of statistical differences of the pixels.

Computer only groups similar kind of pixels in the same class. The analyst is responsible to assign the proper land cover categories for that classified image. Field verification or other information (aerial photographs, maps etc.) will have to be useful to extract the land cover categories (figure 8).

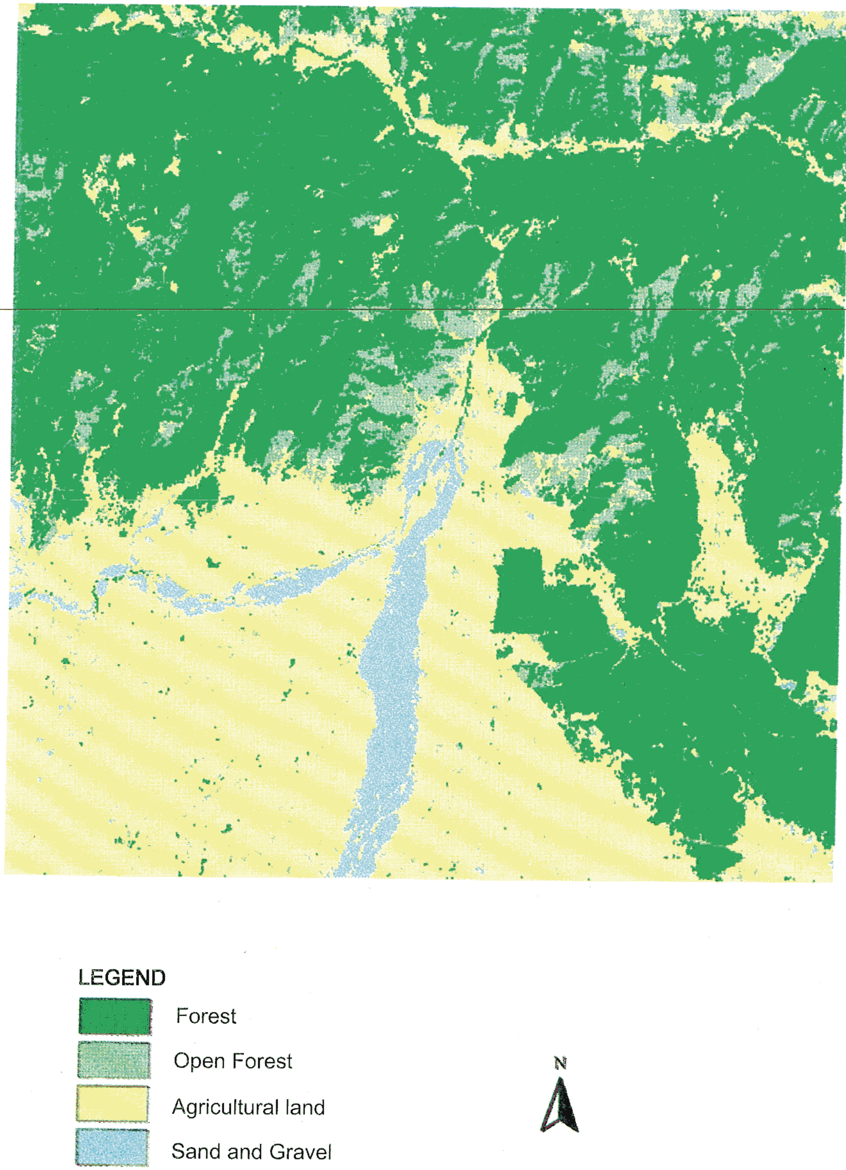


Figure 8. Land-cover classes of Butwal area

1.11 Supervised Classification

In supervised classification, the analyst selects classes. The target of supervised classification is to sortout pixels into well-known classes, e.g., forest, water, cultivated area etc. Supervised classification is used when the classes are known before classification. In this situation, some additional data beside the satellite images are needed. It can be air photos, maps, and other types of field data.

Supervised classification can be divided into two phases. A process of selecting sample areas of classes is called training. The result of the training is a set of signatures, which are statistical criteria for a set of proposed classes. In the classification, pixels are sorted into classes based on the signatures by use of the decision rules. The decision rule is a mathematical algorithm.

Supervised classification leads straight to the final result, to the certain class. Those pixels with no interesting values for any classes can be rejected in the classification.

Human knowledge is essential in applying supervised classification. The analyst must be able to read and interpret the data - image, air photos, maps, etc. Also constraints of the software and computer must be understood. Supervised classification is time-consuming process. Signature needs to be modified according to classification results.

1.12 Global Positioning System (GPS)

In remote sensing, accurate ground co-ordinate is needed not only in geometric correction but also in training sample collection and field verification. Now a days with the use of GPS satellites, a handy GPS receiver can provide accurate enough geographic co-ordinates of any point on the earth. GPS is a technique, used to determine the co-ordinates of the position of GPS receiver. GPS receives radio signals from more than four navigation satellites. Navigation messages includes exact time and orbit elements, which can be converted into the satellite position. The accuracy of GPS receiver is in the order of 10 to 30 meter using a single GPS receiver which is also called single point positioning. In the relative positioning method, two GPS receivers are needed. This method determines the relative relationship between a known point and an unknown point to be measured. The accuracy is in the order of millimetre.

1.13 Use of Remote Sensing Data in Geographical Information System (GIS)

Remote sensing data after geometric correction can be overlaid with the other geographic data. In GIS, there are two uses of remote sensing data; as classified data and as image data. Classified remote sensing data e.g. land cover maps or vegetation maps, can be overlaid onto other geographic data. This enables analysis for environmental monitoring and its change.

Remote sensing data are classified or analysed with other geographic data to obtain a higher accuracy of classification. If digital elevation model (DEM) are given as map data, rice fields, for example, can be checked and located only in flat and low land areas. Digital Elevation Model (DEM) is a computerised map, which shows geographical location of each point, i.e. x co-ordinate, y co-ordinate and altitude. Image data sometimes are also used as image maps, with an overlaid of political boundaries, roads, rivers etc. Such an image can be successfully used for visual interpretation. With the use of DEM, a three dimensional image can be made.

Chapter 2

Application of Remote Sensing in Forest Resource Management

To make aware of and to avail the remotely sensed data, particularly satellite data and technique to the resource managers, a National Remote Sensing Center (NRSC) was established in 1981 through the joint co-operation between HMG/N and USAID. One of the objectives of NRSC was to bring multi-disciplinary scientists to work together for generating useful information for national development. The NRSC rendered services providing new and better information in the form of maps, imageries. The Center was a focal point for remote sensing activities concerning natural resources monitoring and evaluation in the country.

The main achievements of the NRSC were as follows:

- Marshyangdi watershed study for the possibility of hydropower development.
- Study of natural resources of Gulmi districts of appropriate management and planning.
- Arun watershed feasibility study for hydropower production and irrigation purposes.
- Yield study of winter crops of Bhaktapur district.
- Hydrological and geological mapping of Bagmati watershed for developing soil conservation strategy.
- Estimation of forest area on national basis.
- Study of snowline survey and run off prediction.
- Organisation of seminars/training/workshops and exhibitions on national and international basis.

The NRSC organised Asian Conference on Remote Sensing (ACRS) in 1984. The objective of the fifth ACRS were:

- to discuss Asian problems in remote sensing
- to exchange academic and technical information and
- to promote operational applications.

A total of 171 delegates from 15 Asian and non-Asian countries/organisation participated in the fifth ACRS. A total of 11 national reports were presented during the conference. These reports described the overall remote sensing and related activities and application in each country.

2.1 Remote Sensing Application in Forestry

In July 1989 the NRSC was merged with the Forest Survey Division of the Department of Forest Research and Survey (then Forest Survey and Statistics Division under the Ministry of Forests and Soil Conservation) as a Remote Sensing Section. The main activity of this Division is to collect and distribute the forest resources data using conventional and modern technique.

Remotely sensed data, such as, aerial photographs and satellite imageries (Landsat TM, and IRS LISS III) alongwith the aerial photographs and GIS are being in use for national forest inventories. Since 1990, Forest Resource Information System (FRIS) project, funded by Finnish International Development Agency (FINNIDA) was instrumental in using the satellite data for forest resource information. Some of the applications of satellite remote sensing data are described in the following sections.

2.1.1 National Level Forest Area Estimation

Satellite images from Landsat MSS of 1977 were used to estimate the national figure of the forest coverage. The interpretation was updated in 1984. Landuse maps were prepared and visual interpretation was followed to estimate the forest area. Table 1 gives the glimpse of the forest and shrub cover within the country.

Table 1. Forest and shrub cover of Nepal

Category	LRMP 1978-79	NRSC 1984	Master Plan 1985-86	NFI 1994
Forest	38	35.9	37.4	29.0
Shrub	4.7	-	4.8	10.6
Total	42.7	-	42.2	39.6

Source: Forest Resources of Nepal 1999, Publication No. 74

2.1.2 Forest Resource Mapping

Satellite data and images are also used in forest resource mapping. The forest resource maps are prepared either from original false colour image with text and annotation (figure 9) or from image classification. Using the satellite data set of 1990/91, Department of Forest Research and Survey had prepared a map showing forest and shrub areas (woody vegetation) of Nepal (figure 10). NDVI thresholding method was applied for plain area and supervised classification method was applied for the hilly and mountainous area to estimate the forest and shrub cover of Nepal.

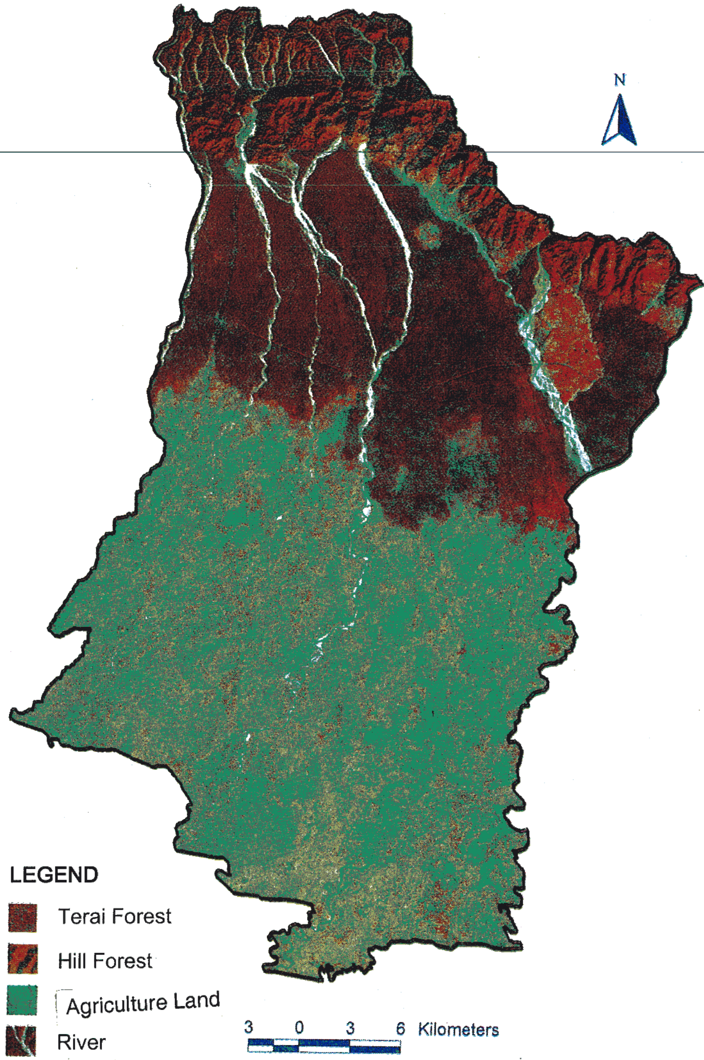


Figure 9. A false colour image of Bara district

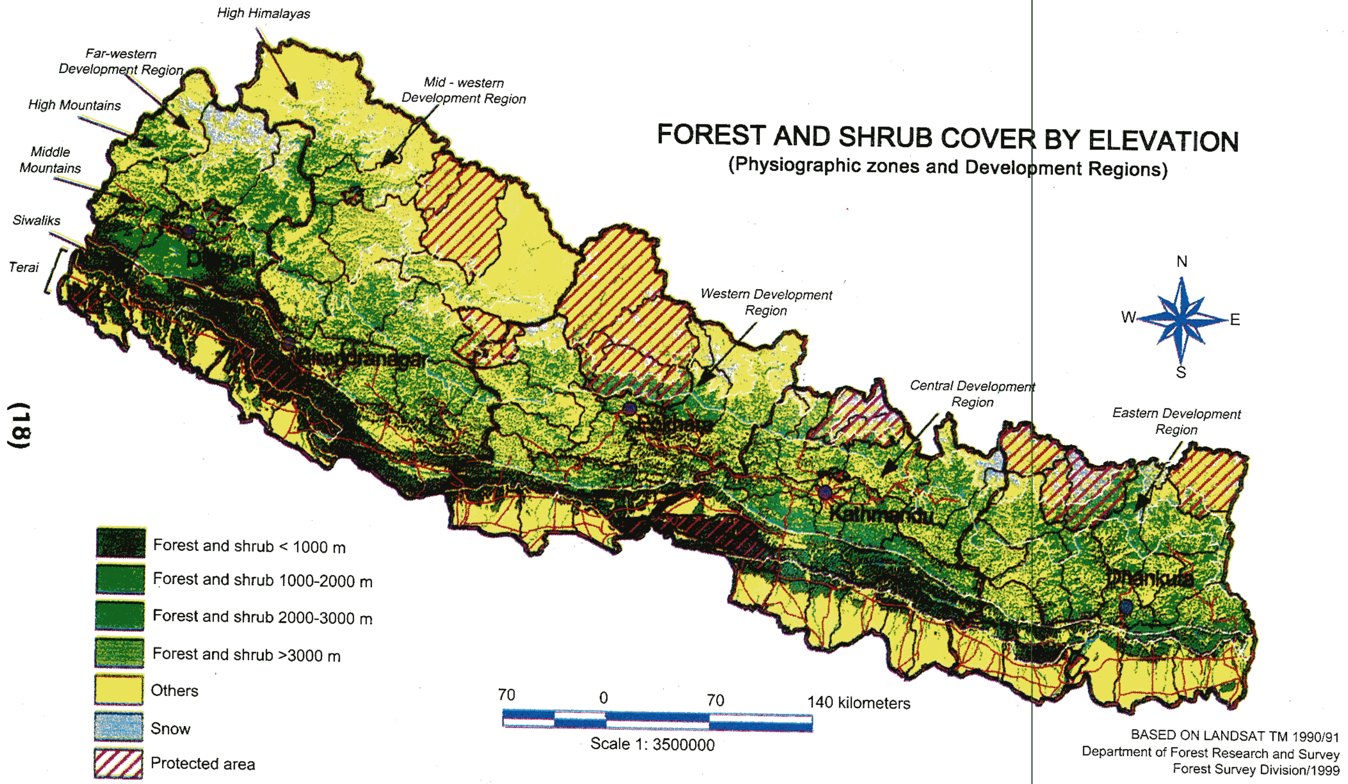


Figure 10. Forest and shrub cover by elevation (based on 1990/91 satellite data)

Similarly, satellite data are being used to prepare vegetation maps. The figures in table below (Table 2) shows the forest and shrub cover by the Development Region of the country.

Table 2. Forest and Shrub cover by Development Region

Region	LRMP 1978-79 Forest and Shrub (1000 ha)	NFI 1989-96 Forest and Shrub (1000 ha)	Change %
FWDR	1049.9	951.3	- 9.4
MWDR	1727.0	1634.4	- 5.4
WDR	1061.3	991.2	- 6.6
CDR	1327.7	1152.4	- 13.2
EDR	1140.8	1098.7	- 3.7
Total	6306.7	5828.0	- 7.6

Source: Forest Resources of Nepal, Publication No. 74.

2.1.3 Forest Resource Assessment

Satellite data and imageries are being used extensively for the forest resource assessment. From this, one can get detailed information of forest (types of forest, its distribution, forest condition, etc.). With the help of field inventory data, woody volume, timber volume, and woody and timber biomass per hectare, number of stems per hectare, species types can be estimated. Incorporating market and economic data, total cost and benefit of harvesting of the forest can be estimated. As an example, detailed information of forest resources of Kailali district, which was prepared using satellite data during 1990/91, is presented in Tables 3, 4 and 5.

Table 3. Per hectare volume and biomass by tree components in Kailali

Species	Volume m^3	V10 cm m^3	V20 cm m^3	StemM 1000 kg	BranchM 1000kg	LeafM 1000 kg	D(g) cm	H(g) m
Acacia catechu	5.9	5	3	6	2	0	38	16
Adina cardifolia	7.8	6	5	5	2	0	85	24
Albizzia spp.	0.2	0	0	0	0	0	67	26
Anogeissus latifolia	2.4	2	1	2	1	0	54	20
Bombax malabaricum	1.0	1	1	0	0	0	80	21
Cedrela toona	0.6	1	0	0	0	0	56	24
Dalbergia sissoo	1.6	1	1	1	1	0	70	27
Eugenia jambolana	5.4	4	3	4	2	0	55	20
Gmelina arborea	0.2	0	0	0	0	0	47	16
Hymenodictyon excelsum	0.5	0	0	0	0	0	68	26
Lagerstroemia parviflora	2.7	2	1	2	1	0	36	15
Lannea grandis	2.2	2	1	1	1	0	49	19
Mitragyna parviflora	0.3	0	0	0	0	0	75	26
Ougeinia dalbergioides	0.2	0	0	0	0	0	25	16
Schleichera trijuga	4.1	3	2	4	2	0	57	19
Shorea robusta	89.7	69	60	79	27	5	58	25
Terminalia belerica	2.1	2	1	1	1	0	53	20
Terminalia tomentosa	25.7	20	17	24	10	1	62	26
Trewia nudiflora	0.3	0	0	0	0	0	28	9
Miscellaneous in Terai	20.6	14	6	15	6	1	145	62
Hard hardwood	143.1	111	92	127	47	7	57	24
Soft hardwood	30.6	22	13	22	9	1	48	17
Timber and construction	122.1	94	82	108	39	7	59	25
Furniture species	130.9	102	87	114	42	7	62	25
Plywood species	1.4	1	1	1	0	0	75	23
Tools, cases, matches	9.5	8	5	7	3	0	58	20
Pulp and paper	0.6	1	0	0	0	0	56	24
Usable together	160.3	122	98	136	50	8	58	23
Fodder species	2.6	2	1	2	1	0	53	20
All species	173.7	133	104	148	56	9	51	22

Table 4. Number of stems per hectare by diameter classes in Kailali

Species	<12.5	12.5-25.0	25.0-50.0	>50.0	Total
Acacia catechu	2	3	8	0	12.9
Adina cardifolia	2	0	2	1	5.0
Albizzia spp.	0	0	0	0	0.2
Anogeissus latifolia	33	1	1	0	34.5
Bombax malabaricum	0	0	0	0	0.3
Cedrela toona	0	0	0	0	0.3
Dalbergia sissoo	0	0	0	1	0.9
Eugenia jambolana	182	1	3	1	187.3
Gmelina arborea	0	0	0	0	0.4
Hymenodictyon excelsum	0	0	0	0	0.2
Lagerstroemia parviflora	17	3	3	0	23.0
Lannea grandis	2	1	1	0	3.8
Mitragyna parviflora	0	0	0	0	0.1
Ougeinia dalbergioides	9	0	0	0	8.5
Schleichera trijuga	124	1	2	1	128.0
Shorea robusta	1833	8	27	14	1881.7
Terminalia belerica	9	0	1	0	10.0
Terminalia tomentosa	512	4	6	4	525.8
Trewia nudiflora	2	1	0	0	3.2
Miscellaneous in Terai	2112	27	15	2	2155.9
Hard hardwood	2388	23	51	23	2485.0
Soft hardwood	2117	28	17	3	2165.2
Timber and construction	2137	14	35	20	2206.4
Furniture species	2166	15	38	21	2240.3
Plywood species	1	0	0	0	0.5
Tools, cases, matches	215	2	4	2	222.6
Pulp and paper	0	0	0	0	0.3
Usable together	3604	43	56	25	3727.9
Fodder species	33	1	1	0	34.9
All species	3698	52	68	25	3843.7

Table 5. Total volume and biomass by tree components in Kailali

Species	Volume m3	V10 cm m3	V20 cm m3	StemM 1000 kg	BranchM 1000kg	LeafM 1000 kg
Acacia catechu	555374	430907	261888	533160	213264	28157
Adina cardifolia	733948	582151	502613	491745	196698	20958
Albizzia spp.	18860	15103	10539	12693	5077	603
Anogeissus latifolia	225682	192491	109881	198600	79440	9812
Bombax malabaricum	90885	78106	61787	33446	13378	1398
Cedrela toona	59020	47047	40209	28330	11332	1256
Dalbergia latifolia	5060	4121	2252	4452	1781	234
Dalbergia sissoo	146653	117846	98683	114389	78242	1144
Eugenia jambolana	510587	398717	244042	393152	157261	17918
Gmelina arborea	20572	16567	8728	9875	3950	500
Hymenodictyon excelsum	44687	35613	34416	22925	9170	969
Lagerstroemia parviflora	251200	178893	86158	213520	85408	11502
Lannea grandis	210188	169640	132118	117705	47082	5601
Mitragyna parviflora	32380	28823	15185	20723	8289	866
Ougeinia dalbergioides	18196	14684	2671	16013	6405	819
Pterocarpus marsipium	13992	12407	12115	10984	4393	453
Schleichera trijuga	385885	322317	182810	420229	168092	19024
Shorea robusta	8412846	6476149	5649905	7403304	2574252	494209
Terminalia belerica	195537	164278	124840	131596	52639	5989
Terminalia tomentosa	2414196	1874789	1628372	2293486	917394	102906
Trewia nudiflora	26203	17043	4296	9223	3689	511
Miscellaneous in Terai	1923532	1290347	576078	1441462	576584	78008
Hard hardwood	13426550	10421652	8588057	11893149	4426676	699704
Soft hardwood	2868934	2046334	1201529	2027863	811145	101333
Timber and construction	11458444	8865807	7685574	10102343	3686353	611747
Furniture species	12279439	9524726	8198484	10695321	3923545	638091
Plywood species	135572	113720	96204	56370	22548	2366
Tools, cases, matches	894761	723425	460556	659500	263800	30673
Pulp and paper	59020	47047	40209	28330	11332	1256
Usable together	15042469	11490426	9238982	12717170	4732284	742332
Fodder species	245686	208550	121328	212131	84853	10453
All species	16295484	12467985	9789585	13921013	5213822	802837

Source: Forest Resources of the Terai districts 1990/91, Publication No. 57

2.1.4 Change Detection

Multi-date satellite data could be used to detect the change in Landuse / land cover. In 1993, Department of Forest Research and Survey (then Forest Research and Survey Centre) had published a report on Forest Resources of the Terai Districts in 1990/91. The objective of the work was to serve the Ministry of Forest and Soil Conservation at macro-level strategic planning. Landuse / landcover change is important to assess resources and planing for sustainable forest management.

The study area covered all the twenty administrative districts (Terai districts) in the South of Nepal. The forest area estimates were calculated for three calculation units (plains, hills and conservation area) by district.

The main results were as follows:

- Forest covers 41%, or 1.4 million hectares of the study area, including plains, hills and conservation areas.
- Forest area in the plains (potential production forest was 546 000 ha.
- Forest area in the national parks (protected forest) was 238 000 ha.
- Net change in forest area in the plains was –99 000 ha in twelve years.
- Rate of deforestation in the plains was 1.3% per year.
- Total stem volume inn the plains was 78 million m^3.
- Mean volume in the plains was 144 m^3/ha.
- Large size timber volume in the plains was 32 million m^3.
- Firewood biomass in the plains was 123 million tons (air dry).
- The main species in the plains was Sal, 43% of the total stem volume.

The differences in forest resources in the plains by district were considerable, with Kailali district having 94,000 ha of forest and 16.3 million m^3 of stem volume as against 3,000 ha and 0.3 million m^3 in Dhanusa district.

Deforestation in the plains between 1978/79 and 1990/91 has been largest in absolute area in Kailali district, 16,000 ha (figure 11).

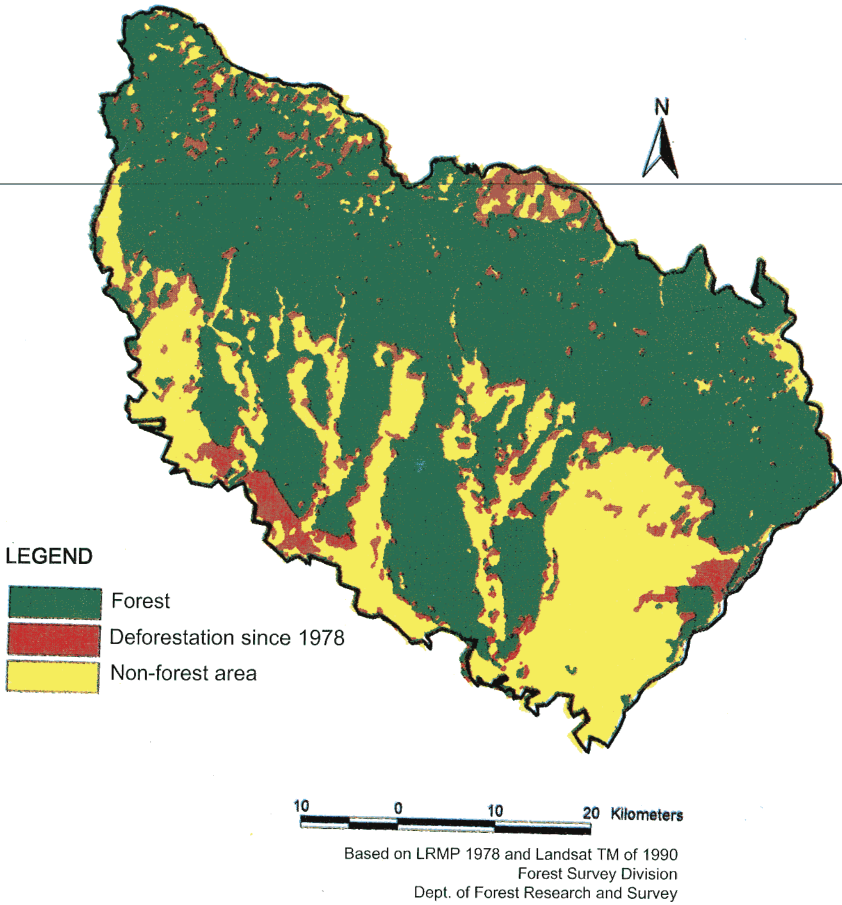


Figure 11. Deforestation in Kailali district between 1978/79 to 1990

2.2 Difficulties and Constraints in Use of Satellite Remote Sensing Data

Although satellite remote sensing data have been used in forestry sector since 1980, there are some difficulties and constraints to fully use the data. The difficulties and constraints can be separated into two categories: technical and organisational.

2.2.1 Technical Difficulties and Constraints

To fully use remote sensing, Data format and their structure should be known in loading the data in computer from CD or other media, for example, Computer Compatible Tape (CCT). Application programme or software is needed to handle and process the remotely sensed data. Various application programmes (software) are available in image processing. Some image processing software are ERDAS, IMAGINE, ILWIS, PCI etc.

As an image involves radiometric as well as geometric errors, these errors should be corrected. Radiometric correction is a method to avoid radiometric (digital value or image value) errors or distortions, while geometric correction is to remove geometric distortions. In some cases atmospheric correction is necessary to remove the influence of external factors such as haze etc.

Radiometric correction is classified into three types: radiometric correction of effects due to sensor sensitivity, radiometric correction for sun angle and topography, and atmospheric correction.

When a sensor aboard on an aircraft or spacecraft observes the emitted or reflected electromagnetic energy, the observed energy does not coincide with the energy emitted or reflected from the same object observed from a short distance. This is due to the sun's azimuth and elevation, atmospheric conditions such as fog, aerosols, sensor's response etc., which influence the observed energy. Therefore, in order to obtain the real irradiance or reflectance, those radiometric distortions must be corrected.

In Nepal, most of the terrain is more or less hilly. With low sun elevation angle, topography causes a lot of variation in spectral response and considerable shadows. There are several methods to reduce the topography effect in the satellite image. Normalisation is one of them. The basic idea of the method is that original radiation values of the image are corrected. After successful correction, the image represents radiation values of the image taken when the sun is in nadir. In the method, a Digital Elevation Model is needed.

Rectification is a process of projecting a data onto a plane, and making it conform to a map projection system. In the rectification process an image is transferred to a map co-ordinate system with common control points from both a map and an image. Quality of the rectification depends strongly on the quality of the map from where the points are measured. On the other hand, those control points must be identified also on the image.

In rectifying an image of the hilly area, a small error is always resulted due to the lack of accurate and enough control points. To minimise the positional errors, enough control points should be taken. New topographic maps of the scale of 1:25,000 are very useful for taking the control points.

Understanding of object and energy (electromagnetic radiation) interaction is the main key issue in visual interpretation. It should be clear that when satellite scan the earth, it does not produce colour image. It only records the response in energy units. These energy units are later converted to produce digital number. Computer system can produce the colour image from these digital numbers. Therefore, some pre-knowledge on the physical process of object energy interaction is essential in the interpretation. Suppose someone finds an object lighter in visible band and darker in infrared band, then one can guess that, the object is water body. In colour image water body has lighter value in blue band and continuously darker in green, red and infrared band respectively. If the water is clear and pure, image data value is almost zero in infrared band. But due to the turgidity in water body, it may have some value close to zero. From this knowledge clear water, turgid water or salty water, can be distinguished. For the sake of general perception, usually water body can be shown in computer display or hardcopy printing in blue colour. Field visit or other knowledge is important to recognise and label the different colours.

Since Nepal is a mountainous country, the satellite image contains considerable shadow areas (figure 12). Winter image contains severe shadow compare to summer image due to low sun elevation angle in the winter. In some places, complete shadow can be seen which means totally loss of information. Cloud is another problem to use the data in forestry. It is very difficult to get the cloud free data of the entire country in one season. If a scene with zero percent cloud cover is not available, a scene having less than five percent cloud can be accepted depending on the specific use of the data. If alternative scene of the cloud cover data is available, image-processing tool like cut and paste can be used to substitute the cloud free data from other scene.

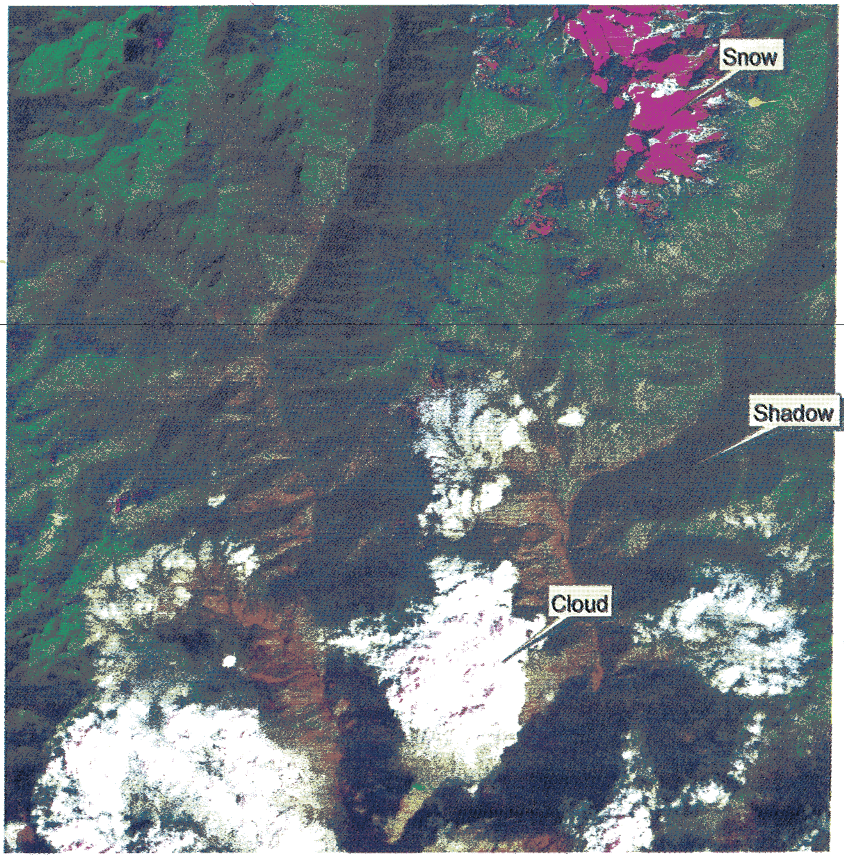


Figure 12. A prominent shadow and cloud problem in remote sensing image

Data availability and accessibility is most important factor to use the data. Even though all most all the satellites have own onboard recording system, for the common user, that option is not so practical. There are some areas in the world, which are not covered by ground receiving station. Therefore a ground receiving station networks should be established.

2.2.2 Organisational Difficulties and Constraints

The cost of remote sensing data is rather expensive so that it is always difficult to purchase satellite data using the limited government resource. There is a lack of co-ordinating agency in the country that is responsible for data acquisition and supply to the entire data user. Data sharing mechanism is rather weak in the country. Usually remote sensing data are purchased from foreign donors. Lack of experienced, motivated and knowledgeable personnel or researcher is always a problem. Staff transfer and promotion is another problem for the sustainable use of the technology. Lack of enough software and hardware, lack of data quality and standard, limitation of data use by clients are some of the organisational constraints.

2.3 Conclusion

There is no doubt that remote sensing and GIS technology are essential and urgently needed for sustainable development and the proper utilization of natural resources such as forest. It is especially true for countries like ours, where 80% of the land area is hill and mountain and to acquire aerial photography for resource monitoring and management is difficult and expensive job.

Nonetheless the Department is initiating to collect and store new satellite data, prepare districtwise vegetation maps, stratification of forest area according to the species on the satellite imageries and districtwise deforestation analysis using the Landsat TM, IRS LISS and ADEOS AVNIR imageries along with the latest aerial photographs.

References

- ERDAS Field Guide Fourth Edition, (1997), ERDAS, Inc. Atlanta Georgia.
- Forest Resources of Nepal, (1999), Department of Forest Research and Survey, Publication No. 74.
- Forest Resources of Terai Districts, (1993), Forest Research and Survey Centre, Publication No. 57.
- Remote Sensing Note, Japan Association on Remote Sensing.