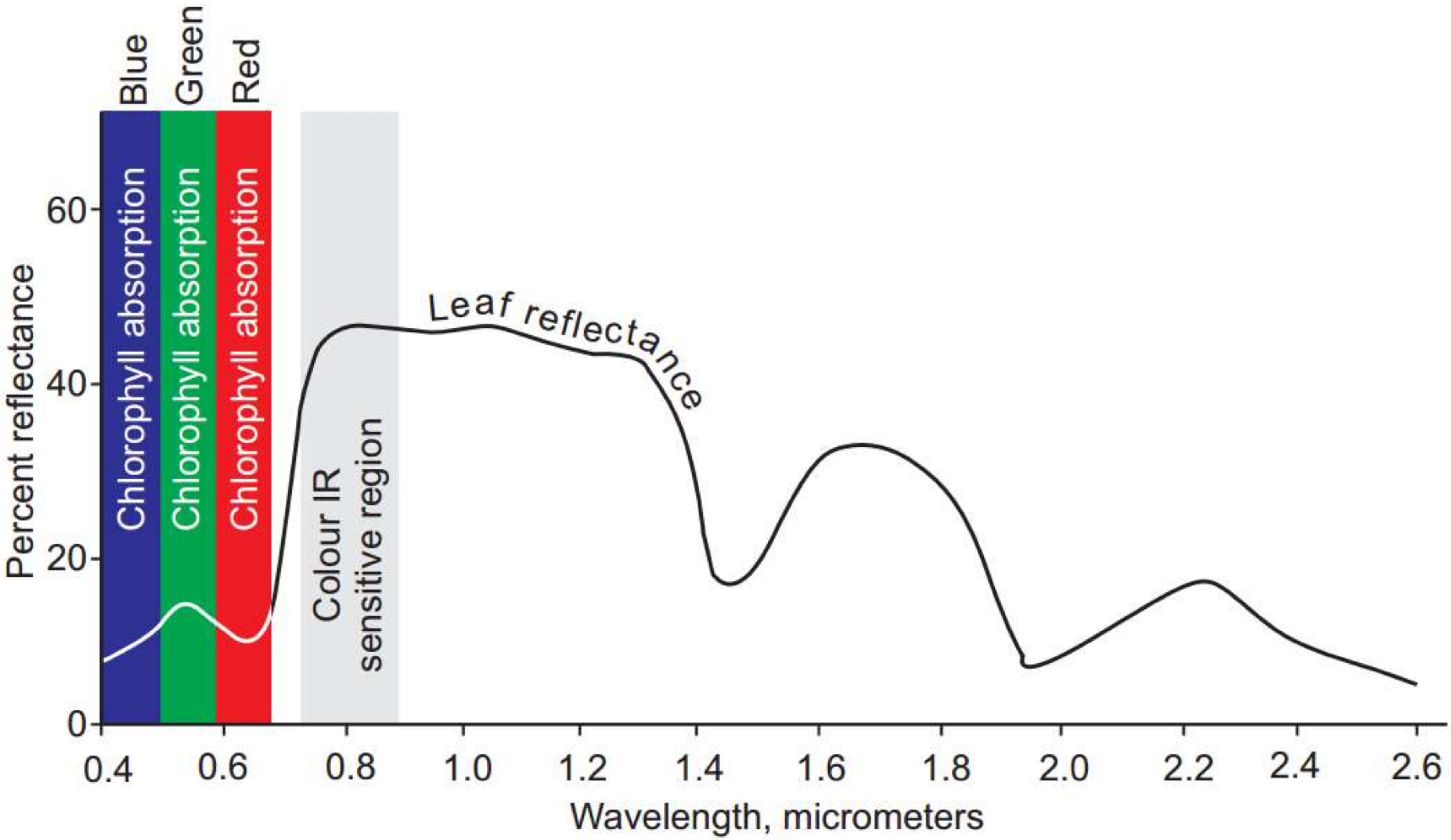
Applications of Remote Sensing and GIS in Forest related studies

Dr. Swarnima Singh,DDUGU,Gorakhpur U.P. India.

Forestry can be simply explained as the science and technology linked with tree resources or forests. According to the Global Forest Resources Assessment 2010 (FRA 2010), “the world’s total forest area was just over 4 billion hectares, corresponding to 31 percent of the total land area or average of 0.6 ha per capita”. Forest as one of the most important resources on this planet plays a pivotal role in the progress of human civilizations. Forestry studies have always been the hot topic since the naissance of this discipline. With the advent of satellite remote sensing, the forestry studies have made the unprecedented development. This introductory review is intended to introduce the basics of remote sensing in forestry studies, summarize the recent development, and elucidate several typical applications in this area



AN IDEAL SPECTRUAL REFLECTANCE CURVE FOR VEGETATION

Vegetation

The reflectance characteristics of vegetation depend on the properties of the leaves including the orientation and the structure of the leaf canopy. The proportion of the radiation reflected in the different parts of the spectrum depends on leaf pigmentation, leaf thickness and composition (cell structure) and on the amount of water in the leaf tissue. Figure shows an ideal reflectance curve from healthy vegetation. In the visible portion of the spectrum, the reflection from the blue and red light is comparatively low since these portions are absorbed by the plant (mainly by chlorophyll) for photosynthesis and the vegetation reflects relatively more green light. The reflectance in the near-infrared is highest but the amount depends on the leaf development and the cell structure of the leaves. In the middle infrared, the reflectance is mainly determined by the free water in the leaf tissue; more free water results in less reflectance. They are therefore called water absorption bands. When the leaves dry out, for an example during the harvest time of the crops, the plant may change colour (for example, to yellow). At this stage there is no photosynthesis, causing reflectance in the red portion of the spectrum to be higher. Also, the leaves will dry out resulting in higher reflectance in the middle infrared whereas the reflectance in the near-infrared may decrease. As a result, optical remote sensing data provide information about the type of plant and also about its health condition.

Remote sensing (Defination) is the “noncontact recording of information from the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum by means of instruments such as cameras, scanners, lasers, linear arrays, and/or area arrays located on platform such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing” (Jensen, 2007). Franklin (2010)

Remote sensing: Aerial photos (i.e. airborne remote sensing) or satellite imagery (i.e. spaceborne remote sensing) are widely used in forest studies. If the earliest platforms such as homing pigeons, kites, and hot air balloons, which were quite uncertain and unstable platforms with relatively low altitude, are taken into account, the history will be even longer (Colwell, 1964). Up to now, hundreds of Earth Observation Satellites are in orbit, and delivering assorted remotely sensed data ranging from optical data to radar data, from multispectral imagery to panchromatic imagery, and from local scale to global scale. Remote sensing has long been identified as an effective and efficient tool in forestry studies, such as forest inventory, forest health and nutrition, forest sustainability, forest growth, and forest ecology (Kohl et al., 2006).

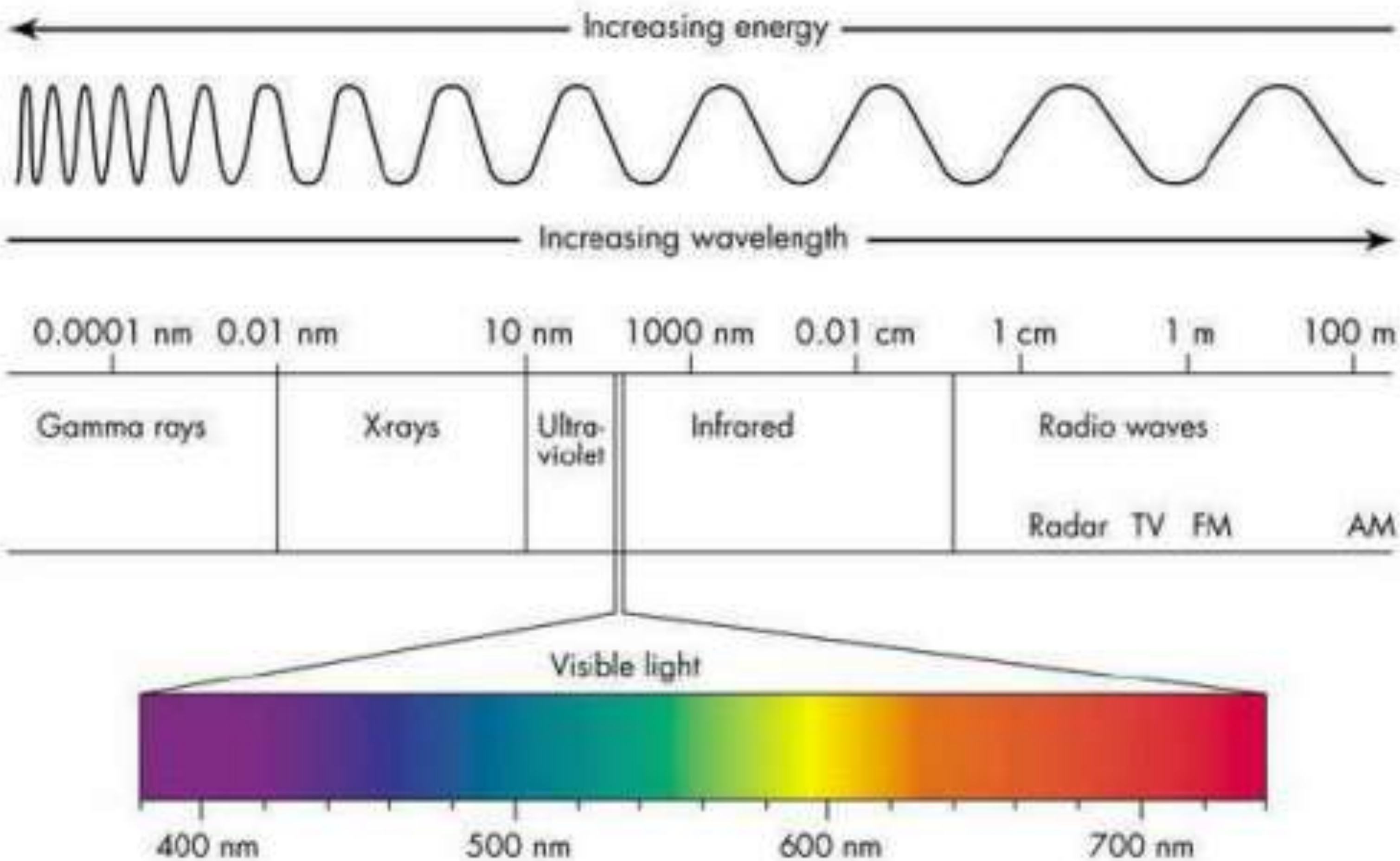
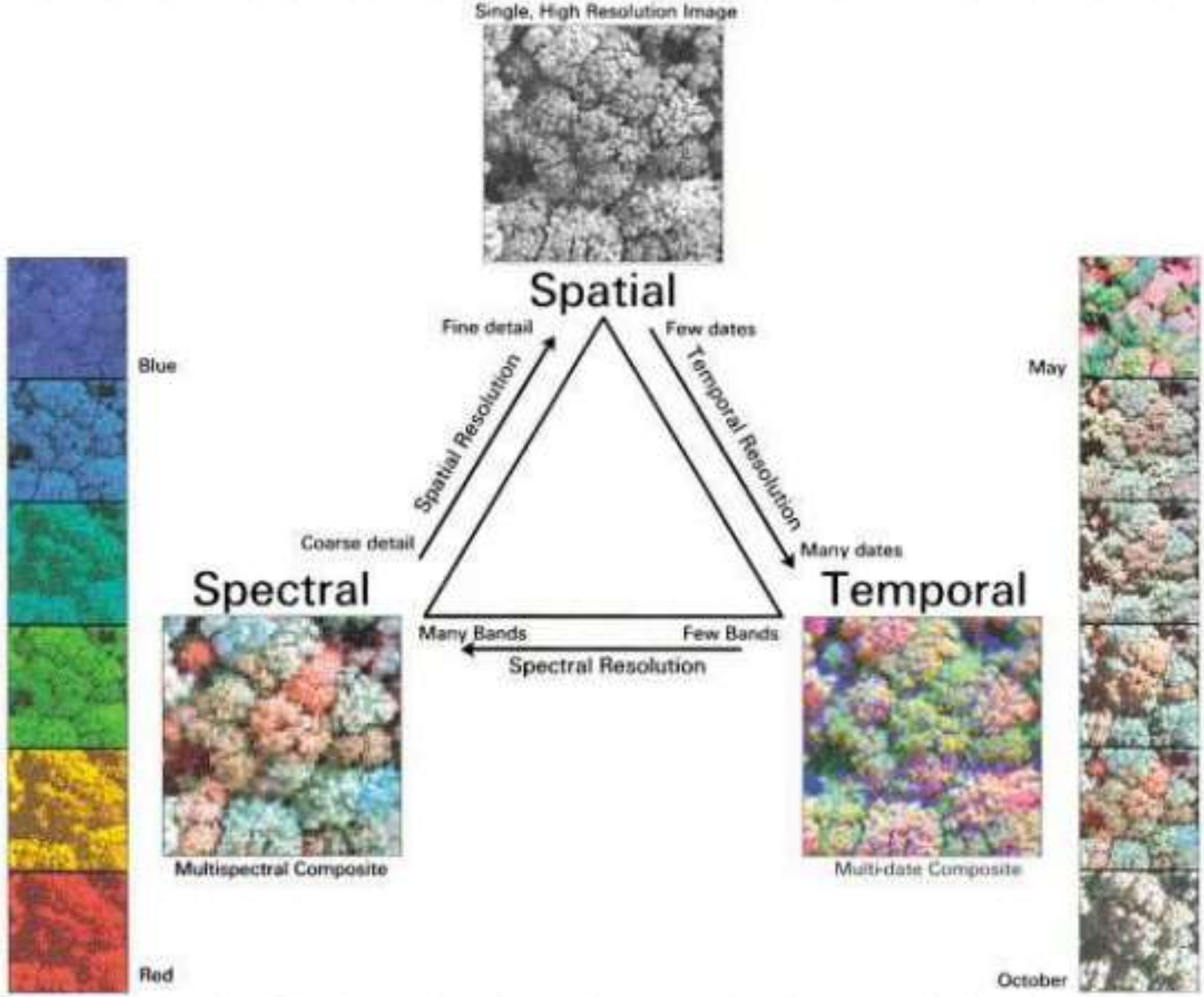


Fig. 1. Electromagnetic spectrum (Courtesy of the Antonine Education, UK)


Single, High Resolution Image
Spatial
Fine detail
Spatial Resolution
Coarse detail
Few dates
Temporal Resolution
Many dates
Spectral
Many Bands
Few Bands
Spectral Resolution
Temporal
Blue
Red
Multispectral Composite
May
October
Multi-date Composite

Satellite Program	Satellite Platform	Sensor	Data Operator
Optical Remote Sensing			
POES (Polar Orbiting Environmental Satellites)	NOAA 18	AVHRR	NOAA
EOS (Earth Observing System)	TERRA/AQUA	MODIS	NASA/USGS
Landsat	LANDSAT 5	TM	NASA/USGS
SPOT (Satellite Pour l'Observation de la Terre)	SPOT 4	HRVIR VEGETATION	Spot Image
	SPOT 5	HRG VEGETATION	Spot Image
IRS (Indian Remote Sensing Satellites)	IRS P6 (ResourceSat-1)	LISS III LISS IV AWiFS	ISRO (India Space Research Organization)
DMC (Disaster Monitoring Constellation)	Beijing-1	SLIM-6	DMC International Imaging Ltd
CBERS (China-Brazil Earth Resources Satellite)	CBERS-2B	CCD HRC IRMSS WFI	CAST (China)/INPE (Brazil)
Digital Globe Constellation	WorldView 2	WV110	DigitalGlobe Corporate
	QuickBird 2	BGIS 2000	DigitalGlobe Corporate
GeoEye	GeoEye-1	GIS MS	GeoEye Inc.
Radar Remote Sensing			
RADARSAT Constellation	RADARSAT 2	SAR	CSA/MDA
TanDEM-X	TanDEM-X	TSX-SAR	DLR/Astrium
TerraSAR	TerraSAR-X	TSX-SAR	DLR/Astrium

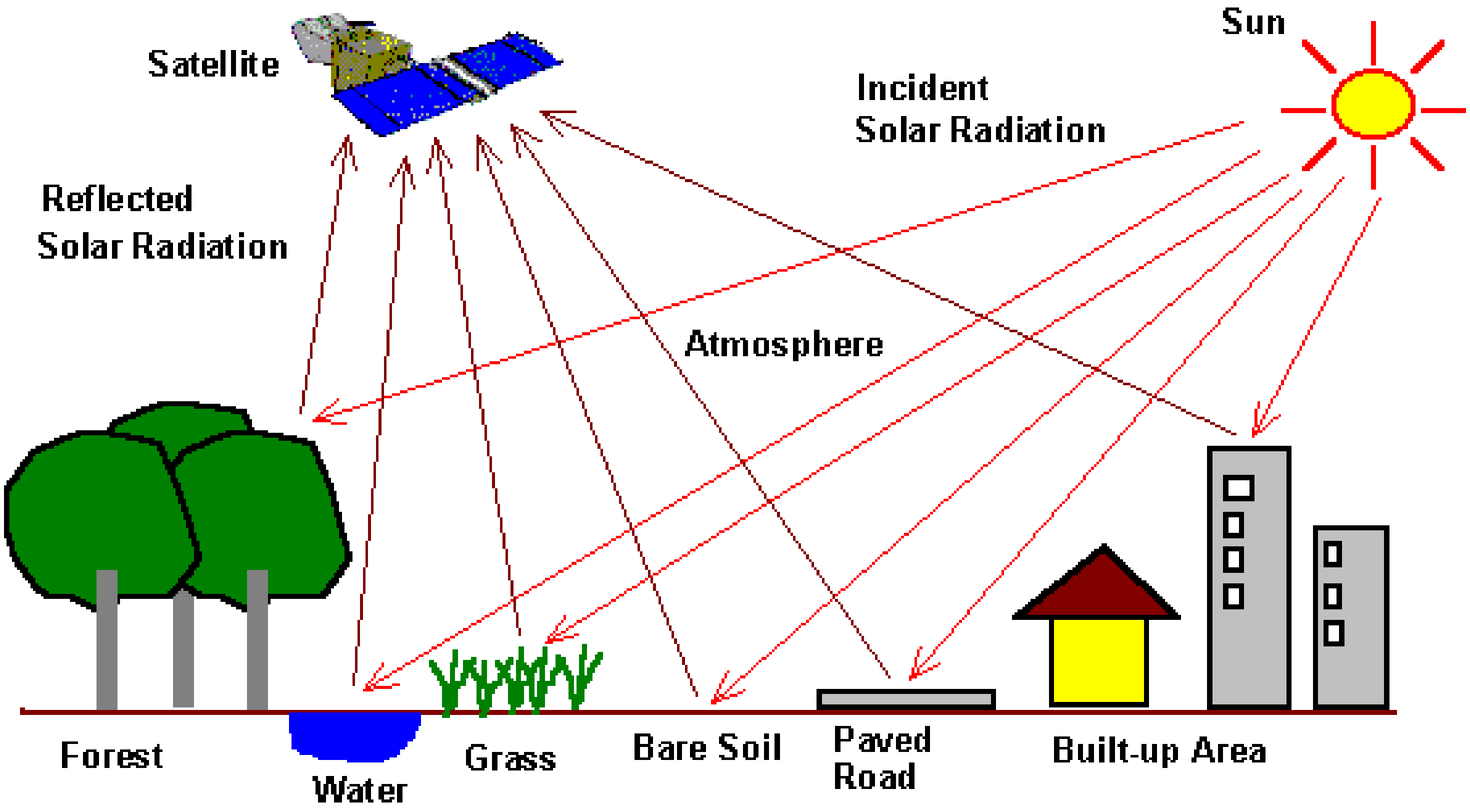
Table 1. The Current Commonly-used Optical and Radar Sensors

Medium resolution sensors	Spatial resolution (m)[a]	Swath (km)	Spectral range (nm) / Bands	Temporal coverage	Revisit (day)
Coarse spatial resolution optical sensors					
NOAA-18 (AVHRR)	1100	2900	Variable / 5	2005-Present	1
Terra/Aqua (MODIS)	250-1000	2330	Variable / 36	1999-Present	1-16
Moderate spatial resolution optical sensors					
Landsat (TM)	30	180	450-2350 / 6	1984-Present	16
IRS-P6 (LISS III)	23.5	141	520-1700 / 4	2003-Present	24
SPOT 4 (HRVIR)	20	60	500-1750 / 4	1998-Present	1-3
SPOT 5 (HRG)	10 (MS); 20 (SWIR)	60	500-1730 / 5	2002-Present	1-3
CBERS-2	20 (Pan and MS)	120	450-890 / 4	2003-Present	3
DMC (SLIM-6)	22/32	600	520-990 / 3	2002-Present	1
Fine spatial resolution optical sensors					
WorldView 2 (WV110)	0.46 (Pan); 1.85 (MS)	16.4	400-1040 / 8	2009-Present	1.1-3.7
QuickBird 2 (BGIS 2000)	0.65 (Pan); 2.62 (MS)	18.0	430-918 / 4	2001-Present	2.5-5.6
GeoEye-1 (GIS MS)	0.41 (Pan); 1.65 (MS)	15.2	450-920 / 4	2008-Present	2.1-8.3

[a] MS = multispectral, SWIR = shortwave infrared, Pan = panchromatic

Table 2. The Detail of the Current Commonly-used Optical Sensors

Optical remote sensing makes use of visible, near infrared and short-waveinfrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground. Different materials reflect and absorb differently at different wavelengths. Thus, the targets can be differentiated by their spectral reflectance signatures in the remotely sensed images.



Optical sensors have been commonly used in forestry studies. However, the use of hyperspectral sensors, Radar and Lidar is still relatively underdeveloped. It is worth paying more attention to the application of hyperspectral sensors, Radar and Lidar in forestry studies

Forest science and management are broadly divided into three categories:
A. Forest biology and ecology (e.g. **forest biomes of the world, forest ecophysiology, forest soils, forest ecosystem ecology, landscape ecology, and forest trees: disease and insect interactions);**
B. Forest management and multiple uses (e.g. forest management and stewardship, nonindustrial private forests, measuring and monitoring forest resources, silviculture and ecosystem management, **forest-wildlife management**, **forest and rangeland management**, **forest and watershed management**, forest and recreation behavior, behavior and management of **forest fires**, timber harvesting, wood products, and economics and the management of forests for wood and amenity values);
C. Forests and society (e.g. **urban forest**, and **social forstry**: the community-based management of natural resources). As a matter of fact, remote sensing has more or less served all the three categories. Several examples in remote sensing of forestry studies are provided as follows. The selected examples were included in the papers that were either highly cited or newly published Science Citation Index (SCI) papers.

APPLICATION IN FORESTRY

Species composition (biodiversity) : Turner et al. (2003) stated that the recent advances in remote sensing, such as the availability of remotely sensed data with high spatial and spectral resolutions, make it possible to detect key environmental parameters, which can be applied to determine the distribution and abundance of species across landscapes via ecological models. This approach, in general referred to as indirect remote sensing of biodiversity, plays a major role in this research area. For example, Defries et al. (2000) applied the 1km Advanced Very High Resolution Radiometer (AVHRR) to estimate and map percentage tree cover and associated proportions of trees with different leaf longevity (evergreen and deciduous) and leaf type (broadleaf and needleleaf).

Forest trees: Disease and insect interactions : Due to the difference between dead, diseased, and healthy trees in visible and near-infrared reflectance values, Everitt et al. (1999) used color-infrared digital imagery and successfully detected oak wilt disease in live oak (Quercus fusiformis). The outbreak of mountain pine beetle (MPB) has resulted in a huge monetary loss in the western of the North America. It is urgent to efficiently survey the location and the extention of beetle impacts. Wulder et al. (2006) indicated the potential and limits of the detection and mapping of MPB using remotely sensed data, and suggested methods and data sources accordingly

Measuring and monitoring forest resources : Cohen et al. (1995) stated that "remote sensing can play a major part in locating mature and old-growth forests", and applied a number of remote sensing techniques to estimate forest age and structure. Over a 1,237,482 ha area was investigated and an accuracy of 82 per cent was obtained. Maps of species richness have been recognized as a useful tool for biodiversity conservation and management due to its capability of explicitly describing information on the spatial distribution and composition of biological communities (Hernandez-Stefanoni et al., 2011). Hernandez-Stefanoni et al. (2011) tested remotely sensed data with regression kriging estimates for improving the accuracy of tree species richness maps, and concluded that this research will make a great step forward in conservation and management of highly diverse tropical forests.

Forest-wildlife management: Stoms and Estes (1993) proposed a framework to guide the application of remotely-sensed data in mapping and monitoring biodiversity. From then on, there are lots of works focusing on this field, e.g. Tuomisto et al. (1995), Nagendra (2001), Kerr and Ostrovsky (2003), Wang et al. (2009), Wang et al. (2010). From the perspective of remote sensing techniques, Franklin et al. (2001) developed an integrated decision tree approach to mapping land cover using remotely sensed data in support of grizzly bear habitat analysis.

Forest fires: Giglio et al. (2003) presented an enhanced contextual fire detection algorithm in order to identify smaller, cooler fires with a significantly lower false alarm rate, and promising results were obtained. Lentile et al. (2006) reviewed “current and potential remote sensing methods used to assess fire behavior and effects and ecological responses to fire”.

Urban forest : Jensen et al. (2003) investigated the relationship between urban forest leaf area index (LAI) and household energy usage in a mid-size city, and concluded that the increase of LAI resulted in the less energy usage. Zhang et al. (2007) applied remote sensing to map the distribution, classification and ecological significance of urban forest in Jinan city.

Watershed Management and Impact Assessment: Over-exploitation of natural resources for meeting the increasing demand for food, fuel, and fiber of the ever growing population has led to environmental degradation and calls for their optimal utilization based on their potential and limitations. Information on the nature, extent, and spatial distribution of natural resources is essential. Spaceborne multispectral measurements made at regular intervals hold immense potential of providing such information in a timely and cost-effective manner, and facilitate studying dynamic phenomenon. The geographic information system (GIS) provides an ideal environment for integration of information on natural resources with the ancillary information for generating derivative information which is useful in decision making. The study was taken up to generate the action plan for land and water resources development and to monitor the progress of its implementation in the Adarsha watershed, Kothapally, Ranga Reddy district, Andhra Pradesh, India. The approach involves generation of thematic maps on various natural resources through a systematic visual interpretation of satellite data, integration of such data with the ancillary information and generation of action plan in the GIS environment, and monitoring vegetation development as a sequel to implementation of action plan by generating Normalized Difference Vegetation Index (NDVI) from the Indian Remote Sensing Satellite (IRS- 1C/-1D) Linear Imaging Self-scanning Sensor (LISS-III) data. Soil erosion by water is the major land degradation process operating in the watershed. There has been an improvement in the vegetation cover owing to implementation of various soil and water conservation measures, which is reflected in the NDVI images of pre- and post-implementation periods

Remote Sensing in Natural Resources Mapping

Create critical information for resource management and scientific research (including but not limited to):

- Phenology and vegetation dynamics
- Habitat condition, suitability, conservation planning
- Ecosystem functions and services
- Biology and biochemistry of ecosystems
- Water and energy cycle
- Climate variability and prediction
- Ecological security
- Sustainable development
- Coastal Management
- Monitoring land-use change
- Mapping and management of natural hazards
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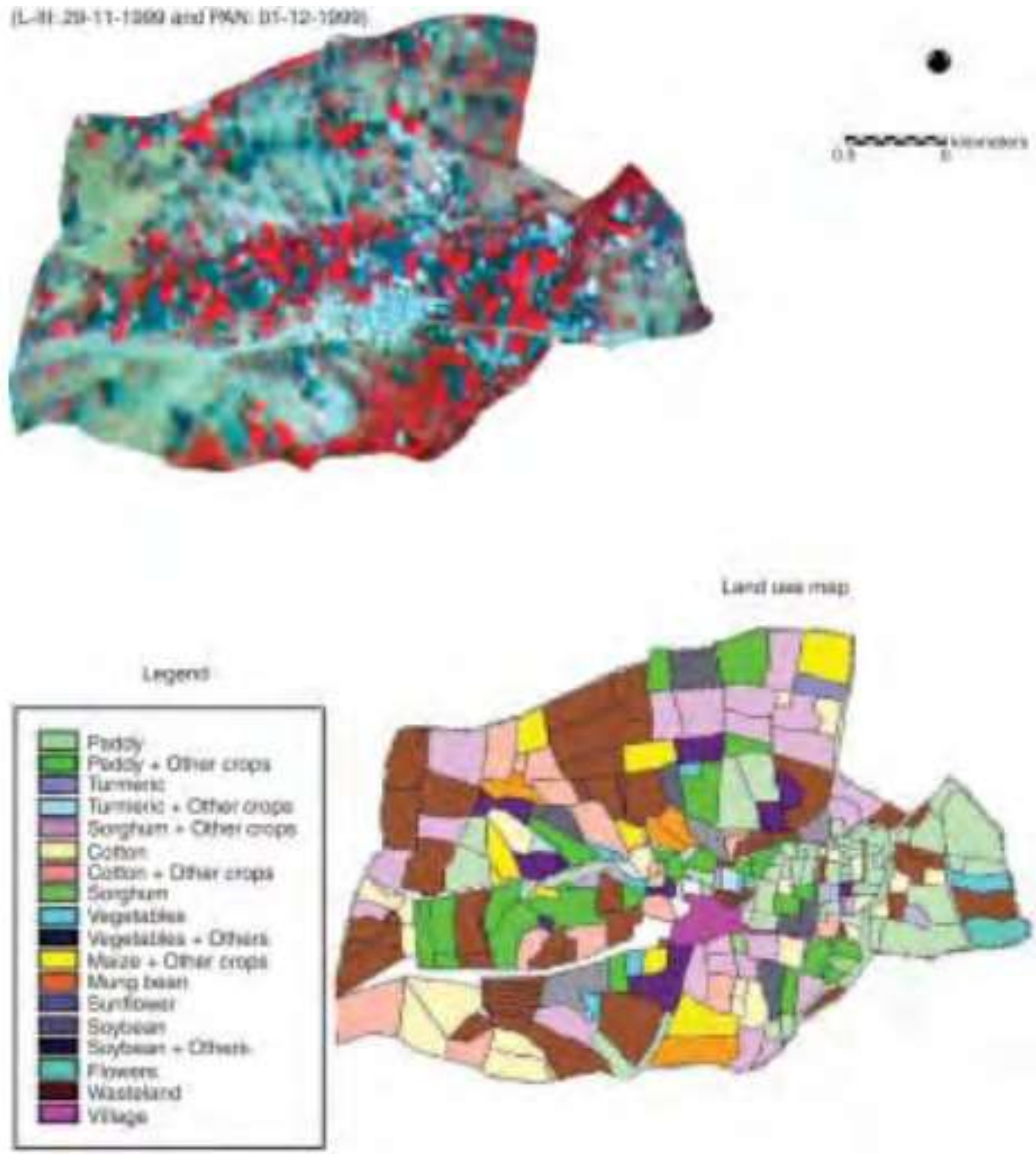


2. LISS-III and PAN merged image and land use map of Adarsha watershed, Kothapally, India.

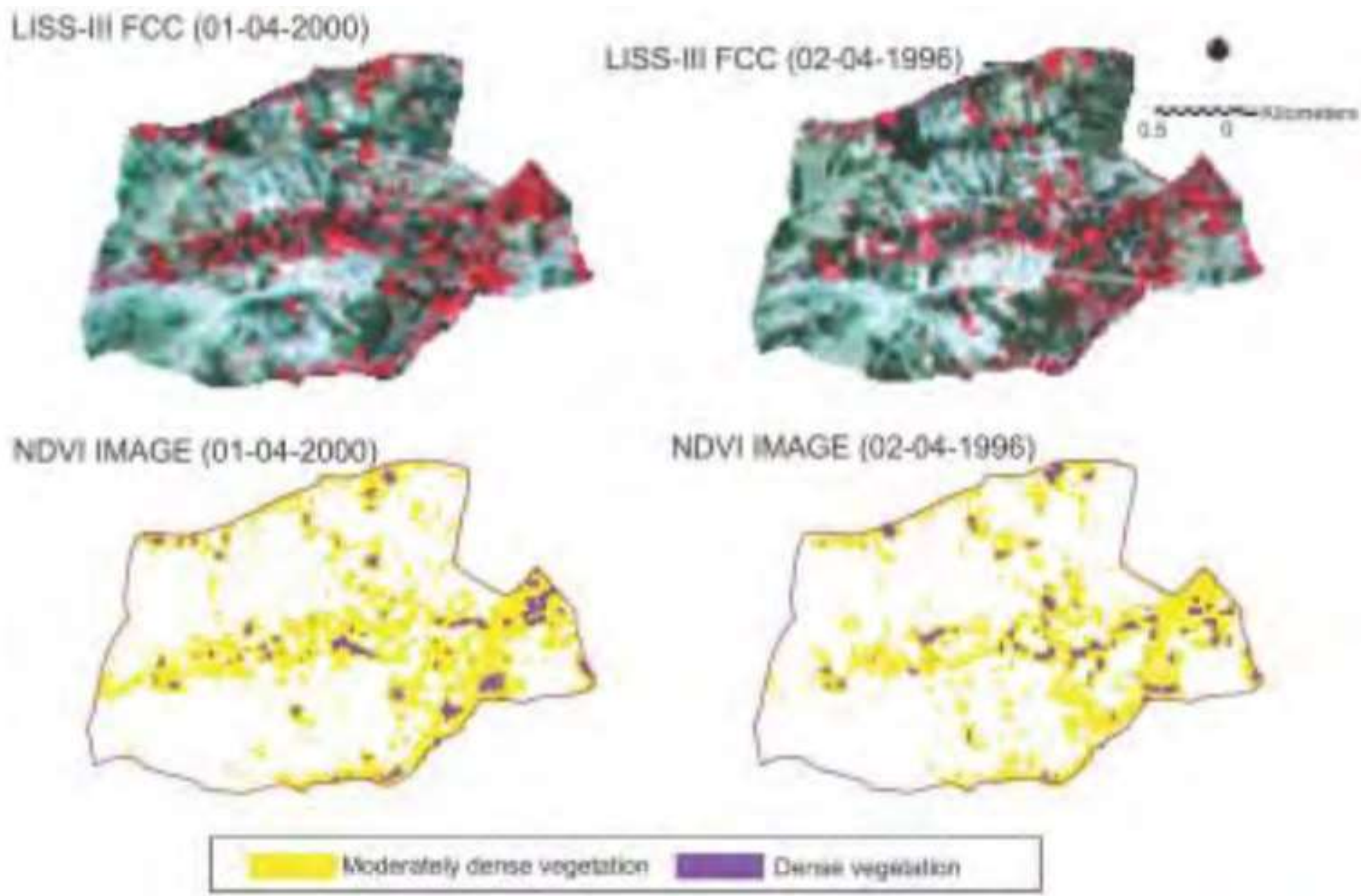


Figure 3. Satellite and NDVI images of Adarsha watershed, Kothapply, India.

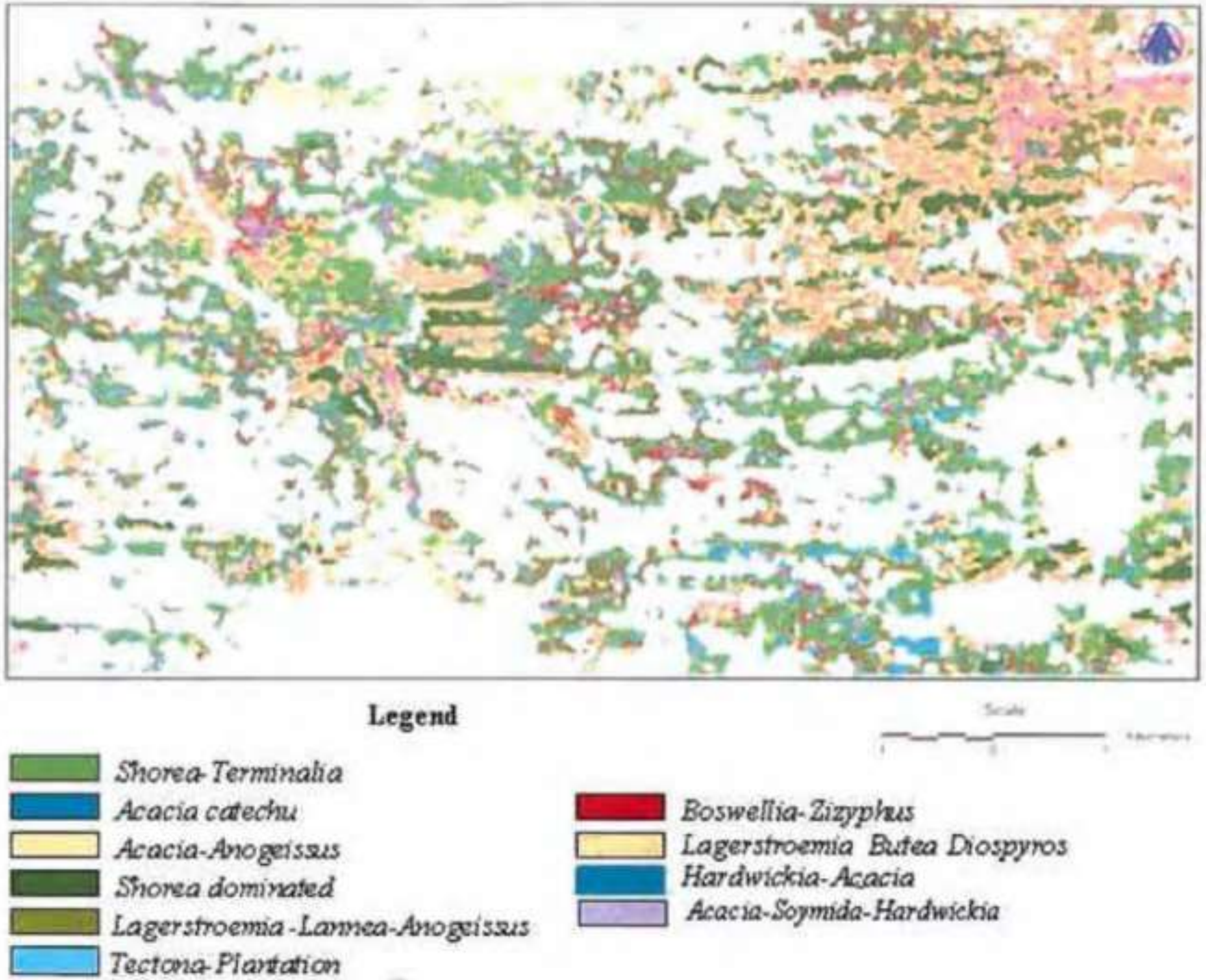
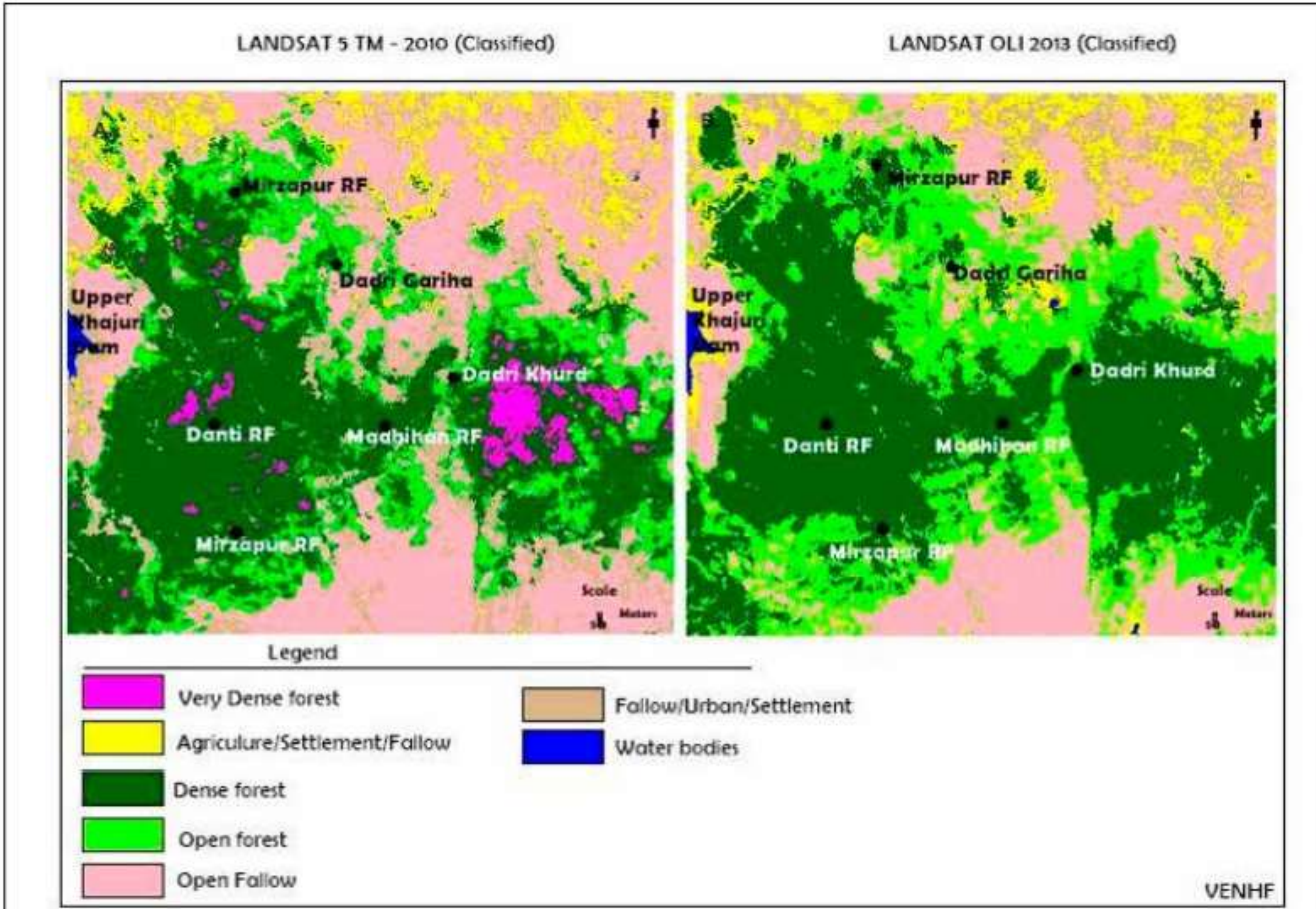


Figure 2. Classified image using IRS-1D LISS III of Hathinala forest area showing distribution of plant communities.



LANDSAT 5 TM - 2010 (Classified)
LANDSAT OLI 2013 (Classified)
Mirzapur RF
Dadri Gariha
Upper Khajuri Dam
Dadri Khurd
Danti RF
Madhihan RF
Mirzapur RF
Scale
Legend
Very Dense forest
Agriculure/Settlement/Fallow
Dense forest
Open forest
Open Fallow
Fallow/Urban/Settlement
Water bodies
VENHF

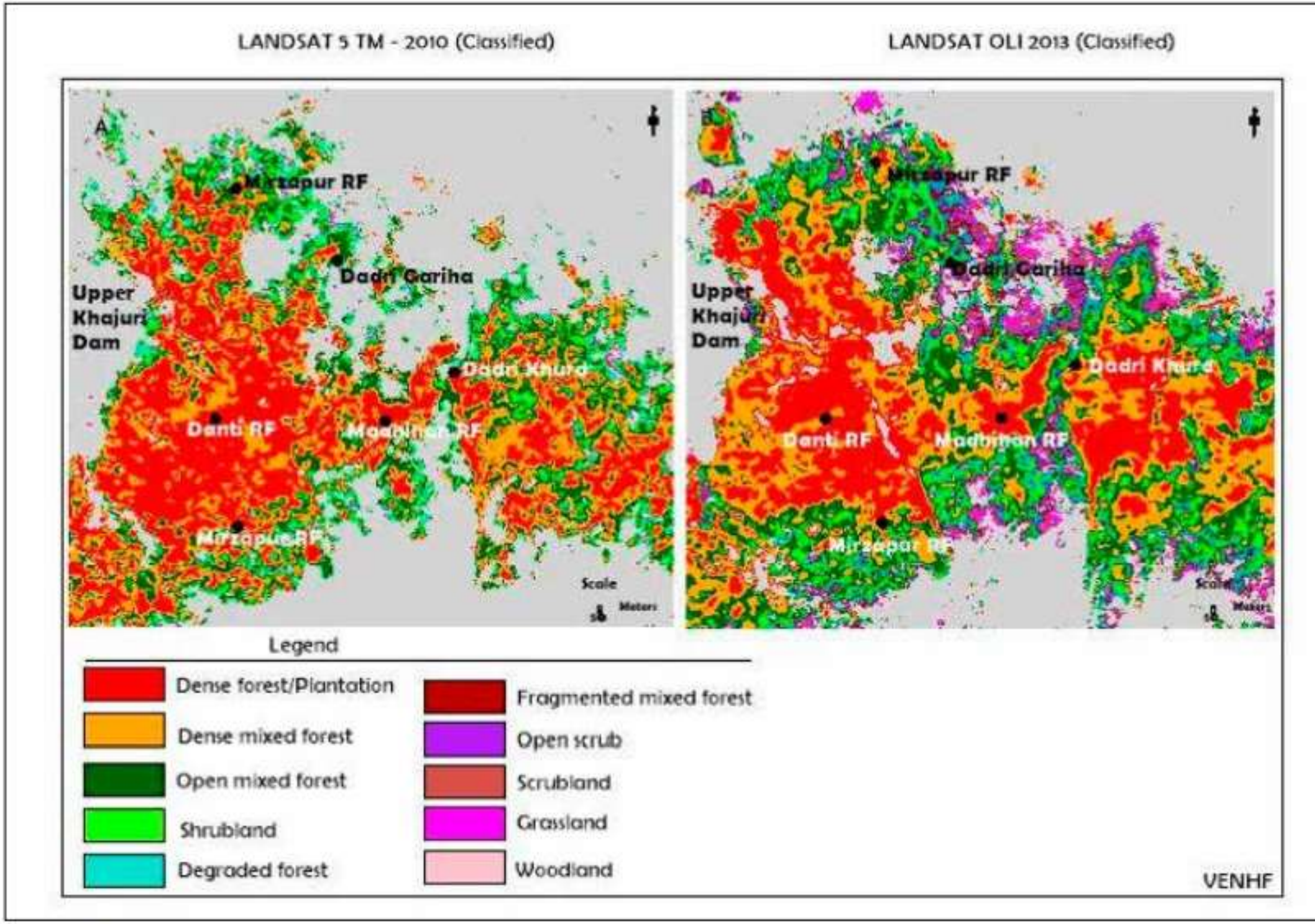


Figure 7. Forest cover classes around Danti, Mirzapur and Madihan

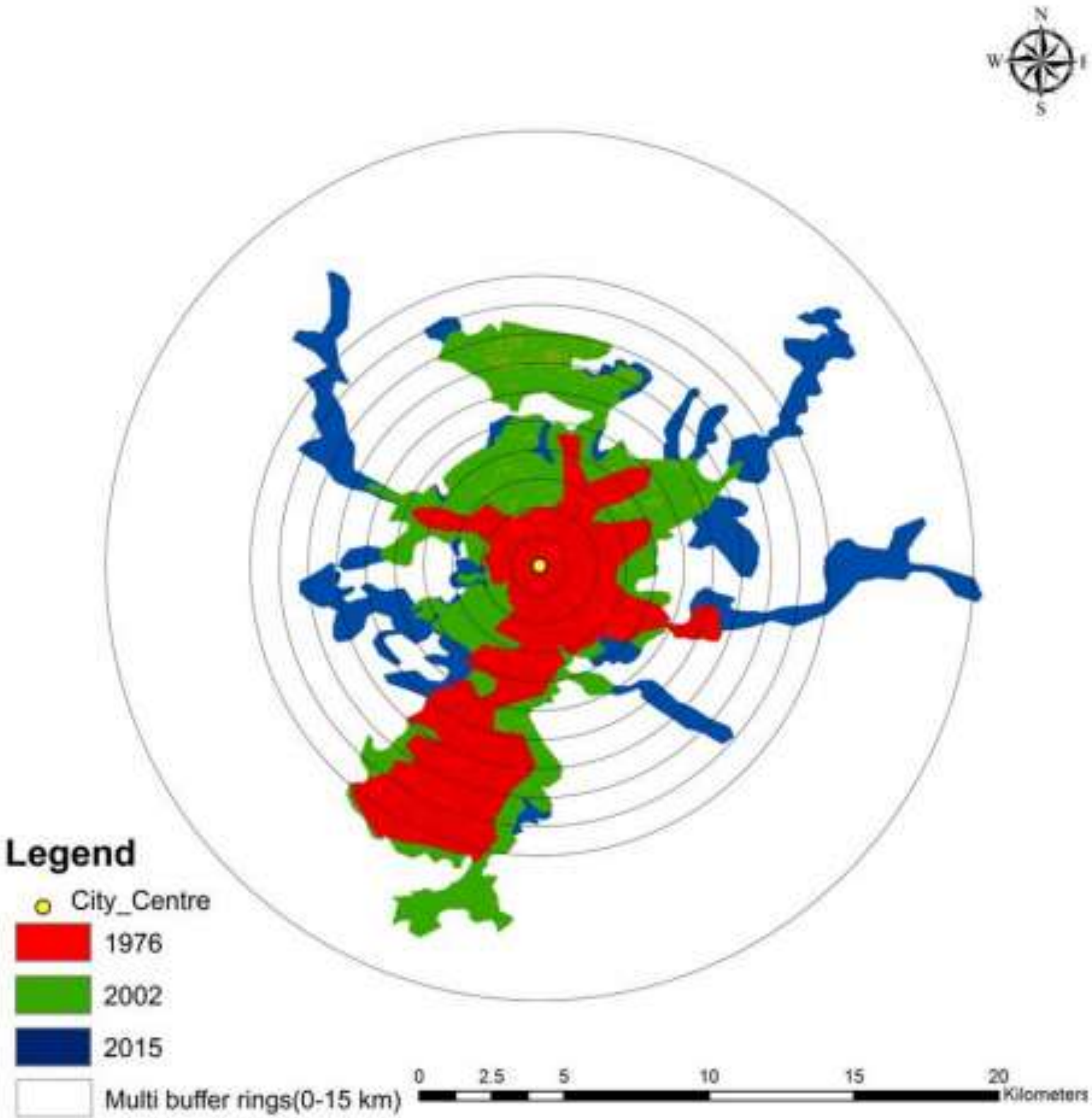
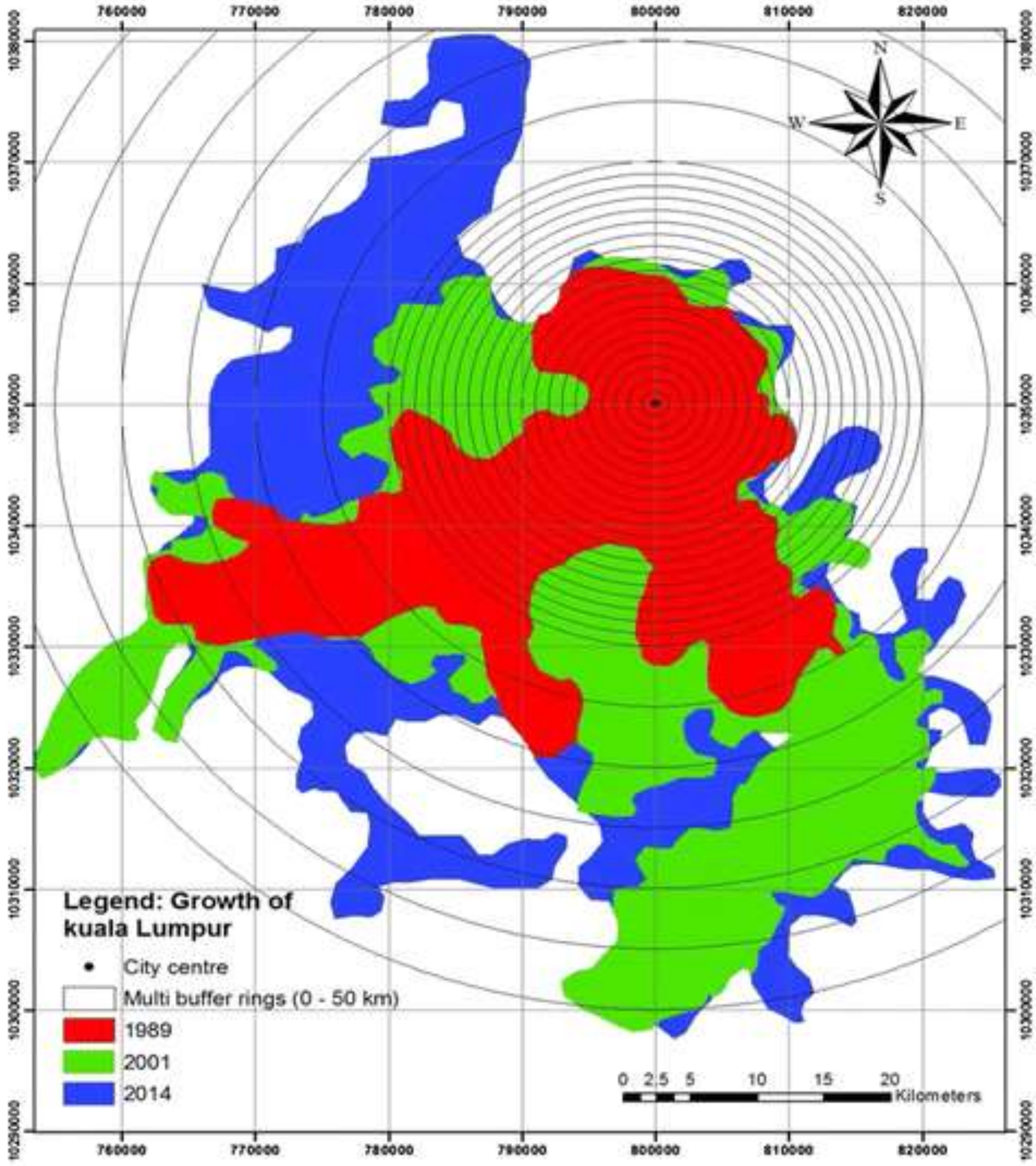


Fig.5 Urban growth of Ranchi city



760000
770000
780000
790000
800000
810000
820000
10380000
10370000
10360000
10350000
10340000
10330000
10320000
10310000
10300000
10290000
N
S
W
E
Legend: Growth of
kuala Lumpur
City centre
Multi buffer rings (0 - 50 km)
1989
2001
2014
0 2.5 5 10 15 20
Kilometers

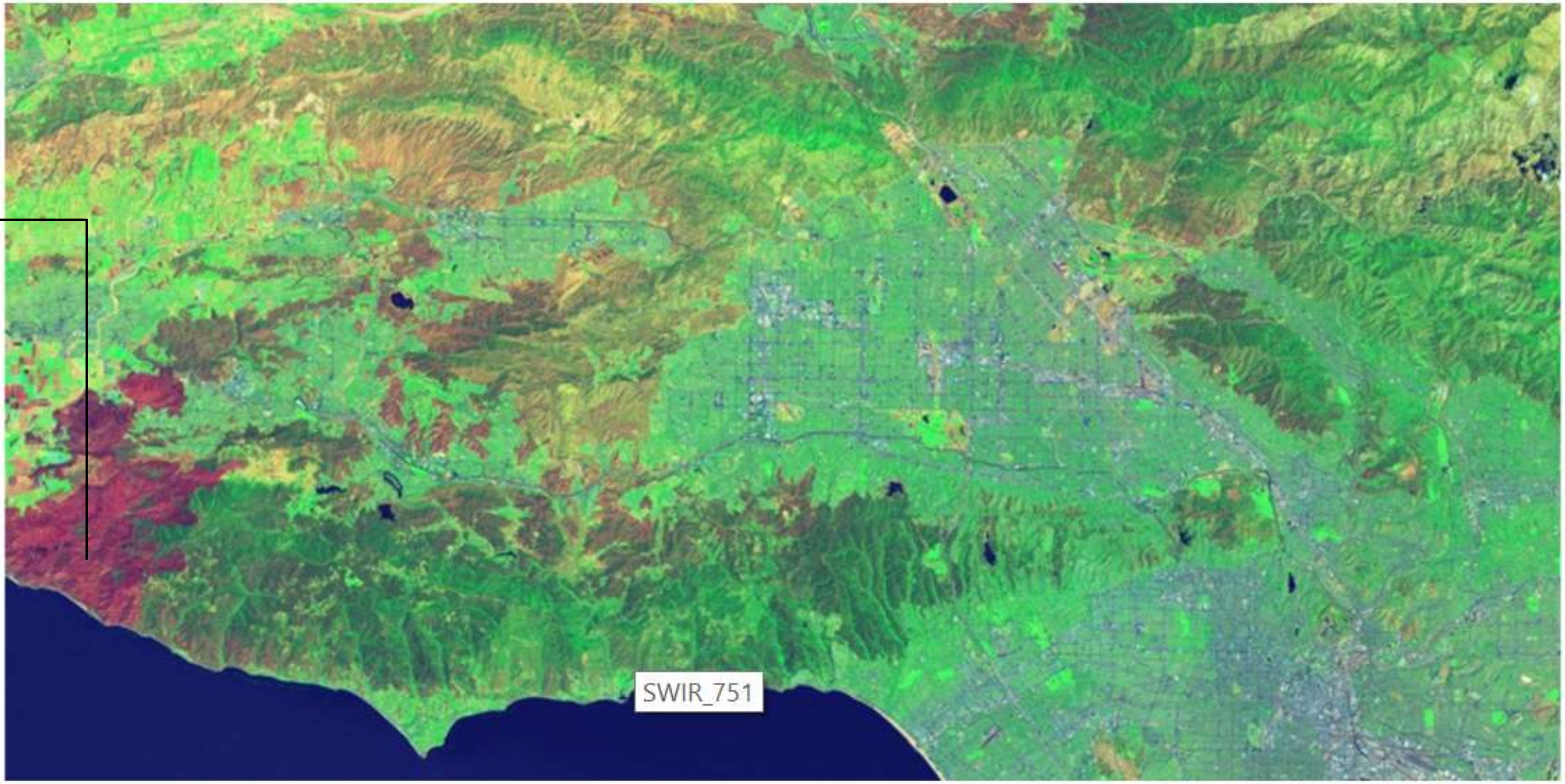
Have a look at the full list of Landsat 8's bands:

Band Number	μm	Resolution
1	0.433–0.453	30 m
2	0.450–0.515	30 m
3	0.525–0.600	30 m
4	0.630–0.680	30 m
5	0.845–0.885	30 m
6	1.560–1.660	30 m
7	2.100–2.300	30 m
8	0.500–0.680	15 m
9	1.360–1.390	30 m
10	10.6-11.2	100 m
11	11.5-12.5	100 m

Of its 11 bands, only those in the very shortest wavelengths (bands 1–4 and 8) sense visible light – all the others are in parts of the spectrum that we can't see. The true-color view from Landsat is less than half of what it sees. To understand the value of all the bands, let's look at them each in turn:

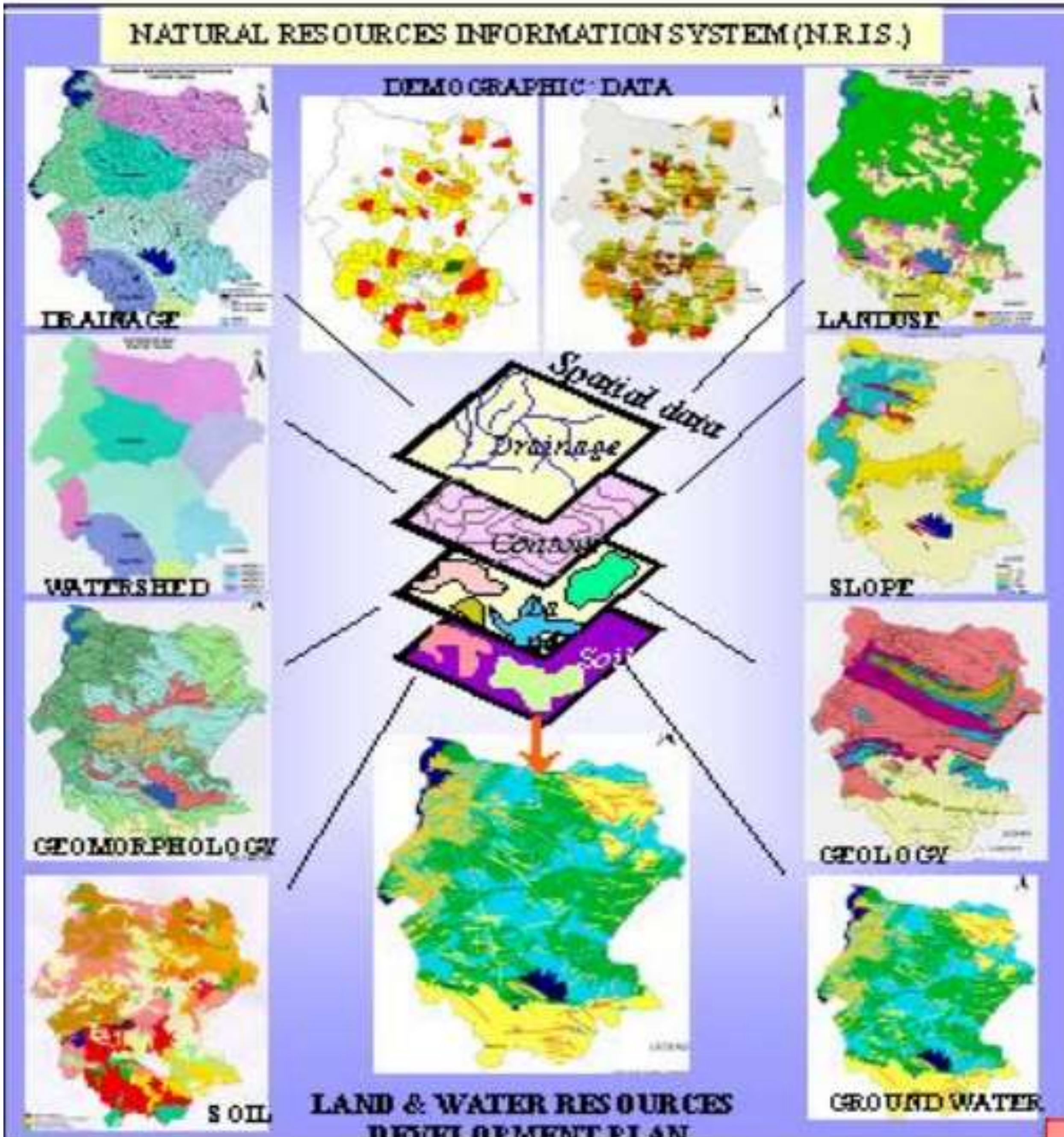
Forest Fire Detection (landsat 8 images) : Band 7-5-1 (R-G-B)

Bands 6 and 7 cover different slices of the shortwave infrared, or SWIR. They are particularly useful for telling wet earth from dry earth, and for geology: rocks and soils that look similar in other bands often have strong contrasts in SWIR. Let's make a false-color image by using SWIR as red, NIR as green, and deep blue as blue (technically, a 7-5-1 image):



The fire scar is now impossible to miss – reflecting strongly in Band 7 and hardly at all in the others, making it red. Previously subtle details of vegetation also become clear. It seems that plants in the canyons north of Malibu are more lush than those on the ridges, which is typical of climates where water is the main constraint on growth. We also see vegetation patterns within LA – some neighborhoods have more foliage (parks, sidewalk trees, lawns) than others.

The Los Angeles Basin is bordered on the north by the San Gabriel Mountains. In this image simulated natural colour image data was draped over digital topography from Aster


NATURAL RESOURCES INFORMATION SYSTEM (N.R.I.S.)
DEMOGRAPHIC DATA
DRAINAGE
LANDUSE
Spatial data
Drainage
Contour
Soil
WATERSHED
SLOPE
GEOMORPHOLOGY
GEOLOGY
SOIL
LAND & WATER RESOURCES DEVELOPMENT PLAN
GROUND WATER

Projects – NRIS, IMSD, S-IMSD, DMIS

- Digital database creation at state and district level for natural resources & socio-economic parameters
  - Generated 19 thematic layers
  - Derived Land and Water Resources Development Plans

Useful for –
Land use planning
Watershed Action Plan
Water resources development

Beneficiaries

- ✓ Land Use Board
- ✓ Agriculture Department
- ✓ Soil and Water Conservation and Watershed Area Development Authority
- ✓ Horticulture
- ✓ Water Resources Department
- ✓ Ground water
- ✓ Town planning
- ✓ Environment Department