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M.Sc. Geo-informatics

APPLICATIONS OF GEOINFORMATICS PART-III

DEPARTMENT OF REMOTE SENSING AND GIS
SCHOOL OF EARTH AND ENVIRONMENT SCIENCE
UTTARAKHAND OPEN UNIVERSITY
HALDWANI (NAINITAL)

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Phone No. 05946-261122, 261123
Toll free No. 18001804025
Fax No. 05946-264232, E. mail info@uou.ac.in
Website: https://uou.ac.in

Board of Studies

Programme Coordinator

Dr. Ranju J. Pandey
Department of Geography & NRM,
Department of Remote Sensing and GIS,
School of Earth and Environment Science,
Uttarakhand Open University, Haldwani

S.No.	Units Written By	Unit No.
1.	Dr. Sneh Gangwar, Assistant Professor Department of Geography Aditi Mahavidyalay College, University of Delhi Delhi Auchandi Road, Bawana, Delhi-110039	1,3,6,7,8 & 9
2.	Dr. D.N.Pant Ex- Scientist, IIRS, Dehradun	2
3.	Dr. Abhilasha Kannojia Assistant Professor Department of Geography Govt. PG College Ramnagar	4 & 5

Course Editor

Dr. Ranju J. Pandey
Department of Geography & NRM,
Department of Remote Sensing and GIS,
School of Earth and Environment Science,
Uttarakhand Open University, Haldwani

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BLOCK 1 : APPLICATIONS OF GEO INFORMATICS IN FOREST

UNIT 1 : INTRODUCTION AND DISTRIBUTION OF FORESTS TYPES IN INDIA

1.1 OBJECTIVES

After reading this unit you should be able:

- To describe forest cover in India
- To analyse major forest types and distribution in India

1.2 INTRODUCTION

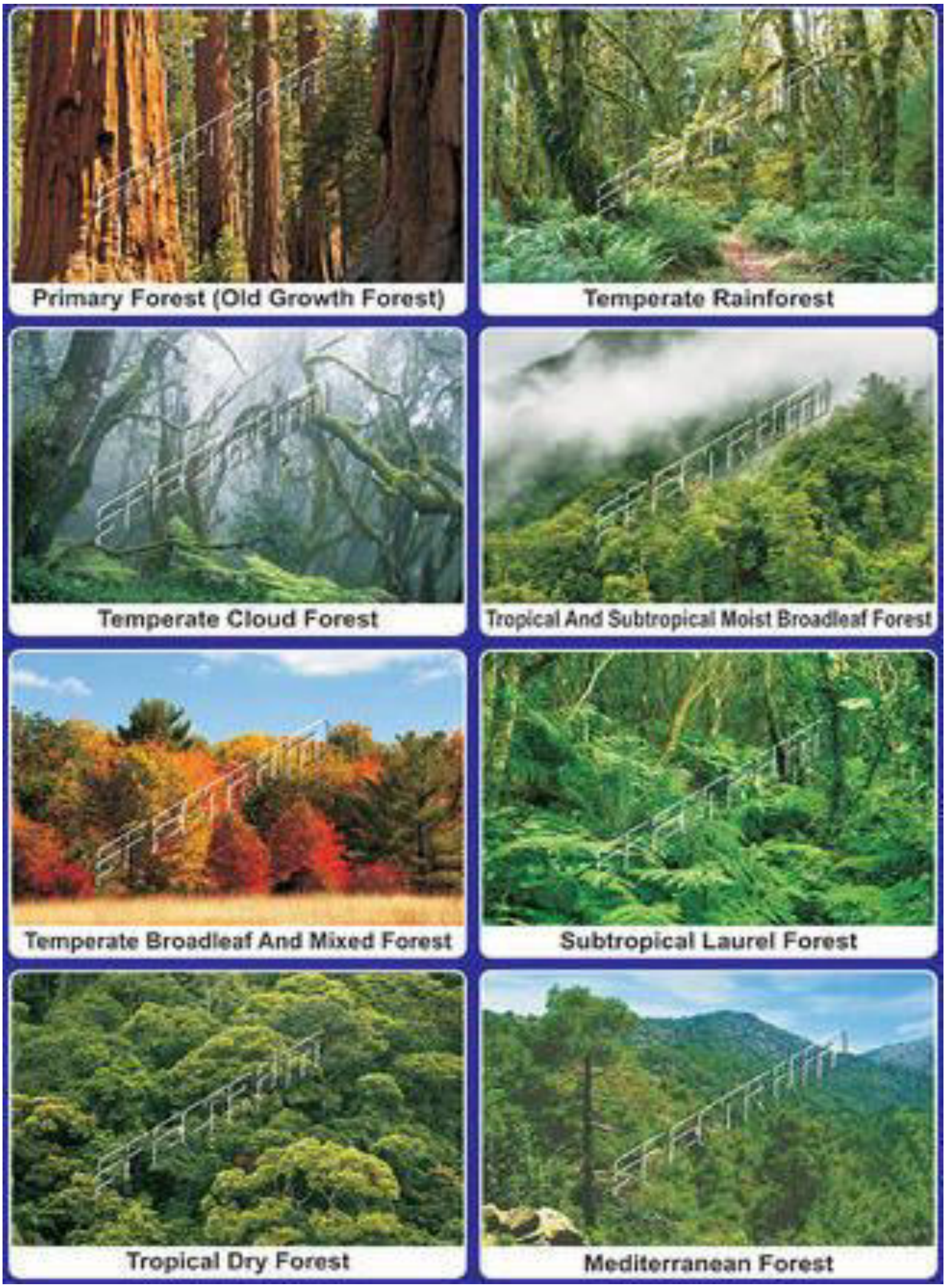
Forests in India are very diverse in their composition with a long evolutionary and geological history, occurring under diverse climatic and edaphic conditions. The forests represent a very unique assemblage of both Indo-Malayan and Australian species indicating the geological and paleo-botanical value of these forests. The forest types of India were classified for the first time in 1936 by Sir HG Champion and compiled his monumental work 'Preliminary Survey of Forest Type of India and Burma' (Champion 1936). Champion and Seth classified India's forests into 16 major types and about 221 sub-type groups; published 'A Revised Survey of the Forest type of India' in 1968. The detailed classification of forest types in India is based on climate, physiognomy, species composition, phenology, topography, soil factors, altitude, aspect, and biotic factors (Champion and Seth, 1968). The forests have been classified into six "major groups ", ranging from tropical to alpine These major groups have been further classified into 16 sub-groups on the basis of temperature and moisture regimes, and more than 200'group categories (see, Singh and Chaturvedi, 2017).

1.3 INTRODUCTION AND DISTRIBUTION OF FORESTS

MAJOR FOREST TYPES IN INDIA

Major Forest Types At the beginning of the 20th century about 30% of land in India was covered with forests. But by the year 2015 the forest cover has been reduced to 21.34%. In 2015, of the existing forests, about 2.61% are very dense forests (canopy cover 70% or more), 9.59% moderately dense forests (canopy cover 40% or more but less than 70%),9.14% open forests (canopy cover 10% or more but less than 40%), and 1.26% scrub forests (canopy cover less than 10%) (FSI 2015). Mizoram, with 88.93 % of forest cover has the highest forest cover in percentage terms, followed by Lakshadweep (84.56%). Madhya Pradesh is having largest total forest cover (77, 462 km2) in India, followed by Arunachal Pradesh (67,248 km2) and Chhattisgarh (55,586 km2) (FSI 2015). The forest types of India have been described on the basis of Champion and Seth (1968).

Figure 1.1: Types of Forest in India



Source: Google

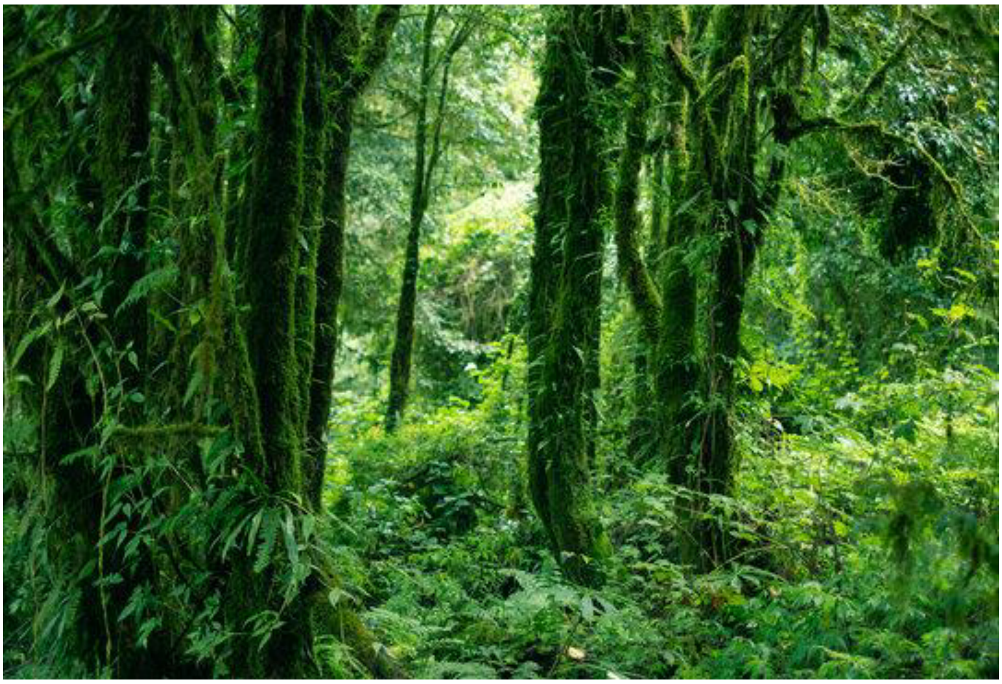
Table 1.1: The major forest type of India

Major Tropical Forest	**Forest Group**
Moist Tropical Forest	Group 1: Tropical Wet Evergreen Forest
	Group 2: Tropical Semi-evergreen Forests
	Group 3: Tropical Moist Deciduous Forests
	Group 4: Littoral and Swamp Forests
Dry Tropical forests	Group 5: Tropical dry deciduous forest
	Group 6: Tropical thorn forests
	Group 7: Tropical dry evergreen forests
Montane Subtropical Forests	Group 8: Subtropical broad-leaved hill forests
	Group 9: Subtropical pine forest
	Group 10: Subtropical dry evergreen forests
Montane Temperate Forests	Group 11: Montane wet temperate forests
	Group 12: Himalayan moist temperate forests
	Group 13: Himalayan dry temperate forests
Sub-alpine forests	Group 14: Sub alpine forests
Alpine Forests	Group 15: Moist-Alpine Scrub
	Group 16: Dry-Alpine Scrub

MOIST TROPICAL FORESTS

These forests are restricted to heavy rainfall areas of the Western Ghats and the island groups of Lakshadweep, Andaman and Nicobar, upper parts of Assam and Tamil Nadu coast. They are at their best in areas having more than 200 cm of rainfall with a short dry season. The trees reach great heights up to 60 metres or even above. Since the region is warm and wet throughout the year, it has a luxuriant vegetation of all kinds — trees, shrubs and creepers giving it a multi-layered structure. There is no definite time for trees to shed their leaves. As such, these forests appear green all the year round. Some of the commercially important trees of this forest are ebony, mahogany, rosewood, rubber and cinchona. The common animals found in these forests are elephant, monkey, lemur and deer. One horned rhinoceroses are found in the jungles of Assam and West Bengal. Besides these animals, plenty of birds, bats, sloth, scorpions and snails are also found in these jungles.

Figure 1.2: Tropical Evergreen Forest



Source: Google

Group 1: Tropical Wet Evergreen

Forest These forests are dense and show 30-45m tall canopy structure with four or five strata, generally found in regions having rainfall in the range of 2000 to > 3000 mm per year. The diversity of tree species is high in these forests. The forests are discontinuously distributed mainly along the Western Ghats, north-eastern India and Andaman and Nicobar. The northern and southern wet tropical evergreen forests are described in Table 1.2.

Table 1.2: The Northern and Southern Wet Tropical Evergreen Forest of India

Southern wet tropical evergreen forests	Northern wet tropical evergreen forests
The southern tropical wet evergreen forests occur in the Western Ghats, and Andaman and Nicobar; the most widely distributed genera are Dipterocarpus and Hopea. In the Western Ghats, rainfall ranges from 1500 to 5000mm; altitude varies from 250 to 1200m. • The variations in climatic conditions results in a large variety of plant formations and high species richness (Pascal et al., 2004).	The northern wet tropical forests occur in upper Assam, northern Bengal and Arunachal Pradesh, dominated by trees of the family Dipterocarpaceae. Bamboos are usually present. Climbers are abundant, palms and canes generally present; abundance of epiphytes, ground cover is mainly composed of evergreen shrubs. Some salient features of these forests are: • The upper Assam valley tropical

• The evergreen forests of the Western Ghats have a very high percentage of species endemic to the region. • The Western Ghats are considered as one of the biodiversity hot spots of the world (Myers et al., 2000). The Nilgiri Biosphere Reserve in the Western Ghats was the first biosphere reserve in India established in the year 1986. • The evergreen forests of Wayanad, Kerala are characterized by high proportion of Mesua ferrea, Palaquium ellipticum, Cullenia sp., and Calophyllum elatum.	wet evergreen forests- Dipterocarpus, Mesua ferrea, Dysoxylum spp, Echinocarpus, and Canarium spp. • The giant Dipterocarpus macrocarpus(Hollong) and Shorea assamica in Assam valley occur in patches, attain high girths up to seven meter and height up to 50m. • The Cachar Tropical Evergreen Forest occur in lower hills and hill slopes of Cachar hills, and the Khasi and Jaintia hills around the Surma valley. The forest is MesuaDipterocarpus-Palaquium formation.

Group 2: Tropical Semi-Evergreen Forest

Forest These forests occur in areas adjoining tropical wet evergreen, and form a transition between the evergreen and moist deciduous forests. Lower canopy is evergreen, whereas canopy species are deciduous for short periods during the dry seasons. Tropical Semi-evergreen Forest type comprises 13.79% of the Indian forest types.

These are dense, multi-strata, 24-36m in height.

- Rainfall ranges from 1500-2500mm per year.
- The canopies are not continuous and species richness lower as compared to evergreen forests.
- Buttressed stems occur in the case of both evergreen and deciduous trees (e.g. Elaeocarpus spp, and Salmalia sp).
- Bamboos, canes, ferns, climbers are common. Epiphytes are abundant including many ferns and orchids.
- These are not climate climax formations, but occur as edaphic sub climax on shallow poor soils. The northern and southern tropical Semi-evergreen forests are described in Table 1.3.

Figure 1.3: Evergreen Forest

Source: Google

Table 1.3: The Northern and southern Tropical Semi-Evergreen Forest in India

Southern Tropical Semi-evergreen Forest	Northern Tropical Semi-evergreen Forest
Distributed in Western Ghats where rainfall gradient is steep, north of Bombay, near Goa, and South of Cochin; Andaman (in the main valley), Tiruneveli (eastern slopes of the southern Western Ghats). i. The forests are composed of both evergreen and deciduous species in the top storey. ii. Upper canopy composed of Xylia and Terminalia, Dipterocarpus, Balanocarpus, Hopea spp. iii. Middle canopy trees belong to family Myrtaceae, Lauraceae, iv. Ground-floor is composed of evergreen shrubs belonging to Rubiaceae and Acanthaceae.	These types of forests occur in moderate to heavy rainfall areas of Assam, West Bengal, and Odisha, include the following types: i. Assam valley and alluvial plains Semievergreen Forest. ii. Eastern submontane Semi-evergreen Forest: Schima-Bauhinia association iii. Sub-Himalayan light alluvial Semi-evergreen Forest: Terminalia- Phoebe association. iv. Cachahar semi-evergreen forest – Assam: mixed semi-deciduous type; Manipur: Tectona, Dipterocarpus hylium.

	v. Odisha tropical semi evergreen forest: occur on the Odisha hills at about 800m and in lower permanently moist valleys. Composed of Artocarpus, Mesua ferrea, Terminalia spp, Michelia sp, Phoebe spp, and Litsea sp.g

Group 3: Tropical Moist Deciduous

These are the most widespread forests of India. They are also called the monsoon forests and spread over the region receiving rainfall between 200 cm and 70 cm. Trees of this forest type shed their leaves for about six to eight weeks in dry summer. On the basis of the availability of water, these forests are further divided into moist and dry deciduous.

Figure 1.4 : Tropical Moist Forest

Source: Google

The former is found in areas receiving rainfall between 200 and 100 cm. These forests exist, therefore, mostly in the eastern part of the country — north-eastern states, along the foothills of the Himalayas, Jharkhand, West Odisha and Chhattisgarh, and on the eastern slopes of the Western Ghats. Teak is the most dominant species of this forest. Bamboos, sal, shisham, sandalwood, khair, kusum, arjun and mulberry are other commercially important species.

Figure 1.5: Distribution of Forest in India

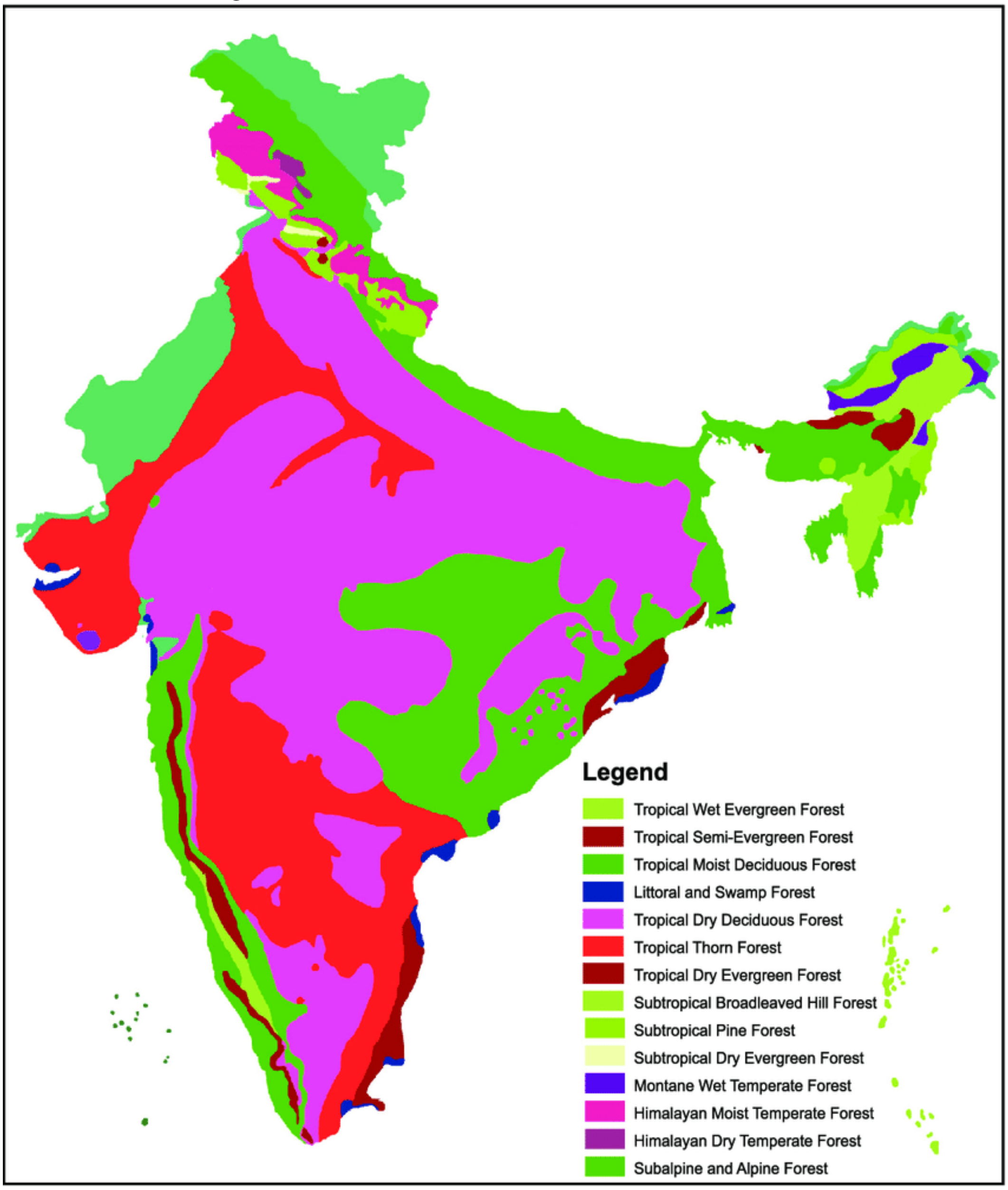
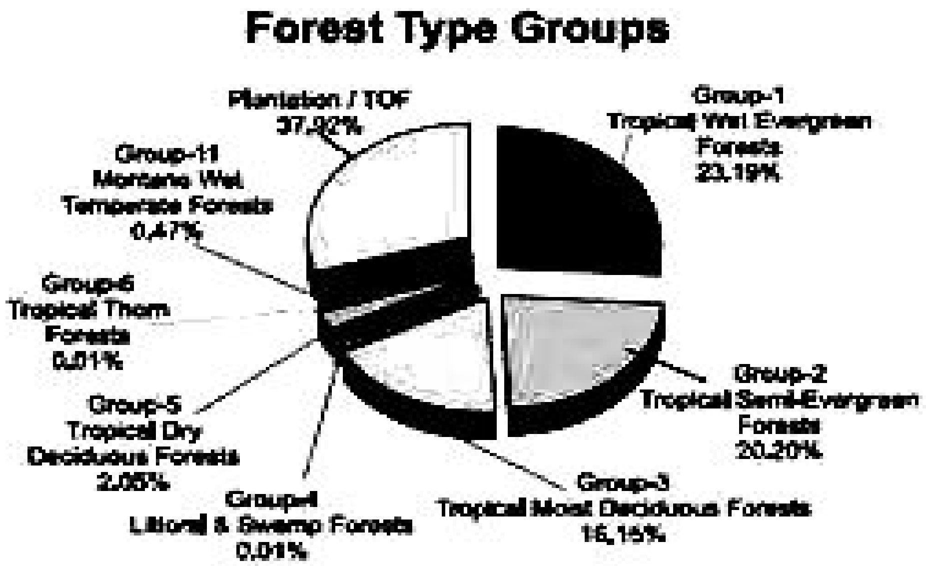


Table 1.4: Percentage distribution of Forest Type across Elevation Zones of India

Forest type / Elevation zone (m)	<100	100-500	500-1000	1000-1500	1500-2000	2000-3000	3000-4200
Tropical Wet evergreen forest	3.05	19.37	63.92	10.36	3.06	0.25	0.00
Tropical Semi evergreen forest	8.10	63.97	23.06	3.60	1.27	0.00	0.00
Tropical Moist deciduous forest	5.58	52.05	34.30	6.55	1.53	0.00	0.00
Tropical Dry deciduous forest	1.73	63.02	33.81	1.44	0.00	0.00	0.00
Littoral and swamp forest	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Tropical Dry evergreen forest	22.61	77.39	0.00	0.00	0.00	0.00	0.00
Tropical Thorn forest	3.82	60.61	35.56	0.00	0.01	0.00	0.00
Subtropical Broadleaved hill forest	0.00	0.09	0.08	70.58	29.26	0.00	0.00
Subtropical Pine forest	0.00	0.00	0.01	19.35	27.37	50.12	3.16
Subtropical Dry evergreen forest	0.00	2.88	39.09	58.02	0.00	0.00	0.00
Montane Wet Temperate forest	0.00	0.00	0.00	0.00	11.47	79.41	9.13
Himalayan Moist Temperate forest	0.00	0.00	0.00	0.00	26.53	58.83	14.63
Himalayan Dry Temperate forest	0.00	0.00	0.00	2.12	10.56	56.03	31.28
Sub Alpine forest	0.00	0.00	0.00	0.00	0.00	7.66	92.34

Figure 1.6: Forest percentage Distribution according to Group



Source: Google

Forest These forests are common in areas where rainfall is 1000 to 2000 mm with a dry season of three to four months. Dominant trees are deciduous, lower storey trees are usually evergreen. The trees shed their leaves in winter months, again become flushed in March-April. These forests comprise 19.73% of India's forest types (FSI 2011). These forests are widely distributed covering both in southern and northern states including Tamil Nadu, Arunachal Pradesh, Assam, Meghalaya, Mizoram, Bihar, West Bengal, Odisha, and Uttarakhand. These forests are usually 2 to 3 strata with a much lower number of species as compared with the tropical evergreen and semi evergreen forests. The canopy trees are light demanding, middle ones are shade tolerant species of shrubs and young trees, and on ground floor are present herbs and saplings. Climbers are abundant. The northern and southern tropical moist deciduous forests are described in Table 1.5.

Table 1.5: The Northern and Southern Tropical Moist Deciduous Forest of India

Southern Moist Deciduous Forests	Northern Moist Deciduous Forests
These forests are distributed in Maharashtra, Mysore, Tamil Nadu, and Arunachal Pradesh. Tectona grandis is dominant in the southern Moist Deciduous Forests with the following variations: i. Very moist teak forests occur in Kerala and Tamil Nadu in high rainfall areas over 2500mm on deep alluvial soils. ii. Moist –teak bearing forests, southern moist mixed deciduous forest and southern secondary moist mixed Deciduous Forest. iii. Moist teak forests are associated with Terminalia spp, Pterocarpus spp, Adina, and Dalbergia latifolia. Bamboos are quite common. Bambusa arundinacea and Dendrocalamus strictus are the most common bamboo.	The northern moist deciduous Forests are dominated by Shorea robusta with the following variations: i. Very moist sal –bearing forests occur in Sikkim, West Bengal, the Garo, Khasi hills, and Jaintia hills, Assam and Meghalaya. These forests are composed of Shorea robusta, Schima wallichii, Stereospermum personatum. ii. Moist Siwalik sal forests occur on Nahan Sandstones, whereas sandy alluvium soil with dry subsoil. iii. Moist peninsular sal forests also occur in Madhya Pradesh, and Odisha; common associates being Pterocarpus marsupium, Anogeissus latifolia, Syzygium cumini, Phoenix acaulis etc. iv. Moist mixed deciduous forests occur in Siwalik Hills of Uttarakhand. In eastern Himalaya in Bengal and Assam.

Group 4: Littoral and Swamp Forests

These forests consist of evergreen species of varying densities and height, usually associated with mesic habitats. These forests are mostly in their developmental stage and are seral in nature.

Figure 1.7: Swampy Forest

Source: Google

i. The littoral forests occur along the coast in the Andaman and Nicobar, Andhra Pradesh, Odisha, and Tamil Nadu. The most characteristic species is tall and evergreen Casuarina on sandy beaches and dunes along the sea face. In Andaman, the forests are dominated by Manilkara littoralis.

ii. The tidal and swamp forests (mangrove scrub) are dominated by several evergreen and semievergreen species in deltas of the Ganga and the Brahmaputra rivers.

iii. Mangroves are found along the east and west coasts of India, the Andaman and Nicobar Islands, the Gulf of Kachchh and Khambat (Gujarat). Sundarban (40% in West Bengal) is the largest mangrove in the world. Mangrove forests are generally dominated by trees of the genera – Rhizophora, Avicennia, Sonneratia, Bruguiera, and Ceriops. Some genera like Heritiera and Xylocarpus. On the drier areas within the salt water mangrove scrub/forest are found palm swamp.

iv. Tropical fresh water swamps such as Myristica swamp forest occur in Travancore, Kerala, contain species such as Myristica spp., Lagerstroemia speciosa.

v. The species like Baringtonia spp, and Syzygium cumini, are found in swamps forests of UP and West Bengal.

II. DRY TROPICAL FORESTS

In regions with less than 70 cm of rainfall, the natural vegetation consists of thorny trees and bushes. This type of vegetation is found in the north-western part of the country, including semi-arid areas of Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Uttar Pradesh and Haryana. Acacias, palms, euphorbias and cacti are the main plant species. Trees are scattered and have long roots penetrating deep into the soil in order to get moisture. The stems are succulent to conserve water. Leaves are mostly thick and small to minimise evaporation. These forests give way to thorn forests and scrubs in arid areas. In these forests, the common animals are rats, mice, rabbits, fox, wolf, tiger, lion, wild ass, horses and camels.

Figure 1.8: Dry Tropical Forest

Source: Google

Group 5: Tropical Dry Deciduous

Forests These are largest forest type of India covering about 38.2% of the forest area of the country. Tropical dry forests occur in climates exhibiting a marked seasonality in rainfall and prolonged drought period over the annual cycle. These forests consist of trees less than 25m high, with a light demanding canopy consisting of deciduous trees. These forests occur from Kanyakumari to the foothills of the Himalaya in low rainfall areas of 800 to 1200mm; large areas of these forests are suitable habitats for wildlife. Dry teak and dry sal communities predominate in the southern and northern regions, respectively. In some areas a mixture of trees like Anogeissus pendula, Boswellia serrata, Hardwickia binata,Acacia nilotica, Madhuca indica, and Butea monosperma occupy the area. Acacia catechu and Dalbergia sissoo are conspicuously present on newly formed soils. The northern and southern tropical Dry Deciduous forests are described in Table 6.

Group 6: Tropical Thorn Forests

These forests are found in low rainfall areas (200 to 800mm) of northern India, peninsular India and central India. Moisture availability is limiting for plant growth. The trees experience prolonged dry periods. The tree height ranges from six to nine meters. Southern Tropical Thorn Forests Occur in Maharashtra, Tamil Nadu and AP. In south India, important species are Acacia chundra , Acacia planifrons and Acacia catechu.. Northern Tropical Thorn Forests occur in semiarid regions of Rajasthan, Punjab, Haryana, northern Gujarat, MP, UP, and Delhi

Figure 1.9: The Thorn Forest and Shrubs

Source: Google

These forests are open, consisting of short trees, generally belonging to thorny tree species. The desert thorn type consists of Acacia senegal, Prosopis spicigera, Prosopis cineraria, Acacia leucophloea, Acacia nilotica, Ziziphus spp, and Salvadora spp. Acacia tortilis and Prosopis chilensis have been widely planted in this region. 2. The desert dune scrub are very open, irregular formations of stunted trees and bushes, these are sparse and thorny. The main species are Acacia senegal, Prosopis spicigera, Acacia Arabica, Tamarix aphylla, Salvadora oleoides.

Figure 1.10: Tropical Thorn Forest Landscape and Vegetation

Source: Google

Table 1.6: The Northern and Southern Tropical Dry Deciduous Forest of India

Southern Tropical Dry Deciduous Forest	Northern Tropical Dry Deciduous Forest
Occupy whole of peninsular India (except coastal Karnataka). These forests are distributed in Maharashtra, Karnataka, Andhra Pradesh, MP, and Tamil Nadu. The main climax types include: i. Dry Teak bearing forest: Tectona grandis, Boswellia serrata, Anogeissus latifolia, Sterculia sp., and Acacia catechu. ii. Dry red sanders bearing forest: Pterocarpus santalinus predominates forming pure associations over extensive areas, and teak is absent. iii. Southern dry mixed deciduous forest: Boswellia serrata is conspicuous, distributed throughout peninsular India;common trees are Anogeissus latifolia, Terminalia tomentosa, and Hardwickia binata. iv. Dry mixed forest with Tectona grandis. v. Sandal (Santalum album) bearing scrub forest.	Occur in Bihar, Bengal, Odisha, Gujarat, UP, Haryana. Shorea robusta is of low quality in these forests. These are of following types: i. Dry Siwalik sal forest are dominated by Shorea robusta, Anogeissus sp., Buchnania lanzan, whereas dry plains sal forests are composed of Shorea robusta, Terminalia tomentosa, Madhuca india , and Diaspyros sp. In Kalesar reserve forest in Haryana, the forests are mainly composed of dry Siwalik Shorea robusta forest, dry plains Shorea robusta forest, northern dry mixed deciduous forests, and the dry tropical riverine forests. ii. Dry peninsular sal forest: Occur in regions of Bihar, MP (Pachmarhi plateau), Odisha, UP, west Bengal, Chhattisgarh (Amarkantak); Shorea robusta mixed with Boswellia serrata. iii. Northern Dry mixed Deciduous

	Forest: Main trees are Anogeissus latifolia, Boswellia serrata. iv. The dry deciduous scrub is distributed throughout the dry deciduous forest zone of India.

Group 7: Tropical Dry Evergreen

Forests The forests are restricted in distribution to Karnataka coast, also reported from the east coast in AP. These are low growing forests; trees are of 9-12 m height, and form a complete canopy. Most conspicuous trees are Manilkara hexandra, Memecylon edule along with Diaspyros, Eugenia, Chloroxylon, Albizzia amara. There is a high diversity of trees, shrubs and herbs in these forests.

(III) MONTANE SUBTROPICAL FORESTS

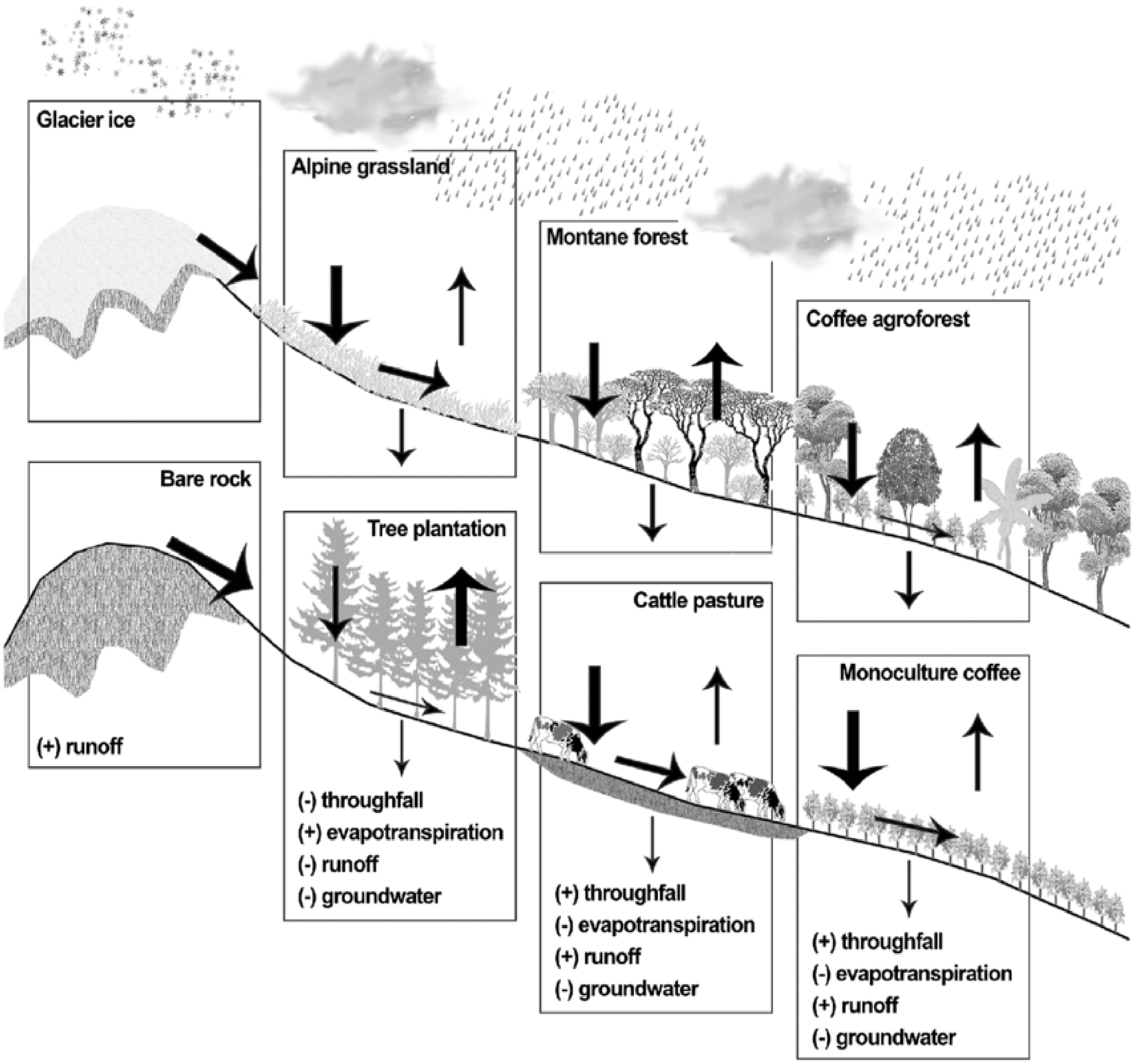
In mountainous areas, the decrease in temperature with increasing altitude leads to the corresponding change in natural vegetation. As such, there is a succession of natural vegetation belts in the same order as we see from the tropical to the tundra region. The wet temperate type of forests is found between a height of 1000 and 2000 metres. Evergreen broad-leaf trees, such as oaks and chestnuts predominate. Between 1500 and 3000 metres, temperate forests containing coniferous trees, like pine, deodar, silver fir, spruce and cedar, are found.

Figure 1.11: Montane Forest

Source: Google

These forests cover mostly the southern slopes of the Himalayas, places having high altitude in southern and north-east India. At higher elevations, temperate grasslands are common. At high altitudes, generally, more than 3,600 metres above the sea level, temperate forests and grasslands give way to the Alpine vegetation. Silver fir, junipers, pines and birches are the common trees of these forests. However, they get progressively stunted as they approach the snow-line. Ultimately, through shrubs and scrubs, they merge into the Alpine grasslands. These are used extensively for grazing by nomadic tribes, like the Gujjars and the Bakarwals. At higher altitudes, mosses and lichens form part of tundra vegetation. The common animals found in these forests are Kashmir stag, spotted dear, wild sheep, jack rabbit, Tibetan antelope, yak, snow leopard, squirrels, Shaggy horn wild ibex, bear and rare red panda, sheep and goats with thick hair.

Figure 1.12: Montane Forest Stratification and Zonation



Group 8: Subtropical Broad Leaved Hill Forests

These forests are of the following types: i. Southern Subtropical Broad Leaved Hill Forests In south India, these forests are found in the hill slopes and tops at about 1000 to 1700m height in Nilgiri, Palani, Tirunelveli, and Mercara hills. Main trees are Calophyllum elatum, Eugenia spp., Dalbergia latifolia, Anogeissus latifolia, Emblica officinalis, Olea dioca, and Phoenix humilis. ii. Central Indian Subtropical Hill Forests Hill top forests occur above 1200m in Madhya Pradesh (Pachmarhi), Bihar, Odisha. In Pachmarhi hills, Manilkara hexandra, Mangifera, Syzygium cumini are conspicuous trees. iii. Northern Subtropical Broad Leaved Hill Forests Occur in Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Nagaland Sikkim, and west Bengal represented by east Himalayan subtropical wet hill forest, Altitude 1000-to 2000m, Occur in Khasi, Jainti and adjacent hills, dense evergreen forests, rarely exceeding 20m height. Important tree species are Quercus, Castanopsis, Alnus, Prunus, Betula and Schima. There is heavy growth of epiphytic mosses, ferns and phanerogams. Subtropical broad leaved hill forest dominated by Quercus serrata, Eugenia praecox, Schima wallichii,Rhus succidanea located located at Imphal, Manipur is shown in Fig. 1.13.

Fig. 1.13

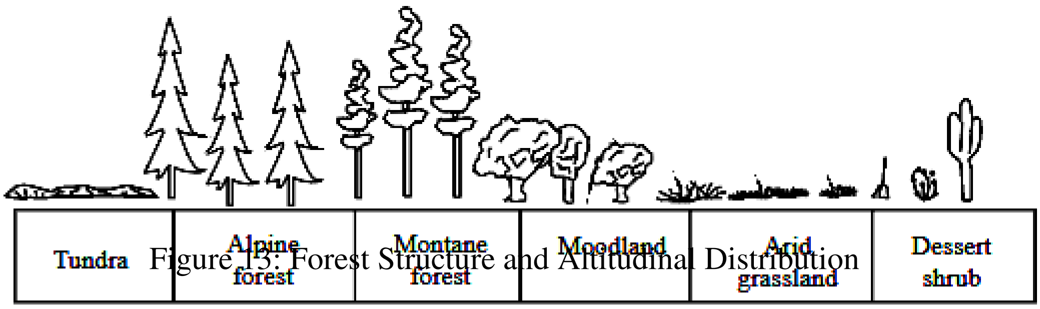
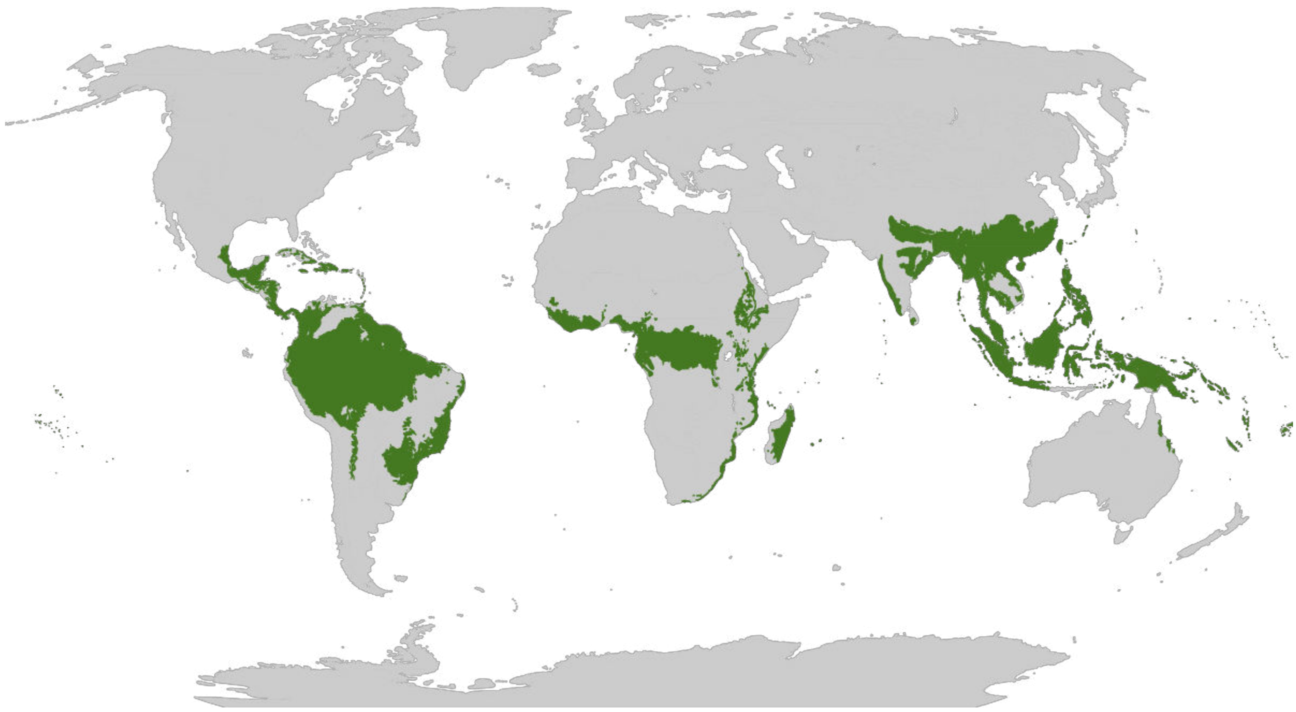


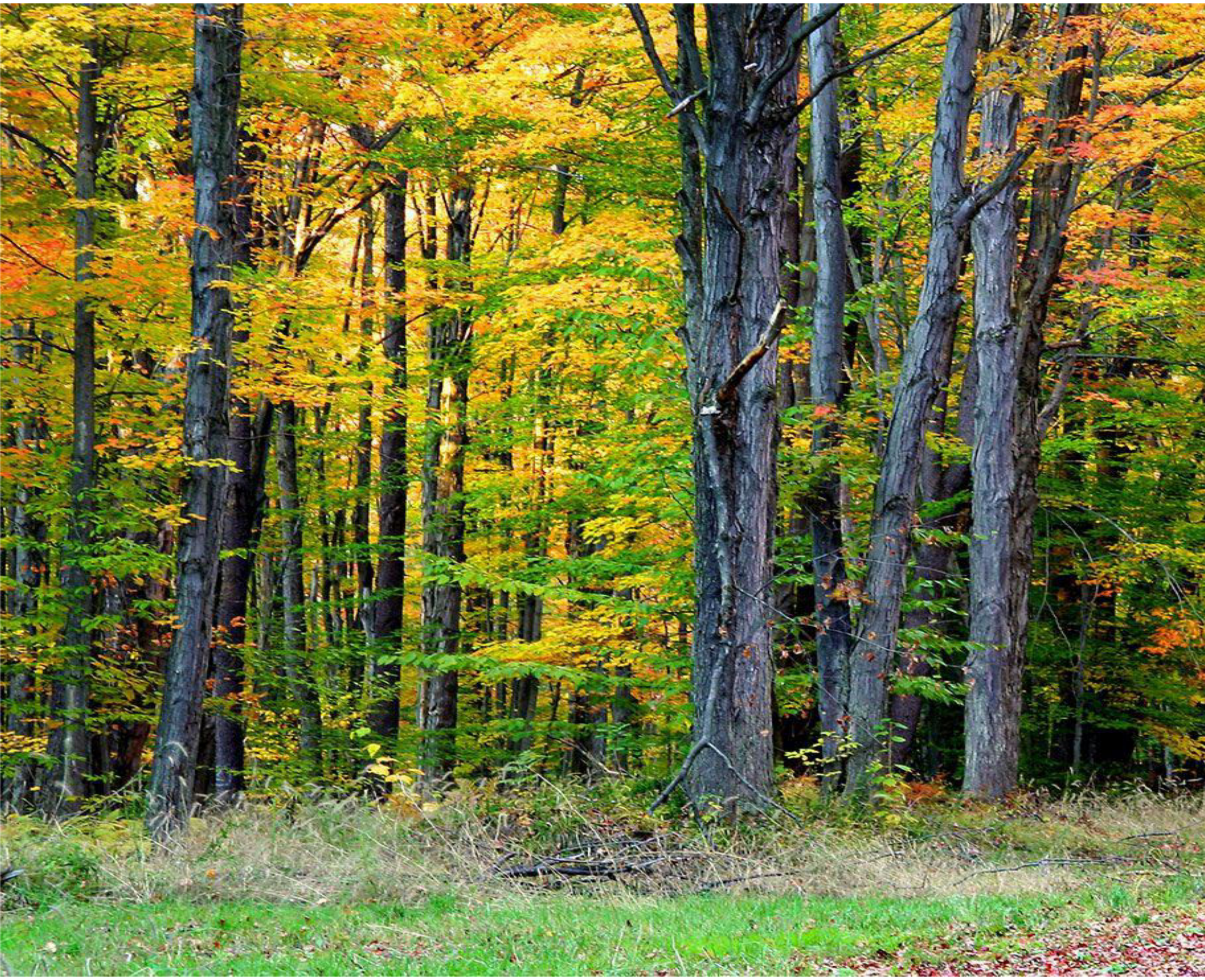
Figure 1.14 Broad Leaved Hill Forest



Source: Google

Group 9: Sub-Tropical Pine Forests

Sub-tropical chir pine (Pinus roxburghii) forests occur throughout the central and western Himalaya between 1000 to 1800m; distributed in Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Uttrakhand. Pinus roxburghii along with broad leaved species is the main characteristics of these forests. Climbers and bamboos are absent. A view of Sub-tropical chir pine (Pinus roxburghii) forest in Morni hills in north-east Haryana is shown figure 5. The forests of Pinus keysia along with Schima wallichii occur in Khasi and Naga Hills, and Manipur hills, in eastern Himalaya (Figure 15). Pinus kesiya is often a pioneer in deforested secondary vegetation, especially if fire has been a factor in the disturbance.



Source: Google

Group 10: Sub-Tropical Dry Evergreen Forests

These forests are distributed in Bhabar tract, Shiwalik hills, and the foothills of western Himalaya. In Punjab, Uttrakhand, and Himachal Pradesh, Olea cuspidata is found on alluvial ground of wider valleys. In Jammu and Kashmir, the dominant species of these scrub forests are Olea cuspidate, Acacia modesta, and Dodonaea viscosa

IV. MONTANE TEMPERATE FORESTS

Group 11: Montane Wet Temperate Forest

Figure:15 Sub-Tropical Pine Forest

Source: Google

The southern Montane wet temperate forests are closed evergreen forest, trees are mostly short boled (not exceeding 6m), and highly branched. The branches are clothed with mosses, ferns and other epiphytes, woody climbers are common. The northern Montane wet temperate forests are a characteristic feature of the eastern Himalaya and are found between 1800 m and 3000 m elevation in high rainfall areas (>2000mm rainfall); The northern and southern Montane wet temperate forests of India are described in Table 1.7.

Group 12: Himalayan Moist Temperate Forests

These forests extend the whole length of the Himalayan region between the sub-tropical pine forest and sub-alpine forests. Altitude ranges from 1500m to 3300m. These are concentrated in the central and western Himalaya, except in areas where rainfall is below 1000 mm. Distributed in Kashmir, Himachal Pradesh, Punjab, Uttrakhand, Darjeeling district of west Bengal, Assam, and Sikkim.

i. Several species of oak predominate in the temperate forests including Quercus leucotrichophora, Quercus. Floribunda, Quercus incana, Quercus semecarpifolia, Quercus dilatata, Q. larginosa. All oak species in Himalayan region are evergreen showing leaf fall in summer, but are never leafless. There are four strata, 25-30m height, tree canopy is dense, herbaceous layer not well developed, grasses generally lacking, and rich in epiphytes. A view of temperate oak forest at Munsiyari Pithoragarh, Uttarakhand in Kumaun Himalaya is shown in Figure 16.

ii. Most Cedrus deodara forests form pure stands, canopy is fairly complete, boles are straight and tall (30-40m), There are scattered oaks and Rhododendron under the conifers. The evergreen Cedrus deodara forest surrounding the Khajjiar lake located at 1920 m above mean sea level in Khajjair, Chamba district, Himachal Pradesh in western Himalaya.

iii. As the altitude increases, the upper form consisting of Abies pindrow, Picea smithiana, and Quercus semecarpifolia becomes dominant.

iv. The eastern Himalayan hills are occupied by Quercus. lineata, Quercus lamellosa, Quercus pachyphylla, Rhododendron spp., Tsuga dumosa, Picea spinulosa and Abies densa.

v. Cupressus torulosa is a conspicuous species found on limestone rocks from Chamba (Himachal Pradesh) to the Aka hills at 1800 to 2800 m.

Table 1.7: Representative tree species of forest types across biographic zones.

Forest Type	Tree Species
Tropical Wet evergreen forest	
Eastern Himalayas	Michelia montana, Mesua ferrea, Dysoxylum binectariferum, Ailanthus integrifolia, Baccaurea ramiflora
Gangetic Plains	Dipterocarpus retusus, Canarium strictum, Shorea assamica, Antidesma montanum, Magnolia hodgsonii
North East	Dipterocarpus turbinatus, Dipterocarpus retusus, Litsea monopetala, Artocarpus chaplasha, Garcinia pedunculata
Deccan	Litsea glabrata, Persea macrantha, Macaranga peltata, Mesua ferrea, Actinodaphne malabarica
Coast	Dysoxylum malabaricum, Macaranga peltata, Olea dioica, Holigarna arnottiana, Calophyllum polyanthum
Weastern Ghat	Hopea parviflora, Holigarna arnottiana, Cullenia exarillata, Vateria indica, Palaquium ellipticum
Islands	Dipterocarpus alatus, Dipterocarpus grandiflorus, Aglaia

	oligophylla, Myristica andamanica, Myristica glaucescens
Tropical Semi evergreen forest	
Western Himalaya	Shorea robusta, Haldina cordifolia, Anogeissus latifolia, Careya arborea, Ficus semicordata
Eastern Himalaya	Terminalia myriocarpa, Tetrameles nudiflora, Mesua ferrea, Dillenia indica, Duabanga sonneratioides
Gangetic Plain	Terminalia bellirica, Syzygium cumini, Litsea monopetala, Casearia graveolens, Stereospermum personatum
Western Ghat	Macaranga peltata, Terminalia paniculata, Knema attenuata, Mesua ferrea, Artocarpus hirsutus
Deccan	Michelia champaca, Macaranga peltata, Protium serratum, Litsea glutinosa, Syzygium nervosum
Island	Pterocarpus dalbergioides, Dipterocarpus gracilis, Celtis wightii, Pterocymbium tinctorium, Artocarpus chaplasha
Littoral and swamp forest	
Coast	Rhizophora mucronata, Excoecaria agallocha, Avicennia marina, Avicennia alba, Bruguiera gymnorrhiza
Island	Rhizophora apiculata, Rhizophora mucronata, Bruguiera gymnorrhiza, Avicennia marina, Avicennia alba
Tropical Dry evergreen forest	
Deccan	Atalantia monophylla, Albizia amara, Manilkara hexandra, Memecylon edule, Mundulea sericea
Coasts	Atalantia monophylla, Albizia amara, Phyllanthus chorisandra, Canthium dicoccum, Prosopis juliflora
Tropical Thorn forest	
Gangatic Plain	Acacia leucophloea, Butea monosperma, Acacia catechu, Prosopis juliflora, Prosopis cineraria
Semi-Arid	Acacia leucophloea, Acacia senegal, Acacia nilotica, Butea monosperma, Prosopis cineraria
Desert	Acacia senegal, Prosopis cineraria, Salvadora oleoides, Capparis decidua, Calligonum polygonoides

Figure 1.16: Himalayan Moist Temperate Forest

Source: Google

Group 13: Himalayan Dry Temperate Forests

Conifers predominate, distributed on 1700 to 3000m altitude, in the inner ranges of Himalaya, rainfall usually less than 1000mm mostly received as snow in winter months. Distributed in Kashmir, Ladhakh, Lahaul, Chamba, inner Garhwal, and Sikkim. ♣ Coniferous forests are tall (30-35m) and have evergreen canopy. ♣ These forests consist of both coniferous and broad-leaved species. In the western Himalaya, the characteristic species are Pinus gerardiana, Cedrus deodara and Juniperus. At higher elevation, Abies pindrow, and Pinus wallichiana are found. ♣ In the eastern Himalaya, the common species are from Abies and Picea. In higher hills, Juniperus wallichiana is common. ♣ Locally, between 2500 and 4000 m elevation, a few other species like Larix griffithiana, Populus eupheretica, Salix spp., Hippophoe spp. and Myricaria spp. also occur.

(V) SUB-ALPINE FORESTS

Group 14: Sub-Alpine Forests

The subalpine forests occur throughout the Himalaya above 3000 m elevation up to the tree limit., rainfall 83-600mm. The forests are mainly evergreen; Rhododendron is common constituent. Tall trees are conifers; Betula utilis is present as the largest deciduous tree and associated with genera like Quercus semecarpifolia, Sorbus, and Rhododendron sp. ♣ Western Himalaya sub-alpine forests reported from Jammu and Kashmir, Himachal Pradesh, and Uttrakhand. In the western Himalaya, there are two types of forests (i) Abies spectabilis and Betula utilis , (ii) west Himalayan sub-alpine birch/fir forest. ♣ In the eastern Himalaya, these forests occur above 3000m. These forests are distributed in Arunachal Pradesh, Sikkim, and west Bengal. There is predominance of Abies densa and Betula utilis, and Rhododendron spp. These are climax formation sself-generatingng with marked resilience.

(VI) ALPINE FORESTS

Group 15: Moist- Alpine Scrub

Moist Alpine Scrub occurs throughout Himalaya, above timber line to 5,500m altitude, composed entirely of species of Rhododendron with some birch (Betula) and other deciduous trees. The tree trunks are short and highly branched, moss and ferns cover the ground. A thick layer of humus is present and soil is generally wet. ♣ In Kumaun, Uttrakhand, Betula utilis and Rhododendron campanulatum scrub forest occur. Rhododendron- Lonicera association occurs in Uttrakhand, in inner Himalaya. ♣ In eastern Himalaya, dense Rhododendron thickets occur at 3350-4600m altitude. These forests are reported from Arunachal Pradesh, Sikkim and west Bengal.

Figure: 1.17 Alpine Forest

Source: Google

Group 16: Dry- Alpine Scrub

It is a xerophytic formation, having predominance of dwarf shrubs; rainfall < 370mm per year. Characteristic plants are Juniperus wallichiana, Lonicera spp, Potentilla spp. Vegetation along the streams is composed of Salix, Myricaria, and Hippophae rhamnoides. These scrub forests are distributed in Jammu and Kashmir, Himachal Pradesh, Uttrakhand, and Arunachal Pradesh. In eastern Himalaya, Juniperus recurva and Juniperus wallichiana occur at an altitude ranging from 3000 to 4600m.

Figure1.18: Dry Alpine Forest

Source: Google

DISTRIBUTION OF FOREST TYPES IN VARIOUS ZONES

Distribution of forest types analysed across the mean annual rainfall zones (4000 mm) based on data of world climate. Littoral and swamp forests are distributed in all six rainfall zones. Wet evergreen forests and semi evergreen forests are predominantly found in rainfall zone of 3000-4000 mm followed by rainfall zone of 2000-3000 mm. Moist deciduous forests (69.64%) and dry deciduous forests (65.20%) are distributed mostly in rainfall zone of 1000-2000 mm. However dry deciduous forests represent 33.89% of area in rainfall zone of 500-1000, while moist deciduous forests have 3.38% of occupancy only.

Table 8: Distribution of Forest in Various Forest Zones

Sl No	Type	Area (KM^2)	% of total
1	2	3	4
1	Tropical wet Evergreen & Semi Evergreen	3877.4413	34.28
2	Tropical Moist Deciduous	3615.9840	31.97
3	Tropical Dry Deciduous	391.3636	3.46
4	Montane Sub- tropical Temperate shoals	386.4210	3.42
5	Plantations	1549.5083	13.70
6	Grass Lands	501.0865	4.43
7	Others	987.6757	8.73
	Total	11309.4754	

1.4 SUMMARY

- Champion and Seth (1968) gave a detailed classification of forest types in India based on climate, physiognomy, species composition, phenology, topography, soil factors, altitude, aspect, and biotic factors.
- The forests have been classified into six major forest types and 16 major groups on the basis of temperature and moisture regimes.
- The tropical wet evergreen forests are dense and show 30-45m tall canopy structure with four or five strata, generally found in the Western Ghats, north-eastern India and Andaman and Nicobar having rainfall in the range of 2000 to > 3000 mm.
- The tropical semi-evergreen forests occur in areas adjoining tropical wet evergreen, and form a transition between evergreen and moist deciduous forests.
- Tropical Moist Deciduous Forests are common in areas where rainfall is 1000 to 2000 mm with a dry season of three to four months, widely distributed covering both southern and northern states.
- Mangroves are found along the east and west coasts of India, the Andaman and Nicobar Islands. Sundarban (is the largest mangrove in the world).

- Tropical Dry Deciduous Forests are largest forest type of India covering about 40% of the forest area of the country, dry teak (Tectona grandis) and dry sal (Shorea robusta) forests predominate in the southern and northern regions of India, respectively.
- Tropical thorn forests are found in low rainfall areas of northern India, peninsular India and central India, moisture availability is limiting for plant growth, the trees experience prolonged dry periods.
- Subtropical Broad Leaved Hill Forests occur in the hill slopes and tops at about 1000 to 1700m height in south India and northern India.
- Sub-tropical chir pine (Pinus roxburghii) forests occur throughout the central and western Himalaya between 1000 to 1800m. The forests of Pinus keysia occur in Khasi and Naga Hills and Manipur hills in eastern Himalaya.
- The southern Montane wet temperate forests Occur in high hills of Tamil Nadu and Kerala on the, Anamalai, Palni and Tiruneveli hills from about 1,500 m upwards. Tiruneveli.
- Northern Montane wet temperate forests are a characteristic feature of the eastern Himalaya and are found between 1800 m and 3000 m elevation in high rainfall areas (>2000mm rainfall). xiii. Himalayan Moist Temperate Forests are distributed in northern India at altitude ranging from 1500m to 3300m. Several species of oak predominate in the temperate forests.
- The Himalayan Dry Temperate Forest: Conifers predominate, 1700 to 3000m altitude, in the inner ranges of Himalaya, rainfall usually less than 1000mm.
- Sub-Alpine Forests occur throughout the Himalaya above 3000 m elevation up to the tree limit.
- The new classification of forest types has been proposed reflecting the present ecological, climatic, bio-geographic and edaphic influences on the vegetation composition and stand formation.

1.5 GLOSSARY

- Tropical wet evergreen- A type of forests is dense and show 30-45m tall canopy structure with four or five strata, generally found in the Western Ghats, north-eastern India.
- Tropical Moist Deciduous- A type of forests is common in areas where rainfall is 1000 to 2000 mm with a dry season of three to four months, widely distributed covering both southern and northern states.
- Tropical Dry Deciduous- A type of forests is largest forest type of India covering about 40% of the forest area of the country, dry teak and dry sal forests predominate in the southern and northern regions of India

1.6 ANSWER TO CHECK YOUR PROGRESS

1. Where is the Himalayan Dry Temperate Forest found?
2. Where is the Dry Alpine Forest found?
3. Where is the Alpine Forest found?
4. Define Sub-Tropical Pine Forests?
5. Define Sub-Tropical Evergreen Forests?
6. Define Tropical Thorn Forests?

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1.8 TERMINAL QUESTIONS

1. Explain Forest distribution with suitable examples.
2. Describe Tropical Forest?
3. What do you understand by thorny and shrub forest. Describe them with suitable diagrams.
4. What are the three broad categories of forest in India.
5. Explain the major factors for growth of forest.
6. Examine the high altitudinal forest resource in India.

UNIT 2 - INTERACTION OF EMR WITH VEGETATION, SPECTRAL AND TEMPORAL CHARACTERISTICS OF VEGETATION

2.1 OBJECTIVES

After reading this unit you should be able to:

- Definitions and concepts
- EMR Interaction with Vegetation
- Spectral Characteristics for Green Vegetation in Relation to Wavelength
- Vegetation Reflectance
- Factors Affecting Spectral Reflectance of Vegetation
- Spectral Reflectance Change in Relation to Temporal Characteristics of Vegetation
- Reflectance of Vegetation Canopy
- Composite Reflectance

2.2 INTRODUCTION

You have already studied electromagnetic radiation (EMR) and its interaction with matter, reflection types, complexities of reflection phenomenon with respect to natural surfaces reflectance measurement methods and energy sources in reflectance remote sensing. In this unit you will be learning the aspect related to interaction of EMR with vegetation and its spectral and temporal characteristics. Let us first understand the vegetation and its physiognomy, structure, biomass and why remote sensing is needed for its scientific management and development.

In strict sense forests are the types of vegetation dominated by trees. Vegetation, particularly forest, is characterized by their structure and function. Due to inherent characteristics of the plants, all the plants do not attain same height and try to find their niche in an ecosystem. These results in stratification of vegetation called storey. Each forest has its own structural characteristics. The term vegetation structure is used with different meanings. Primary elements of structure of vegetation are growth form, stratification and coverage. In the vegetation ecology, vegetation structure may be studied at least at five level, viz., vegetation physiognomy, biomass, life form, floristic and stand structure. These levels of vegetation are hierarchically integrated in that the first level includes the second, the second includes the third and so on. The level 1 i.e., vegetation physiognomy is the most general one. Primary recognition and determination of formations and communities are done based on the appearance (physiognomy). Physiognomy of vegetation is sensed/captured through optical remote sensors, thus provides means to further processing.

For scientific management of forest vegetation, we need its stratification, mapping and analysis with respect to its type, physiognomy, species composition, structural variability, biomass and occurrence in different site and topographical condition. Remote sensing based EMR interactions, spectral reflectance characteristics are the most well-known and documented methods for the said purpose.

Vegetation has a unique spectral signature and the different reflectance characteristics with respect to their types and heterogeneous nature Plants that are stressed or diseased can also be identified by their distinct spectral signatures. The leaf pigments, cell structure and water content all impact the spectral reflectance of vegetation. For example, broad leaved trees have a higher reflectance in the near infrared compared to conifers.

Interaction of EMR with vegetation in visible, near infrared (NIR) and middle infrared (mir) region needs to understand first the interaction of EMR with overall vegetation community and with a typical leaf. Generally, a leaf is built up of layers of structural fibrous organic pigmented matter, water filled cells and air spaces. Each of the following features like pigmentation, physiological structure and water content have an effect on the reflectance, absorbance and transmittance properties of a green leaf.

Interaction of radiation with plant leaves is extremely complex. General features of this interaction have been studied but many spectral features are yet unexplained. Gates *et al.,* (1965) are considered pioneers, who have studied spectral characteristics of leaf reflection, transmission and absorption. Optical properties of plants have been further studied to understand the mechanisms involved by Gausman & Allen (1973), Wooley (1971) and Allen *et al.,* (1970).

2.3INTERACTION OF EMR WITH VEGETATION, SPECTRAL AND TEMPORAL CHARACTERISTICS OF VEGETATION.

DEFINITIONS AND CONCEPTS

Vegetation

Vegetation, either in natural or cultural form, may be defined in many ways.

- Vegetation is usually defined as the mosaic of plant communities in the landscape.
- Vegetation is an assemblage of plant species and the ground cover they provide.
- The vegetation may be defined as "the organization in space of the individuals that form a stand (vegetation type or a plant association)" Dansereau (1957) or mosaic of plant formations and communities.
- Vegetation may be defined as all the plants or plant life of a place, taken as a whole.
- The term vegetation used in ecology refers to dominant plant growth forms or structural characteristics, e.g., forest vegetation, grassland vegetation.
- Vegetation is often chosen as the basis for the classification of terrestrial ecosystems because it generally integrates the ecological processes acting on a site or landscape more measurably than any other factor or set of factors. Vegetation is a critical component of energy flow in ecosystems and provides habitat for many organisms. In addition, vegetation is often used to infer soil and climate patterns. For these reasons, a classification of terrestrial ecological communities based on vegetation can serve to describe many facets of ecological patterns across the landscape.

Vegetation Structure

- Vegetation structure represents the overall morphology and architecture of a plant community, such as the vertical layers of plants of different heights in an agro-forestry system, the presence/absence of gaps in the forest canopy, or the horizontal spacing of individual plants.
- Vegetation structure is defined as the organization of individuals in space that constitutes a stand of plants.

- Vertical vegetation structure includes the number of plants /trees per unit area, width and density of vegetation layers, maximum canopy height, leaf area index and vegetation cover whereas horizontal structure represent the coefficient of variation of number, forest cover /forest vegetation density (proportion of vegetation/forest canopy occupied by tree crowns and overall vegetation cover.
- The structure provided by plants supports delivering ecosystem services. For example, vegetation can delay precipitation run-off via canopy interception and thereby prevent flooding and provides resilience to erosion.
- Also, complex forests have stronger mitigation effects on climate extremes than pastures do, through evaporative cooling of many additive leaf layers].
- Vegetation structural variables, such as the Leaf Area Index (LAI), can be used as proxies for productivity and terrestrial carbon stocks.
- In most habitats, vegetation provides the main structure of the environment. This complexity can facilitate biodiversity and ecosystem services.

Physiognomy

- Physiognomy is a combination of the external appearance of vegetation, its vertical structure, and the growth forms of the dominant trees.
- Physiognomy is an emergent trait of the vegetation community.
- Physiognomy is concerned with Architecture / Life Forms, Leaf Area Index, Phenology, Plant Functional Types.
- Vegetation possesses two principal properties, floristic composition and physiognomy.

Chlorophyll

- A chemical compound in leaves called chlorophyll.
- Chlorophyll makes plants green.
- Chlorophyll is basically a group of green pigments used by organisms that convert sunlight into energy via photosynthesis.
- Plants use chlorophyll to trap energy from the sun. Without this energy, plants would be unable to initiate the process of photosynthesis, which converts water and carbon dioxide into starches that plants can use for food.

EMR INTERACTIONS WITH VEGETATION

EMR interaction with earth surface and atmosphere has already been explained in the previous unit. The following is particularly with reference to vegetation:

Electromagnetic radiation (EMR) that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface vegetation communities and other cover types. There are three forms of interaction that can take place when energy strikes, or is incident i) upon the surface. These are: absorption (A)**;** transmission (T)**;** and reflection (R)**.** The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

Figure 2.1: EMR Interaction with tree/plant leaves

Absorption (A) occurs when radiation (energy) is absorbed into the target while transmission (T) occurs when radiation passes through a target. Reflection (R) occurs when radiation "bounces" off the target and is redirected. In remote sensing, we are most interested in measuring the radiation reflected from targets (Figure 2.1). We refer to two types of reflection, which represent the two extreme ends of the way in which energy is reflected from a target: specular reflection and diffuse reflection. When a surface is smooth, we get specular or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction (Figure 2.2). Diffuse reflection occurs when the surface is rough and the energy is reflected almost uniformly in all directions. Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors. Whether a particular target reflects specularly or diffusely, or somewhere in between, depends on the surface roughness of the feature in comparison to the wavelength of the incoming radiation.

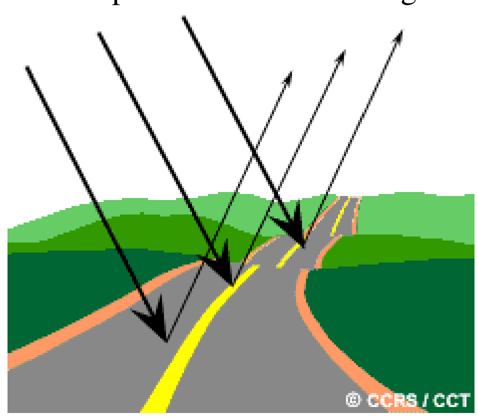

Figure 2.2: Specular Reflection

If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate. For example, fine-grained sand would appear fairly smooth to long wavelength microwaves but would appear quite rough to the visible wavelengths. In case of trees diffuse reflection take place where tree leaves are very small and needle like shape (Figure 2.3). Here the radiant energy is intermingled with leaves and the reflection is scattered all around.

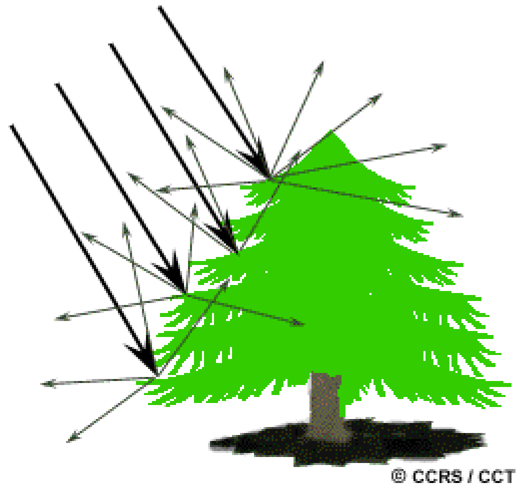

Figure 2.3: Diffuse Reflection

Let's take a look at a couple of examples of targets at the Earth's surface and how energy at the visible and infrared wavelengths interacts with them.

Leaves: Chlorophyll of leaves strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths (Figure 2.4). Leaves appear "greenest" to us in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow (yellow is a combination of red and green wavelengths). The internal structure of healthy leaves acts as excellent diffuse reflectors of near-infrared wavelengths. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us at these wavelengths. In fact, measuring and monitoring the near-IR reflectance is one way that scientists can determine how healthy (or unhealthy) vegetation may be.

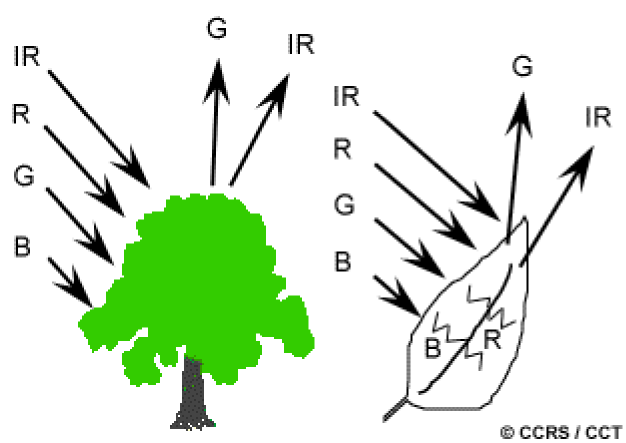

Figure 2.4: Chlorophyll of tree leaves strongly absorbs radiation in the red (R) and blue (B) Wavelengths but reflects green wavelengths. IR reflectance from tree leaves is Directly related to health and amount of chlorophyll content

Water: Longer visible wavelength and near infrared radiation is absorbed more by water than shorter visible wavelengths (Figure 2.5). Thus, water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near infrared wavelengths. If there is suspended sediment present in the upper layers of the water body, then this will allow better reflectivity and a brighter appearance of the water. The apparent colour of the water will show a slight shift to longer wavelengths. Suspended sediment (S) can be easily confused with shallow (but clear) water, since these two phenomena appear very similar. Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear greener in colour when algae is present. The topography of the water surface (rough, smooth, floating materials, etc.) can also lead to complications for water-related interpretation due to potential problems of specular reflection and other influences on colour and brightness.

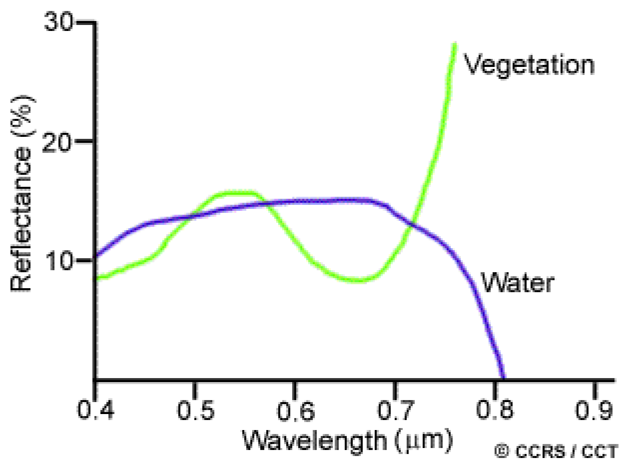

Figure 2.5: Spectral curve of water and vegetation reflectance within visible and IR band

We can see from these examples that, depending on the complex make-up of the target that is being looked at, and the wavelengths of radiation involved, we can observe very different responses to the mechanisms of absorption, transmission, and reflection. By measuring the energy that is reflected (or emitted) by targets on the Earth's surface over a variety of different wavelengths, we can build up a **spectral response** for that object. By comparing the response patterns of different features, we may be able to distinguish between them, where we might not be able to, if we only compared them at one wavelength. For example, water and vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared. Spectral response can be quite variable, even for the same target type, and can also vary with time (e.g., "green-ness" of leaves) and location. Knowing where to "look" spectrally and understanding the factors which influence the spectral response of the features of interest are μcritical to correctly interpreting the interaction of electromagnetic radiation with the surface.

SPECTRAL CHARACTERISTICS FOR GREEN VEGETATION IN RELATION TO WAVELENGTH

The following paragraphs are highlighting the above-mentioned spectral reflectance behavior of leaves in relation to wavelengths:

To understand interaction of EMR with vegetation, first we have to understand the interaction of EMR with a typical leaf. Leaf reflectance in optical and infrared wavelengths (0.4–2.5 µm) is controlled by a number of different biochemical and physical variables, including chlorophyll and other leaf pigments, nitrogen, water, and internal leaf structure and leaf surface variables. Specific absorption features for individual plant pigments and compounds dominate in visible (0.4 – 0.7 µm) and shortwave inferred (SWIR, ~ 1.3–2.5 µm) wavelengths, with the positions of the absorption features controlled by the vibrational and rotational properties of the molecules present.

Generally, a leaf is built up of layers of structural fibrous organic matter, within which are pigmented, water filled cells and air spaces. Each of the following features has an effect on the reflectance, absorbance and transmittance properties of a green leaf:

- Pigmentation
- Physiological Structure
- Water Content

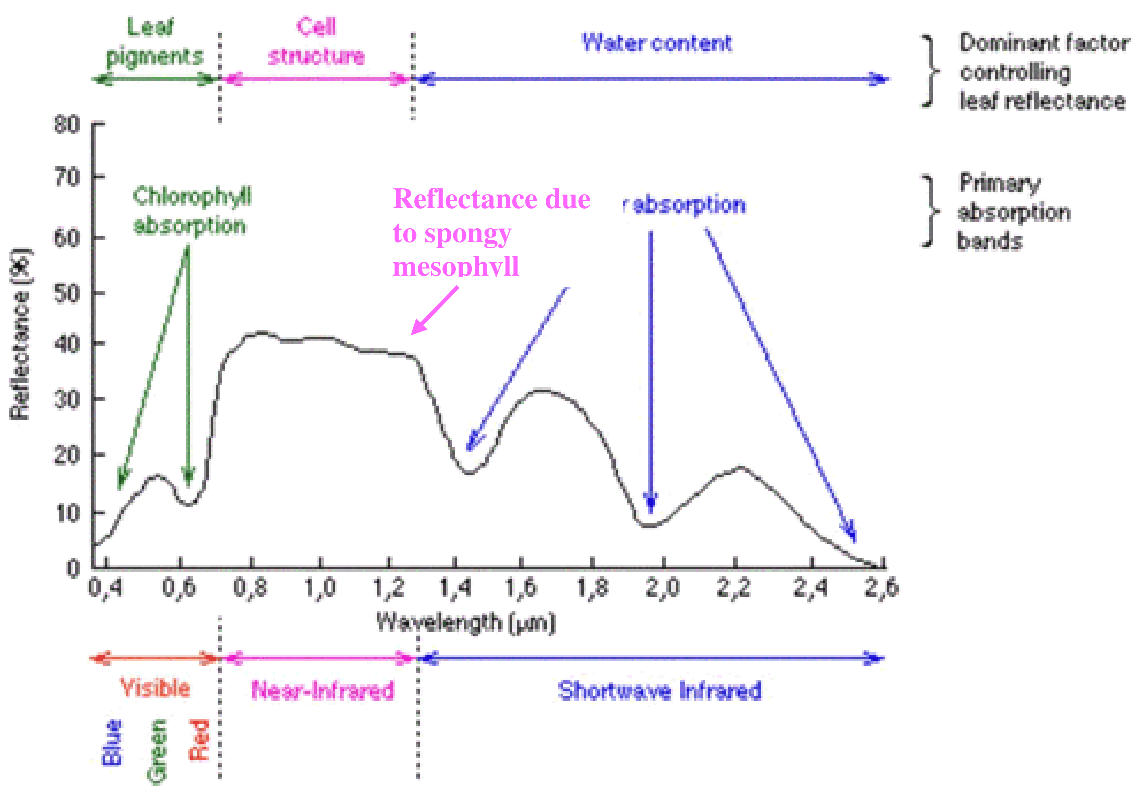

Figure 2.6: Spectral characteristics for green vegetation within the wavelength range of 0.4–2.6 µm.

Important observations from the above figure:

- Small peak at green wavelengths (0.55 µ m)
- Absorption band at red wavelengths (0.65 µ m)
- Near-infrared edge around 0.70 µ m
- Near-infrared plateau
- Water absorption bands (1.4 and 1.9 µ m)
- Black-body behaviour above 2. 5µ m

The figure has shown typical spectral properties of green leaves, from which the following main observations emerge:

Spectral Range	Properties
Visible (0.4 µm - 0.7 µm)	Low reflectance, low transmittance, high absorption mainly due to chlorophyll centred in the blue (0.45 µm) and the red (0.67 µm) wavelength zone, although other leaf pigments like xanthophyll, carotenoids, and anthocyanins also affect absorption, and small peak centred at 0.55 µm in the yellow-green region.
Near-infrared (0.7 µ m - 1.3 µm)	Low absorption, high reflectance, high transmittance as leaf pigments and cellulose of cell walls are transparent. Near-infrared plateau between 0.7 and 1.3 µm and near-infrared edge around 0.7 µm
Middle-infrared (1.3 µm - 2.5 µm)	Strong water absorption bands at 1.4, 1.9 and 2.7 µm

VEGETATION REFLECTANCE

Study of the vegetation spectral reflectance involves study of following four parameters:

- Reflection of plant parts.
- Reflection of plant canopies
- Nature and state of plant canopies and
- Structure and texture of plant canopies

It is the synthesis of the above parameters, which will be required to fully understand the remote sensing data collected from space borne and aerial platforms. They have been attempted for crop canopies through the development of models but not yet fully achieved. It will be initially required to discuss the electromagnetic spectrum and its interaction with vegetation canopies. Subsequent factors affecting the spectral reflectance of plant canopies with its possible applications in remote sensing technology would be discussed.

The vegetation reflectance is influenced by the reflectance characteristics of individual plant organs, canopy organization, type, growth stage of plants, structure and texture of the canopies. The synthesis of the above four aspects provides true reflectance characteristic. However, various authors without fully achieving models to determine vegetation reflectance characteristics have studied effect of individual parameters.

- **Nature of the Plant**

Numerous measurements have been performed to evaluate the spectral response of various categories of plants with a spectrophotometer (Figure 2.7).

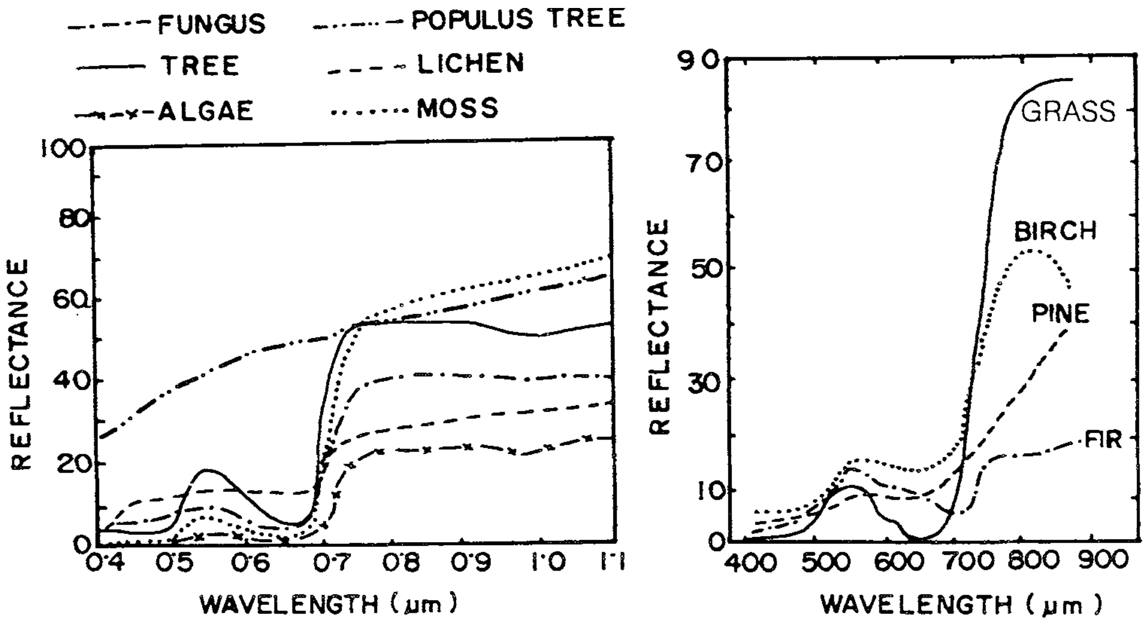

Figure 2.7: Spectral Reflectance of Species of Plants Belonging to Various Groups

The studies have lead to following general conclusions:

For a plant in its normal state i.e., typical and healthy the spectral reflectance is specific of the group, the species and even of the variety at a given stage in its phenological evolution. The general aspects of spectral reflectance of healthy plant in the range from 0.4 to 2.6 µm is shown in figure 2. 8.

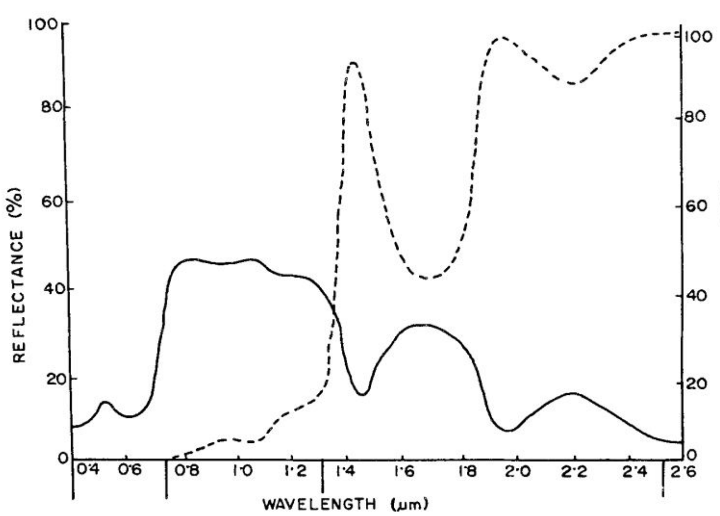

Figure 2.8. Spectral response of typical vegetation

The figure shows five striking features concerning the absorption –

- high in the ultraviolet and the blue
- reduced in the green
- high in the red
- very low in the near infrared

The very abrupt increase in reflectance near 0.7 µm and the fairly abrupt decrease near 1.5 µm is present for all mature, healthy green leaves. Very high; further in the far infrared >3.0 µm. Thus, the typical spectral curve of plant is divided into three prominent zones correlated with morphological characteristics of the leaves (Gates, 1971).

- **Pigment Absorption Zone**

The important pigments, *viz.* chlorophyll, xanthophylls and carotenoids absorb energy strongly in ultraviolet blue and red regions of the EMR. The reflectance and transmittance are weak. The absorbed energy of this part of this spectrum is utilized for the photosynthetic activity.

- **Multidioptric Reflectance Zone**

In this zone, the reflectance is high, while the absorptance remains weak. All the unabsorbed energy (30 to 70% according to the type of plant) is transmitted. They reflectance is essentially due to the internal structure of the leaf and the radiation is able to penetrate. The reflectance from internal structure is of physical more than chemical nature. Apart front the contribution of the waxy cuticle, the magnitude of the reflectance depends primarily upon the amount of spongy mesophyll.

- **Hydric Zone**

Amount of water inside the leaf affect the pattern of spectral reflectance with water specific absorption bands at 1.45 µm, 1.95 µm and 2.6 µm. Liquid water in a leaf causes strong absorption throughout middle infrared region. Beyond 2.5 µm the reflectance becomes less than 5% due to atmospheric absorption and beyond 3 µm the vegetation starts acting as quasi blackbody (Gates *et al.,* 1965).

FACTORS AFFECTING SPECTRAL REFLECTANCE OF VEGETATION

There are numerous factors either internal of the plant or external coming from the environmental conditions have an influence on the specific spectral reflectance. The above descriptions are true only for a normal, mature and healthy vegetation. The factors which affect the spectral reflectance of leaves are leaf structure, maturity, pigmentation, sun exposition, phyllotaxis, pubescence, turgidity (water content) nutritional status and, disease etc. Important factors are pigmentation, nutritional status, anatomy of leaves and water content. While, sun exposition and phyllotaxy affects the canopy reflectance, phenological state and disease are linked to the primary factors affecting the spectral reflectance.

- **Pigmentation**

Low content of pigmentation results in higher reflectance and vice-versa. Moreover, different pigments show different spectral response. Yellowing of leaf, which is a stage in phenological cycle, or in certain diseases, breaking down of chlorophyll takes place thus letting the presence of carotene and xanthophyll more evident. During this stage, leaf shows sharp increase in reflectance starting at 0.50 μm.

- **Nutritional Status**

Due to deficiency of Nitrogen accounts in the increases of reflectance in 0.5 to 0.7 μm and 0.7 to 1.3 μm region but it decreases in 1.3 to 2.5 μm region. The increase of reflectance from 0.5 to 0.7 μm is due to the fact that light absorption in the spectral region is affected by pigment concentration, which essentially depends on the nitrogen concentration. Increase of reflectance from 0.7 to 1.3 μm might be related to an increase in the inter-cellular spaces (Gausman *et al.,* 1967). Reflectance decreases from 1.3 to 2.5 μm might be directly related to greater water content of leaves (Thomas *et al.,* 1966). Al Abbas *et al.,* (1974*)* have studied the chlorophyll concentration of leaves of Maize in normal and nutrient deficiency treatments resulting on to low absorptance in the range from 0.53 to 0.75 μm. Potassium deficient in leaves have lowest leaf thickness and leaf moisture content resulting into highest reflectance in infrared region from 0.75 to 1.3 μm. Sulphur, Magnesium and Nitrogen deficient plants have higher moisture content and also showed on increased absorption at wavelength interval between 1.3 and 2.5 μm.

- **Leaf Anatomy**

The influence of internal structure of leaf is very significant. Prominent anatomical variations, which affect the spectral reflectance, are plant cell wall, intercellular spaces, epidermis, palisade and mesophyll cells. When the radiation falls on the leaf surface, a part of the energy is reflected back from the leaf surface. The reflection takes place as per cuticle thickness. Rest of the energy passes through the leaf and strikes the lower leaves after interacting with the internal cellular structures.

Conclusively, multiple leaf layers cause higher reflectance (up to 85 percent) in the near infrared region. This is due to the additive reflectance, energy transmitted through the first (upper most) layers of leaves and reflection from a second layer is partially transmitted back through the first layer.

- **Morphological Adaptations**

Thorns are reported to have role in the heat balance of desert plants. Studies carried out with the spectral properties of plants having thorn have indicated that absorptance of energy is largely altered by thorns thereby reducing direct solar radiation at cuticular surface since by the thorns present the radiation is absorbed, more in the thorn themselves and less in the cuticle and spongy tissue of the plant. Thus, if the incident radiation is absorbed strongly by the thorny mat and heat will be radiated back to the sky and less of it will be transferred by conduction to the underlying cuticle. It is probable that this is an important role for the dense thorn mats, but the function of thorns distributed generally over the surface of a cactus may be different. Thorns, however, also have other functions serving for example as a determent to predation.

Role of trichomes, including hairs, thorns and bristles on the surface of leaves is not well understood. Suggested function include reflection of radiation, re-radiation, reflection and absorption of radiation to protect plant pigments and cells against too much radiation of certain wavelengths, reflection of radiation into the mesophyll in order to provide increased light for photosynthesis, shading for the leaf surface, reduce water loss for a leaf, insulation against heat loss and reducing the effect of wind on the leaf boundary layer. The pubescence significantly increases the total diffused reflection in the 0.75 – 1.0 μm but decrease them in the 1.0 to 2.5 μm. It has very little effect on the reflectance of light from 0.5 to 0.75 μm.

SPECTRAL REFLECTANCE CHANGE IN RELATION TO TEMPORAL CHARACTERISTICS OF VEGETATION

Forest vegetation change dynamics with respect to its type, growth, health, structure and phonological condition is a known factor. Vegetation coverage dynamics is affected by climatic, topography and human activities, which is an important indicator reflecting the regional ecological environment. Revealing the spatial-temporal characteristics of vegetation coverage is of great significance to the protection and management of ecological environment. In order to find out these changes we need the timely information so that a judicious approach could be linked for the betterment. Following points are self-explanatory under this sub-topic:

- **Seasonal Reflectance Change**

The changes that occur in the spectral properties of plant leaves during the growing season are significant. The young folded, compact, underdeveloped leaf exhibits lack of chlorophyll. Absorption in the visible ranges is caused by proto-chlorophyll and anthocyanin. Gradually the leaf becomes more and more green, which decreases red reflectance. Finally, a fully open leaf shows the normal spectral characteristics with the green reflectance strong and the red and blue spectral regions much absorbed. The near infrared reflectance decreases as the leaf opens. The striking decrease appears to be caused by the unfolding and expansion of the leaf and resultant loss of a multitude of reflecting surfaces, which existed in the much-folded very young leaf.

As the leaf matures, the light green colour darkens and chlorophyll absorption becomes well developed in the red region. However, the near infrared reflectance increases due to the development of air spaces in the mesophyll and the presence of many reflecting surfaces within a leaf. Gradually, no change in the visible part of the spectrum is noticed an increase in the reflection in near infrared region. A stage comes, when the reflection characteristics become fairly stable throughout the visible and near infrared and variation from leaf to leaf is also reduced. After this stage, green reflectance increases dramatically as the blue and red absorption weakens. The characteristic progressively becomes more and more prominent as the chlorophyll disappears. This stage is called as senescence in phenological stage. With the most of pigmentation gone, the leaf becomes dry and collapsed cells throughout its structure. At this stage the leaf had a brown dead appearance. It is interest to note that the near infrared reflectance over the range 0.7- 0.9 μm diminishes strongly but the reflectance in the region beyond 0.9 μm changes very little.

- **External Factors Affecting Spectral Reflectance**

The influence of the external factors on the spectral reflectance is due to the alteration they bring in the plant proper, water content and turgescence, mesophyll structure, evapo-transpiration, pigmentation and metabolism. The external factors are connected:

- At ground level
    - to the water availability for the plant
    - to trophic mineral ions availability with specific evidence for nitrogen, iron, potassium, phosphorus, calcium or magnesium in the chlorophyll.
    - to the toxic mineral salts presence in the substrate.

- From atmosphere
    - climatic factors (winds, air moisture content, temperature, sunshine conditions) on which depend the CO^2 acceptance and evapo-transpiration.
    - seasonal variations
    - toxic pollutants (especially fluorine, sulphur dioxide)
    - deposition of dust/particulate matter

- By biological pathogenic agents
    - parasites
    - predators

Disease Infestation

Effect of disease on spectral characteristics of plants can be understood, when it is related to the type of disease. The spectral changes due to different type of plant disease are discussed below:

- **Trophic Diseases**

Due to decrease in pigment content reflectance is increased in the region of 0.4 to 0.7 μm. The spectral response in the far infrared is expected to change due to the higher metabolism in the affected areas influencing leaf temperature. Variation in the leaf inner structure should not be important in the case of powdery mildew, as the pathogen lives on the leaf surface, affecting the sole epidermis. The presence of the mould formed by the pathogen on the leaf may cause modification in the response of the visible region.

- **Auxonic Diseases**

In this group of disease, the growth capability of the plant or of a part of it is mainly affected. This type of disease can be caused due to nutritional stress, chemical agents (for instance herbicides), bacteria, fungi and viruses' symptomatology of this kind of diseases present heterogeneous characteristics. Hence, it does not seem possible to give any indication on the spectral response. However, common characteristic is decrease in chlorophyll content thus, a variation of the response in the visible region is expected. The similar effect can be expected due to the change in the morphology of the plants.

- **Necrotic Diseases**

Pathogen presence results in an alteration of pigment content, leaf structure and water balance. Due to this fact variation in the leaf spectral response in the whole wavelength interval (0.4 to 2.6 μm) can be expected. Reflectance of infected areas is always higher than that of healthy areas and differences are more evident in the chlorophyll absorptance bands (0.5 – 0.7 μm) and water (1.45 and 1.95 μm). These differences have been related to a decrease of chlorophyll and water in decreased tissue.

- **Vascular Diseases**

These diseases are characterized by the location of the pathogens along the vascular elements thus, interfering with the plant water supply. The spectrum consists of various level of chlorosis and especially partial or total with agents of this group of diseases are mainly fungi and bacterial. Obviously, as the water stress becomes prominent, the spectral response in the middle infrared region (1.3 to 2.5 μm) shows clear indication. The variations will be more evident at the three peaks of highest water absorption *i.e.*, 1.45, 1.95 and 2.6 μm. Water stress will cause change in the inner leaf structure also which will lead to change in the spectral response in the wavelength interval from 0.5 to 0.7 μm is expected to change also.

- **Lytic Diseases**

The main characteristic of this group of diseases from the symptomatological point of view is the formations of 'rots' as an effect of the tissue disintegration. The water balance of the plant and the inner structure of leaf are mainly affected. Consequently, the pigment content of the affected areas is modified. It causes variation in the spectral response in the whole wavelength interval of 0.5 to 2.5 μm. Most prominent affect is expected in the form of higher reflectance in the visible portion of the spectrum due to lowering of pigment concentration.

- **Epiphytic Diseases**

Here, disease is caused by the so-called epiphytic plants, which utilize the host as support. The dust or particulate matter acts as screen affecting photosynthesis and spectral response is expected to change in the range of 0.5 to 0.7 um due to presence of extraneous substances (Figure 2.9).

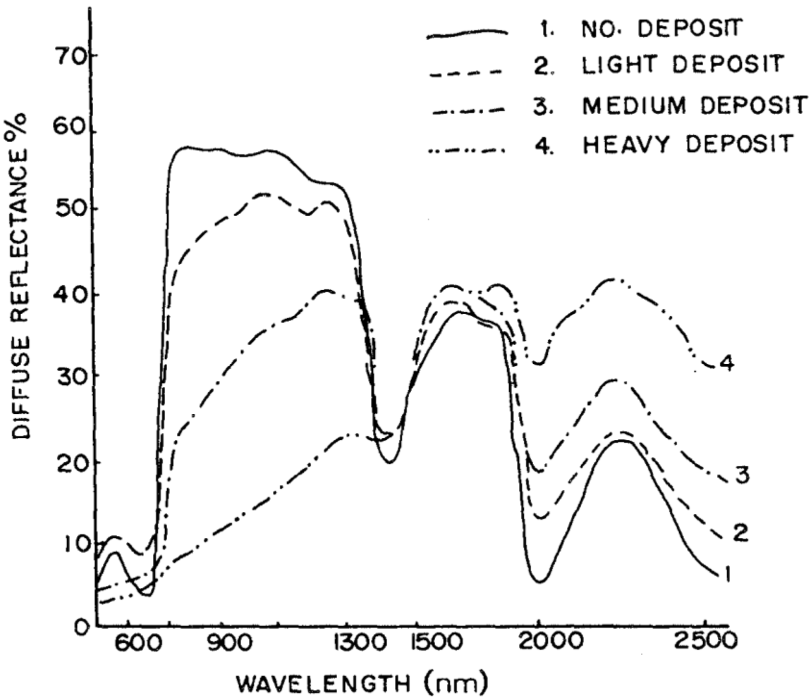

Figure 2.9. Spectral response of leaves of Citrus affected by fungus (*Capnodium citri*)

REFLECTANCE OF VEGETATION CANOPIES

The spectral reflectance as measured on separate organs by means of spectrophotometer may present fundamental of spectral characteristic but necessarily, they do not allow a straightforward interpretation of the information obtained by remote sensing on a scene.

The spectral response of vegetation canopies needs to be studied keeping in view following points:

- Vegetation coverage on the soil may vary, which gives rise to composite reflectance of soil and vegetation. The ratio describing the actual rate of cover may be related to the "leaf area index (LAI)". LAI is also reported to be correlated with crown closure and crown diameter.

- Phyllotaxy of plants combined with canopy architecture depending on this parameter the incoming radiation penetrates inside the vegetation cover by multiple reflectance and transmissions, acting more specifically on the infrared part of the spectrum. The resultant canopy reflectance is consequently less than the one featured by single leaves and rarely exceeds 30%. The rate of diffusion increases with the leaf irregularities and the sun elevation.

- The irradiance declination, which is controlled by the time and the season. Generally, the more vertical to the canopy the more intensively the radiance penetrates the cover.

Strong reflectance as a function of wavelength and accordingly to the structure of canopy and phenological status. In order to set up the canopy reflectance from the spectral properties of single organs. Reflectance models have to be built up.

COMPOSITE REFLECTANCE

In natural conditions the elementary area on ground as resolved by the IFOV of a sensor (the pixel in the image) is most of the time composed of mixed elements (vegetation and underlying soil) this leads to spectral reflectance curves without the clear maximum and minimum values otherwise typical of vegetation. This mixing occurs when the density of the plant or of the lower as a whole is too low or at the transition between two vegetation types. The resulting reflectance of the heterogeneous area appears as being in between the typical reflectance of the constitutive elements, it shows a "composite reflectance" $\rho(\lambda)$, which can be derived from the proper reflectance $\rho\propto(\lambda)$ of each of the elements.

Thus, the reflectance of a soil area A is partially covered with vegetation may be expressed as a composite reflectance

$$\rho = \frac{A\nu\, P\nu - As\, P\, s}{A} \quad \text{With } A = A\nu + As$$

$P\nu$ and Ps being the specific reflectance of the vegetation and soil respectively.

In the visible region of EMR usually $Ps > P\,\nu$

In the near infrared conversely $Ps < P\nu$

A composite reflectance is difficult to interpret, when the spatial variability and area resolved are both greater. It can be inferred from the various phenomenon outlines above how a remote sensing technology can be benefited with study of spectral signatures of vegetation.

- choice of spectral bands
- choice of spectral bandwidth according to information content
- optimal irradiance conditions (day of the year and time)
- sensitive periods in the vegetative cycle of the plants

When satellite data is given for interpretation, one has to keep in mind the facts how the data have been acquired. It will be required to process the data for useful information extraction.

2.4 SUMMARY

Spectral properties of plants have been utilized in the context of their usefulness in studying vegetation from remote sensing platforms. A synthesis of data on spectral

properties, vegetation types, and growth and energy conditions provide valuable information about biomass and productivity.

Vegetation has a unique spectral signature and the different reflectance characteristics with respect to their types and heterogeneous nature Plants that are stressed or diseased can also be identified by their distinct spectral signatures. The leaf pigments, cell structure and water content all impact the spectral reflectance of vegetation. For example, broad leaved trees have a higher reflectance in the near infrared compared to conifers.
Interaction of EMR with vegetation in visible, near infrared (NIR) and middle infrared (MIR) region needs to understand first the interaction of EMR with overall vegetation community and with a typical leaf. Generally, a leaf is built up of layers of structural fibrous organic pigmented matter, water filled cells and air spaces. Each of the features like pigmentation, physiological structure and water content have an effect on the reflectance, absorbance and transmittance properties of a green leaf.
In this unit remote sensing based EMR interaction with vegetation, the spectral and temporal characteristics of vegetation in relation to different wavelengths have been explained under the sub-heads - definitions and concepts, EMR Interaction with Vegetation, spectral characteristics for green vegetation in relation to wavelength, vegetation reflectance, factors affecting spectral reflectance of vegetation, spectral reflectance change in relation to temporal characteristics of vegetation, reflectance of vegetation canopy and composite reflectance.

2.5 GLOSSARY

Anthocyanins: Anthocyanins are water-soluble vacuolar pigments that, depending on their pH, may appear red, purple, blue or black.

Mesophyll: The mesophyll is a soft spongy material located between the upper and lower epidermal surfaces, and is where photosynthesis takes place. It also contains the chloroplasts that give leaves their glossy green appearance.

Plant Pigment: A plant pigment is any type of colored substance produced by a plant. In general, any chemical compound which absorbs visible radiation between about 380 nm (violet) and 760 nm (ruby-red) is considered a pigment. There are many different plant pigments, and they are found in different classes of organic compounds. Plant pigments give color to leaves, flowers, and fruits and are also important in controlling photosynthesis, growth, and development.

Phyllotaxis: In botany, phyllotaxis or phyllotaxy is the arrangement of leaves on a plant stem

Pubescence: The state of being in or reaching puberty. It is also called as a covering of fine, soft hairs.

Phonology/Phenology: Phenology is the study of the timing of the biological events in plants and animals such as flowering, leafing, hibernation, reproduction, and migration. You may also
say it as outer appearance of plant/forest vegetation.

Xanthophyll, Carotenoide, carotenes : Xanthophylls (originally phylloxanthins) are yellow pigments that occur widely in nature and form one of two major divisions of the carotenoid group; the other division is formed by the carotenes. As both are carotenoids, xanthophylls and carotenes are similar in structure, but xanthophylls contain oxygen atoms while carotenes are purely hydrocarbons, which do not contain oxygen. Their content of oxygen causes xanthopylls to be more polar (in molecular structure) than carotenes, and causes their separation from carotenes in many types of chromatography. (Carotenes are usually more orange in color than xanthophylls.) Xanthophylls present their oxygen either as hydroxyl groups and/or as hydrogen atoms substituted by oxygen atoms when acting as a bridge to form epoxides.

Like other carotenoids, xanthophylls are found in highest quantity in the leaves of most green plants, where they act to modulate light energy and perhaps serve as a non-photochemical quenching agent to deal with triplet chlorophyll (an excited form of chlorophyll)[*citation needed*], which is overproduced at high light levels in photosynthesis. Caratotenoides are an essential component of all photosynthetic organisms due to their eminent photoprotective and antioxidant properties.

2. 6 ANSWER TO CHECK YOUR PROGRESS

- Define Vegetation Reflectance.
- Write a note on factors affecting Spectral Reflectance of Vegetation.

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2.8 TERMINAL QUESTIONS

Q.1 Explain the EMR Interaction with Vegetation?
Q.2 Explain Spectral Reflectance Change in Relation to Temporal Characteristics of Vegetation?
Q.3 Define Reflectance of Vegetation Canopy?
Q.4 Describe Composite Reflectance?
Q.5 Define Spectral Characteristics for Green Vegetation in Relation to Wavelength?

UNIT 3 - FOREST COVERS TYPE AND FOREST DENSITY MAPPING, FOREST COVER CHANGE DETECTION, FOREST MANAGEMENT, BIOMASS AND BIO-DIVERSITY STUDIES

3.1 OBJECTIVES

After reading this unit you should be able:

- To understand Remote Sensing and Forest Cover Mapping
- To explore forest cover change and forest management by using remote sensing and GIS.
- To discover biodiversity studies.

3.2 INTRODUCTION

Remote sensing is the acquisition of information about some feature of interest without coming into direct contact with it. Popular forms of remote sensing used in the environmental sciences are images of the Earth's surface acquired from sensors mounted on airborne and spaceborne platforms. Remote sensing has been used for mapping the distribution of forest ecosystems, global fluctuations in plant productivity with season, and the three-dimensional (3D) structure of forests. The range and diversity of sensing systems, as well as the variety of applications, have evolved greatly over the last century. The types of images used range widely from conventional aerial photographs that capture a view similar to that observed by the human eye to images that reveal elements that might be invisible to the human eye, such as the physical structure and chemical composition of the Earth's surface. Remotely sensed imagery provides a view of the Earth's surface in such a way that allows features on it to be identified, located, and characterized. Moreover, although each image provides a snapshot of the environment, it is commonly possible to acquire imagery repeatedly in time. As a result, remote sensing has been used in a diverse range of forest ecology and management applications from mapping invasive species to monitoring land-cover changes, such as habitat fragmentation, to estimating biophysical and biochemical properties of forests. This Primer seeks to briefly review the role of remote sensing in forest ecology and management. It focuses on non-terrestrial forms of remote sensing (i.e., it does not include terrestrial laser scanning or field spectroscopy); reviews the range of sensors, platforms, applications, classification methods, and choices of remote-sensing systems; and concludes by indicating future directions in this rapidly evolving interdisciplinary field.

3.3 FOREST COVERS TYPE AND FOREST DENSITY MAPPING, FOREST COVER CHANGE DETECTION, FOREST MANAGEMENT, BIOMASS AND BIO-DIVERSITY STUDIES

NEED TO CLASSIFY LAND USE AND LAND COVER

Land use describes how a parcel of land is used (such as for agriculture, residences, or industry), whereas land cover de scribes the materials (such as vegetation, rocks, or buildings) that are present on the surface. For example, the land cover of an area may be evergreen forest, but the land use may be lumbering, recreation, oil extraction, or various combinations of activities. Accurate, current information on land use and cover is essential for many planning activities. Remote sensing methods are becoming increasingly important for mapping land use and land cover for the following reasons:

1. Large areas can be imaged quickly and repetitively.
2. Images can be acquired with a spatial resolution that matches the degree of detail required for the survey.
3. Remote sensing images eliminate the problems of surface access that often hamper ground surveys.
4. Images provide a perspective that is lacking for ground surveys.
5. Image interpretation is faster and less expensive than conducting ground surveys.
6. Images provide an objective, permanent data set that may be interpreted for a wide range of specific land uses and land covers, such as forestry, agriculture, and urban growth.

There are some disadvantages to remote sensing surveys:

1. Some types of land use may not be distinguishable on images.
2. Most images lack the horizontal perspective that is valuable for identifying many categories of land use.

Remote sensing interpretations should be supplemented by ground checks. The following section describes a system for classifying land use and land cover that is based on the interpretation of remote sensing images. A succeeding section uses the system to interpret images of the Los Angeles region.

THE UBIQUITY OF REMOTE SENSING: SIX KEY REASONS

Given that many forests environmental variables can be estimated directly in the field, why has remote sensing become an important data source? We note six key reasons for this situation:

- First, remotely sensed imagery provides a synoptic view. The vantage provided by an Earth-observing sensor ensures that imagery captures a complete picture of the environment in its field of view. Thus, every visible feature, including its location and its location relative to that of all others in the imaged area, is captured. In short, this gives imagery a map-like format that provides a complete survey of the imaged area rather than field data, which are often based on a very limited set of samples from which inter-sample site information would have to be inferred by some form of interpolation. Because of this complete survey, remote sensing allows wall-to-wall mapping and monitoring of important ecological variables, such as land-cover change.
- Second, remotely sensed data are available everywhere and often at a range of spatial and temporal scales. Key environmental remote-sensing systems, such as those carried by the Landsat satellites, have provided a constantly updateable stream of imagery for the entire planet since the 1970s. Availability can sometimes be constrained by technical problems or cloud cover, but in principle, imagery should be available everywhere irrespectively of location, enabling *inter alia* study of sites no matter how remote or hazardous they might be. Furthermore, historical remote-sensing data allow us to go back in time to look at the causes of present environmental issues.

- Third, remotely sensed imagery has a high degree of homogeneity. Critically, data from key environmental remote-sensing systems are acquired under relatively fixed conditions, and the data captured relate to the way in which radiation interacts with the environment, which is constant in space and time; there are no human-induced complications, such as differences in measurement practices from one country to another.
- Fourth, the imagery contains, or can easily be converted to, digital images and as such can be easily integrated with other spatial datasets in a geographical information system.
- Fifth, per unit area, remote sensing is an inexpensive way to acquire data. Although the financial costs associated with remote sensing can sometimes be very large—for example, it is expensive to build, launch, and operate satellite remote-sensing systems, making some imagery expensive—much is freely available. Additionally, although commercial remote-sensing systems can appear costly, the data still provide inexpensive assessment on a unit-area basis. More critically, however, there has been an increasing trend to make key datasets for environmental science research freely and openly available. For example, the complete archive of the influential Landsat series of satellites is freely available, and recently the European Space Agency (ESA) launched a suite of new satellites and provides the data collected for free. Resources such as Google Earth Engine (GEE) also provide easy access to vast global datasets.
- Sixth and finally, not only are data more readily available, but there has also been an increasing trend toward the provision of data products as well as the image data themselves. This reduces both the need for expert knowledge of remote sensing and image analysis and the communication gap between experts and environmental scientists, which has historically been a concern. Environmental scientists can now easily access science-quality data products obtained from remote sensing (e.g., leaf area index, land use, and land cover), although expert knowledge might still sometimes be needed.

THE FIVE PHASES OF FOREST MAPPING FROM TREE SPECIES

Some perspective can be gained by examining these events and considerations over time and projecting them into the near future. Five development phases, slightly overlapping, appear to characterize the development of satellite imagery and its use for tropical forest cover mapping.

1. **The Landsat MSS period, 1972 to the early-1980s**. This period is characterized by the availability of relatively coarse resolution imagery and incipient development of complementary technologies--high speed computer hardware and software, tropical forest analysis methodologies and GIS. During this time, the potential for satellite imagery use was often oversold, and without necessary technical backup components, many users became disillusioned.
2. **High resolution imagery from 1982 to present**. This period, which also coincides with the availability of low resolution AVHRR imagery, marks the availability of

imagery from the Landsat Thematic Mapper and the French SPOT satellite, and a corresponding step-wise improvement in the utility of remote sensing for many purposes. However, it also marks the commercialization of satellite imagery and a large increase in its cost.

3. A third phase, **the promotion of major national and international tropical forest assessments**, began in the late 1980s in response to global climate change concerns and continues, with additional concern for biodiversity loss. It is driven by political and scientific pressures to determine levels of deforestation and loss of habitat/biodiversity and to determine the role of deforestation in global climate change (the greenhouse effect). This phase makes use of the high-speed computer hardware and software developed during the 80s along with higher resolution imagery, imagery analysis software, and more flexible GIS systems and applications. The end of this phase will be marked by public reporting on the results and the reconciliation of differing results and methodologies.
4. A fourth phase is likely to involve **the portrayal and interpretation of the results of forest mapping from space in terms of globally important habitats of biodiversity and forest cover**, anticipated to begin in 1994. This work will entail the integration via GIS of remotely sensed information ("top down") with site specific, "bottom up" information from ecosystem research plots, habitat management units, and socioeconomic census data. That is, in addition to more and more ground truthing and the establishment of permanent plots to verify and adjust "top down" results, scientists from a variety of disciplines will be incorporating their own field research-based "bottom up" findings via GIS overlays. From this work will flow information of fundamental importance to international and national actions addressing tropical forest ecosystem management and conservation as well as climate change research.
   The calibration or validation of various global models, especially of the carbon cycle and of global climate will mark this phase as well. The resulting improved projections and timetables of climate change will exert an important influence on national and international decisions concerning greenhouse gas emissions.
5. **The initiation of global forest monitoring**, also anticipated to begin in 1994, will complete the phased development of efforts to address tropical forest cover dynamics. Its outlines have already been sketched by the TREES project and more recently by Skole, Justice and Malingreau. The politics of national responses to international conventions on tropical forests and biodiversity conservation will come into play to influence the eventual scope, authority, and participation in monitoring and evaluation work.

THE STATUS OF GLOBAL FOREST COVER MAPPING

Four ongoing surveys of tropical forest cover and tropical deforestation are briefly described next. A detailed survey and description of these efforts has also been compiled in an atlas format index under a separate cover. Early results of these multi-year surveys are already revising previous estimates of deforestation rates.

- **Pathfinder**. The Pathfinder survey is sponsored by NASA and the U.S. Environmental Protection Agency (EPA). It is one piece of the global carbon research of the U.S. Global Change Research Program that is developing the scientific basis for policies related to global change. Underway since 1992, Pathfinder mapping will cover 75 percent of the world's tropical forested area. The program's researchers will measure tropical forest cover and change at three points in time -- early 1970s, 1980s and 1990s -- on all the continents. The mapping is being implemented as two parts, one by NASA's Goddard Space Flight Center, with university-based researchers as partners, and the other by EPA researchers. The first of the two Pathfinder sub-projects is being carried out by the Universities of Maryland and New Hampshire. They are acquiring and interpreting approximately 2,700 Landsat images (900 images at three points in time) to determine tropical forest cover and change in Southeastern Asia (University of New Hampshire), South America and Africa (University of Maryland). USAID has underwritten some of the work corresponding to Central Africa. Preliminary results of work in South America and Central Africa have already been published. In the second sub-project, tropical forest cover of Mexico, Central America and the Caribbean is being mapped by the EPA as part of a land cover map of North America. EPA researchers in Las Vegas, Nevada will map ground cover and vegetative change. This work was just getting underway in the Fall of 1993. In both cases vegetation will be classified into six categories -- forest, nonforest vegetation, deforested areas, regenerated forest cover, cloud and water cover and "unknown".

- **FAO**. Satellite imagery figured strategically in the FAO's decennial World Forest Resources Assessment, whose report for tropical countries was published in November 1993. The assessment employed Landsat satellite imagery to analyze forest cover at two points in time (1981 and 1990) for a 10 percent sample of the world's tropical forests. The sample comprised 117 sites statistically chosen from four broad ecological zones (tropical rainforest, moist deciduous forest, dry deciduous forest, and upland formations). For each site comparable Landsat scenes for the two dates were acquired, analyzed, and field checked. The objective was to provide more precise estimates of forest cover and change at the regional and global levels than would be possible with existing data. Thirty-one of the 47 sample sites in Africa had been analyzed by the end of 1993 and the results are reported in the report mentioned above; work continues in other regions. The analytical results and other available information are being merged into a GIS system that identifies four classes of natural woody vegetation (continuous closed canopy and continuous open canopy forests, fragmented forests, and shrubs) as well as forest plantations. FAO measured change in these types of cover during the interval of study and, among other analyses, interpreted change as a function of population density.
- The assessment also employed AVHRR imagery and analysis in West Africa and the Amazon to study the effect of forest fragmentation on forest degradation and, by inference, biodiversity loss.
- **TREES**. The TREES project is sponsored by the European Space Agency and the Commission of European Communities (CEC). The project, based at the CEC's Joint Research Center in Ispra, Italy, is also mapping global tropical forest cover. The work manifests the European community's concern over the relationship of global warming

and forest cover loss. To some extent it duplicates the Pathfinder efforts to map forest cover, however the methods and the time frame differ. TREES aims initially to establish a baseline of tropical forest cover for the late 1980s on the basis of 1.1 kilometer resolution Advanced Very High Resolution Radiometer (AVHRR) imagery, available from NOAA (at a cost of $100 per scene) and from TIROS satellite ground receiving stations around the world. Validation of image classification will employ the results of the FAO sample scenes as well as by "nesting" higher resolution SPOT and Landsat TM imagery into the AVHRR scenes. A second phase of TREES will then monitor active deforestation areas, identified with AVHRR imagery, by means of higher resolution images from the European ERS-1 satellite, SPOT and Landsat. A third phase of TREES will model tropical deforestation, examining the dynamics and biospheric role of tropical forests.

- AVHRR imagery was selected to determine forest cover and change in the mid-1980s as an alternative to the high cost of the commercialized Landsat imagery. Initial success led to the foundation for the TREES project. While other organizations also use the AVHRR resource, such as The Woods Hole Research Center, TREES seems to be the leading proponent. The TREES project plans to model factors affecting tropical deforestation, including population. However, as in the case of data on forest cover change over time, time series of demographic data of sufficient detail, i.e. for the smallest sub-national units, are also lacking or unavailable for analysis. Coordinated efforts have recently begun to compile the most detailed demographic data possible, under the aegis of CIESIN, and, like ongoing U.S. efforts to map tropical forest changes, the data compilations are underwritten by the U.S. Global Change Research Program.
- **PANAMAZONIA**. The PANAMAZONIA project is a large-scale South American effort to map the forest cover of the Amazon Basin at two points in time (mid-1980s and late 1980s), and will distinguish only forest and nonforest vegetation. Areas deforested during the period will be plotted. A completion date has not been set. This survey, led by Brazil's INPE, involves the cooperation of eight Amazonian Basin countries. Independently of this effort INPE has surveyed forest cover in the Brazilian portion of the Amazon basin since 1978. Much of the project consists of training by Brazilians of neighbouring country technicians in satellite image interpretation methods and the mapping of those portions of the Amazon falling within their boundaries.
- Together these mapping efforts cover most of the world's tropical forests at comparable levels of detail and time periods. An exception is the forests of Central Africa which lie in the one area of the tropics lacking a Landsat ground receiving station. Few images of the area have been recorded and downloaded to other receiving stations, and consequently there is poor MSS and TM coverage over time. Coverage is poor for the 10-meter resolution panchromatic sensor aboard the continuously recording SPOT satellite as well, due to cloud cover in the lower Congo Basin. Only small-scale AVHRR imagery is available for long-term comparison (since approximately 1979).

THE RELATIONSHIP BETWEEN REMOTE SENSING AND GIS, FOREST INVENTORY AND FOREST PLANNING

The field of remote sensing has a relationship with other fields, such as Geographical Information Systems/Technology (GIS/GIT), forest inventory, and forest planning. It is worth clarifying the definition and roll of remote sensing in relation to these other fields. A GIS consists of four components, namely data acquisition, data storage, data analysis, and map production. Remote sensing fills the function of "data acquisition" in a GIS; the remote sensing data input may be raw data (e.g., images) or processed data (e.g., map data derived from remote sensing). The field of forest inventory is concerned with techniques and methods for measuring and estimation of forest resources. Forest inventory can be done with manual methods, but remote sensing plays an increasing role for providing both wall-to-wall data and as ancillary data in statistical estimations of forest resources. Remote sensing and forest inventory have an intertwined relationship, which can be described as having two main interactions:

- Remote sensing data acquisition for forest inventory purposes, and
- Forest inventory data use as reference data to help interpret remote sensing data (i.e., training data) or to use in validation of the map or product from remote sensing (i.e., validation data).

Note that the subject area of remote sensing differs from the subject areas of inventory, planning, and GIS. Remote sensing data are used within the process of forest inventory, and they are analysed or displayed within a GIS. However, the subject of remote sensing includes not just measuring (i.e., inventory), but also knowledge of how to acquire and process the raw remotely sensed in a correct way. This may require background knowledge in physics, statistics, photogrammetry, programming, and certainly geography. The subject of remote sensing also involves knowing which remote sensing data source is best suited for the purpose (i.e., strengths and limitations), and how to perform and present an accuracy assessment of the map products from remote sensing data.

APPLICATION OF REMOTE SENSING IN FORESTRY

Within forest ecology and management, there is a diverse range of applications for remote sensing, including the measurement of cover, vegetation structure, vegetation chemistry and moisture, biodiversity, and soil characteristics. These variables are critical for understanding forest ecosystem functions and processes, as well as classifying forests into specific communities, ecosystems, and biomes. For forestry applications, remote-sensing measurements can be used for producing forest inventories for calculating the number of trees per acre, the basal area, and the value of timber. For forest monitoring, measuring change in these variables is important for understanding ecosystem dynamics and anthropogenic impacts in both the short term (i.e., fire) and long term (i.e., climate change). From the day-to-day management perspective, monitoring forest change is critical for determining potential risks such as fire hazard due to fuel loads and overall forest health. Finally, forest monitoring with remote-sensing approaches underpins policies such as Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation (REDD+) and Roundtable on Sustainable Palm Oil certification.

Remote sensing can be used for mapping and measuring virtually all key forest variables (e.g., tree density and basal area); this table highlights particularly common applications for specific remote-sensing systems. The double checkmarks refer to more common applications, and the single checkmarks refer to fewer common applications. It is important to note that there are examples in the literature for nearly all sensor and platform combinations. For example, UAV-mounted SAR is possible, but its application so far is unusual. Although measuring foliage projective cover with hyperspectral imagery is technically not a problem, in many cases it would be simpler to use multispectral imagery. Finally, remote-sensing data such as spectral indices (e.g., NDVI) can be used as inputs into physical and empirical models for characterizing a vast range of forest variables.

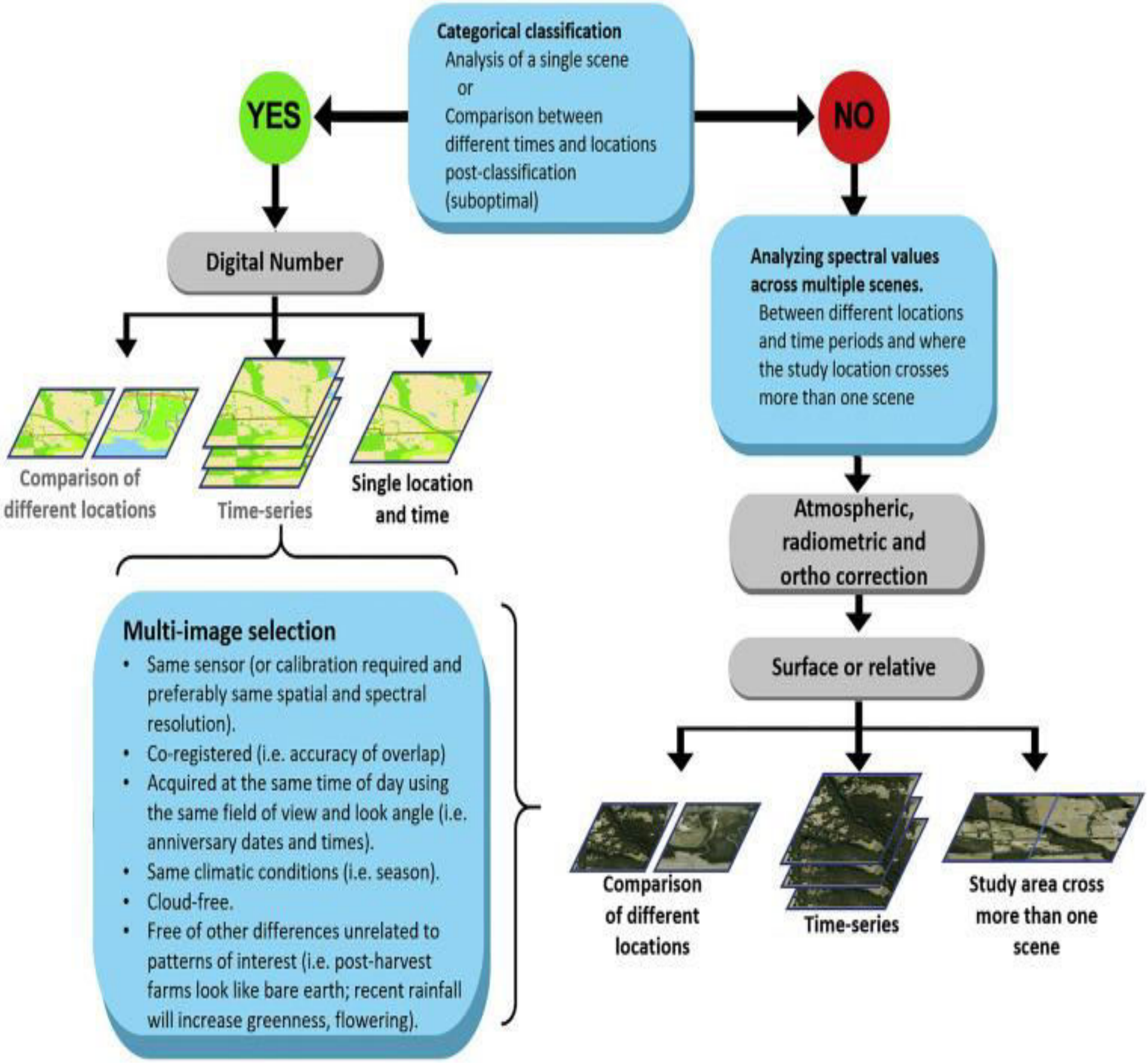


Figure 3.1: Remote Sensing and Forestry
Source: Google

There are a range of ways in which remote sensing is used to represent different forest variables. Both optical and SAR data are provided in a (flat) raster format (i.e., as a grid of values), whereas LiDAR data are represented by 3D point clouds (Figure 3.1). These data are then classified into either categorical or continuous outputs. For example, land use and land cover are categorical, whereas foliage projective cover is continuous. However, depending on the resolution, the same variable can be represented as continuous or categorical. For example, medium-resolution Landsat can be used for classifying pixels according to the percentage of foliage projective cover, whereas high-resolution 5-cm data derived from a UAV can characterize the actual canopy extent. These two perspectives for representing forest variables determine the general types of analyses conducted with remote-sensing data. For continuous biophysical measurements (e.g., the fraction of absorbed photosynthetically active radiation and biomass), the correlation between field measurements and vegetation indices, such as the normalized difference vegetation index (NDVI), is most common. However, for categorical mapping, classification algorithms such as the maximum likelihood classifier and machine-learning approaches such as Random Forests are "supervised" with training data. For high-spatial-resolution data, pixels can be aggregated first to form objects that represent natural spatial units of relevance (e.g., individual trees) on the basis of their similar spectral and textural properties. Rather than being classified as pixels, these image objects are classified according to a method known as geographic object-based image analysis.

Where remote sensing can really demonstrate its great potential is in measuring forest variables for multiple time periods or between multiple locations. Although any remote-sensing application requires the acquisition of high-quality cloud-free data, for applications where more than a single scene is analysed, this is even more important. A key decision point that will depend on the type of analysis is whether to pre-process data to reduce atmospheric effects (i.e., illumination and cloud haze). For certain applications, radiometric correction is necessary for converting the raw remote-sensing data (digital numbers) into surface reflectance, which represents the fraction of incoming solar radiation that is reflected from Earth's surface.

LAND USE/LAND COVER MAPPING

A knowledge of land use and land cover is important for many planning and management activities and is considered an essential element for modeling and understanding the earth as a system. Land cover maps are presently being developed from local to national to global scales. The use of panchromatic, medium-scale aerial photographs to map land use has been an accepted practice since the 1940s. More recently, small-scale aerial photographs and satellite images have been utilized for land use/land cover mapping.

The term land cover relates to the type of feature present on the surface of the earth. Corn fields, lakes, maple trees, and concrete highways are all examples of land cover types. The term land use relates to the human activity or economic function associated with a specific piece of land. As an example, a tract of land on the fringe of an urban area may be used for single-family housing. Depending on the level of mapping detail, its land use could be described as urban use, residential use, or single-family residential use. The same tract of land would have a land cover consisting of roofs, pavement, grass, and trees. For a study of the socioeconomic aspects of land use planning (school requirements, municipal services, tax income, etc.), it would be important to know that the use of this land is for single-family dwellings. For a hydrologic study of rainfall-runoff characteristics, it would be important to know the amount and distribution of roofs, pavement, grass, and trees in this tract. Thus, a knowledge of both land use and land cover can be important for land planning and land management activities.

The USGS devised a land use and land cover classification system for use with remote sensor data in the mid-1970s. The basic and structure of this system are still valid today. A number of more recent land use/land cover mapping efforts follow these basic concepts and, although their mapping units may be more detailed or more specialized, and they may use more recent remote sensing systems as data sources, they still follow the basic structure originally set forth by the USGS. In the remainder of this section, we first explain the USGS land use and land cover classification system, then describe some ongoing land use/land cover mapping efforts in the United States and elsewhere. Ideally, land use and land cover information should be presented on separate maps and not intermixed as in the USGS classification system. From a practical standpoint, however, it is often most efficient to mix the two systems when remote sensing data form the principal data source for such mapping activities. While land cover information can be directly interpreted from appropriate remote sensing images, information about human activity on the land (land use) cannot always be inferred directly from land cover. As an ex ample, extensive recreational activities covering large tracts of land are not particularly amenable to interpretation from aerial photographs or satellite images. For instance, hunting is a common and pervasive recreational use occurring on land that would be classified as some type of forest, range, wetland, or agricultural land during either a ground survey or image interpretation. Thus, additional information sources are needed to supplement the land cover data. Supplemental information is also necessary for determining the use of such lands as parks, game refuges, or water conservation districts that may have land uses coincident with administrative boundaries not usually identifiable on remote sensor images. Recognizing that some information cannot be derived from remote sensing data, the USGS system is based on categories that can be reasonably interpreted from aerial or space imagery.

The USGS land use and land cover classification system was designed according to the following criteria: (1) the minimum level of interpretation accuracy using remotely sensed data should be at least 85 percent, (2) the accuracy of interpretation for the several categories should be about equal, (3) repeatable results should be obtainable from one interpreter to another and from one time of sensing to another, (4) the classification system should be applicable over extensive areas, (5) the categorization should permit land use to be inferred from the land cover types, (6) the classification system should be suitable for use with remote sensor data obtained at different times of the year, (7) categories should be divisible into more detailed sub categories that can be obtained from large-scale imagery or ground surveys, (8) aggregation of categories must be possible, (9) comparison with future land use and land cover data should be possible, and (10) multiple uses of land should be recognized when possible.

It is important to note that these criteria were developed prior to the widespread use of satellite imagery and computer-assisted classification techniques. While most of the 10 criteria have withstood the test of time, experience has shown that the first two criteria regarding overall and per class consistency and accuracy are not always attainable when mapping land use and land cover over large, complex geographic areas. In particular, when using computer-assisted classification methods, it is frequently not possible to map consistently at a single level of the USGS hierarchy. This is typically due to the occasionally ambiguous relationship between land cover and spectral response and the implications of land use on land cover. The basic USGS land use and land cover classification system for use with remote sensor data is shown in Table 3.1. The system is designed to use four “levels” of information, two of which are detailed in Table 3.1. A multilevel system has been devised because different degrees of detail can be obtained from different aerial and space images, depending on the sensor system and image resolution. The USGS classification system also provides for the inclusion of more detailed land use/land cover categories in Levels III and IV. Levels I and II, with classifications specified by the USGS (Table 3.1), are principally of interest to users who desire information on a nationwide, interstate, or state-wide basis. Levels III and IV can be utilized to provide information at a resolution appropriate for regional (multicounty), county, or local planning and management activities. Again, as shown in Table 3.1, Level I and II categories are specified by the USGS. It is intended that Levels III and IV be designed by the local users of the USGS system, keeping in mind that the categories in each level must aggregate into the categories in the next higher level. Figure 3.2 illustrates a sample aggregation of classifications for Levels III, II, and I.

Table 3.1 lists representative image interpretation formats for the four USGS land use and land cover classification levels. Level I was originally designed for use with low to moderate resolution satellite data such as Landsat Multispectral Scanner (MSS) images. (See Chapter 6 for a description of the Landsat satellites and the other satellite systems mentioned below.) Image resolutions of 20 to 100 m are appropriate for this level of mapping.

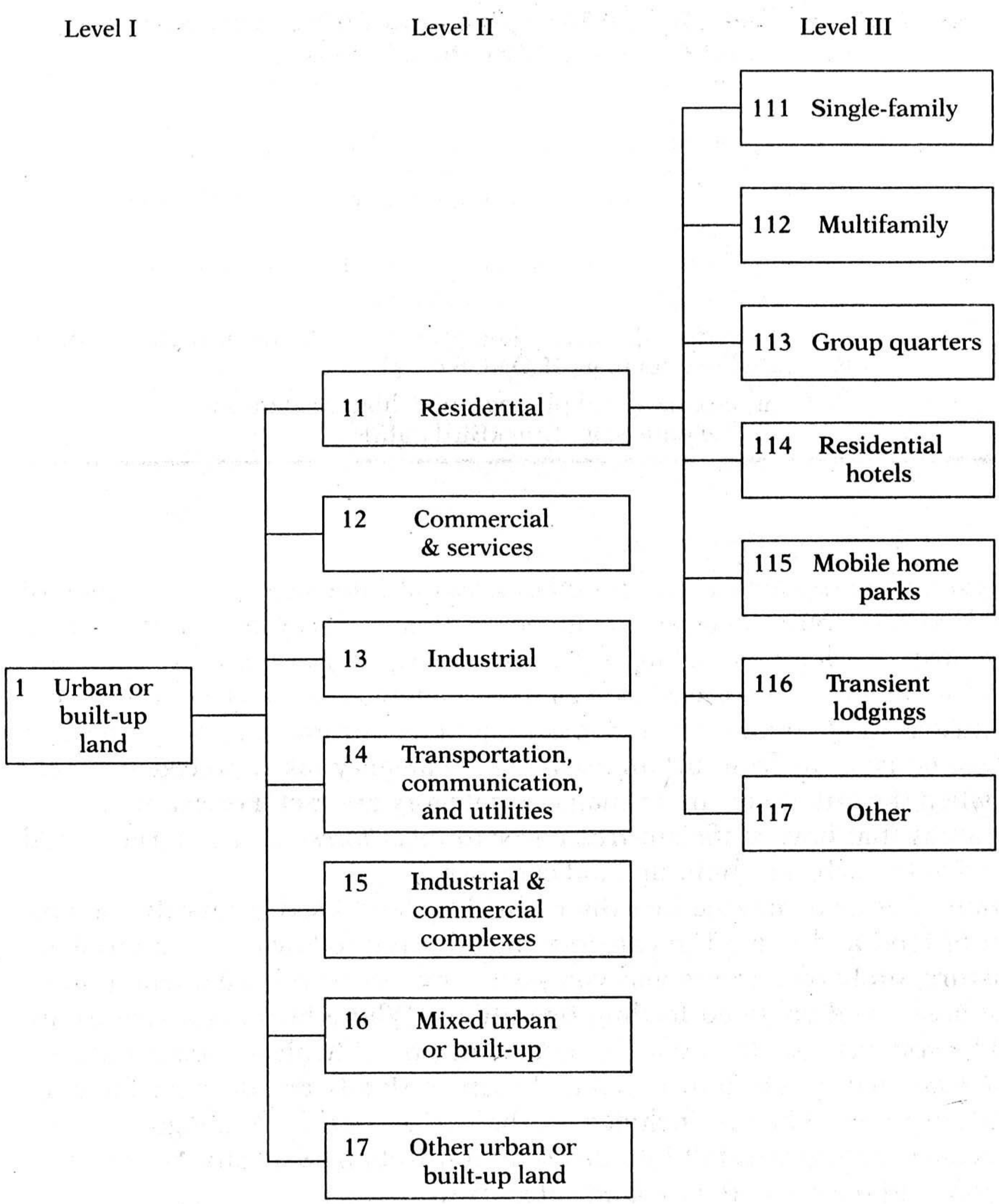


Figure 3.2: Land use Classification on Various Level

Level II was designed for use with small-scale aerial photographs. Image resolutions of 5 to 20 m are appropriate for this level of mapping. The most widely used image type for this level has been high altitude color infrared photographs. However, small-scale panchromatic aerial photographs (Figure 3.3) and various moderate resolution satellite systems are also representative data sources for many Level II mapping categories.

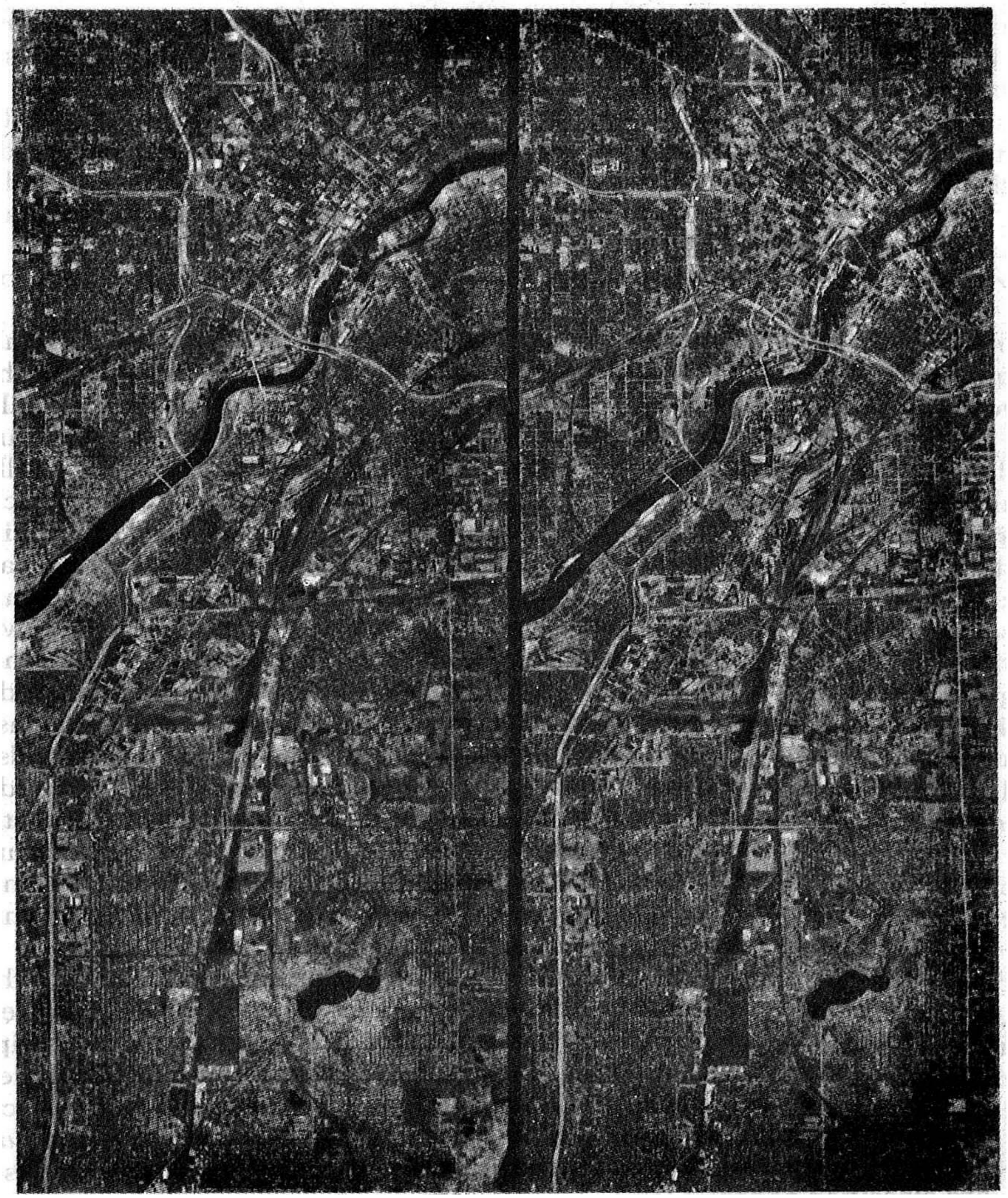


Figure 3.3: Remote Sensing and Land Use Classification

The general relationships shown in Table 3.2 are not intended to restrict users to particular data sources or scales, either in the original imagery or in the final map products. For example, Level I land use/land cover information, while efficiently and economically gathered over large areas by the Landsat MSS, could also be interpreted from conventional medium-scale photographs or compiled from a ground survey.

For mapping at Level III, substantial amounts of supplemental information, in addition to that obtained from medium-scale images, may need to be acquired. At this level, a resolution of 1 to 5 m is appropriate. Both aerial photo graphs and high resolution satellite data can be used as data sources at this level. Mapping at Level IV also requires substantial amounts of supplemental in formation, in addition to that obtained from aerial images. At this level, are solution of 0.25 to 1.0 m is appropriate. Large-scale aerial photographs are often the most appropriate form of remotely sensed data for this level of map ping, although high-resolution satellite data could be appropriate in many applications.

TABLE 3.1: USGS Land Use/Land Cover Classification System for Use with Remote Sensor Data

Level I	Level II
1 Urban or built-up land	11 Residential
	12 Commercial and service
	13 Industrial
	14 Transportation, communications, & utilities
	15 Industrial and commercial complexes
	16 Mixed urban or built-up land
	17 Other urban or built-up land
2 Agricultural land	21 Cropland and pasture
	22 Orchards, groves, vineyards, nurseries, and ornamental horticultural areas
	23 Confined feeding operations
	24 Other agricultural land
3 Rangeland	31 Herbaceous range land
	32 Shrub and brush rangeland
	33 Mixed range land
4 Forest land	41 Deciduous forest land
	42 Evergreen forest land
	43 Mixed forest land
5 Water	51 Streams and canals
	52 Lakes
	53 Reservoirs
	54 Bays and estuaries
6 Wetland	61 Forested wetland
	62 Non forested wetland
7 Barren land	71 Dry salt flats
	72 Beaches
	73 Sandy areas other than beaches
	74 Bare exposed rock
	75 Strip mines, quarries, and gravel pits

	76 Transitional areas
	77 Mixed barren land
8 Tundra	81 Shrub and brush tundra
	82 Herbaceous tundra
	83 Bare ground tundra
	84 Wet tundra
	85 Mixed tundra
9 Perennial snow or ice	91 Perennial snowfields
	92 Glaciers

The USGS definitions for Level I classes are set forth in the following paragraphs. This system is intended to account for 100 percent of the earth's land surface (including inland water bodies). Each Level II subcategory is explained in Anderson et al. (1976) but is not detailed here.

TABLE 3.2: Representative Image Interpretation Formats for Various Land Use/Land Cover Classification Levels

Land Use/Land Cover Classification Level	Representative Format for Image Interpretation
I	Low to moderate resolution satellite data (e.g., Landsat MSS data)
II	Small-scale aerial photographs; moderate resolution satellite data (e.g., Landsat TM data)
III	Medium-scale aerial photographs; moderate or high resolution satellite data (e.g., IKONOS data)
IV	Large-scale aerial photographs; high resolution satellite data (e.g., QuickBird data)

Urban or built-up land is composed of areas of intensive use with much of the land covered by structures. Included in this category are cities; towns; villages; strip developments along highways; transportation, power, and communication facilities; and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas. This category takes precedence over others when the criteria for more than one category are met. For example, residential areas that have sufficient tree cover to meet forest land criteria should be placed in the urban or built-up land category.

Agricultural land may be broadly defined as land used primarily for production of food and fiber. The category includes the following uses: cropland and pasture, orchards, groves and vineyards, nurseries and ornamental horticultural areas, and confined feeding operations. Where farming activities are limited by soil wetness, the exact boundary may be difficult to locate and agricultural land may grade into wetland. When wetlands are drained for agricultural purposes, they are included in the agricultural land category. When such drainage enterprises fall into disuse and if wetland vegetation is re established, the land reverts to the wetland category.

Rangeland historically has been defined as land where the potential natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs and where natural grazing was an important influence in its pre-settlement state. Under this traditional definition, most of the rangelands in the United States are in the western range, the area to the west of an irregular north-south line that cuts through the Dakotas, Nebraska, Kansas, Oklahoma, and Texas. Range lands also are found in additional regions, such as the Flint Hills (eastern Te Kansas), the south eastern states, and Alaska. The historical connotation of rangeland is expanded in the USGS classification to include those areas in the eastern states called brushlands.
Forest land represents areas that have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the cli mate or water regime. Lands from which trees have been removed to less than 10 percent crown closure but that have not been developed for other uses are also included. For example, lands on which there are rotation cycles of clear cutting and block planting are part of the forest land category. Forest land that is extensively grazed, as in the south eastern United States, would also be included in this category because the dominant cover is forest and the dominant activities are forest related. Areas that meet the criteria for forest land and also urban and built-up land are placed in the latter category. Forested areas that have wetland characteristics are placed in the wetland class.
The water category includes streams, canals, lakes, reservoirs, bays, and estuaries.
The wetland category designates those areas where the water table is at, near, or above the land surface for a significant part of most years. The hydro logic regime is such that aquatic or hydrophytic vegetation is usually established, although alluvial and tidal flats may be non-vegetated. Examples of wetlands include marshes, mudflats, and swamps situated on the shallow mar gins of bays, lakes, ponds, streams, and artificial impoundments such as reservoirs. Included are wet meadows or perched bogs in high mountain valleys and seasonally wet or flooded basins, playas, or potholes with no surface water outflow. Shallow water areas where aquatic vegetation is submerged are classified as water and are not included in the wetland category. Areas in which soil wetness or flooding is so short-lived that no typical wetland vegetation is developed belong in other categories. Cultivated wetlands such as the flooded fields associated with rice production and developed cranberry bogs are classified as agricultural land. Uncultivated wetlands from which wild rice, cattails, and so forth are harvested are retained in the wetland category, as are wetlands grazed by livestock. Wetland areas drained for any purpose belong to the other land use/land cover categories such as urban or built-up land, agricultural land, rangeland, or forest land. If the drainage is discontinued and wetland conditions resume, the classification will revert to wetland. Wetlands managed for wildlife purposes are properly classified as wetland.
Barren land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. This category includes such areas as dry salt flats, beaches, bare exposed rock, strip mines, quarries, and gravel pits. Wet, non-vegetated barren lands are included in the wetland category. Agricultural land temporarily without vegetative cover because of cropping season or tillage practices is considered agricultural land. Areas of intensively managed forest land that have clear-cut blocks evident are classified as forest land.

Tundra is the term applied to the treeless regions beyond the geographic limit of the boreal forest and above the altitudinal limit of trees in high mountain ranges. In North America, tundra occurs primarily in Alaska and northern Canada and in isolated areas of the high mountain ranges.

Perennial snow or ice areas occur because of a combination of environ mental factors that cause these features to survive the summer melting season. In so doing, they persist as relatively permanent features on the landscape.

As noted above, some parcels of land could be placed into more than one category, and specific definitions are necessary to explain the classification priorities. This comes about because the USGS land use/land cover classification system contains a mixture of land activity, land cover, and land condition attributes.

Several land use/land cover mapping efforts that have been undertaken in the United States and elsewhere use the USGS land use/land cover classification system, or variations thereof.

The Multi-Resolution Land Characteristics (MRLC) Consortium is a group of federal agencies that first joined together in 1993 to purchase Landsat-5 imagery for the conterminous United States and to develop a land cover dataset called the National Land Cover Dataset (NLCD 1992). In 1999, a second generation MRLC consortium was formed to purchase three dates of Landsat-7 imagery for the entire United States and to coordinate the production of a comprehensive land cover database for the nation called the National Land Cover Database (NLCD 2001). The MRLC consortium is specifically designed to meet the current needs of federal agencies for nationally consistent satellite remote sensing and land cover data. However, the consortium also provides imagery and land cover data as public domain information, all of which can be accessed through the MRLC website (see Appendix B). Federal agencies included in the MRLC are the United States Geologic Survey, Environmental Protection Agency, Forest Service, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, National Park Ser vice, Natural Resources Conservation Service, Bureau of Land Management, Fish and Wildlife Service, and Office of Surface Mining.

FORESTRY AND REMOTE SENSING APPLICATIONS

Forestry is concerned with the management of forests for wood, forage, water, wildlife, and recreation. Because the principal raw product from forests is wood, forestry is especially concerned with timber management, maintenance and improvement of existing forest stands, and fire control. Forests of one type or another cover nearly a third of the world’s land area. They are distributed unevenly and their resource value varies widely.

Visual image interpretation provides a feasible means of monitoring many of the world’s forest conditions. We will be concerned principally with the application of visual image interpretation to tree species identification. studying harvested areas, timber cruising, and the assessment of disease and insect infestations.

The visual image interpretation process for tree species identification is generally more complex than for agricultural crop identification. A given area of forest land is often occupied by a complex mixture of many tree species, as contrasted with agricultural land where large, relatively uniform fields typically are encountered. Also, foresters may be interested in the species composition of the “forest understory,” which is often blocked from view on aerial and satellite images by the crowns of the large trees.

Tree species can be identified on aerial and satellite images through the process of elimination. The first step is to eliminate those species whose presence in an area is impossible or improbable because of location, physiography, or climate. The second step is to establish which groups of species do occur in the area, based on a knowledge of the common species associations and their requirements. The final stage is the identification of individual tree species using basic image interpretation principles.

The image characteristics of shape, size, pattern, shadow, tone, and texture, as described in Section, are used by interpreters in tree species identification. Individual tree species have their own characteristic crown shape and size. As illustrated in Figures 3.4 and 3.5, some species have rounded crowns, some have cone-shaped crowns, and some have star-shaped crowns. Variations of these basic crown shapes also occur. In dense stands, the arrangement of tree crowns produces a pattern that is distinct for many species. When trees are isolated, shadows often provide a profile image of trees that is useful in species identification. Toward the edges of aerial images, relief displacement can afford somewhat of a profile view of trees. Image tone depends on many factors, and it is not generally possible to correlate absolute tonal values with individual tree species. Relative tones on a single image, or a group of images, may be of great value in delineating adjacent stands of different species. Variations in crown texture are important in species identification. Some species have a tufted appearance, others appear smooth, and still others look billowy

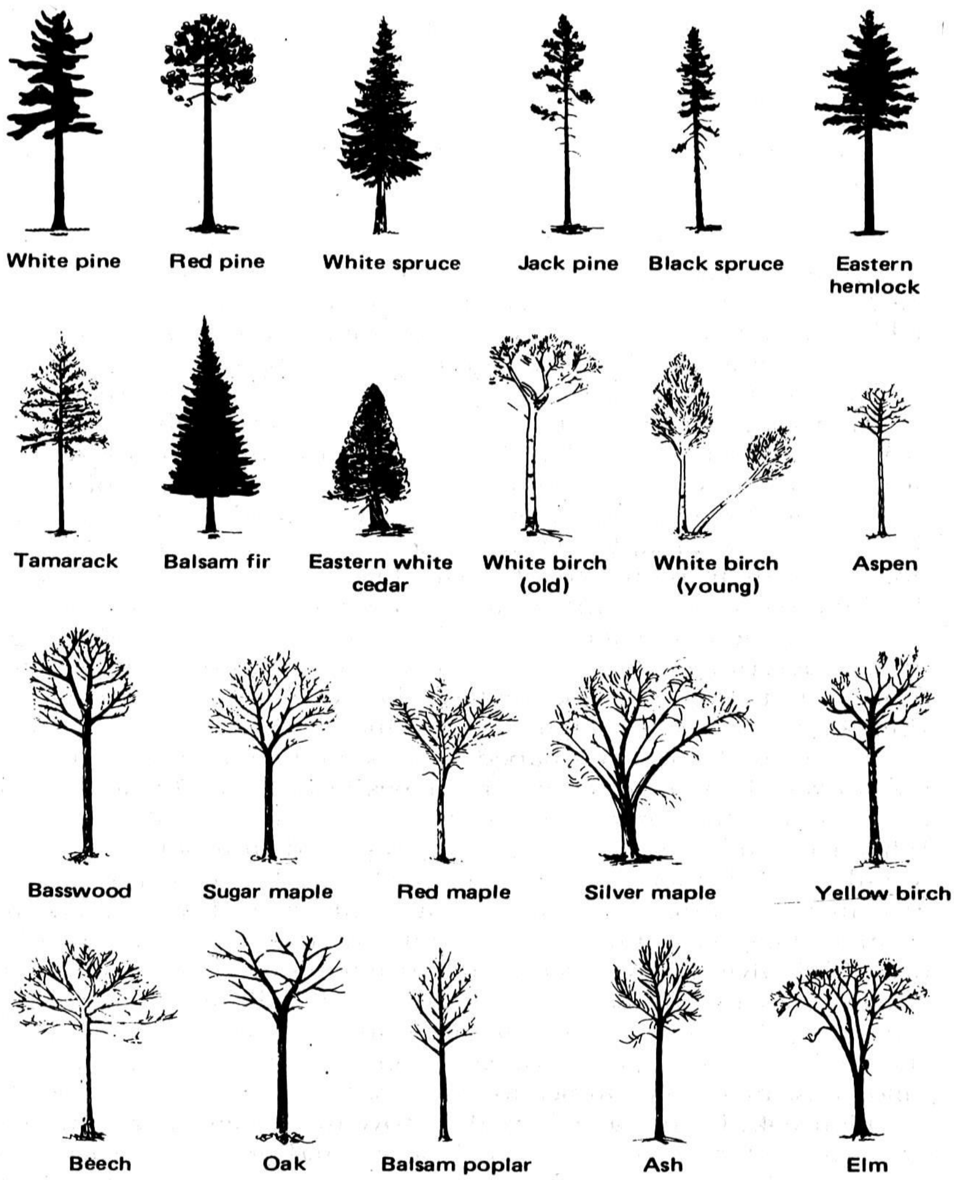
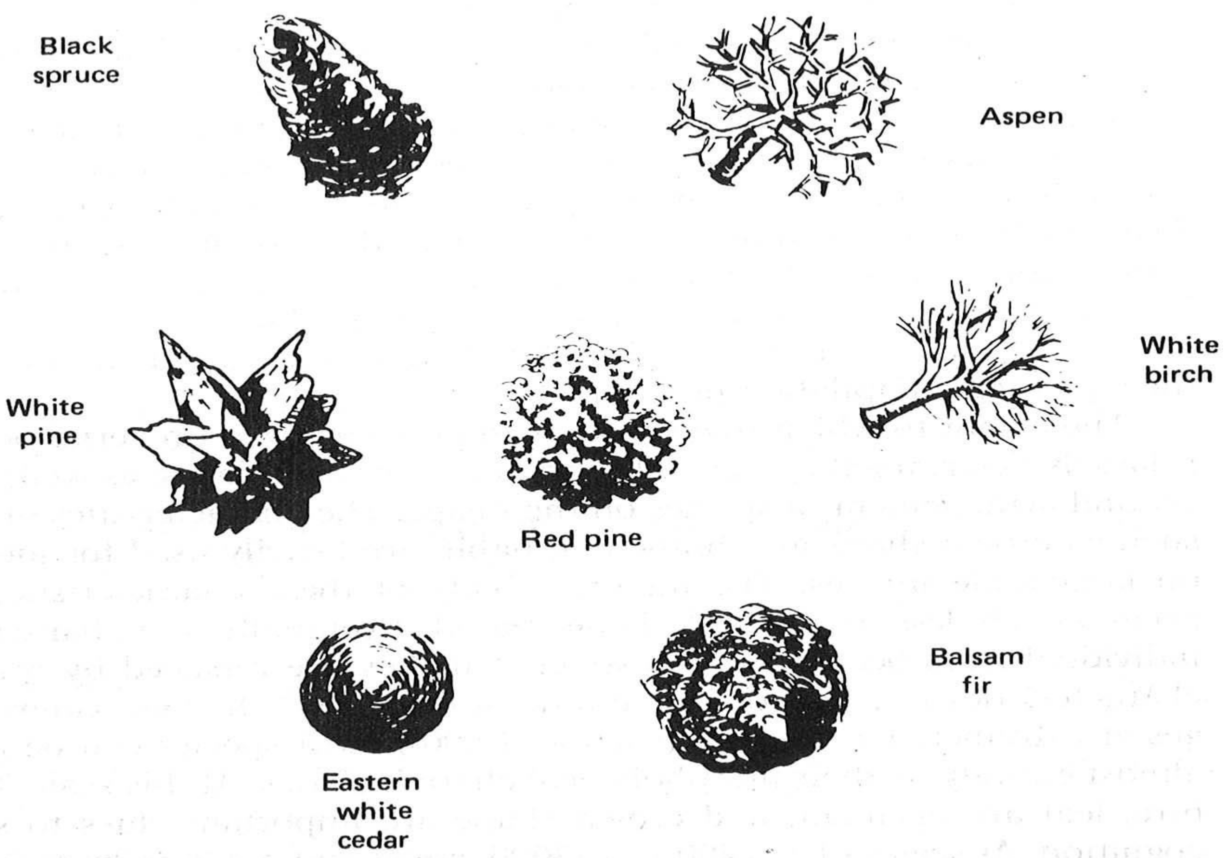


Figure 3.4: Forest cover Mapping in Remote Sensing through Tree shape



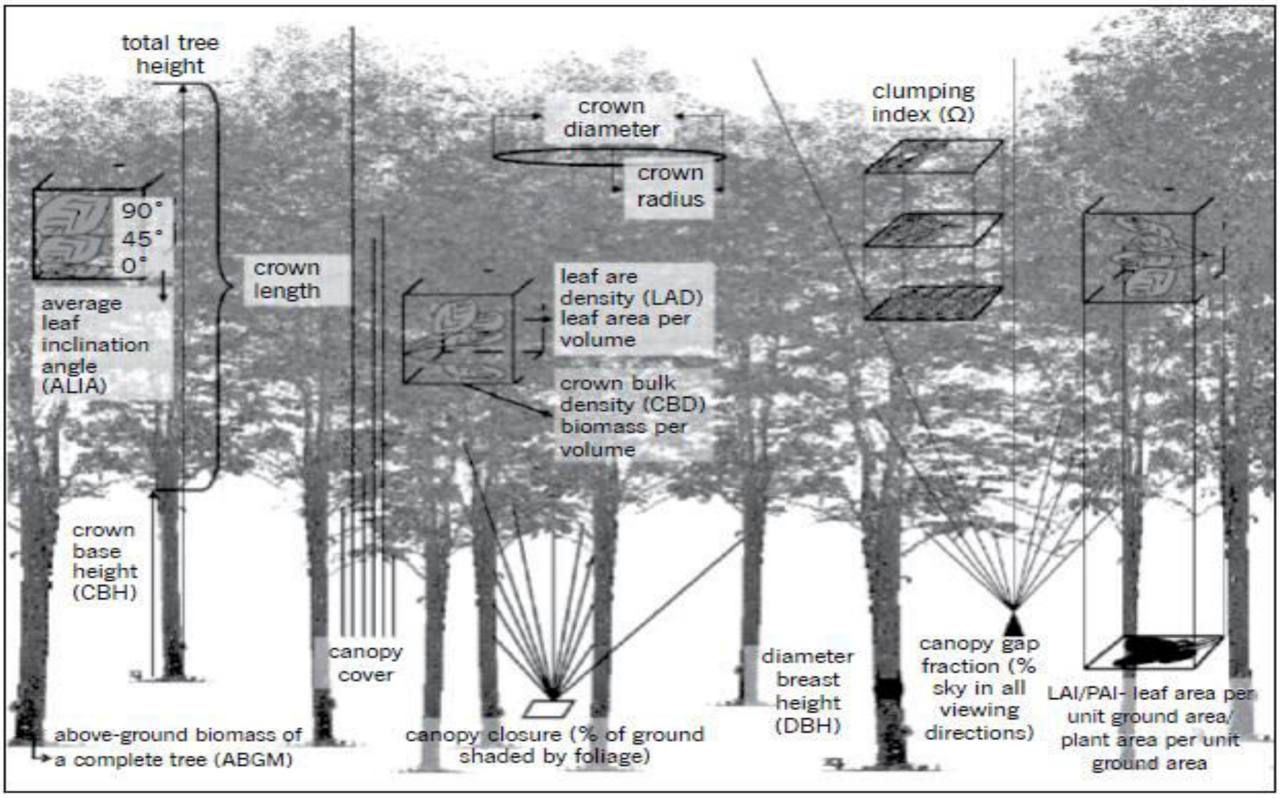


Figure 3.5: Major Structural Characteristics of Forest Canopy

Figure 3.6, illustrates how the above-described image characteristics can be used to identify tree species. A pure stand of black spruce (outlined area) surrounded by aspen is shown in Figure 3.6. Black spruce are coniferous trees with very slender crowns and pointed tops. In pure stands, the canopy is regular in pattern and the tree height is even or changes gradually with the quality of the site. The crown texture of dense black spruce stands is carpet like in appearance. In contrast, aspen are deciduous trees with rounded crowns that are more widely spaced and more variable in size and density than the spruce trees. The striking difference in image texture between black spruce and aspen is apparent in Figure 3.6.

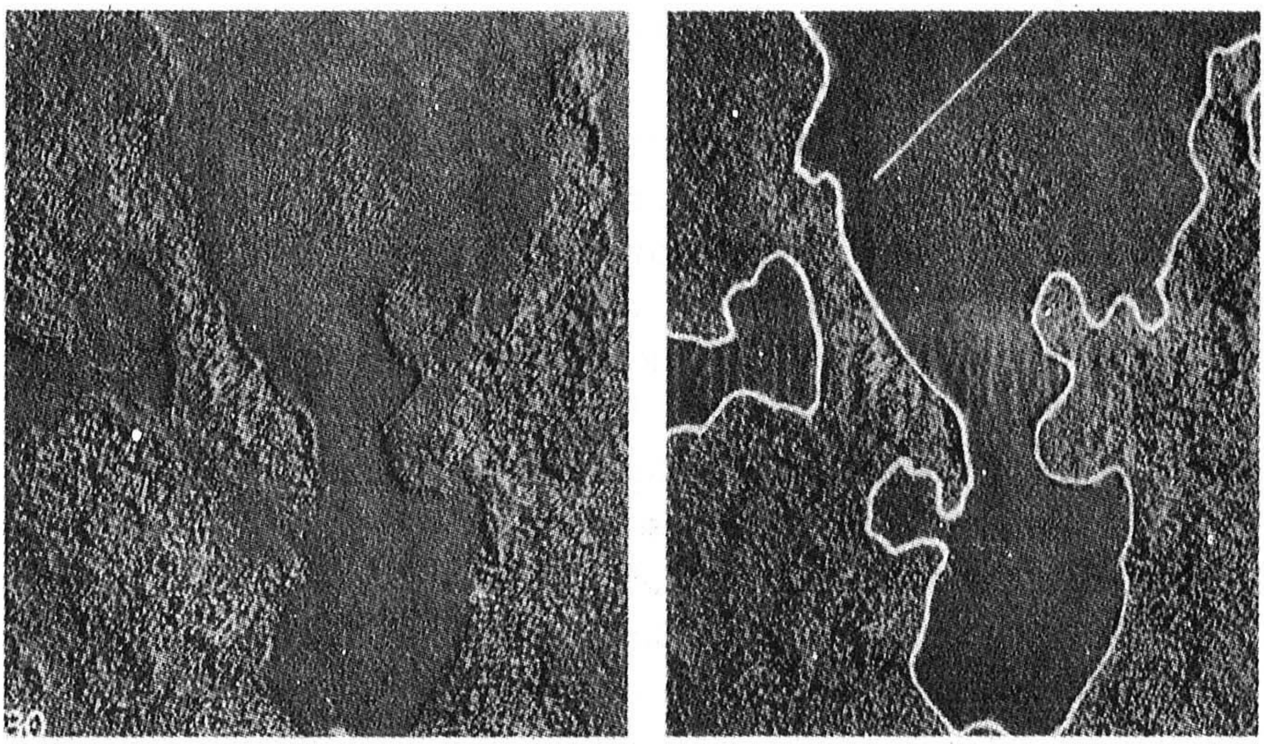


Figure 3.6: Different Image Texture of Various Variety of Tres Species

The process of tree species identification using visual image interpretation is not as simple as might be implied by the straightforward examples shown in these figures. Naturally, the process is easiest to accomplish when dealing with pure, even-aged stands. Under other conditions, species identification can be as much of an art as a science. Identification of tree species has, however, been very successful when practiced by skilled, experienced interpreters. Field visitation is virtually always used to aid the interpreter in the type map compilation process. The extent to which tree species can be recognized on aerial photographs is largely determined by the scale and quality of the images, as well as the variety and arrangement of species on the image. The characteristics of tree form, such as crown shape and branching habit, are heavily used for identification on large-scale images. The interpretability of these characteristics becomes progressively less as the scale is decreased. Eventually, the characteristics of individual trees become so indistinct that they are replaced by overall stand characteristics in terms of image tone, texture, and shadow pattern. On images at extremely large scales (such as 1:600), most species can be recognized almost entirely by their morphological characteristics. At this scale, twig structure, leaf arrangement, and crown shape are important clues to species re cognition. At scales of 1:2400 to 1:3000, small and medium branches are still visible and individual crowns can be clearly distinguished. At i: 8000, individual trees can still be separated, except when growing in dense stands, but it is not always possible to describe crown shape. At 1:15,840 (Figure 3.6), crown shape can still be determined from tree shadows for large trees growing in the open. At scales smaller than 1: 20,000, individual trees generally cannot be recognized when growing in stands, and stand tone and texture become the important identifying criteria (Sayn-Wittgenstein, 1961). This is particularly true when satellite data sources are employed.

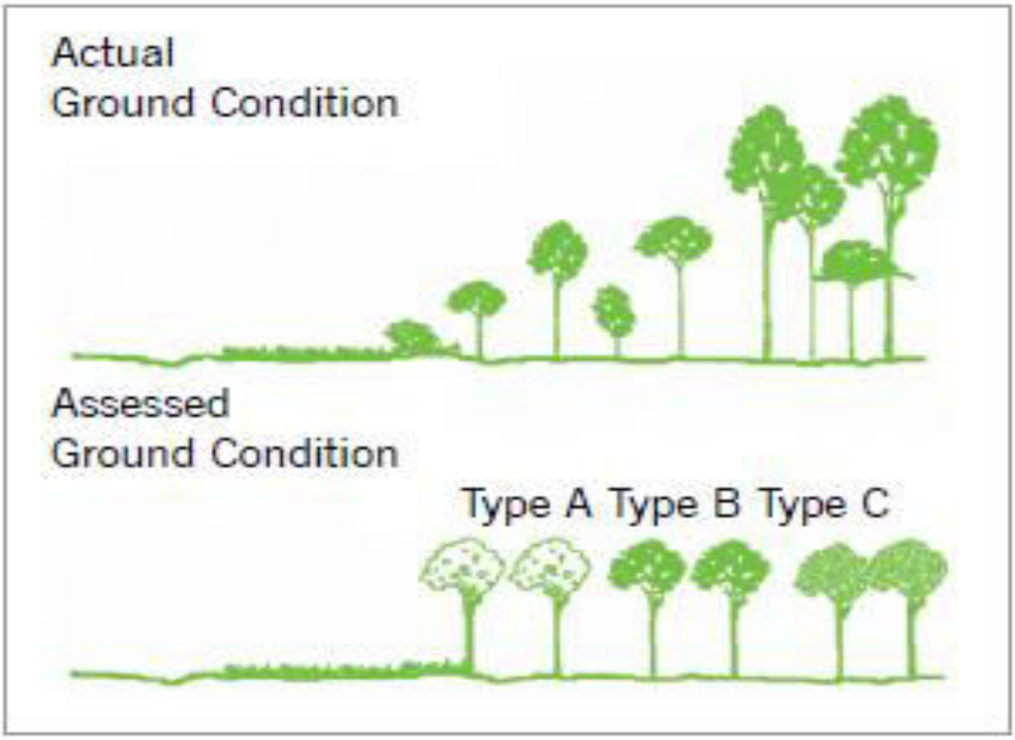


Figure 3.7: Canopy Cover on Ground and assessed using Remote Sensing

Historically, the format most widely used for tree species identification has been black and white photographic paper prints at a scale of 1:15,840 to 1:24,000. Black and white infrared paper prints are especially valuable in separating evergreen from deciduous types. However, color and color infrared films, as well as digital frame cameras and video cameras and also high re solution multiband satellite images, are being used with increasing frequency. It is difficult to develop visual image interpretation keys for tree species identification because individual stands vary considerably in appearance de pending on age, site conditions, geographic location, geomorphic setting, and other factors. However, a number of elimination keys have been developed for use with aerial photographs that have proven to be valuable interpretive tools when utilized by experienced image interpreters. Tables 3.3 and 3.4 are examples of such keys.

TABLE 3.3: Air photo Interpretation Key for the Identification of Hardwoods in Summer

1. Crowns compact, dense, large	
2. Crowns very symmetrical and very smooth, oblong or oval; trees form small portion of stand	Basswood
2. Crowns irregularly rounded (sometimes symmetrical), billowy, or tufted	
3. Surface of crown not smooth, but billowy	Oak
3. Crowns rounded, sometimes symmetrical, smooth surfaced	Sugar maple, "beech"
3. Crowns irregularly rounded or tufted	Yellow birch
1. Crowns small or, if large, open or multiple	
6. Crowns small or, if large, open and irregular, revealing light-colored trunk	
7. Trunk chalk white, often forked; trees tend to grow in clumps	White birch
7. Trunk light, but not white, undivided trunk reaching high into crown, generally not in clumps	Aspen
6. Crown medium sized or large; trunk dark	
8. Crown tufted or narrow and pointed	
9. Trunk often divided, crown tufted	Red maple
9. Undivided trunk, crown narrow	Balsam poplar
8. Crowns flat topped or rounded	
10. Crowns medium sized, rounded; undivided trunk; branches ascending	Ash
10. Crowns large, wide; trunk divided into big spreading branches	
11. Top of crown appears pitted	Elm
11. Top of crown closed	Silver maple

"A local tone-key showing levels 4 and 5 is usually necessary to distinguish these species. Source: From Sayn-Wittgenstein, 1961. Copyright 1961, American Society of Photogrammetry. Reproduced with permission. Phenological correlations are useful in tree species identification. Changes in the appearance of trees in the different seasons of the year sometimes enable discrimination of species that are indistinguishable on single dates. The most obvious example is the separation of deciduous and evergreen trees that is easily made on images acquired when the deciduous foliage has fallen. This distinction can also be discerned on spring images acquired shortly after the flushing of leaves or on fall images acquired after the trees have turned color. For example, in the summer, panchromatic and color photographs show little difference in tone between deciduous and evergreen trees. Differences in tones are generally quite striking, however, on summer color infrared and black and white infrared photographs.

TABLE 3.4: Air photo Interpretation Key for the Identification of Conifers

1. Crowns small; if large, then definitely cone shaped Crowns broadly conical, usually rounded tip; branches not prominent	Cedar
Crowns narrow, often cylindrical: trees frequently grow in swamps	Swamp-type black spruce
Crowns conical, deciduous, very light toned in fall, usually associated with black spruce	Tamarack
Crowns narrowly conical, very symmetrical, top pointed; branches less prominent than in white spruce	Balsam fir
Crowns narrowly conical; top often appears obtuse on photograph (except northern white spruce); branches more prominent than in balsam fir	White spruce, black spruce (except swamp type)
Crowns irregular, sometimes with pointed top; have thinner foliage and smoother texture than spruce and balsam fir	Jack pine
1. Crowns large and spreading, not narrowly conical; top often not well defined	
2. Crowns very dense, irregular or broadly conical Individual branches very prominent; crown usually irregular	White pine
Individual branches rarely very prominent; crown usually conical	Eastern hemlock
2. Crowns open, oval (circular in plain view)	Red pine

In spring images, differences in the time at which species leaf out can provide valuable clues for species recognition. For example, trembling aspen and white birch consistently are among the first trees to leaf out, while the oaks, ashes, and large-tooth aspen are among the last. These two groups could be distinguished on images acquired shortly after trembling aspen and white birch have leafed out. Tone differences between hardwoods, which are small during the summer, become definite during the fall, when some species turn yellow and others red or brown. The best species distinctions in the fall are obtained on images acquired when fall coloring is at its peak, rather than when some trees have lost their leaves.

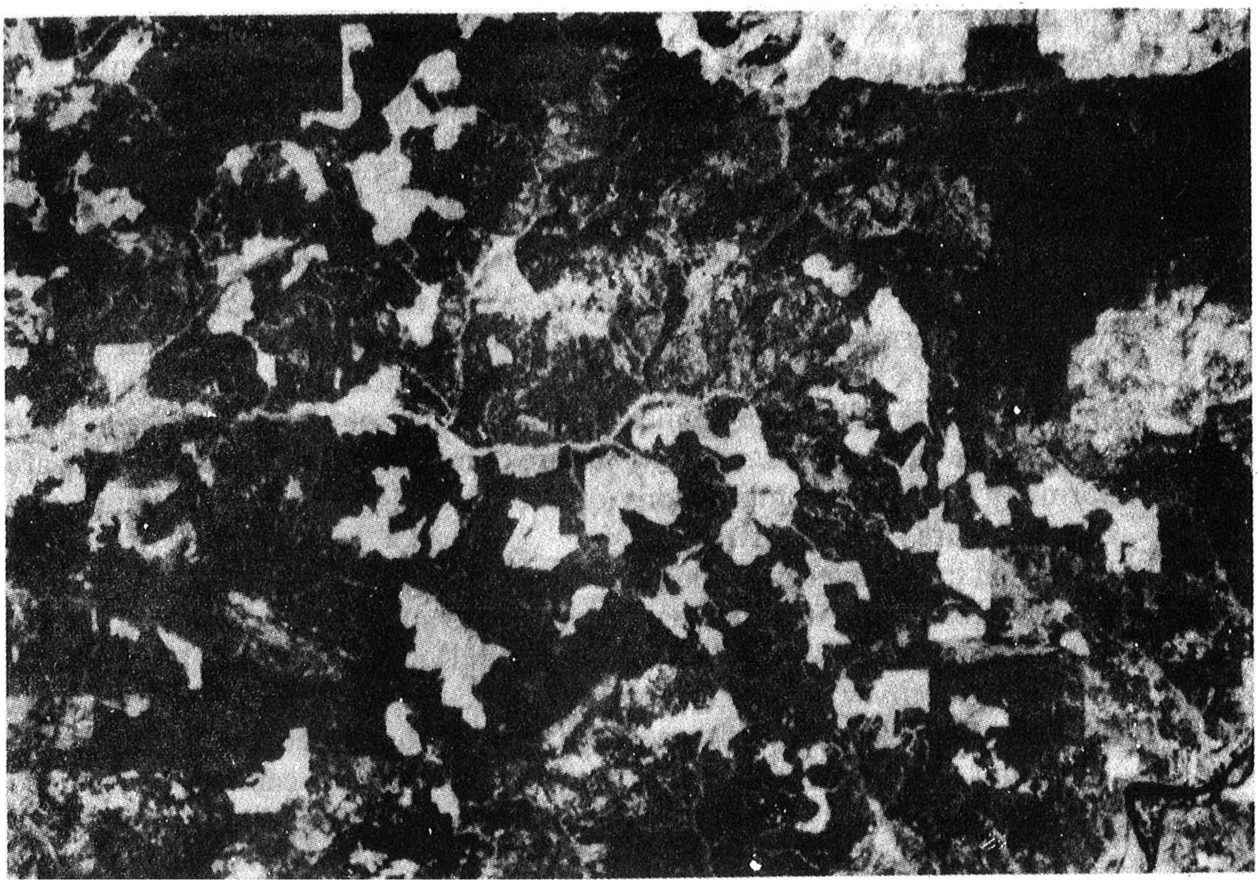


Figure 3.8: Satellite Image showing Timber

Harvested areas are clearly visible on many aerial and satellite images. Figure 8, shows a satellite image illustrating timber harvesting in the north western United States. Here the darker toned areas are dense stands of Douglas fir and the lighter toned areas are recently cleared areas consisting of tree stumps, shrubs, and various grasses, in areas where essentially all trees have been removed during the harvesting operations. Mottled, inter mediate toned areas have been replanted with Douglas fir trees and are at an intermediate growth stage. (For other examples of satellite images showing timber harvesting).

Visual image interpretation is used extensively for "timber cruising." The primary objective of such operations is to determine the volume of timber that de might be harvested from an individual tree or (more commonly) a stand of trees. To be successful, image-based timber cruising requires a highly skilled interpreter working with both aerial or satellite and ground data. Image measurements on individual trees or stands are statistically related to ground measurements of tree volume in selected plots. The results are then extrapolated to large areas. The image measurements most often used are (1) tree height or stand height, (2) tree-crown diameter, (3) density of stocking, and (4) stand area.

The height of an individual tree, or the mean height of a stand of trees, is normally determined by measuring relief displacement or image parallax. The task of measuring tree-crown diameters is no different from obtaining other distance measurements on images. Ground distances are obtained from image distances via the scale relationship. The process is expedited by the use of special-purpose overlays similar to dot grids. Overlays are also used to measure the density of stocking in an area in terms of the crown closure or percentage of the ground area covered by tree crowns. Alternatively, some measure of the number of individual crowns per unit area may be made. The accuracy of these measurements is influenced by such factors as the band(s) in which the image is sensed, the season of image acquisition, and the amount of shadow in the images.

Once data on individual trees or stands are extracted from images, they are statistically related (using multiple regression) with ground data on timber volume to prepare volume tables. The volume of individual trees is normally determined as a function of species, crown diameter, and height. This method of timber volume estimation is practical only on large-scale images and is normally used to measure the volume of scattered trees in open areas. More frequently, stand volumes are of interest. Stand volume tables are normally based on combinations of species, height, crown diameter, and crown closure (Table 3.5).

Visual image interpretation has been used in many instances to survey forest and urban shade tree damage from disease and insect infestations as well as from other causes. A variety of image bands and scales have been utilized for damage surveys. Although panchromatic photographs have often been used, the most successful surveys have typically used medium- or large-scale color and color infrared photographs (digital frame cameras and video cameras can also be used, as well as high resolution multiband satellite images). Some types of tree disease damage due to bacteria, fungus, virus, and other agents that have been detected using visual image interpretation are ash dieback, beech bark disease, Douglas fir root rot, Dutch elm disease, maple die back, oak wilt, and white pine blister rust. Some types of insect damage that have been detected are those caused by the balsam wooly aphid, black-headed budworm, Black Hills bark beetle, Douglas fir beetle, gypsy moth larva, pine butterfly, mountain pine beetle, southern pine beetle, spruce budworm, western hemlock looper, western pine beetle, and white pine weevil. Other types of forest damage that have been detected include those resulting from air pollution (e.g., ozone, sulfur dioxide, “smog”), animals (e.g., beaver, deer, porcupine), fire, frost, moisture stress, soil salinity, nutrient imbalance, and storms.

In this discussion we have highlighted the application of visual image interpretation to tree species identification, studying harvested areas, timber cruising, and forest damage assessment. However, the forest management applications of visual image interpretation extend far beyond the scope of these four activities. Additional applications include such tasks as forest land appraisal, timber harvest planning, monitoring logging and reforestation, planning and assessing applications of herbicides and fertilizer in forest stands, assessing plant vigor and health in forest nurseries, mapping “forest fuels” to assess fire potential, planning fire suppression activities, assessing potential slope failures and soil erosion, planning forest roads, inventorying forest recreation resources, censusing wildlife and assessing wildlife habitat, and monitoring vegetation re-growth in fire lanes and power line rights-of-way.

TABLE 3.5: Estimated Volume of Kentucky Hardwood Stands

Average Stand Height (m)	Average Crown Diameter (m)	Estimated Volume (m'/ha) at Selected Crown Closures								
		15%	25%	35%	45%	55%	65%	75%	85%	95%
9	3-4	21	26	30	33	36	40	44	49	54
12	3-4	25	30	35	39	42	46	49	53	56
15	3-4	28	33	39	44	49	54	58	63	68
18	3-4	39	7	55	61	67	72	78	84	90
21	3-4	63	75	85	93	98	103	107	112	117
9	5-6	24	28	31	35	38	43	48	52	57
12	5-6	28	31	35	40	45	50	55	59	64
15	5-6	31	37	42	47	52	58	64	70	76
18	5-6	42	51	59	66	73	77	84	87	87
21	5-6	70	80	91	98	105	108	112	115	119
24	5-6	105	114	122	128	133	138	142	147	152
12	7-8	35	44	52	59	66	72	78	84	90
15	7-8	42	52	63	70	77	83	89	94	100
18	7-8	63	73	84	89	94	99	104	108	113
21	7-8	94	103	112	117	122	127	132	136	141
24	7-8	122	133	143	49	154	159	163	168	173
27	7-8	155	165	175	180	185	190	195	199	204
30	7-8	190	200	210	215	220	224	227	231	234
12	9+	59	72	84	89	94	99	104	108	113
15	9+	73	84	94	100	105	110	114	119	124
18	9+	91	101	110	115	120	125	130	135	140
21	9+	119	129	138	145	150	155	160	165	170
24	9+	150	159	168	175	182	186	190	195	200
27	9+	182	190	200	205	210	215	220	225	230
30	9+	213	222	231	236	241	245	248	252	255
33	9+	252	259	266	271	276	281	286	290	295

Figure 3.6: Attributes used to Characterize stand structure

Stand Element	Attribute
Foliage	Foliage height diversity
	Foliage density within different strata
Canopy Cover	Canopy Cover
	Gap size classes
	Average gap size and proportion of canopy in gaps
	Proportion of tree crowns with broken and dead tops
Tree diameter	Tree Diameter at Breast Height (DBH)
	Diameter distribution
	Number of large trees
	Tree size diversity
Tree height	Height of overstory
	Horizontal variation in height
	Median height
Tree spacing	Stem density
Biomass	Basal area
	Volume
Composition	Diversity
	Richness
	Relative abundance

RANGELAND APPLICATIONS

Rangeland has historically been defined as land where the potential natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs and where animal grazing was an important influence in its pre-settlement state. Rangelands not only provide forage for domestic and wild animals, they also represent areas potentially supporting land uses as varied as intensive agriculture, recreation, and housing. Rangeland management utilizes rangeland science and practical experience for the purpose of the protection, improvement, and continued welfare of the basic rangeland resources, including soils, vegetation, endangered plants and animals, wilderness, water, and historical sites.

Rangeland management places emphasis on the following: (1) determining the suitability of vegetation for multiple uses, (2) designing and implementing vegetation improvements, (3) understanding the social and economic effects of alternative land uses, (4) controlling range pests and undesirable vegetation, (5) determining multiple-use carrying capacities, (6) reducing or eliminating soil erosion and protecting soil stability, (7) reclaiming soil and vegetation on disturbed areas, (8) designing and controlling livestock grazing systems, (9) coordinating rangeland management activities with other resource managers, (10) protecting and maintaining environmental quality, (11) mediating land use conflicts, and (12) furnishing information to policymaker.

Given the expanse and remoteness of rangelands and the diversity and intensity of pressures upon them, visual image interpretation has been shown to be a valuable range management tool. A physical-measurement oriented list of range management activities that have some potential for being accomplished by image interpretation techniques includes: (1) inventory and classification of rangeland vegetation, (2) determination of carrying capacity of rangeland plant communities, (3) determination of the productivity of rangeland plant communities, (4) condition classification and trend monitoring, (5) determination of forage and browse utilization, (6) determination of range readiness for grazing, (7) kind, class, and breed of livestock using a range area, (8) measurement of watershed values, including measurements of erosion, (9) making wildlife censuses and evaluations of rangelands for wildlife habitat, (10) evaluating the recreational use of rangelands, (11) judging and measuring the improvement potential of various range sites, and (12) implementing intensive grazing management systems. Table 6 outlines the appropriate rangeland management uses of imagery of various scales.

TABLE 3.6: Appropriate Rangeland Management Uses of Aerial and Satellite Imagery of Various Scales

Imagery Scale	**Rangeland Management Uses**
1:100 to 1:500	Species identification, including grasses and seedlings, identification and measurement of erosion features, forage production estimates, rodent activities in the surface soil, assessment of the amounts of other surface features such as litter, and wildlife habitat assessment.
1:600 to 1:2000	Species measurements, erosion estimates over larger land areas, condition and trend assessment, production and utilization estimates, and wildlife habitat assessment.
1:5000 to 1:10,000	Detailed vegetation mapping, condition and trend assessment, production and utilization estimates, and wildlife habitat assessment.
1:15,000 to 1:30,000	Vegetation mapping at the habitat-type or ecological site level, allotment management planning, and planning for multiple use, including wildlife habitat assessment.
1:30,000 to 1:80,000	Planning for range management, vegetation and soil unit mapping on a pasture or allotment basis, and multiple-use

	planning, including wildlife habitat mapping.
1:100,000 to 1:2,500,000	Synoptic views for planning rangeland use and mapping large vegetation zones covering large areas such as entire mountain ranges.

WETLAND MAPPING

The value of the world's wetland systems has gained increased recognition. Wetlands contribute to a healthy environment in many ways. They act to retain water during dry periods, thus keeping the water table high and relatively stable. During periods of flooding, they act to reduce flood levels and to trap suspended solids and attached nutrients. Thus, streams flowing into lakes by way of wetland areas will transport fewer suspended solids and nutrients to the lakes than if they flow directly into the lakes. The removal of such wetland systems because of urbanization or other factors typically causes lake water quality to worsen. In addition, wetlands are important feeding, breeding, and drinking areas for wildlife and provide a stopping place and refuge for waterfowl. As with any natural habitat, wetlands are important in supporting species diversity and have a complex and important food web. Scientific values of wetlands include a record of biological and botanical events of the past, a place to study biological relationships, and a place for teaching. It is especially easy to obtain a feel for the biological world by studying a wetland. Other human uses include low intensity recreation and aesthetic enjoyment.

Accompanying the increased interest in wetlands has been an increased emphasis on inventorying. The design of any particular wetland inventory is dependent on the objectives to be met by that inventory. Thus, a clearly defined purpose must be established before the inventory is even contemplated. Wetland inventories may be designed to meet the general needs of a broad range of users or to fulfil a very specific purpose for a particular application. Multipurpose and single-purpose inventories are both valid ways of obtaining wetland information, but the former minimizes duplication of effort. To perform a wetlands inventory, a classification system must be devised that will provide the information necessary to the inventory users. The system should be based primarily on enduring wetland characteristics so that the inventory does not become outdated too quickly, but the classification should also accommodate user information requirements for ephemeral wetland characteristics. In addition, the inventory system must provide a de tailed description of specifically what is considered to be a wetland. If the wetland definition used for various "wetland maps" is not clearly stated, then it is not possible to tell if apparent wetland changes noted between maps of different ages result from actual wetland changes or are due to differences in concepts of what is considered a wetland.

At the federal level in the United States, four principal agencies are involved with wetland identification and delineation: (1) the Environmental Protection Agency, (2) the Army Corps of Engineers, (3) the Natural Resources Conservation Service, and (4) the Fish and Wildlife Service. The Environmental Protection Agency is concerned principally with water quality, the Army Corps of Engineers is concerned principally with navigable water issues that may be related to wetlands, the Natural Resources Conservation Service is concerned principally with identifying and mapping wetlands, and the Fish and Wildlife Service is principally interested in the use of wetlands for wildlife habitat. In 1989, these four agencies produced a Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineation, 1989), which provides a common basis for identifying and delineating wetlands. There is general agreement on the three basic elements for identifying wetlands: (1) hydrophytic vegetation, (2) hydric soils, and (3) wetland hydrology. Hydrophytic vegetation is defined as macrophytic plant life growing in water, soil, or substrate that is at least periodically deficient in oxygen as a result of excessive water content. Hydric soils are defined as soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic (lacking free oxygen) conditions in the upper part. In general, hydric soils are flooded, ponded, or saturated for 1 week or more during the period when soil temperatures are above biologic zero (5°C) and usually support hydrophytic vegetation. Wetland hydrology refers to conditions of permanent or periodic inundation, or soil saturation to the surface, at least seasonally, hydrologic conditions that are the driving forces behind wetland formation. Numerous factors influence the wetness of an area, including precipitation, stratigraphy, topography, soil permeability, and plant cover. All wetlands typically have at least a seasonal abundance of water that may come from direct precipitation, overbank flooding, surface water runoff resulting from precipitation or snow melt, groundwater discharge, or tidal flooding.

Color infrared photography has been the preferred film type for wetlands image interpretation. It provides interpreters with a high level of contrast in image tone and color between wetland and non-wetland environments, and moist soil spectral reflectance patterns contrast more distinctively with less moist soils on color infrared film than on panchromatic or normal color films. Other multiband image types (e.g., multispectral scanners, hyperspectral scanners) can also be used, but should include at least one visible band and one near-infrared band. An example of wetland mapping is shown in Figures 3.7 and 3.8.

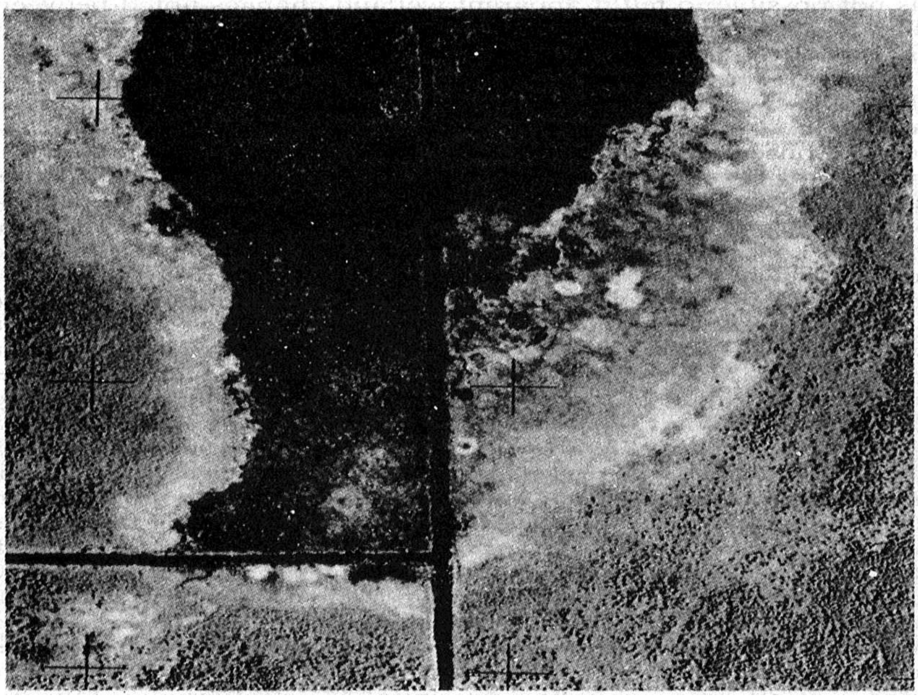


Figure 3.7: Wetland Mapping though Remote Sensing

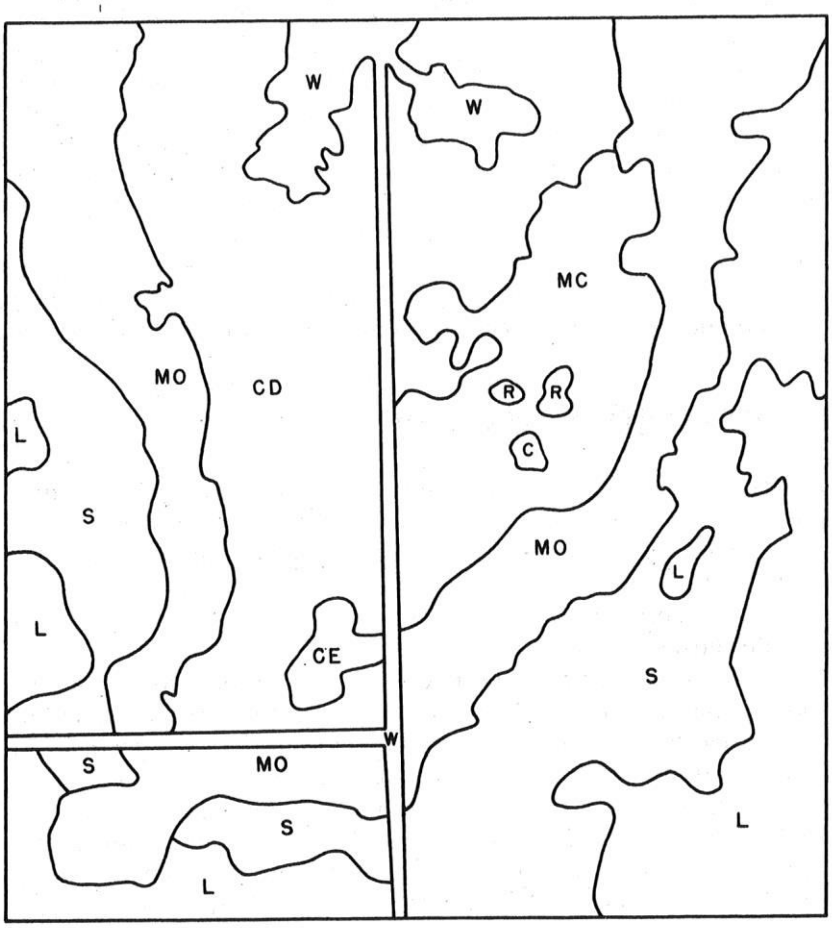


Figure 3.8: Wetland Categorization and Mapping

LASER AND LIDAR MAPPING

Laser scanning provides accurate three-dimensional measurements of vegetation and other surfaces. Airborne laser scanning has revolutionized forestry opportunities to efficiently produce forest maps with forest variables such as timber volume, basal area, tree height and trunk diameter. Through terrestrial (ground-based) laser scanning, it is possible to rapidly obtain field data with extensive information in comparison to traditional manual measurements. These instruments can be placed on a stative or can be a mobile system (eg., on an ATV or a backpack with an operator). Information from terrestrial systems can be used to calibrate remote sensing data collected from airborne systems.

On its way to the ground, the transmitted laser pulse can be reflected by the ground or objects above the ground such as tree crowns, trunks, other vegetation, rocks, buildings and more. A hard and compact surface results in a single distinct return pulse, but when the laser beam hits for example a tree crown or the edge of a roof, just a part of the pulse is reflected while the remainder continues travelling. Water has low reflectance and therefore has virtually no return. Also a measure of the reflected radiation referred to as "intensity" is often recorded together with the coordinates for each detected laser return. Many laser systems use near-infrared light and a surface that reflects much light in this wavelength range (such as living vegetation) therefore appears "bright" in the intensity data. The intensity of the return pulses is difficult to interpret, because the amount of light reflected from vegetation depends on leaf angles, vegetation density, and other reasons. Figure 3.7 illustrates how the reflection from different layers of vegetation and finally from the ground can give multiple returns from a transmitted laser pulse. The number of registered returns can vary between scanners. The forest often gives the first return from the canopy and the last returns from the ground. (There are also scanners that sample the whole laser return with high frequency, so called full-waveform laser). The height distribution of the laser points (the returns) occurs below the actual tree height distribution. This is partly because the laser beam penetrates the part of the tree crown before enough energy is reflected to trigger a measurement in the detector, and partly because the pulses not only hit the treetops, but also the tree crowns' sides. Dense vegetation can also cause returns from the ground and vegetation to blend together so that the ground return will be partially masked. It may lead to the return being registered early and for the ground height to be overestimated. The transmitted laser pulse duration is in the order of meters, but the uncertainty in the measurements against a hard surface should not exceed a few inches. Of great importance for the measurements is therefore the algorithm (calculation rule) that determines at what signal strength a detector will register a return. A common method is to register a return is when the peak of the return signal has reached a certain percentage, for example 50%, of its maximum value. In this way timing is not affected by the pulse peak power, but only by its width Peaks that do not reach above a certain threshold, the detection threshold, are not recorded at all.

The pre-processing of the data is done in the manner described in below. Then the work can be roughly divided into the following steps: • Assign height to all the laser returns over ground level • Detecting individual trees in the laser data and delineate tree crowns using segmentation • Calculate the measure from the laser data that describes the individual trees • Connect the trees in the laser data with trees inventoried and coordinate set in the field • Develop regression functions for variables to be estimated • Applying functions on all detected trees. Many of the processing steps above require special software. Analysis of individual trees in the laser data is therefore primarily done by researchers, as well as a few specialized companies.

Estimation of tree variables

Estimation of height, diameter, volume, etc. of individual trees can be done using, for example, regression or k-MSN, similar to the area-based estimation. Regression models describing the relationship between the dependent (forest) and independent variables (from lasers or aerial photographs). The relationship is then applied to all detected trees within the scanned area. Among the benefits of laser estimation of individual trees is that species can be estimated from the tree crown shape, and that better information about the tree size distribution can be obtained. To get unbiased results, meaning that the wood volume, number of stems, etc., on average, will be estimated correctly at the stand level, one must compensate for the trees that are not detected in the laser data. One method called semi-ITC achieves this by connecting all field measured trees to a segment, although in some cases it means that a segment has several field measured trees associated with it (Breidenbach et al. 2010).

Fuelwood collection and shifting cultivation

Fuelwood collection and shifting cultivation both cause low intensity yet noticeable changes in forest structure. Since fuelwood collection for traditional energy does not usually cause extended forest canopy change but mostly affects forest density, it is often difficult to detect using RS methods. Few RS methods have been reported so far for this use, and such studies have had to rely heavily on ground data for calibration and for disentangling the underlying causes of the observed changes. However, harvesting of firewood and production of charcoal are very common practices in rural areas of developing countries, although their intensity varies from place to Estimations of forest degradation resulting from domestic consumption can be difficult to document and estimate at larger scales. It is significant that in much of the literature estimating fuelwood impact on forests, RS methods were not applied, and few spatially explicit mappings of fuel-related forest degradation have been carried out. Bolognesi *et al* quantified the impact of charcoal production on forest cover loss using very high spatial resolution satellite imagery (0.5 m). By using literature, and local knowledge-based assumptions on ranges of kiln and tree parameters, they estimated an average production of 24 000 tons of charcoal and 2.7% tree loss for the 2 year interval (2011–2013). Ryan *et al* quantified drivers of forest degradation in Mozambique by relating the biomass change to field-identified drivers. They found that charcoal production was responsible for about 13% of the biomass loss in the study area. Low intensity forest degradation from fuelwood gathering could not be successfully monitored with Landsat images and requires higher spatial resolution images. Shifting cultivation causes temporal vegetation dynamics: trees are cut down and burned, the land is used for a few years for agriculture, and thereafter left fallow, such that secondary forest grows. It is often cited as being responsible for deforestation as well as forest degradation in tropical regions, although this would only occur if the land did not regenerate forest during the fallow. We note however that in some countries shifting cultivation is considered to be an agricultural land use and therefore not a temporary use of forest. In this case, the initial change from forest to shifting cultivation is considered to represent deforestation and subsequently the area remains non forest and is not monitored for forest emissions. This is a pragmatic approach for countries and avoids having to try to capture ongoing degradation in shifting cultivation systems, but in most cases, it does not reflect reality, since typically shifting cultivation involves cyclical use of forest land with periods of fallow which are characterised by natural regeneration of (secondary) forest. Shifting cultivation leaves cleared patches that are sometimes considerably larger than those caused by selective logging (sometimes up to 1–3 ha, although most parcels are significantly less than 1 ha). A challenge in the quantification of small-scale shifting cultivation is that it produces a mosaic landscape that is often misclassified in a system of discrete land cover classes. These patches may be visible for a few years but they become covered with secondary vegetation and disappear in the longer term (10–20 years). Not surprisingly, there is often confusion about whether clearances observed are temporary, for shifting cultivation, or permanent, indicating long term land use change, when the change analysis is done using RS. They found an overall reduction in the area dominated by shifting cultivation, although some regions showed an expansion. Again, though they could assess the area change, they could not show how much biomass was lost. Shifting cultivation exemplifies the problem of estimating changes in carbon stocks in forests and woodlands, although high frequency time series radar data have shown promising results in detecting carbon change in shifting cultivation. It is worth mentioning that although in some parts of the world free cattle grazing in forests is an additional cause of forest degradation, as a result of browsing on young tree shoots and trampling of soil, we were not able to find any scientific articles which attempt to assess this through RS. Human collection of cattle fodder from forests is also a potential degradation factor which has not been addressed in this sense.

FOREST AND RANGE FIRES

Remote sensing and GIS are becoming significant tools for managing forest and range resources, which includes combating fires. **Before a Fire** During a fire season, it is important to assess the changing potential for fires in order to plan suppression measures. In the Great Plains of the United States the National Weather Service issues daily grassland fire danger warnings during periods of fire hazard. A fire danger index is calculated by integrating daily weather conditions (humidity, wind speed, cloud cover, and temperature) with an estimate of the percentage of green composition (PGC), which represents the fuel condition. State forestry agencies estimate PGC by clipping vegetation from predetermined sample sites and measuring the percentage of green components. A shortcoming of the warning index is that the PGC information is measured at fewer than three sites within a state and at intervals of 2 weeks or longer. A greater number of sample sites and reduced time between measurements could improve the accuracy of fire danger warnings. Eidenshenk and others (1989, 1990) demon started that NDVI data from AVHRR could be converted into PGC information for grasslands of the northern Great Plains. Fire danger ratings based on PGC derived from NDVI compared favourably with ratings based on traditional field measurements of PGC. During the 1988 fire season weekly NDVI maps were generated for the northern Great Plains, using methods described in Chapter 12. These maps were converted into PGC values and combined with daily weather data to produce maps of the fire danger index. Figure 13-35 is a fire danger index map using NDVI data for grasslands in South Dakota for June 6, 1988. These maps are significant improvements over the traditional maps. **During a Fire** Once a fire breaks out, its progress must be monitored in order to deploy personnel and equipment for suppression. Forest fires are routinely monitored by aircraft thermal IR scanners that record the fire front, despite dense smoke cover. GPSS are used in the aircraft and by fire crews to coordinate their efforts. **After a Fire** After a fire is extinguished, the area must be surveyed to assess damage, plan rehabilitation efforts, and monitor recovery of the forest. Remote sensing and GIS play vital roles in all three aspects. The U.S. Forest Service is using TM images acquired before and after a wildfire to assess damage to vegetation and monitor its recovery.

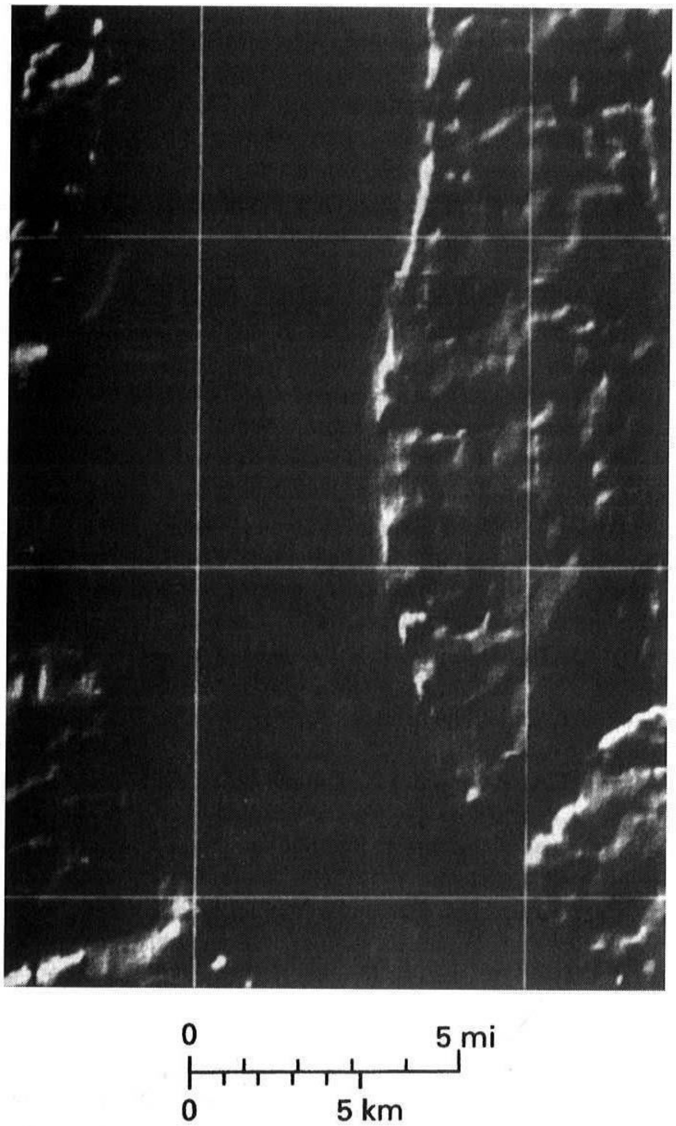


Figure 3.9: Satellite Image

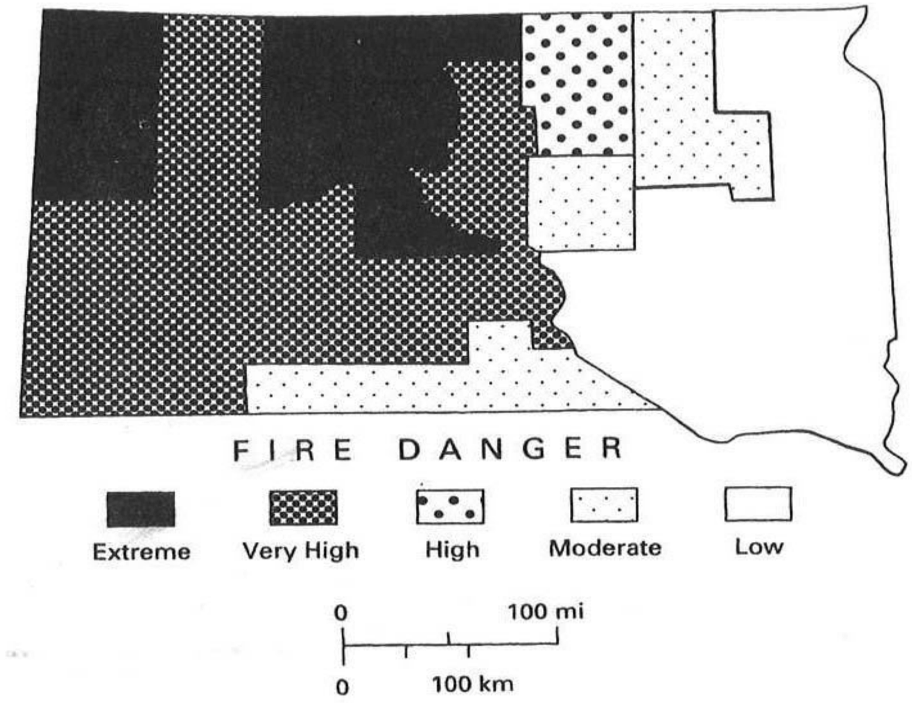


Figure 3.10: Forest Fire Mapping

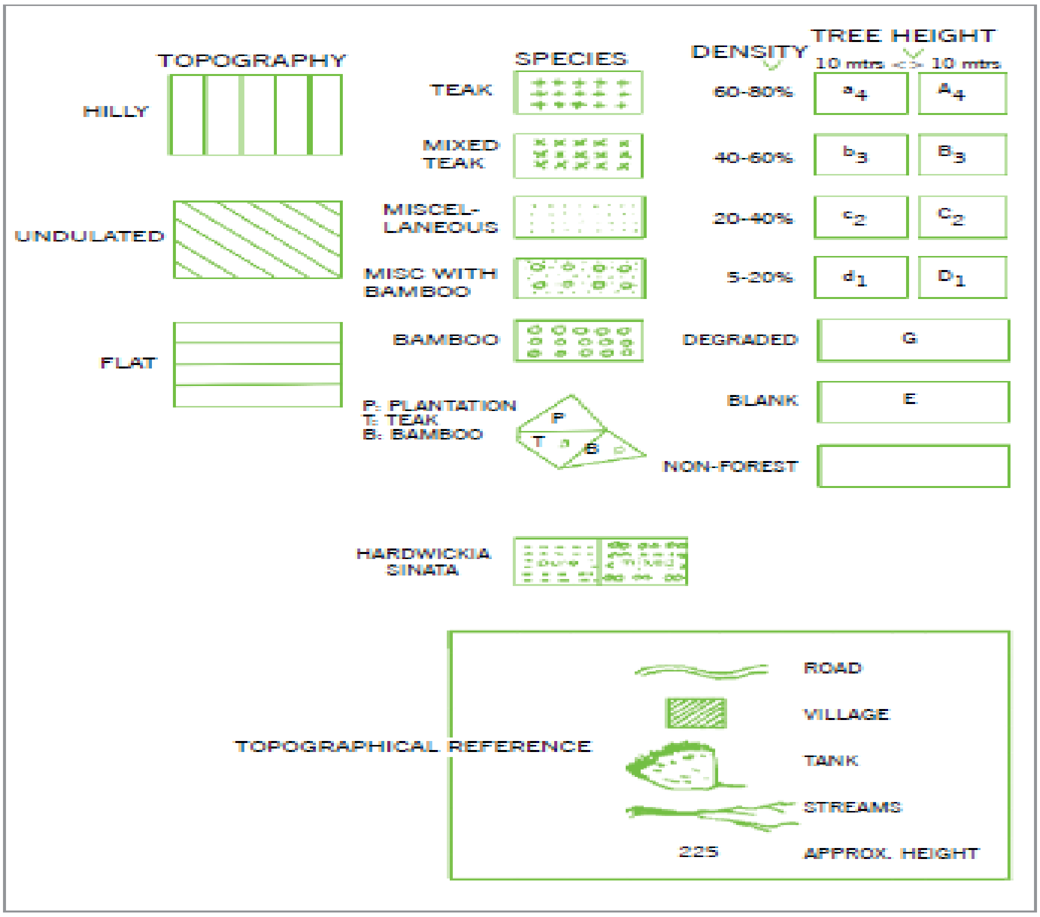


Figure 3.11: Forest Mapping

Quantifying and reporting the extent of forest resources is one of the primary objectives of forest resource assessments across geopolitical scales (e.g. local, regional, national and international). The first national forest cover monitoring in India was carried out for 1972-75 and 1981-83 time periods using LANDSAT Multispectral scanner (MSS) data by the National Remote Sensing Centre (NRSC then NRSA). The Government of India established the Forest Survey of India (FSI) which has adopted the technology and carried out forest cover monitoring in India every two years since 1987.

Class	Description
Very Dense Forest	Tree canopy density > 70 per cent
Moderately Dense Forest	Tree canopy density > 40 per cent
Open Forest	Tree canopy density > 10 per cent
Scrub	Canopy density < 10 per cent
Non-forest	All other land and water

Figure 3.12: Canopy Density Classes and Cover Mapping

Satellite remote sensing has been operationally used in India for several decades. The satellite-based monitoring of India's forest has contributed to informing policy and effective conservation and protection of India's forests. Newer methods of analysis of satellite remote sensing data have led to the development of automated approaches to the detection of forest change. The reliable and confident detection of a change from a forested to a non-forested state is now realizable at annual time scales. The need of the future is to improve i.e., further reduce the temporal scale to sub-annual scales and improve the sensitivity of the analysis to detect subtle changes in fractional cover. The availability of three-dimensional data from active sensors particularly waveform LiDAR from the GEDI mission and microwave data in the L- and S bands from the ISRO-NASA NISAR mission offer exciting new possibilities for the characterization of India's forest vegetation.

3.4 SUMMARY

With the launch into orbit of the Earth Resources Technology Satellite 1 (the first of the Landsat series of satellites), canopy cover could be mapped from remotely sensed imagery from space platforms. Smedes *et al.* (1970) distinguished three levels of coniferous forest canopy density (40-95 per cent; 15-40 per cent; and 0-15 per cent). Heller (1975) mapped crown closure with ERTS-1 satellite data as a level III parameter and attempted to distinguish healthy pine defined as canopy cover > 50 per cent. Madhavan Unni *et al.* (1985) compared the digital classification of multispectral data obtained from LANDSAT from an airborne multispectral scanner with photo-interpretation techniques. The classes mapped combined

topography, species. Canopy density and tree height for use as the first stage for a multistage sampling design for quantitative evaluation of forest resources. They make a call for the use of enhanced data from future satellites 'to make analysis and interpretation easier, more detailed and accurate' and for developing methods for texture analysis, integrating the multi-temporal data and incorporating topographic information from other sources into the analysis. These methods have since been developed and applied to quantitatively estimate forests in India and globally.

3.5 GLOSSARY

- LiDAR- Light Detection and Ranging
- NASA- National Aeronautics and Space Administration
- SAR- Synthetic Aperture Radar
- Land use- Involves the management and modifications of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures ana managed woods.
- Land cover- Land cover is the physical material at the surface of the Earth. Land covers include grass, asphalt, trees, bare ground etc.
- LANDSAT- Landsat satellites have the optimal ground resolution and spectral bands to efficiently track land use and to document land change, urbanization, biomass changes and natural changes.
- NRSC- National Remote Sensing Centre

3.6 ANSWER TO CHECK YOUR PROGRESS

Q1. Define land use?
Q2. Define Land cover?
Q3. Write the short note on LANDSAT?
Q4. Write the uses of SAR?
Q5. Write the short note on Forest mapping?

3.7 REFERENCES

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3.8 TERMINAL QUESTIONS

1. Explain Forest Cover Mapping and Density Cover using remote sensing data.
2. What do you understand by change detection. Explain how forest change detection and mapping can be done using remote sensing data.
3. Elaborate forest management with suitable examples using remote sensing.
4. How forest diversity can be mapped.
5. Describe Forest disaster mapping using Geoinformatic technologies and satellite images.

BLOCK 2 : APPLICATIONS OF GEO-INFORMATICS IN HAZARD MAPPING

UNIT 4 : HAZARDS AND THEIR TYPES

4.1 OBJECTIVES

After reading this unit you should be able to:

- Introduction to hazard and its classification
- Understanding concept of Hazard identification
- Introduction to Hazard characteristic
- Understanding hazard assessment
- Concept of Hazard mapping

4.2 INTRODUCTION

The word Hazard was likely to originate either from French word *hasard* , a gme of dice predating craps , or from Arabic *Ial- zahr* which means "the Die".in the modern world , hazards are Uncommon or Extraordinary Occasions within the normal (or man-made) environment that adversely influences human lives, properties or exercises to the degree of causing a catastrophe is known as Hazard. **Hazard** is possibly harming physical occasions, marvels, or human activities that cause misfortune of life, property harm, social and financial disturbance, or environmental corruption (Makoka & Kaplan, 2005). FEMA (1997) define hazards as events or a physical condition that have potential to cause fatalities, injury, property and infrastructure damage, agricultural loos, environmental damage interruption to business or any other type of loss or harm. They are outside components that influence the society or components at hazard. Hazards have the potential to cause catastrophes. (UNISDR 2009). A hazards may not be a disaster every time. Disaster is the impact of natural hazards over vulnerable people (Cannon 1994). The determines factors that would decide whether a hazard becomes a disaster are *Risk* and *Vulnerability*

Every living being involve a few frames of risk to life, property or anything which holds esteem to them. The source of this risk is called hazard. Risks can be as extraordinary as atomic emergency to as straightforward as street mischances. The vulnerability of people in an area, which are exposed to hazards, then the disaster in determine. Intensity and duration of any hazards will determine the depth and extent of disaster.

Hazards were to a great extent considered as acts of God, divine powers of Nature in human history. This idea was so predestinationist, non-reverberate that social actions were causing disaster. This was seen in Etkin (2015) Lisbon seismic tremor in 1755, the seismic tremor addressed a logical viewpoint of dangers and their roots due to the similarity within the crushed houses. There has been a progressive rise of the term Hazard as menace to mankind.

Alexander (2000) depicted hazards as exceptional geophysical events capable to cause catastrophes. Cutter, Hewitt and UNISDR to depict hazards as dangers to human well-being, property or environment. It is to be famous that the hazard is the threat of occasions but not the likelihood of its occurrence or the real occasion.

Hazards are moreover examined within the setting of vulnerability. Numerous research about how hazards show itself when it interatomic with the vulnerability. Prominent analysts Quarantelli, Wisner, Cutter, Hewitt, Blaikie, Cannon, Davis, Chapman have contended in comparable lines. The concept of hazards and their appearances are subjected to time and space. The impact varies person to place. For example, crossing a busy road might not be hazard for young people while differently abled people, pregnant women and elderly consider the situation Hazardous.

Disaster thrives on under devolvement, economic dependency, vulnerability of a nation. The frequency of disaster only reinforces the inequalities.it has been found in the recent research that economic dependency increase both the frequency and impact of natural hazards.

Earthquake is a natural hazard, its occurrence at a non-habited area will be of no concern than same natural phenomena occurring in densely populated built up area. Thus, perspective is also considered in understanding Hazard. Thus, Hazards are not always considered wicked. In some cases, certain hazards such as Flood brings new fertile soils welcomed by farmers as long no harm was caused to human and its built environment.

4.3 Hazard and Its Type

Hazards can be classified in many dimensions. the most general classification of hazards is its origin. EM – DAT has classified the hazards as following

a) Natural
b) Man-made or Anthropogenic

Table 4.1: Natural hazards can be further divided into following categories:-

Biological	Geophysical	Hydrological	Meteorological	Climatological
*Epidemic (Viral infection, Bacteria Infection, Parasite infection, Fungal Infection)	*Earthquakes *Volcano *Mass Movements (Rockfall,	*Flood *Mass Movement (Rockfall, Landslides,	*Storm (Tropical cyclone, Extra Tropical cyclone, Local Storm)	*Extreme Temperature (Heat waves, Cold Waves, Extreme winter

*Animal stampede *Insect Infection	Landslides, Avalanches, Subsidence)	Avalanches, Subsidence)		conditions) *Drought *Wildfires

Source- *Guha-sapir et.al, 2009*

It is to understand that each category and its sub group need to be defined in their respective scenario. Thus, definition of each group are as follows:

1) **Geo physical -** Geophysical encompasses all the earth related phenomena taking place underneath the earth's crust which result in geological and tectonic activities. This energetic nature of earth's crust resulted in geophysical hazards.
2) **Hydrological** – all the phenomena arising due imbalance in earth's hydrological cycle.
3) **Meteorological** – Events caused sudden and adverse change in the atmospheric process.
4) **Climatological –** Such events are events that brought about by drastic fluctuations of climate states and variabilities.
5) **Biological -** Biological catastrophe result due to exposure to microorganism such as germs and bacteria

Coppola in his book *Introduction to International Disaster Management* has classified hazards into groups and sub groups.

1) Natural hazards -
    a. Tectonic hazards – Earthquakes, Tsunami
    b. Mass movement Hazards
    c. Meteorological Hazards
    d. Biological hazards
    e. Meteorites strike-
2) Technological Hazards -
    a. Transportation hazards
    b. Infrastructure Hazards
    c. Industrial hazards
    d. Structural fires and failures
3) Social (Intentional, civil and political) Hazards

However, hazards could not be natural because any disaster need requires interaction with the humans and their built environments. Though there are multiple factors responsible for the origin of Hazard.

The onset of Hazards can be sudden or slow. Basis on the onset speed of hazard arrival they can be classified as following.

a. **Fast Onset Hazards – events** such as earthquakes, Cyclones, landslides represent fast onset hazards. These events are sudden didn't allow to response or to take mitigation measures.
b. **Slow onset Hazards -** most common categories of slow onset hazards are temperature rise and associated climatic changes. e.g, Sea level rise, river erosion, ecosystem damage and air pollution etc.

Frequency is the recurrence interval if the disaster. Imp
Recurrence is the repeat interim of the disaster. the impact may be a function of size and frequency of catastrophe. The magnitude-frequency concept is for the most part a reverse relationship between size and frequency. Based on the frequency of hazards classification are as follows: -

a. Single time Hazards - include events which occur once. They do not follow a pattern. E.g., Earthquakes, volcanic eruption.
b. Recurrent Hazards – are those events which occur in certain seasonal time period. E.g., Cyclone, Floods etc.

Characteristic of Hazards

Threats either natural or Man-made both feature similar characteristics. Similarities regarding the intensity magnitude, impacts and timing about the characterises of hazards are as following –

1) **Magnitude:** The Richter or Moment Magnitude scales for earthquakes, the Saffir-Simpson scale for hurricanes, and the Fujita scale for tornadoes are scales measuring energy release in an event.
2) **Intensity:** Intensity measures the severity of an event subjected to human experience. The intensity deal with event severity.
3) **Frequency: D**escribe how often an event of equal magnitude occurs.
4) **Duration:** Duration is another measure how long an event lasts.

5) **Seasonality or sequencing of Event:** Natural and man-made disasters are random but in some cases few disasters showcase recurrency in their behaviour. E.g., Hurricanes and Tornado in United states.
6) **Location: T**his characteristic of hazards is location oriented. This feature of hazard allows to measure and analysis the impact in geographical context. Aerial extent and spatial dispersion are the two dominant measure of an event. Areal extent measure space covered by an event while spatial dispersion includes measurement of hazard distribution over a space.
7) **Exposure:** This feature determines the magnitude of damage. Earthquakes and hurricanes will have massive impact on built environment, it is a choice to settle in low lying coastal areas or follow non seismic resistant built practice.

Hazard Identification

Hazard identification is not simple task to perform. It is the initial effective step in disaster management. Identifying and profiling of hazards is the logical first initiate while assessing risk of a community. Disaster management should consider all possible scenario that could manifest with in a community as a consequence to its geology, location, hydrological, biological, economic, technological, political and social factors. In this hazard assessment as it is generally referred, must include physical hazards that have existed and must also consider secondary hazards triggered due to primary events and also count the social condition and the reaction. In risk assessment and risk analysis identifying past and possible in future.

require to record the data and document it in such way that it highlights the hazard and the need of action to prevent and mitigate it. The general definition of hazard identification is as follow:

Hazard identification is the process to recognise and then recording the data of possible hazards that may or may not present currently in the region. Hazard identification are large part of disaster management. Hazard profiling is the initial step, identifying hazard in its local context which include the general description of hazard, collecting its historic background, local vulnerability, potential consequences and the likelihood damage.

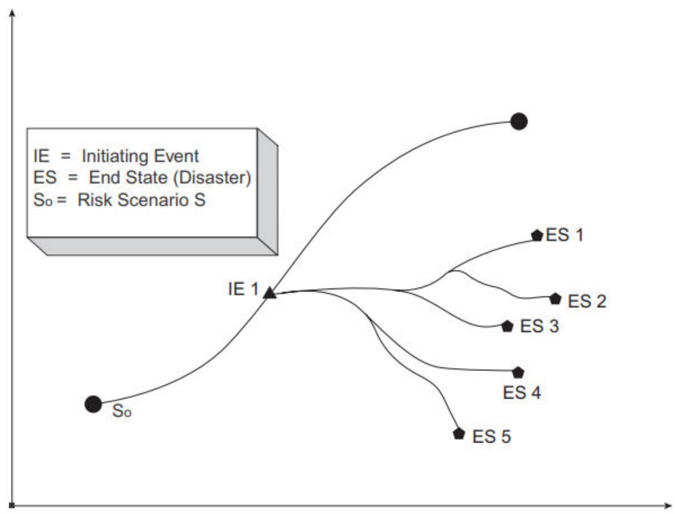
Hazard identification method can be descriptive or predictive. In both the method cost and time effective methodology is established that recognise the need and capability of people, community or organisation while performing hazard assessment.

Hazard identification include following actions: -

- *Brain storming process*: In this process disaster manger with their own knowledge and experience identify possible hazard list, this method is the most effective. the method
- include workshop, structured interviews and questionnaire. The collected data is corelated with past evidences.
- *Historical evidences:* Past records in media, archives, records in in town city data base, government records and other collective sources. Information in internet, library and also in memory with community historic records, official records maintaining hazard date, magnitude, damages are collected and consider in process of hazard assessment.
- *Analysing existing strategies and plan of action:* within government bodies contain action plans and strategies. National and local data of transportation, dams, work reports and plans are vital in assessment. Other source of information include fire, emergency management, land use plans, building codes, flood ordinance. Countries having risk reduction plan and climate change adaptation strategies are of significant insight.
- *Hazard identification in similar region:* Countries sharing similar geographical terrain, geology, climate and other similar characteristics have likelihood of sharing similar hazard profile. Countries share hazards impact even if a particular hazard doesn't fall in the jurisdiction, cases like Chernobyl represent such cases.
- *Considering maps for hazard identification of the region:* many international, non-profit organisation maintain and record hazard profile, mapping history of hazard. CRED The Centre for Research on Epidemiology of Disasters has developed such map's, United Nations are such organisation.

Secondary hazards can be identified by simple using the brainstorming process. However, hazard identification and sequencing can be achieved by performing event tree and fault tree. Event tree provide option to explore multiple outcome that might be from particular instigating event. The event tree has two methods, the first start looking at the consequences of a single hazard, then later explore the subsequent outcomes. The process is followed till all possible secondary effects have been listed. This is a scenario-based methodology.

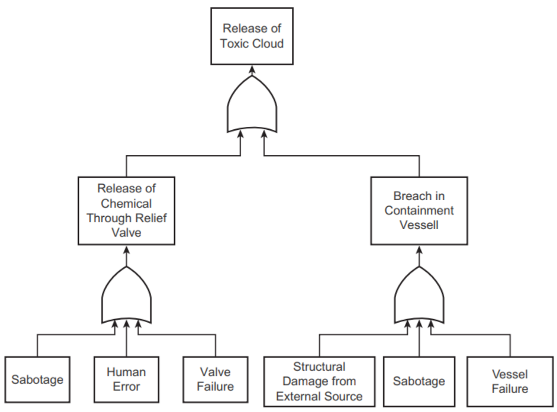
Figure 4.1 – Event tree



Source: Kaplan, 1997

Fault tree is different from event tree in that they are focused on end state or on result and its trace back the possible initiating hazard that could have triggered the consequence.

Figure 4.2: Fault tree analysis



Source: Slovic et al., 1979

Hazard Analysis or Assessment

Identifying hazard help understand possible threats it poses to the community and the potential damage. After the identification of hazard, further process needs more description for risk analysis. The descriptive process is termed as *hazard analysis or hazard profiling*, enabling more calculation of risk upon which action can be taken.

Every hazard is analysed separately considering its unique impact on each community. Each hazard calculated in different manner in respect to climate, location, topography, built environment, region, social aspect such as political, religious beliefs are other factors. Earlier Risk statements are created, identifying each hazard its cause and effect.

Risk profile is more detailed report of hazards. There are several methods to generate risk profile, which help determine appropriate mitigation and preparedness measures. Base map should have flowing aspects: - fema 1998

- Geographic aspect: This includes the topography, terrains, drainage pattern, tectonic detail and other relevant features.
- Built Environment: this includes land use pattern, building type, essential services, hazardous material and their location.
- Infrastructure: this includes rail and road network, airport, pipelines, bridges, communication facilities, school, hospitals, public buildings, among others.
- Demography: this includes population size, density, income, specially needed population, such as old people, children, pregnant women and others.
- Risk and coverage: this includes the facilities, services available, emergency services, first responders such as fire, police, doctors and other responders.

The main purpose of hazard assessment is to minimise the risk of casualty or injury. There are two type of hazard assessment:

1) Formal Hazard Assessment: This type of assessment is carried at individual level. This targets every job within the society. Every aspect of position is analysed to detailed assessment of hazards and risk. Following are the steps for formal hazard assessment which include as following:
   - Identifying each position
   - Segregating into discrete tasks
   - Assessing risk associated with each hazard
   - Suggesting mitigation measures
   - Overseeing implementation of each mitigation measures
   - Periodic evaluation of hazard, risk and mitigation measures

2) . Site Specific Hazard Assessment: This includes more localised level of assessment. The hazards are identified region wise. Such type of procedure is also known as Field level hazard assessment (FLHA). This assessment ensures the ongoing safety of the community or society. It is through these assessment disasters manger is able to identify new or unexpected hazards and needed mitigation and preparedness measures.

Hazard Mapping

According to UNDRO (United Nations Disaster Relief Co- Ordinator) define hazard mapping as a process of establishing geographical where and to what extent a particular event is likely to pose threats to individual, community, property, infrastructure and economic activities. It is a process involving identification of a hazard and displaying it spatial variation or physical condition. For example, potential earthquake, flood region, hazardous material site etc. the main objective is to provide information on the range of expected damage and possible disaster prevention actions. Disaster is unpredictable. However, preventive measurement can mitigate the disaster effect. Flood maps, landslides map, shake map are some specific types of hazard map. Hazard map can be of two types: -

1) . Resident – Educating Types: the objective of such type of map are to provide information about risk at particular area.
2) Administrative Informative Type: the main objective of this map is to inform administration, which can be used in early warning and in evacuation plan.

The probability of hazard to occur vary from place to place. The map use synthesize data on natural hazards, combining with socio economic data to facilitate analysis. This information help disaster management to process, also gapping the communication between planners and decision makers. There are two major techniques: -

1) Multi Hazard Mapping
2) Critical Facilities Mapping

1) Multiple Hazard Mapping (MHM)

Single hazard is studied, gathering its valuable information in the study area, the map appears with varying scale, coverage and other relevant detail. There is difficulty with these types of maps to use in risk analysis due to the inability to conveniently overlay them on each other for study. Different information from them can be combined in a single map to give a composite picture of magnitude, frequency and are that to be affected from a natural hazard.

Scale of map vary with uses.

- Regional scale hazard map is drawn on 1: 100,000 to 1: 250,000. they are useful during regional planning.
- In urban land use medium scale hazard map are drawn on 1: 10,000 to 1: 25,000.
- Site investigation for infrastructure projects required large scale hazard map of 1: 1,000 to 1: 5,000.

The multiple hazard map (MHM) is also termed as composite, synthesis or overlay map. These maps are great tool for awareness of natural hazards and for analysing vulnerability and risk, especially when mapping critical facilities. The first thing to consider is to plot base map of place. For best possible use, it is important to use existing map or controlled photograph, rather going through difficult and time-consuming process. The scale use to create base map depend on information to be shown. After choosing a scale following factors should be consider: -

- Number of hazards to be shown
- Hazard element to be shown
- Range of severity of hazard
- area to be covered
- proposed use of the map

Hazard maps are different from any other maps, expert of the subject can understand it. For the use of planner or decision maker translation is needed. The information must depict hazard expected effect of community, property, infrastructure, therefore must include location, likelihood of occurrence and its severity.

Despites its importance in the field of integrated development planning, planners and decision makers must consider the credibility, accuracy and content of MHM are no better than individual hazard information.

2) Critical facilities Mapping (CFM)

These maps are developed by keeping existing infrastructure in mind. “Critical Facilities” is the term defies man-made infrastructure, are assets, system and network either physical or virtual - that are essential for the proper functioning of a society’s economy, health facilities, safety, security of national level. Disruption in these essential services cause serious harm, property damage and disruption of vital services.

The main objective of critical facilities map (CFM) is to convey information to the planners and decision makers in effective and accurate manner, the location, capacity and service area of critical facilities. When combined with multi hazard map, critical hazard map can show area require more information. Also, these map help differentiate different hazard location and required risk reduction measurement, area in immediate attention when a hazardous event occur.

Some of the benefits of critical facility map are as following:

- Feature available or absence of services in the area.
- Identification of Facilities in need of upgradation and expansion.
- Assessing the impact of a potential development ton existing infrastructure.
- Hazard assessment become more apparent.

Mapping Techniques and Tools

Community Perception: the main objective is to restore local experience into simple map. Tools used in rural development activities include; **Participatory** Rural **Appraisal (PRA)** and **Rapid Rural Appraisal (RRA**). The metho is cost effective and the outcome reflect local perception of hazards.

Historic Events Documentation: Historic events, documenting these pat events and their reports provide useful information.

Scientific Research: are research from different discipline carried out with experts' team. Example; in a landslide hazard mapping expert skill from the field of geology, geomorphologist, geo – technical engineer is required.

Data collection over large area for a extensive time period is done. These types of research are usually multidisciplinary, each having sophisticated and accurate tools and techniques getting refine over time.

Geographic Information System Models: computer-based models used open access data for prediction of hazard. GIS is quipped with remote sensing data for map making.

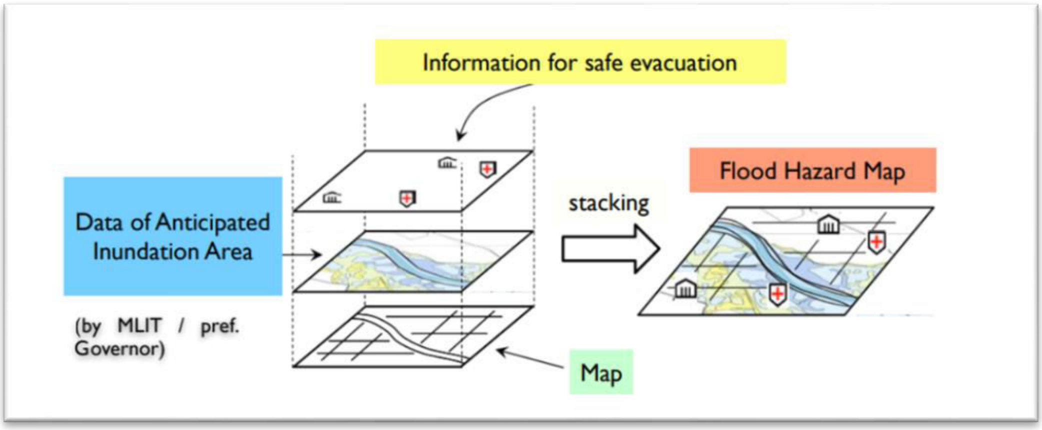
4.4 SUMMARY

Hazards are part of human history, however with the development in civilisation human induced events are equally contributing on hazard list with natural ones. Exposure to risk is the source of hazards. Worldwide these arrays of hazards which are limitless, unpredictable must be manage by assessing individual genetics, its spatial movements, habitat, activities and geographic location. Hazard primary source is the prime factor in dictating it. Factors like socio economic status, industrial development detects origin of hazard either technological or intentional or natural characteristic.

With globalization, changes in global climate pattern have intensity and magnitude of hazards. The module discusses disaster management hazard identification process, their characteristic and their analysis.

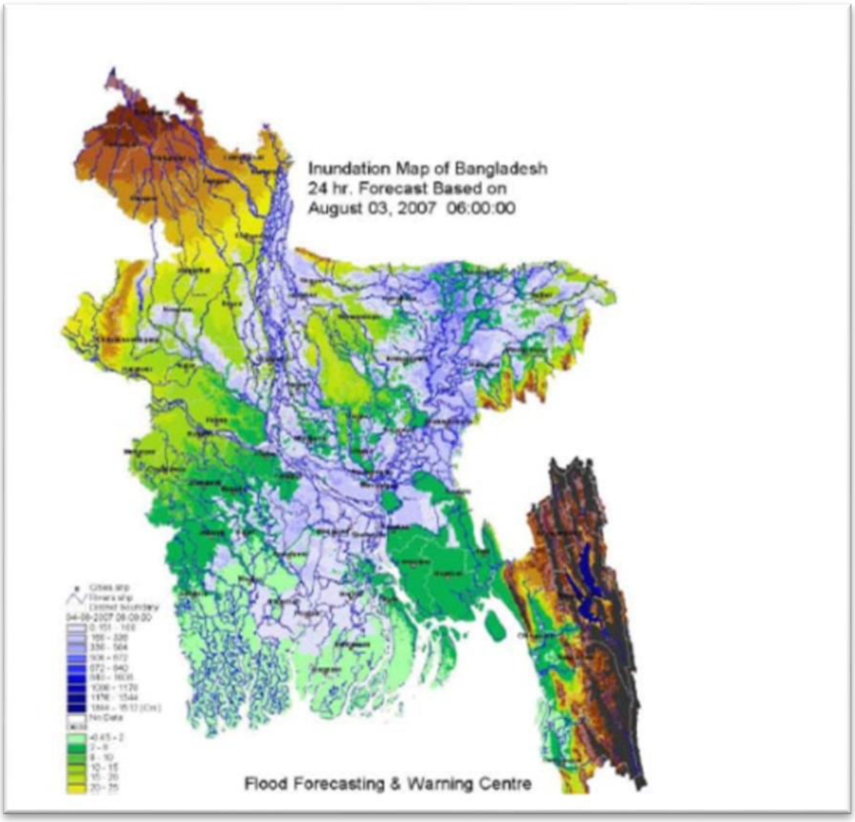
Hazard mapping is the tool to display source of potential consequence of hazard, analysis of risk zones and the expected damage of a region and its community. hazard is the element of risk. Techniques involve identification of hazards, the associated risk, factors responsible for the vulnerability. Mapping tolls involve expert advice, research, indigenous knowledge and use of latest software.

Example 01: (A). process of preparing of Flood Hazard Map



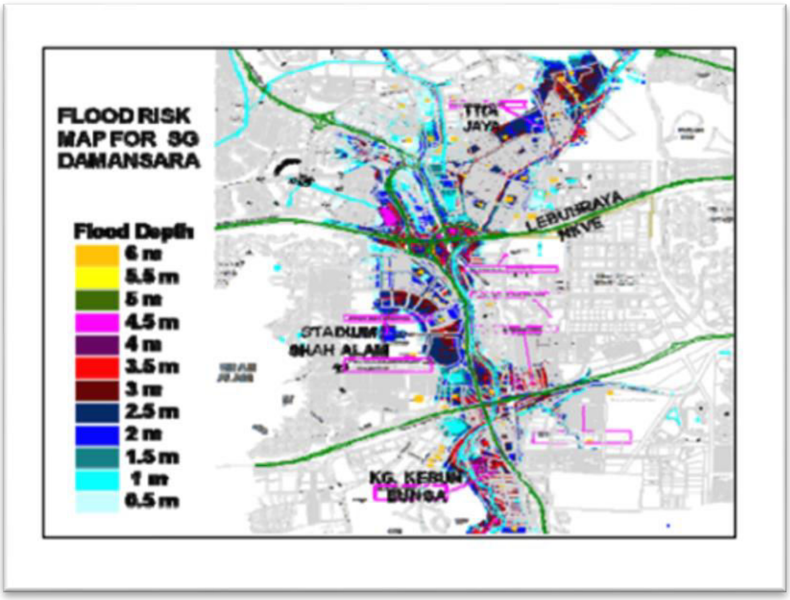
Source: Shigenobu Tanaka, 2008/ 9332_localdisastermanagementhazardmappin (1).pdf

Example02 : Map showing Flood Forecast and Early Warning Centre



Source: Shigenobu Tanaka & Daisuke Kuribayashi ,2010/Microsoft Word - 表紙4164.docx (unisdr.org)

Example3: Map showing Flood Hazard Mapping of Malaysia



Source: Shigenobu Tanaka & Daisuke Kuribayashi ,2010/

Microsoft Word - 表紙4164.docx (unisdr.org)

4.5 GLOSSARY

- Hazard- a hazard is source of potential damage, harm on individual, community, infrastructure and economy.
- Intentional hazard- it means any source of harm or damage created by deliberate action or planned course of action.
- Natural hazard- Any event that is a natural phenomenon that might have an adverse effect on human and other living beings and environment
- Disaster- Disaster are series of disruption to the functioning of a community that exceed its capacity to cope using its resources and an external assistance is need
- Rapid Rural Appraisal (RRA)- RRA is a bridge between formal survey and understanding research methods. This approach is to identify individuals in need of primary health care. This method has been used primarily in agricultural
- Rural Appraisal (PRA) Participatory- This is an approach used for communication and transfer of knowledge. This approach focuses on stimulation of participation by local people.
- Geographic Information System (GIS)- GIS is computer system that analyse and display geographical referenced information. it uses data that is attached to a unique location.
-

Multiple Hazard Mapping (MHM)

Any area having more than one hazard , this approach help assessing the vulnerability and risk the region and create hazard map. In this one map display different hazard in a single region.

Critical facilities Mapping (CFM)

This map convey clear and accurate location of critical facilities and their capacity and services available .

4.6 ANSWER TO CHECK YOUR PROGRESS

1) What is a hazard?

A. Something that can cause harm or injury to a person/people

B. A purposeful assessment of the environment

C. Something that requires control measure

D. None of the above.

(Ans a)

2) What is a Pyroclastic flow?

    A. fast-moving current of hot gas and volcanic matter

    B. A purposeful assessment of the environment

    C. Something that requires control measure

    D. None of the above

    (Ans a)

3) What is GIS

    a. A computer models
    b. Geographic Information System
    c. Geography Intellectual System

    Geological International society

    (Ans b)

4) What is FEMA

    a. Foreign Exchange Management Act
    b. Federal Emergency Management Agency
    c. Flavour And Extract Manufactures Association
    d. None of the Above

    (Ans b)

5) Geo Physical Hazards are: -

    a. Earthquake
    b. Flood
    c. Cyclone
    d. Lahar

    (Ans a)

6) Intentional Hazards are:-

    a. Civil and political riots
    b. Food security
    c. Tsunami
    d. None of the above

    (Ans a)

7) Magnitude is ………………….

    a. This is the strength of a hazard

b. Scale to measure length
c. Numerical sign to radius
d. Type of earthquake
(Ans a)

8) CRED stands for ……….
a. Credit card bill payment app
b. Centre for emergency data and services
c. The Centre for Research on Epidemiology of Disasters
d. None of the above
(Ans c)

9) Biological hazards are ……….
a. Human induced
b. Natural hazards
c. A & B Both
d. None of the above
(Ans a)

10) Identify Exposure in below mentioned sentence
a. homes built below sea level
b. high maintenance building
c. exposure to radiation
d. physically challenged people
(Ans a)

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4.8 TERMINAL QUESTIONS

1) Define Hazard and classify its various types.
2) Explain hazard mapping and its techniques.
3) What do you understand by hazard identification and clarify the characteristic of hazard.

UNIT 5 : SIGNIFICANT OF HAZARD VULNERABILITY AND RISK

5.1 OBJECTIVES

After reading this unit you should be able to:

- Introducing concept of Hazard, Vulnerability and risk
- Defining vulnerability and its types
- Developing Conceptual understanding of risk assessment
- Understanding risk perception
- Understanding concept of vulnerability components.

5.2 INTRODUCTION

Life of all form pose some kind of risk and the source of that risk range widely, wide range of hazards which are still new in nature and yet to understand. Hazards are limitless and intimidating, as a global society it is a necessity to aggregate all possible hazards. With Advance innovation and technology, we witness disaster in some part of the world. Majority of these hazards does not reflect any direct or indirect impact on human being, but they challenge the notion of disaster. Hazard is limited to geographical location, spatial movement, personal habits, activities and finances, education. A nation geographical location dictates its geological, hydrological and metrological forces that are acting and possible. Vulnerability of the nation which depends on the economic, industrial and semipolitical factors. They often result in destruction, injury and casualty, disruption of normal life also posts disaster development. They have been part of human since the dawn of our existence. Human civilization in response made attempts to decrease their vulnerability and exposure of these exposure. Disaster cannot be treated as ornament adoring our historic records rather such events are served to guide and experience. Historic events show complete annihilation of entire civilisation, epidemics and pandemics resize population concentration around the world. Bubonic plague (Black Plague) has diminished almost 50 percentage of population across Europe during fourteenth century. Historic theories evident that history's great civilization, which include Mayans (modern Guatemala, western part of Honduras and El Salavador, Yucatan peninsula part of Mexico), The Norse (Scandinavian region), the Minoans (central and eastern Crete), old Egyptian Empire were complete defeated by floods, famines, earthquakes, Tsunami and other global disasters (Fagan 1999). In eighth and ninth century widespread drought due to shift in monsoon resulting in mass crop failure and to starvation, believed to be responsible for the fall of Mayan civilization in Mexico and Tang dynasty in China. (Sheridan 2007). Disaster causes great damage and lose of human lives, habitat and livelihoods. Hazard and disaster have always been existed in natural process until human existed, so to calculate the likelihood or consequences of hazards. To qualify as hazard or disaster it need to be in action and must maintain likelihood of affecting or result in adverse impact on community. With the presence of human, follows the episodes of hazards and disasters. Historic evidence across the globe provides evidence of such disasters occurred in different part of the world in past. Historic archeologically evidences that our ancestors faced same risk that existed today.

Nature has present human kind with opportunity and risk which vary greatly. The concept of disaster was considered as “act of god”, but with growing awareness understanding it is accepted as human induced that created the condition for disaster events. There has also been a growth in understanding that *Hazards* are natural but to turn into a disaster it has to effect vulnerable society.

Various socio-economic factors increase the vulnerability and risk of livelihood of people dwelling at high-risk areas. Year 2021 show an increase in the number of disaster events and extensive economic loose, which is evident from the fact that 101.8 million people have been affected solely in the year 2021 in comparison to 193.4 million combined from 2001 to 2020.

Hazard

An event which is rare or extreme either in man-made or natural environment having adverse effect on human lives, properties to the extend causing disaster termed as **Hazard.** there has been gradual emergence of the term Hazard as threat to human kind. definition of UNISDR portray hazard as threats potential to effect human well-being, property and environment. Hazards are analysis on the basis of vulnerability.

The concept of hazard are manifestation of time and space. The impact of hazard varies with place and people. For example, young people will of be threaten by busy traffic whereas elderly and physically challenged people will find the situation hazardous. Hazard can be categories into different categories and sub categories: natural and man-made, technological hazards and intentional hazards. This category represents one of many ways hazards can be sub divided. Other classification involves more categories. Often when hazard become disaster, secondary hazards are manifested. They may be not of same category or intensity, for instance landslide led to floods or lake Tsunamis. Natural hazards are classifying under following categories: geological hazards, meteorological hazards, climatological, hydrological and biological, further can be subdivided into tectonic, mass movement, cyclones etc.

Man-made or technological hazards are inevitable result of technology and innovation. They are the consequence of failed technology and tend to less understood than their natural counterparts. As the dependency and scope of innovation in technology is rise so does the frequency of such events. the most common are related to industry, transportation, infrastructure and buildings.

This category of hazard is Intentional, which are born out of conscious behaviour and decision of people acting on anti-social and anti-national activities. These are new and emerging hazards as biological, chemical and radiological weapons. Hazard identification can be done by several methods. It can be descriptive or predictive. It is important to keep in mind that whichever method is consider it must have cost and time effective analysis to specify needs and capabilities of individual, agency or organization and society performance in an event.

The identification of hazard allows disaster mangers to identify the existing hazard. after identification description process is required called *Hazard analysis or hazard profiling*, enable to calculate risk and planning action based on assessment.

Type of hazards - Hazards can be categories based on source of origin, intensity, magnitude and many other dimensions. The most common is according to its origin. based on origin hazards can be classified as following: -

A. Natural occurring Hazards
B. Technological Hazards

For a natural event to categories as Disaster it need to interact with human population, therefore no disasters are natural. By definition any natural event when interact with humans, their built environment and cause damage will be a disaster. however, forces that bring forth these disasters are in fact natural phenomena that appear regardless of human presence. It is fact that human action accelerates the effects of these natural occurring phenomena, such as case of flooding in slope of wetlands or landslides due to removal of vegetation. Any vulnerable community that has been affected and suffer casualty or damage from a natural phenomenon are natural disasters.

The second group of hazards are the negative consequence of human conscious decision and innovation technology resulting in damage to property and destruction of life and environment. Such type of hazard ranges from chemical spills to power failure or bugs on computer programming and transportation related accidents. In terms of human history, they are relatively new in nature and little is known about their potential or likelihood consequence. There are many factors which can trigger technological hazards including natural events, which are unknown therefore they are difficult to predict. The impact region can vary from single city block to great geographical area. Technological hazards are known and unknown risk associate to technology that is chosen by the society. Between 1980 to 2006 there was high percentage of technological hazards, they outnumbered natural disaster.

VULNERABILITY

Vulnerability is the concept where two identical events in different part of world may have different consequence for instance earthquake of almost equal magnitude and intensity could cause less death in Los Angeles but higher in Gujarat, India.

The word is derived from Latin term *Vulnerabilis*, which means "to Wound", vulnerability is the scale of inclination / propensity of an individual, community, nation to incur the consequence of a disaster. the factors include Physical, social, economic and environmental. Vulnerability means a characteristic of a induvial or community in terms of their capacity to anticipate, cope, resist and recover from the impact of disaster. multiple factors are responsible to which some one's life and livelihood will be at risk.

According to United nation Office fir Disaster Risk Reduction (2007), has identify Vulnerability as "a set of conditions and attributes that is susceptible to damage of a hazard. Thus, vulnerability is defined as the magnitude of loss due to a potential threat. The community, region or individual vulnerability will be low or high depending on its geographical, social and other factors.

Centre for Environment Education (2007) define vulnerability as "a set of surrounding and procedures resulting out of physical, social and environmental factors which increase the susceptibility of a society to the impact of hazards." If vulnerability is high then bigger will be the effect.

Lewis (1999) define vulnerability "In a physical, social and natural space inhabited by individual or group and their characteristic behaviour, within which they are differentiated according to their varying (less or more) vulnerability". The characteristic is combination of various factors driven from class, gender and ethnicity. Other related terms include resilience, susceptibility, adaptability, fragility and Risk (Ben and Luce 1993).

Birkma (2007) identify Vulnerability as internal strength, this is an internal factor that potentially affect the magnitude of an event, it can also depend the vulnerability transform hazard into disaster. The manifestation of hazard which interacts with already existing vulnerabilities and scenario create multidimensional disasters. These pre-existing vulnerability of a society, group or system create disasters. Individual position in society and access to resources depends on its interaction to multiple vulnerability. These resources include social, political and economy; thus, these factors determine the susceptibility and resilience of individual. For instance, marginalised group of society are located on disaster prone region and have multiple effect of a disaster, often not recover from the adverse impact of events after many years. Such groups which are more prone to higher loss, damage and suffering in context of hazards have key characteristics which include class, caste, gender, disability, age. The concept of vulnerability is varying magnitude of vulnerability from low to high.

Livelihood is an important concept in vulnerability, this mean individual or community has an income or access to resource that can be used or exchanged to satisfy the need. Vulnerability is closely co related to socio – economic condition.

Hooke (1999) stated that population living in less access to resources are in high risk of vulnerability. Such groups "needs are not fulfilled by traditional entity or does not feel safe in using standard resources provided in pre and post disaster preparedness, relief and recovery".

Lewis (1999) define Vulnerability as "the degree of susceptibility to a natural hazard". Natural disasters like earthquake, flood or cyclone have their impact on human-built environment, the magnitude of the damage and casualty will depend on the society decision and action plan against any hazard over a time. Therefore social, political and institutional factors are the determining factors of a society susceptibility. He (Lewis) further defines vulnerability as "result of prevailing conditions within which a disaster may occur".

Cannon (1994) has classified Vulnerability into three major aspects: -

1) Livelihood Resilience – this is the degree of resilience of individual or group 's livelihood for resisting the impact of a disaster. This also include the economic resilience, its capacity to recover back.
2) Health Component - this includes individuals' strength and the operation of social measures. example; preventing medicine.
3) Degree of Preparedness – This is the protection available to an individual or group for a given hazard. People's ability to protect themselves depends on their livelihood strength.

   These three components can be summarised in following Table. Hazard impact can be seen on a person or group which could be less or greater according to these characteristics. A highly vulnerable group can be affected badly by less magnitude earthquake while less vulnerable might not get severally effected.

Table 5.1: Vulnerability and its Components

Vulnerability Type	Components	Determinants
Livelihood vulnerability	Income opportunities Livelihood type Entry qualification Assets and savings Health status	Class position Gender Ethnicity Age Action of state
Self – Protection	Social protection Hazard protection Location	Socio economic: in above mention context, technical ability or availability
Social protection	In above context Building regulation Technical interventions	Level of scientific knowledge, Level of technical practices and engineering sued by state and dominant groups

Source: Cannon (1994)

TYPE OF VULNERABILITY

According to Lewis (1999) vulnerability can be categorised into following types:

1) **Physical Vulnerability**: UNISR defined this as "another type of Vulnerability". This vulnerability is the Physical component of Individual or assets and infrastructure. This is determined by population density pattern, location of settlement, access to resources, material and design of settlement etc. For example, non-seismic resistant house located in a seismic prone zone are likely to collapse.
2) **Social Vulnerability:** This vulnerability is associated with people and community and manifestation on different caste and creed in society. The vulnerability is due to the different social groups based on age, gender, religion, ethnicity. According to UNISDR this vulnerability is the incapability of people, society and organization to encounter the impact of disaster.

3) **Economic Vulnerability** – This vulnerability is defined as the exposure of an economy of individual or community. Economic status of individual or community establish its access to available resources thus determining its vulnerability. Rich people cope up the adverse impact a disaster in comparison to poor people.
4) **Environmental Vulnerability** – is defined as a functioning of environmental exposure, sensitivity and its adaptive capacity. Environmental degradation and behaviour can contribute to disaster risk. According to UNISDR, resource depletion of natural resources is reason of environmental vulnerability.

According to Cannon 1994: A hazard need not turn to be disaster as Disaster are the impact of natural hazard and vulnerable community and environment. The table below show the relationship between Vulnerability and hazard. Hazard act as provoked mechanism to disaster, the depth and magnitude of disaster will be depending on the intensity and duration of the hazard. other factors such as social, environmental, economic and health vulnerability.

Risk

The concept of risk has been interpretated and used by various disciplines. Risk is the measurement of expected loss to human, property, disruption of economic activity happed because of a particular hazard. Therefore, combined effect of vulnerability and hazard is Risk.

The concept of risk in disaster management has various interpretations where probability of a hazard that will happen at a given time and space. According to WHO (modified in 1998) Risk is refer to potential damage or loss from a hazard to a given element of risk, over a specific time period. The word is derived from "*riscare*" meaning "run into danger". For example, a person walking on tightrope is **vulnerable** because its exposure to hazard. The **risk** is probability of falling down and getting injured. The **hazard** is falling down the rope. If suppose the rope is only 1meter high from ground then the risk is less than wire above 50 meters. In a scenario where crowd is below the rope, there might be a possibility of crowd getting injured due to walker fall, in this case the crowd and the walker both are **Vulnerable**. If tightrope walker uses a safety harness or net the injury is **mitigated** to a extend. Presence of ambulance and paramedic will reduce the damage of injury, this will be **preparedness.**

Risk Perception

Empirical research identifies the way people perceive risk, how they live with it and what measurements they take to manage it. According to Covello and Jhonson 1987 has quoted "that society select particular risk for attention and risk therefore "exaggerated or minimize according to their social, cultural and moral acceptability''. Risk is influenced by individual experience, by its memories so it has been perceived by people and it ignore the probability of the event occurrence, therefore risk is socially constructed. Risk is having been adopted by people comfort, this adjusts the riskiness in presence of safety measures, and called "Risk Thermostal" by Adams.

Different type of risk creates different action and reaction. Man-made and natural disaster both don't share same type of resentment. Man-made disaster generates high moral distress and the cost are probably perceived high because it is not necessary that people would avoid damage to other people. These modern risks are of great concern due to their potential for catastrophic effect, inequity between those who generate the risk and those who bear the consequence. Example include accidents at Chernobyl and Bhopal.

Risk Assessment

Scientific quantification of risk based on the analysis of hazard, vulnerability and capacity is called *Risk Assessment*. this process involve data gathering of different hazards, based on statistical analysis, predict the probability of hazard occurrence and their future impact. The concept to understand disaster, its cause and their impact is important to conduct risk assessment. After the assessment of vulnerability and hazard is completed following risk assessment for disaster must be evaluated.

- **Risk Assessment of Multi Hazard:** A geographical entity based on its location will have multiple hazards. It is vital to identify hazard existing in the region and its impact on present infrastructure, also on different group of people. They're coping capacity to recover from various hazards.
- **Risk Assessment on Multi Sectoral:** hazards impact various sector of the society and impact them in different range. Hazards like drought and earthquake both have different effect on building structure. Likewise, the impact of drought and earthquake on agriculture would be completely different.
- **Risk Assessment on Multi Level:** Risk assessment must be carried out at different level of wards. These levels are integrated to the district level to state level and at last to the country disaster institution.

- **Risk Assessment of Multi Stakeholders:** Involvement stakeholders on different level must be involve while assessment.
- **Risk Assessment of Multiphase:** Understanding different hazard phases that help disaster manager to mitigate the impact. Considering these phases which include response, recovery, mitigation and prevention while planning risk assessment is vital.

Types of Risk Assessment

Risk assessment to a hazard zone have to consider situation pre and post disaster. before assessing different phase developing understanding of different risk is crucial. Following section discuss different type of risk assessment:

a) **Qualitative risk assessment:** In this the risk is described in different categories from high, medium to low. These categories are based on expert judgement.

b) **Semi Quantitative Risk Assessment: T**he risk is expressed in terms of different incidents. These incidents are based on relative ranking and weights assigned by means of certain criteria.

c) Quantitative risk assessment: when risk is expressed in quotative terms. This type of assessment is systematic and formal in nature. Such assessment is approach to determine the nature and extend of risk a hazard possess also to evaluate the current situation of exposure. In disaster risk assessment identification of hazard, reviewing the technical characteristic of hazard such as its location, intensity, its frequency also analysing social, physical, environmental, health and economic dimension of risk scenario. Quantitative risk assessment includes following dimensions:

A). **Probability:** it is expressed in between 0 – 1 probability of having predefined loss.

B). Economic Dimension: expected loss and damage in quantification is expressed in monetary terms and are calculated as following:

i. Maximum probability loss - where the maximum loss possible is expected for a particular time.

ii. Average yearly loss – when losses per year is annually calculated.

iii. Loss exceedance curve- it provides representation of probability of certain level of loss exceeding in a given time period.

C). **Assessing Risk to Population**: Quantification of population at risk in an exposed environment. Population at risk can be assess as following manner:

I. Individual Risk - Identifying individual risk, in a scenario of impact.

II. Community / Society Risk: community is representation of individual; vulnerable and exposed individual extrapolate the community showing range of vulnerability.

5.3 SIGNIFICANCE OF HAZARDS VULNERABILITY AND RISK

The concept of risk has been interpreted by various disciplines and varies in different context. For instance, risk is used by insurance specialist versus stockbrokers or physician, disaster managers with their own deviation on *Risk.* It is not exceptional to use risk in a positive manner to denote as "Opportunity" (Jardine and Hrudey 1997, p. 490). Such variation may come from different regions of world.

The Arabic *risq* means "anything that has been given to you [by God] and from which you draw profit'' (Kedar 1970), possibly explaining why some may use the term in relation to fortune or opportunity. The Latin *risicum* which portrays a particular situation confronted by mariners endeavouring to circumvent t he threat postured by an obstruction reef appear to be more fitting induction for utilize in connection to catastrophe administration, where the term's implication is continuously negative.

But among the disaster manager the term holds no positive definition, for them the most common definition of *Risk* is the likelihood of an event to occur multiple times, having multiple consequence:

Risk = Likelihood × Consequence (Ansell and Wharton 1992)

In context of disaster *Risk* is measurement of anticipated loss due to a Hazard. Thus, risk is integrated consequence of hazard and vulnerability. Risk has multiple meaning in context to disaster management. It is explained as the probability of a hazard to emerge at a given time and space (WHO 1998 modified). The term also refers to the estimated loss due to a hazard and to a given element of risk, over a specific time period (Coburn et al). Therefore, Risk is a probability to estimate a potential Hazard, that can be evaluated.

Table 5.2: Relationship between Hazard, Vulnerability and Disaster

Natural Disaster	**Vulnerability** (A measure of the person or group's level of)	**Socio Economic and political factors**	**National and International Policy Economy**
Flood Cyclone Earthquake Drought Volcanic Eruption Biological Human Modification May reduce or increase impact of hazards	**Preparedness:** Self-protection + Social protection In conjunction with **Resilience :** Strength of livelihood (income & assets) Recoverability of livelihood **Health:** Social precautions Individual strength	**Class:** Income Assets holding Livelihood qualification And opportunity **Gender :** Household Security, Nutrition, Health **Ethnicity:** Income Assets Livelihood Discrimination **State :** Institutional support Training Regional bias	The manner in which surplus in generated and allocated Social power and control Civil security Demographic shifts (Growth, Migration and Urbanization) Debt crises Environmental degradation

Source; Cannon 1994

5.4 SUMMARY

Hazards are events potential to damage physically, human activities and community to a extend that cause loss of life, injury, damage to property, disruption social and economic services and environmental degradation. They can be man-made or natural. Risk assessment is the scientific quantification based on exposure, hazard, vulnerability and the coping capacity of community. There are different components of assessment to risk are Hazard : a manmade or natural event having probability or likelihood to occur and have potential adverse impact; Exposure : situation of infrastructure, community its capacity and other tangible assets located in hazard prone region; Vulnerability : assets and community inability to resist or response in an event , its most likelihood of getting damage during hazardous event. Vulnerability is the compromised or reduced capacity of an individual or community to cope with or recover from a disastrous event. Vulnerability is the susceptibility to be affected by disaster or hazard. risk is the probability of getting injured by a potential hazard at given time space. Coping to hazardous events can be challenging.

Hazard assessment is the concept to identify and ranking of hazards which potentially can affect an area. identifying chain reaction of hazards that can trigger another hazard, identifying secondary and tertiary hazards which might occur due to primary hazard and to prepare accordingly is Hazard assessment.

Vulnerability concept is a multi- layered process. The concept is highly complex and circumstantial. Vulnerability is based on socio economic condition, exposure and risk. Vulnerability is inherent condition between human and its environment, condition result due to resilience of the system, sensitive to exposure and the stress induced by hazard.

5.5 GLOSSARY

- **Hazard - A**n act or phenomena having potential to harm or produce undesirable consequences to an individual or community. They may occur from natural process and can also result due human action.
- **Emergency-** A situation caused by the impending or sudden occurrence of an event that require immediate concern.
- **Disaster-** Caused due to man-made or natural consequences, an event which have negative impact on community, good services and environment, affecting community potential to response.
- **Resilience-** The ability to cope and the capacity that disaster impact is mitigate.

- **Preparedness-** It is the measure which allow government, community, different organisations and individuals to response rapidly in a disastrous event.
- **Risk-** Risk is a concept that show an event or force posing danger to people and what they value. Risk description are typically state in term of likelihood of harm or loss due to any hazard.
- **Risk Ana lysis -** Method used to analysis to object at risk. It focusses mainly to increase the understanding of substantive qualities, likelihood and conditions of hazard or risk and finding options to manage it.
- **Risk characteristic-** This is summary of information about a hazard that focus on the needs and measurement of decision makers and of affected community.

5.6 ANSWER TO CHECK YOUR PROGRESS

1. What is the main objective of risk characterisation?

a) Estimation of the potential for adverse health or ecological effects to occur from exposure to a stressor

b) Determination of pathways

c) Estimation of exposure

d) Collection of data

(Ans – a)

2. Which of the following is not a component of risk characterisation?

a) Study of exposure duration, frequency, and magnitude

b) Study of pathways and receptors

c) Study of toxicity values

d) Chemical analysis

(Ans- d)

3. What is the final stage of risk assessment?

a) Hazard identification

b) Risk characterisation

c) Exposure assessment

d) Toxicity assessment

(Ans- b)

4. What is vulnerability measurement

a. individual protection

b. social protection

c. state protection

d. policy protection

e. Both a & b

(Ans a & b)

5. which among the following is not natural hazard

a. Landslide

b. Volcanic eruption

c. Dam failure

d. Cyclones

6. Vulnerability is classified into _______ types.

a. Two

b. Three & four

c. One

d. Six

(Ans b)

7. What is different type of hazards

a. Man made

b. Natural

c. Technological

d. Transportation hazards

e. Both a & b

(Ans a & c)

8. Risk assessment is ________ phase initiate

a. Post disaster phase

b. Pre disaster phase

c. During disaster phase

d. None of the above.

(Ans b)

9. Economic vulnerability is _________.

a. Having access to available resources.

b. Not having access to available resources.

c. Identifying available resources

d. None of the above.

(Ans b)

10. Floods are __________ induced disaster.

a. Natural

b. Technological

c. Social

d. Anthropogenic

(Ans a).

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5.8 TERMINAL QUESTIONS

1. Define Following :

a. Disaster

b. Emergency

c. Hazard

d. Vulnerability

e. Risk

2. Difference Vulnerability and Susceptibility and their relationship with community capacity.

3. What do you understand by Hazard and Define Its Type.

4. Describe Vulnerability and Its different Type.

UNIT 6 : RS AND GIS BASED GEO DATA CREATION

6.1 OBJECTIVES

After reading this unit you will be able:

1. To understand the remote sensing and GIS
2. To know about Types of Data in these Technologies
3. To describe Geo Spatial data in Hazard and Disaster.

6.2 INTRODUCTION

Data which are geographically referenced describe both the location and characteristics of spatial features on the Earth's surface. For example, to describe a tourist place, we need to refer to its location (i.e., where it is?) and its characteristics (i.e., name, classification, number of tourists visiting that location, etc.). Therefore, geoinformatics involves two components of geographic data. First component is spatial data, which relate to the geometry of spatial features, and the second component is non-spatial or attributes data, which provide information about spatial features.

Before defining 'data', it is better to give you an analogy of a field. You shouldn't have much difficulty in mentally visualising a field in reality or on a map. You will find that defining a field is not so simple. Will the definition of a field depend on the defined physical boundary or ownership or the purpose for which the land is being used? When we try to define a field, we find that there is no universally valid definition, and the definition depends on the matter which is being highlighted. 'Data' or datum in the singular is derived from Latin word, which means 'having been' or that which is 'given'. A similar concept is contained in the French translation of data as 'donnée', which also means 'given'. In other words, data are those things on which understanding and explanations are based. ***Data*** contains information which is represented in the format of digit, letter and symbol that is used to describe status, behaviour and the outcome of geographical objects. Let us put it more simply. Data are those things on which understanding, explanations and inferences are based. Let us now understand what are ***geographic, geospatial and spatial data***. The three terms are used interchangeably referring to data having a spatial component. As you know 'geographic' refers to the Earth's surface and near surface hence geographic data would refer to any data related to Earth's surface and near surface. '***Geospatial***' specifically refers to location relative to the Earth's hence, 'geospatial data' refers to any data related to any features and phenomenon related to Earth and has location as one of its attributes.

Further, it does not necessarily refer to the surface of the Earth but also above (as in weather) or below (as in ground water) the Earth. The term 'spatial' is a broad term which refers not only to the space of Earth's surface but to any space. Hence, ***'spatial data'*** may refer to any data related to any planet, cosmos and even of human body also. Thus, 'geospatial data' is a subset of 'spatial data'. The terms '***geospatial data***' and '***geographic data***' are often used interchangeably. However, 'geospatial data' is considered more precise in many contexts than 'geographic data' because it is also used in ways that do not necessarily involve a graphic representation of the information.

6.3 RS AND GIS BASED GEO DATA CREATION

REMOTE SENSING SYSTEM

Because of technical and financial limitations, there is no perfect remote-sensing system. Remote-sensing systems are typically the result of a trade-off between spatial, temporal, and radiometric resolutions. The choice of system will depend on this trade-off, the costs of purchasing and processing the historic archives, and the archives' availability.

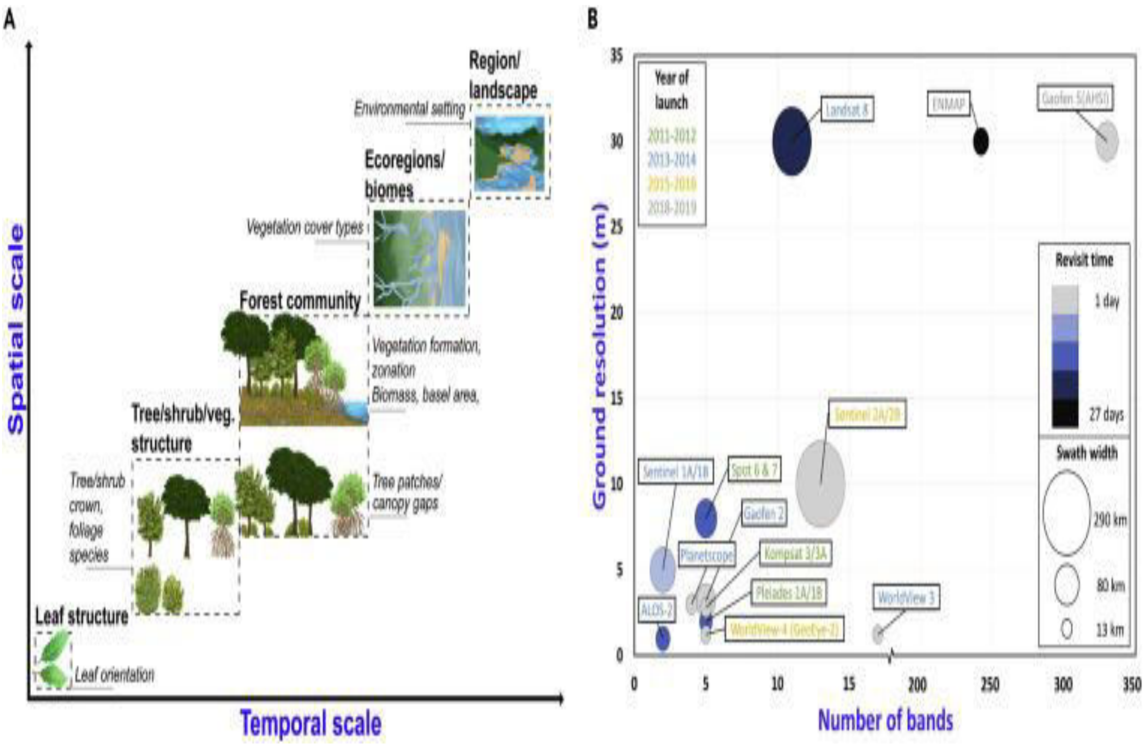


Figure 6.1. Ecological and Remote-Sensing Scales

For example, whereas purchasing a UAV system is relatively inexpensive, paying to have a team fly and then process data to create high-quality ortho-mosaics could mean that for many applications, purchasing high-resolution WorldView 3 31-cm panchromatic satellite imagery might be cheaper and produce better-quality and more consistent results. Although SAR has great promise for remote sensing in cloudy parts of the world (such as the tropics), the data can be very noisy, and for the majority of applications, if a single scene of cloud-free imagery can be acquired, the resulting outputs can be much more informative because of the greater amount of information provided by optical data.

in Figure 6.1, (Left) Spatial and temporal scales of ecological phenomenon (concept adapted from Kamal et al., 2015). (Right) Based on publicly available data, a remote-sensing sensor's spatial and temporal resolution and swath width for a sample of individual Earth observation satellites and satellite pairs (i.e., Sentinels 1A and 1B) launched after 2010. All values are for standard acquisition modes for the primary sensor (i.e., for archival purposes rather than for tasking). The spatial resolution is based on the band with the highest spatial resolution (excluding the panchromatic band). The number of bands includes the panchromatic band for multispectral sensors and the number of polarizations for SAR (ALOS-2, Sentinels 1A and 1B). Note that some remote-sensing systems, especially SAR, will have multiple modes with different resolutions that are often used when a sensor is tasked for a specific scene. The majority of satellites provide complete wall-to-wall coverage of the globe each revisit, but some primarily acquire data in tasking mode. Key decisions in the selection of remote-sensing data will be determined through matching the spatial and temporal scales of the ecological phenomenon in question with the scale of the remote-sensing system. For example, UAV data can capture millimeter-scale spatial-resolution data, but at this scale the remote-sensing image captures tree branches, ground cover through gaps in the canopies, individual leaves at different angles, and shadows. For many classification algorithms, it is better to not differentiate between the individual elements of a tree, and for many ecological applications such precision is unnecessary.

EMERGING TECHNOLOGIES AND APPROACHES

The field of remote sensing is evolving rapidly, especially because it is at the interface between engineering, computer science, geography, and various disciplines that utilize the technology to support forest ecology and management. The number, range, and performance (i.e., number of bands and spatial resolution) of platforms and sensors are increasing dramatically, and more diverse players ranging from governments to private industry are developing and operating remote-sensing systems. Earth observation systems are now being launched and operated as satellite constellations rather than single satellites, as was the case in the past. This provides greater revisit time and also supports data-fusion products (i.e., combining multispectral and SAR data) through overlapping image footprints and similar spatial resolutions. Recently, the ESA launched the Sentinel satellite constellation, which includes two multispectral satellites and two SAR satellites. The Sentinel series is expected to be joined by another ESA Earth observation satellite in 2024, the Fluorescence Explorer, to monitor chlorophyll fluorescence in terrestrial vegetation. Meanwhile, China recently launched the Gaofen (GF) series, which includes high-resolution multispectral (GF-1 and GF-2), SAR (GF-3), and hyperspectral (GF-5) remote-sensing satellites. At the other end of the spectrum, the private company Planet Labs has launched over 351 satellites, and more than 140 of these are in operation today (as of April 21, 2020). Its satellite constellation includes over 100 small (~5 kg) dove satellites that provide 3.7-m spatial-resolution imagery daily. Closer to the ground, UAV remote sensing has a significant role in providing smaller organizations and research groups with the ability to capture remote-sensing imagery at unprecedented spatial resolutions and at any time. The most common sensors used are multispectral red-green-blue (RGB) and near-infrared radiation (NIR) sensors, although there is a trend toward miniaturizing all forms of sensor technology, including LiDAR and hyperspectral sensors. The production costs are also decreasing, meaning that such technologies are likely to become much more affordable and ubiquitous. For example, the cost of an airborne LiDAR survey can be quite prohibitive, which has meant that its application has been limited and is rarely used for monitoring where frequent recapture is required, even though it is unmatched in its ability to capture the 3D structure of forest ecosystems.

In parallel with the rapid advance in sensor technology and platforms, the classification and processing of remote-sensing imagery are advancing in leaps and bounds. Techniques from computer vision, along with the use of machine-learning methods (including deep learning), are now being applied to remote sensing, and we are likely to see a dramatic transformation in the algorithms being applied, especially for specific types of applications, such feature detection. These approaches usually require high-performance computing, which is commonly provided in the cloud. Although private networks have been and continue to be developed, the freely available GEE platform has had enormous uptake in the remote-sensing community and beyond. It is a combination of image repository (it includes nearly all freely available remote-sensing imagery and products, such as surface reflectance and vegetation indices), high-performance computing, and web-based mapping application. Cloud computing has great potential for reducing remote-sensing workflows and also the ability to process data at much larger and even global extents. Using GEE computationally intensive applications, such as multitemporal mosaics (i.e., creating an image where pixels are based on the median annual value) and temporal trend analyses (e.g., analyses of disturbance and recovery with Land Trendr), is simplified. What formerly would have required huge computing resources, expertise, and a team of people can now be done on a desktop with an internet connection by a single operator.

Although processing methods and remote-sensing systems are advancing rapidly, freely available data from Landsat, the Moderate Resolution Imaging Spectroradiometer (MODIS), and the new Sentinel satellites are likely to still have critical roles in supporting forest ecology and management across the world, especially in developing nations. Most of the world's high-biodiversity and intact forests are found within the tropics in developing nations with limited budgets and technical expertise. Moreover, additional remote-sensing technical challenges are that, unlike temperate forests (which are often dominated by a single species), forests in these landscapes can be highly diverse and structurally complex and frequent cloud cover must be dealt with. However, the future is promising, remote-sensing data are coming down in price across the board, UAV technology is cheaper, there is more freely available remote-sensing data and pre-processed data products (i.e., Landsat surface reflectance products), and with platforms such as GEE, there is a reduced requirement for expensive information-technology infrastructure. These advances are resulting in a greater democratization of remote sensing to support forest management and conservation in parts of the world where environmental issues are the most pressing.

REMOTE SENSING DATA TYPE

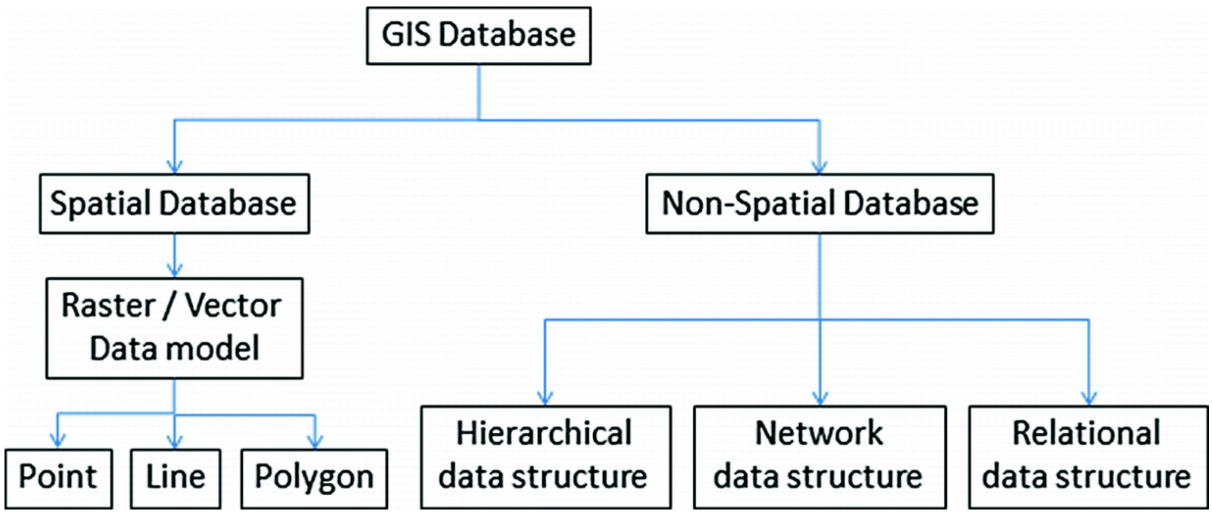
There is a fundamental dichotomy in the use of remotely sensed data between the original (or raw) data collected by the sensor and the products which are commonly extracted from these raw data. We examine each separately in the next sections. ***Raw*** Remote Sensing Data In general, remote sensing image data represent the result of a one-dimensional sampling in the time domain and a two-dimensional sampling in the spatial domain. Basic properties of a remote sensor can be summarized as (Davis and Simonett, 1991; Strahler et al., 1986): spectral coverage and resolution spectral dimensionality (i.e., number of bands) radiometric resolution (quantization) instantaneous and angular field of view (IFOV) point spread function (PSF) temporal response function We briefly discuss some of the fundamental data types which arise from remote sensing systems, from the perspective of the acquisition and recording process.

After studying about what is data and geospatial data, we will now study about types of data. Data can be broadly classified into primary and secondary data. ***Primary data*** refers to data collected by the first-hand fieldwork and survey. ***Secondary data*** are those which are found in published sources, such as official statistics and maps or derived from primary data, or are gathered by some external agency. Similarly, geospatial data can also be categorised into primary and secondary geospatial data.

- Primary data can be collected from the sources, such as from ground survey (including GPS survey), aerial photography and satellite remote sensing, etc.
- Secondary data can be acquired by converting existing maps or other documents into a suitable digital form. Data derived after some processing of primary geospatial data are also the examples of secondary geospatial data.

The geospatial data has two components based on location and its characteristics. The location (also known as geometry or shape) represents spatial component, whereas the characteristics represent the attributes or nonspatial component. Hence, the two basic data types commonly used in geoinformatics tools are:

1. Spatial Data
2. Non-spatial Data



Types of Data

There are other names of data also which are given based on their characteristics and origin such as:

- Temporal Data
- Metadata
- Measured Data
- Inferred Data
- Imported (converted) Data

These kinds of data could be either spatial or non-spatial or both.

1. **Spatial Data:** To qualify as spatial data, a data should have following characteristics:

i. it should have reference to locations on Earth's surface.
ii. it should have an explicit relationship between geometric and attribute aspects of the information represented.
iii. it should be organised in a particular theme, and
iv. it should have features, such as area, line or point.

Spatial data records the relationship among and about geographically distinguishable features. Examples include the location of a rain gauge, area submerged under flood, the route a delivery truck takes, the extent of damage from a forest fire or a tourist place. Like other kinds of data, spatial data can be categorised into primary and secondary spatial data. Representation of real-world features as discrete objects is done through two modes of data representation, which embody the linkage between the real-world domain of geographic data and computer representation of these features.

2. **Non-spatial/Attribute Data:** Non-spatial data generally records information about the objects represented as the spatial data, such as material used to construct a building, the type of rain gauge used to measure rainfall intensity, or land use. ***Non-spatial data*** also known as ***attribute (tabular) data*** are the descriptive data that are linked to spatial data as shown in Figure below Attribute data are collected and compiled for specific project work, like districts in the states, census tracts, name of cities, and so on, and often comes packaged with map data.
    - **Temporal Data:** The temporal dimension received relatively little attention during the early developmental years of GIS, as compared to the spatial component. ***Temporal data*** represents a state in time, such as the land-use, cropping, natural disaster and urban planning patterns. It could be either spatial data or non-spatial data. You can consider the example of temporal data which includes weather pattern and other environmental variables, study of demographic trends, monitoring traffic conditions, and so on. Temporal data records information about how a parameter changes over time. Most data collection activities happen over an easily quantifiable period of time, whose length may range from an hour to a year or even longer, depending upon the requirement of project work. Although in some circumstances, the duration of data collection may be only minutes or even fraction of a second. For example, automated weather stations may be synchronised to record simultaneously wind directions and other meteorological variables (temperature, humidity, etc.) at different points on or over the Earth's surface. Temporal data could be better understood while dealing with population census, which are held in most countries in the first or second year of a decade.
    - **Metadata:** ***Metadata*** are information about the data, their contents, sources, accuracy, methods of collection, and other descriptions that help ensure the data are collected appropriately. Metadata allows the transfer of important information about the data along with a data set. Information, such as the method of data acquisition, source of attributes recorded with the data, and similar details are all essential information about the data to be used in

geoinformatics. The geoinformatics community has created standards for metadata. These standards include structured fields (absolutely essential for the software to read the data) and unstructured metadata (that is designed for humans to read and evaluate the suitability of the dataset for their needs). The Federal Geographic Data Committee (FGDC) established one metadata standard called the Content Standard for Digital Geospatial Metadata (CSDGM). A similar (and mostly compatible) ISO 19115 standard for geographic information metadata is also widely used.

- **Measured Data:** The ***measured data*** is the physically collected data, such as the data collected by the surveyors determining the location of a pipeline. As long as the measurement process is well understood and thoroughly checked, this source is generally considered as the most reliable. When checking measured data, it is critical to identify all potential sources of error because something as simple as transcribing field notes incorrectly can greatly diminish the usefulness of data.
- **Inferred Data:** Data calculated from other data are known as ***inferred data***. One example would be types of crops in a given field, which are inferred from the electromagnetic radiation reflected from the field. While using inferred data, it is important to understand the source of base data underlying the inferences, as well as the model used to perform the calculations. Both factors influence the accuracy and reliability of inferred data.
- **Imported (and Converted) Data:** ***Imported data*** is also referred to as ***converted data*.** It is rare that all data used in a decision-making process come from the same source or even the same organisation. Rather, data are usually imported into or converted from disparate sources. When using such data, you must fully understand the process used to perform the conversion, the original source of the data, and the manipulation carried out on the data. Thus, metadata are critical here, because they transmit vital ancillary information with the actual data set.

SOURCES OF GEO DATA

we will discuss about different sources of geospatial data which you can acquire either on cost or for free. We will also briefly discuss about how to find data and the kind of data available at different sources. First, we will discuss about different sources of raster data, followed by the vector data.

Sources of Raster Data

Though, raster data can be obtained in a number of ways; the most common ways are by means of aerial photography and satellite remote sensing. In aerial photography, an aeroplane flies over an area, with a camera mounted underneath it. The photographs in digital format are imported into a computer and used. If the photographs are printed on hardcopy print then these are used either as such or converted into digital form (raster form) with the use of a high-quality scanner. The digital data are then imported into a computer and used.

Satellite images are recorded when satellites orbiting the Earth capture signals from earth surface features of the area they are passing over. Once the image has been recorded, it is transmitted back to Earth receiving stations, electronically. You know that this process of capturing raster data from an aeroplane or satellite is called remote sensing. Here, we shall discuss about the sources of raster data which have already been acquired and archived by data providers, and are made available for users. Satellite data providers provide satellite images in several data formats with a variety of products created. We will discuss here the commonly used raster datasets viz. remote sensing satellite data, digital elevation model data and derived raster products.

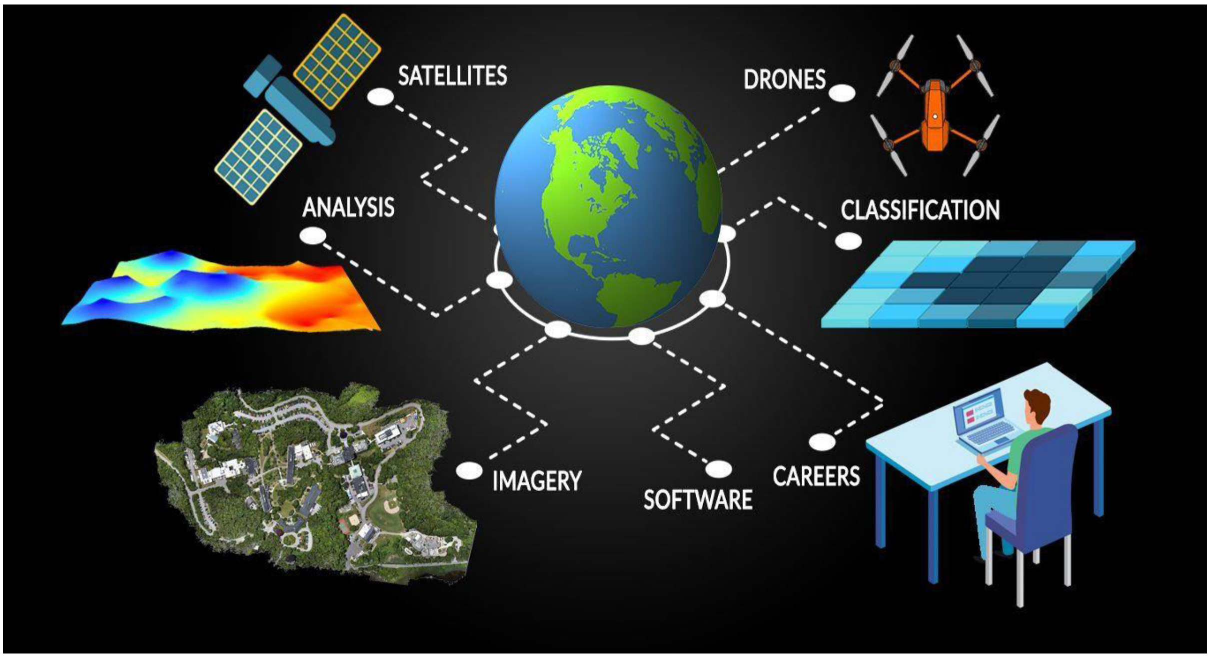


Figure 6.2: Remote Sensing Data

1. **Remote Sensing Satellite Data:** In India, user can acquire remote sensing data from National Data Centre (NDC) of National Remote Sensing Centre (NRSC), of ISRO, which is located at Hyderabad. Remote sensing data from many satellites are available at the GLCF (Global Land Cover Facility) website at http:// glcf.umiacs.umd.edu/data, as shown in Figure below. The GLCF is a center for land cover science with a focus on research using remotely sensed satellite data and products to assess land cover change from local to global scales. The archived Landsat orthorectified imagery for all the bands (ETM-PAN, TM and MSS data) is freely downloadable. These data are associated with locational accuracy of better than 50 meters. The data are useful for many of the natural resources mapping, monitoring, change detection studies, etc. Besides the Landsat data, some selected data from ASTER, IKONOS, Quickbird, Orbview, MODIS, SRTM, etc. are also available. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data are available from the Terra satellite at http://asterweb.jpl.nasa.gov. There is more than one website which is offering fully or partially downloadable ASTER data for some parts of the Earth. Some of them are mentioned below:

- www.orthocoverage.com/download.

- http://edcdaac.usgs.gov/datapool/datapool.asp.
- www.cr.usgs.gov.
- https://lpdaac.usgs.gov.

The data broadly serve three categories of users based on size of the data and objective of the study namely, Local Observations, Regional Monitoring, and Global Mapping. The remote sensing data could also be obtained from the Google Earth and ISRO Bhuvan about which we shall discuss in the following paragraphs.

I. Google Earth: You might be using Google Earth, which has a large number of images and other geographic information (Figure). The free Google Earth basic program consists of thousands of satellite/aerial photographs that are updated periodically. The increasing popular program allows users to view their homes or any other area of interest around the world in a matter of seconds. According to the type of information it provides, we can put the Google Earth under category of hybrid database provider, because, in addition to image canvas, vector database comprising administrative/political boundaries, important place names, image scale, acquisition date, tourist places, and other information are available. Google Earth has QuickBird images to its browser covering important places, like cities, airports, industrial and others. Viewers can browse their area of interest and fly through at variable angles, altitudes, scales and information. Geographic coordinates could be derived for any place. Navigation tools are provided for pan, zoom, visualise and fly through. By paying nominal price, the user can download QuickBird images from the server.

Figure 6.3: Google Earth

II. **Bhuvan:** It is a geoportal of Indian Space Research Organisation (ISRO) showcasing Indian imaging capabilities in multi-sensor, multi-platform and multi-temporal domain (Figure). This Earth browser gives a gateway to explore and discover virtual Earth in 3D space with specific emphasis on Indian regions. Bhuvan on its portal provides a range of services enabling visualization of various thematic data generated from different national missions and projects carried out by NRSC (National Remote Sensing Centre), Hyderabad. You will study the services provided by Bhuvan in the following paragraphs, which include land, weather, ocean and disaster services.

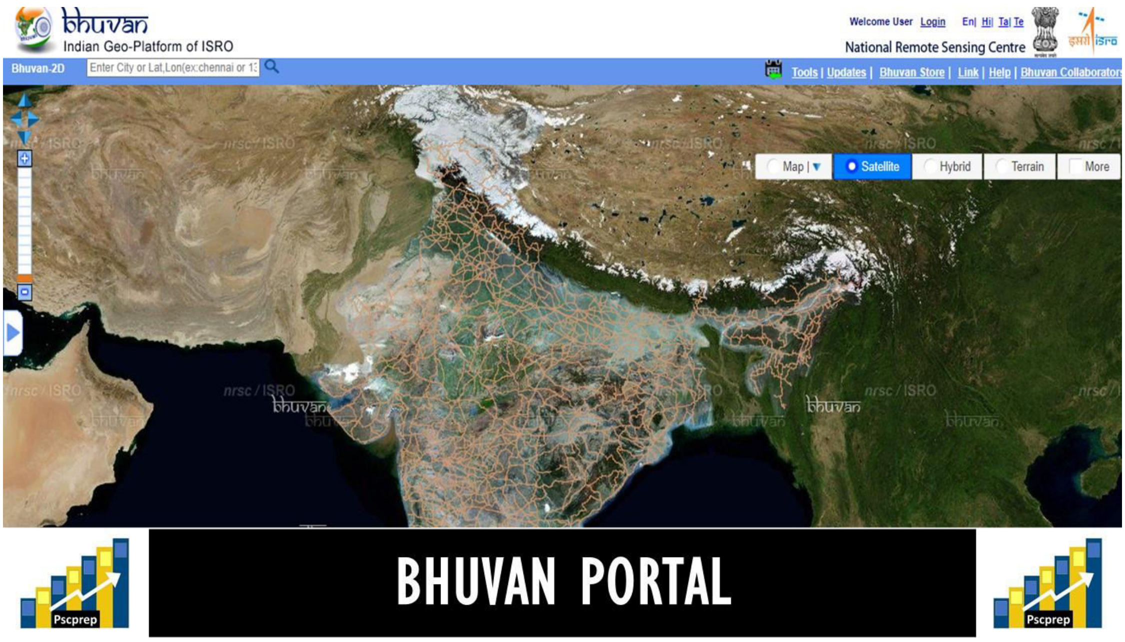


Figure 6.4: Bhuvan Portal

a) **Land Services:** Through this service, Bhuvan lets users visualise thematic information which are critical for developmental activities. The 'Land services' link provides information on a variety of themes such as:

- groundwater potential zones and groundwater recharge areas
- land use/ land cover
- crop assessment and crop production forecasts
- watershed development
- national, state and district level wastelands information.

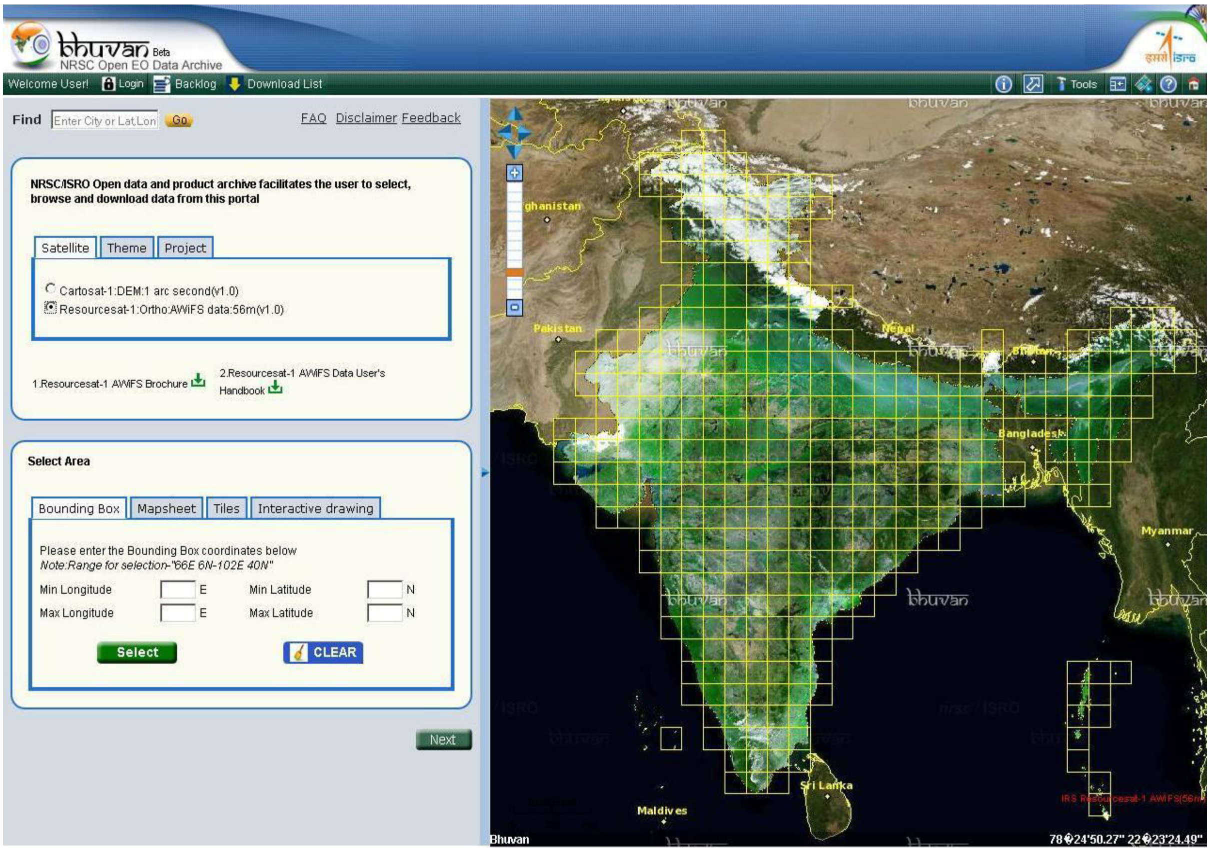


Figure 6.5: Land Services in Bhuvan Portal

b) **Weather Services:** One of the key elements for improved weather forecast and services is observation. Augmentation of the current observation network is essential for providing weather and related information at local level. ISRO's programs on Disaster Management Support and Village Resource Centre (VRC) have weather information as a critical component. Several major user agencies in the country such as Indian Meteorological Department (IMD), Snow and Avalanche Study Establishment (SASE), Central Water Commission (CWC), State Agricultural Departments / Universities require automated systems for weather data collection from remote and inaccessible areas. Automatic Weather Station (AWS) transmits meteorological data every hour from remote stations installed in the foot print of INSAT / KALPANA satellite. On Bhuvan, this service gives information on latitude, longitude, temperature, pressure, wind, and humidity of the chosen location.

Ocean Services: The data showcased on Bhuvan about the Potential Fishing Zones (PFZ) contain information about distance, direction, and depth of the potential fishing zones.

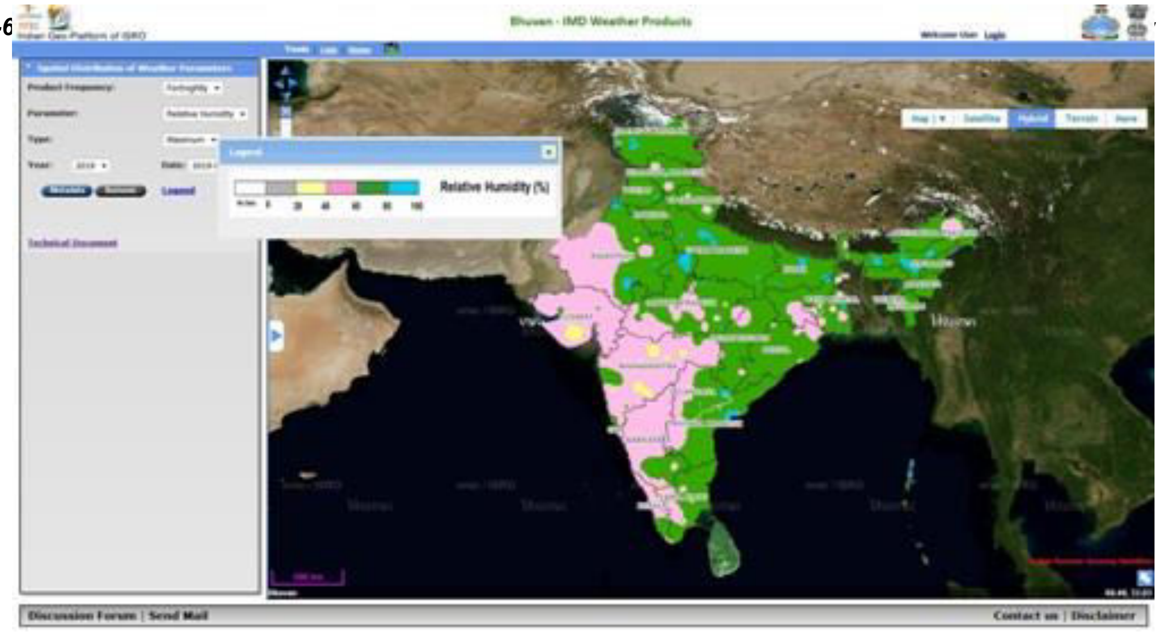


Figure 6.6: Weather-related data and services on Bhuvan Portal

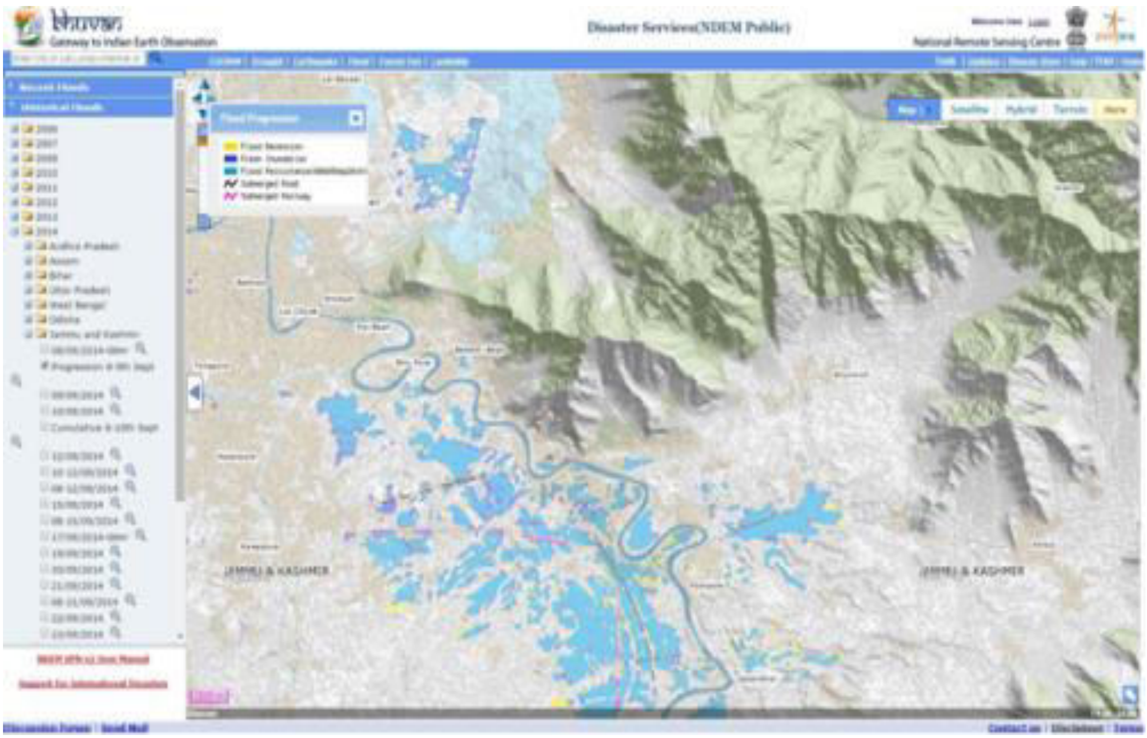
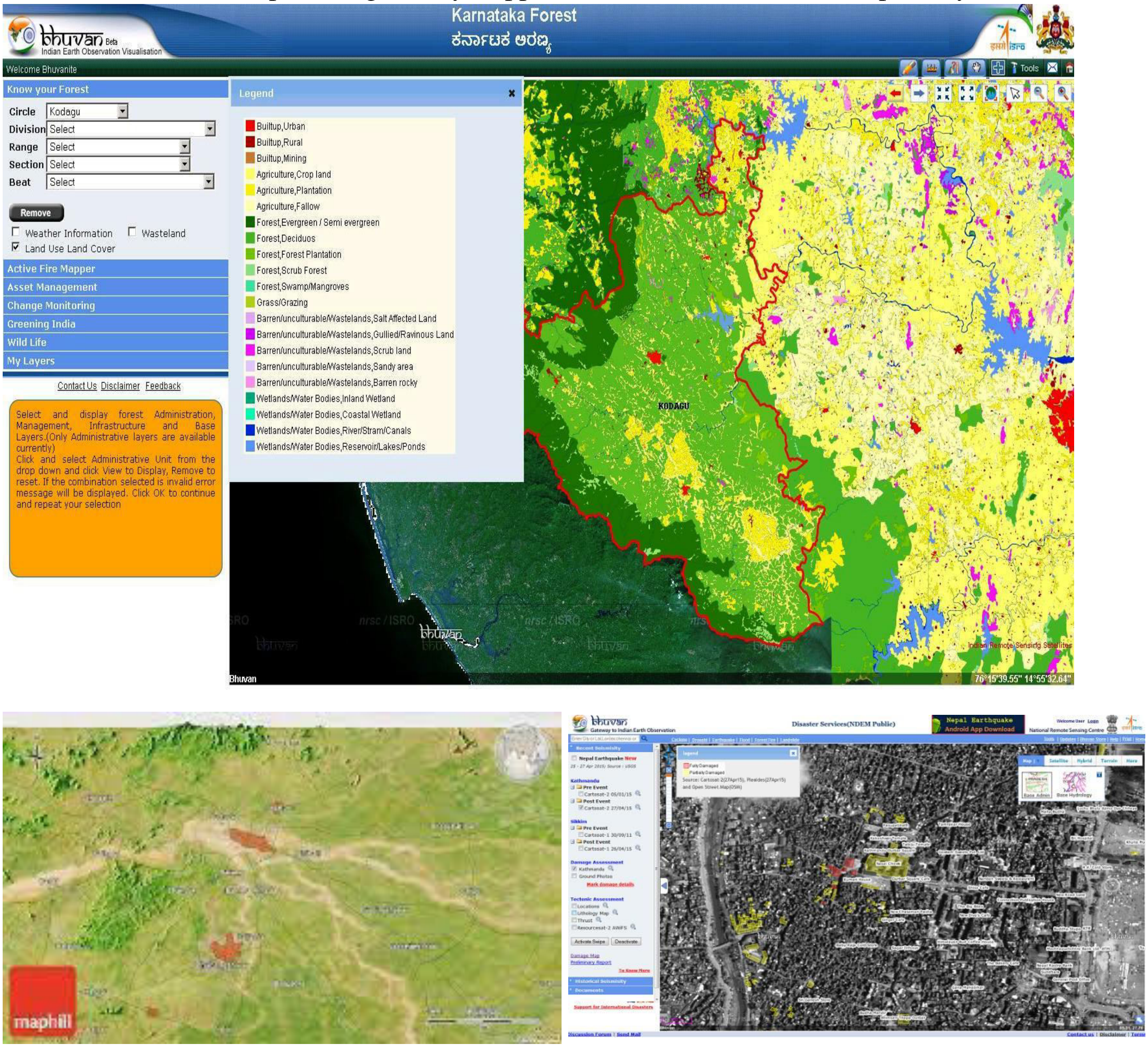


Figure 6.7: Elevation data and services on Bhuvan Portal

Disaster Services: The Disaster Management Support (DMS) program of ISRO, commits to providing timely support and services from aero-space systems, both



imaging and communications, for strengthening the resolves of disaster management in the country. These include creation of digital data base for facilitating hazard zonation, damage assessment, etc., monitoring of major natural disasters using satellite and aerial data, development of appropriate techniques and tools for decision support, establishing satellite based reliable communication network, deployment of

Figure 6.8: Bhuvan Portal Sources for Disaster related information and Data

emergency communication equipments and research and development work towards early warning of disasters.

III. **Space Shuttle Images:** A good collection of digital astronaut photographs are available at the website of the Johnson Space Centre, USA (Figure). The site hosts digital data of the entire world taken during different space missions, and hence provides data of different time scales. However, the digital astronaut images require some processing before these can actually be used by the users. The website provides links to different webpages wherein users can search data their interest.

IV. Digital Elevation Model: Following Digital Elevation Model data can be obtained by users for their work:

- Shuttle Radar Topographic Mission (SRTM) DEM Data
- ASTER DEM
- GTOPO30
- ETOPO5 5-minute gridded elevation data
- HYDRO1k
- ETOPO2 2-Minute Gridded Global Relief Data
- Land topography
- Gridded Global Topography
- Terraserver, etc.

a) **Shuttle Radar Topographic Mission (SRTM) DEM Data:** The SRTM is a joint project between the National Imagery and Mapping Agency (NIMA) and the National Aeronautics and Space Administration (NASA). The objective of this project is to produce digital topographic data for the Earth’s surface (between 60ºN & 56°S latitudes), with data points located every 1-arc-second (approximately 30 m) on a latitude/ longitude grid. The absolute vertical accuracy of the elevation data is 16m. The data can be tailored to meet the needs of the military, civil, and scientific user communities. Other uses of the data include drainage modeling, realistic flight simulators, and site suitability for cell phone tower locations, navigation safety, improved mapping tasks, flood control, soil conservation, reforestation, volcano monitoring, earthquake research, and glacier movement monitoring. The data could be downloaded freely from http://srtm.usgs.gov.

b) **ASTER DEM:** Land Processes Distributed Active Archive Centre (LPDAAC) offers ASTER image data DEM products (Fig.). The 30m DEM product is available in GeoTiff format via the FTP (File Transfer Protocal) mode from https://wist.echo.nasa.gov/wist-bin/api/ims.cgi?mode=MAINSRCH&JS=1 or www.gdem.aster.ersdac.or.jp/index.jsp.

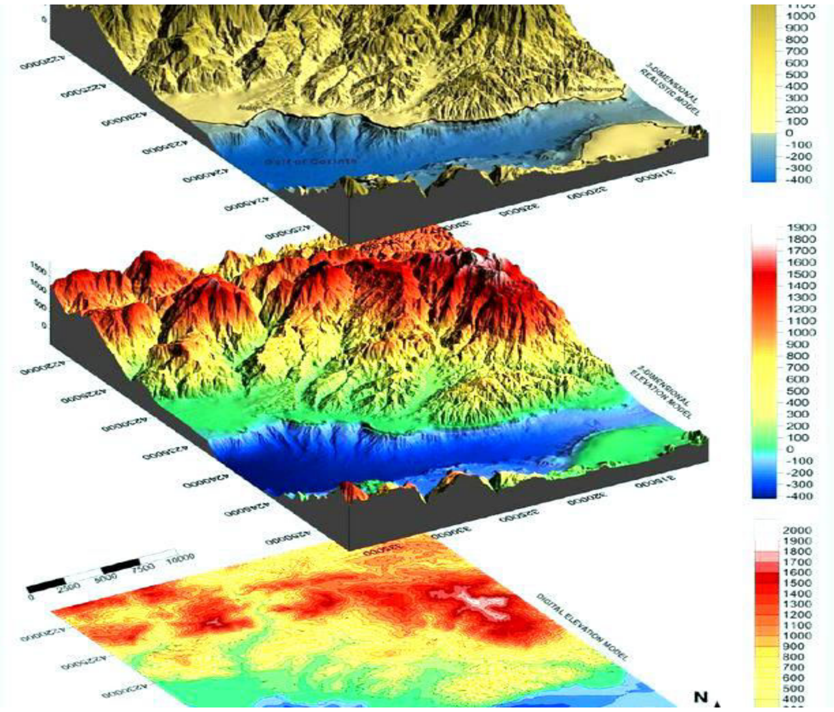


Figure 6.9: Digital Elevation Model

c) **GTOPO30:** It is a global DEM with horizontal grid spacing of 30-arc seconds (approx 1 km). GTOPO30 was derived from several raster and vector sources of topographic information. GTOPO30 project was completed in 1996 and developed over a 3-year period through a collaborative effort led by staff at the USGS's Earth Resources Observation and Science (EROS) Centre. The DEM data is available for download from the website http://eros.usgs.gov/#/ Find_Data/Products_and_Data_Available/gtopo30_info.

d) **HYDRO1k:** It is a geographic database developed to provide comprehensive and consistent global coverage of topographically derived data sets, including streams, drainage basins and ancillary layers derived from the USGS' 30 arc-second DEM of the world GTOPO30. HYDRO1k provides a suite of georeferenced data sets, both raster and vector, which will be of value for all users who need to organise, evaluate, or process hydrologic information on a continental scale. Its main goal is to provide to users, on a continent-by-continent basis, hydrologically corrected DEMs with ancillary data sets for use in continental and regional scale modeling and analyses. The data can be downloaded from http:// eros.usgs.gov/#/Find_Data/Products_and_Data_ Available/HYDRO1K. The major applications of GTOPO30 and HYDRO1K are:
   - Terrain Visualisation
   - Hydrologic Modeling
   - Geological Applications
   - Viewsheds Signal Propagation
   - Remote Sensing Data Processing, etc.

e) **ETOPO2 2-Minute Gridded Global Relief Data***:* Newly created global elevation database gridded at 2-minute (lat-long) resolution is available at http://www.ngdc.noaa.gov/mgg/global/etopo2.html. The GEODAS data access system allows searching, extraction, display, and reformatting of the data. Color shaded relief images derived from the data displayed as 64, 512, and 1350-pixel squares representing 45° square areas.

f) **Land Topography:** It is from the GLOBE project, an internationally designed, developed, and independently peer reviewed global digital DEM, at a latitude-longitude grid spacing of 30 arc-seconds. It is part of focus on the International Geosphere- Biosphere Programme and its data and information system.

g) **Gridded Global Topography:** The Global Land One-kilometer Base Elevation (GLOBE) project is a 30-arc-second (1-km) gridded, quality controlled global DEM. Global Relief: ETOPO2 supersedes Terrain Base and ETOPO5 were produced at an 8 km nominal grid (5' resolution). ETOPO2 contains more detailed 2' gridded data, which can be downloaded from www.ngdc.noaa.gov/mgg/topo/topo.html.

h) **Terra Server:** TerraServer.com was founded with the purpose of finding a commercial market for satellite imagery and aerial images. The company procured a series of high-resolution satellite images for some specific areas. It became the first to release these images to the general public on April 17, 2000 and major internet provider (www.terraserver.com). User may view and buy images and many different stock image products available. Through partnerships with many leading imagery providers, it has assembled the largest variety of aerial and satellite imagery on the internet.

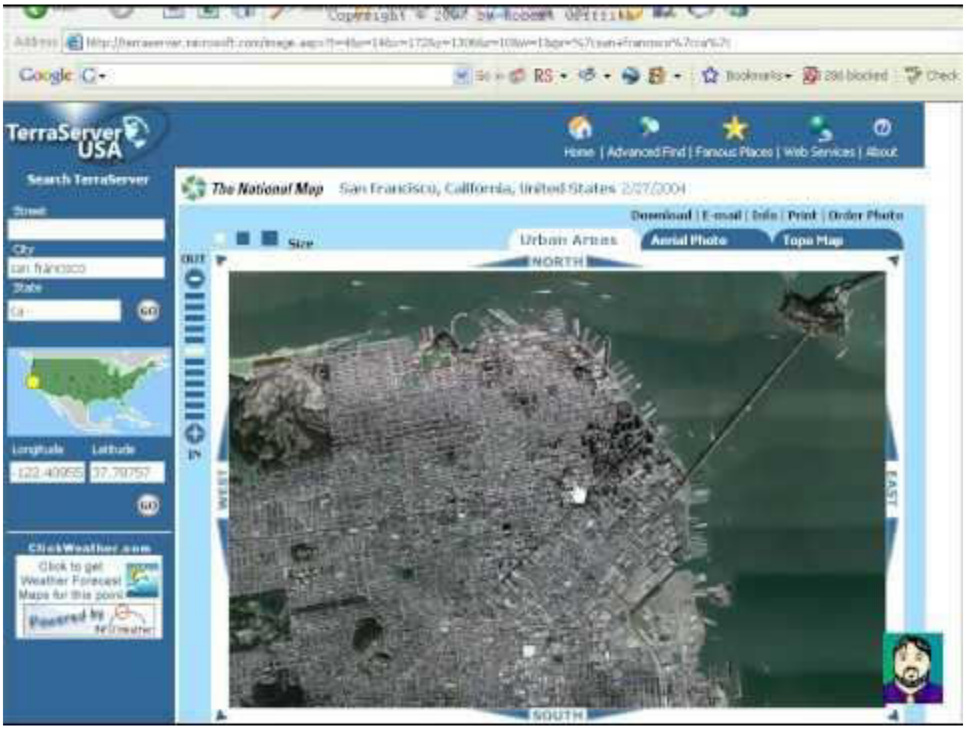


Figure 6.10: Terra Server Portal

i) **Derived Raster Products**: Some of the commonly used derived raster products include the followings: land use/landcover maps, normalised Difference Vegetation Index (NDVI) maps, SPOT vegetation data, biodiversity hotspot maps, coral Reef hotspot maps. The GLCF and NOAA websites also host several raster products, as shown in Figure.

Sources of Vector Data

There are many sources of vector data from where we can obtain vector data either at some cost or freely. However, you need to be sure and careful while using these maps with regard to their appropriateness and accuracy. The Digital Chart of the World (DCW) is an Environmental Systems Research Institute Inc. (ESRI) product, originally developed for the US Defense Mapping Agency (DMA). It is a vector cartographic dataset based at 1:1,000,000-scale Operational Navigation Chart (ONC) series, which is the largest scale basemap source with global coverage. The stock of Omni resources comprising international topographic maps at all scales is one of the largest of any map dealer worldwide. All worldwide topographic maps at 1:250,000 are available. It also stocks most of the topographic maps available worldwide at 1:50,000 scale, especially Europe, Central America & South America. Topographic maps at 1:25,000 scale for selected countries, like U.K, France, Switzerland, Belgium, U.S and other parts of the world are also available. Besides, topographic maps at 1:25,000 scale for many major cities worldwide are available. In India, there are several data centres from where one can procure data.

The Survey of India (SOI), Dehradun supplies topographic products (on both hardcopy and digital form) to its users at 1:25,000; 1:50,000 and 1:250,000 scales. The various types of maps published and distributed by SOI are given on http://www.surveyofindia.gov.in/maps.html. National Atlas and Thematic Mapping Organisation (NATMO) is a premier national thematic maps and atlas-making organisation, under the Union Ministry of Science & Technology, which publishes several maps and atlases at small scales (http://natmo.gov.in/). Geological Survey of India (GSI) is one of the oldest survey organisations in the world and a premier organisation of Earth science studies. It is custodian of geoscientific database developed over 150 years. The main products of GSI constitute different memoirs, records, journals, bulletins, different thematic maps and atlases, and geological mapping on 1:50,000 scale for entire India. Reconnaitary survey covers 97% of Exclusive Economic Zone (2.02 million sq.km) (www.gsi.gov.in/page2.htm). Airborne geophysical survey covers 2.07 million sq.km in geologically critical areas at 1: 25,000 scale mapping (www.gsi.gov.in/page2.htm)**.** National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), a national soil survey organisation with its headquarters at the Indian Agricultural Research Institute (IARI) and four Regional Centres at Bangalore, Delhi, Kolkata and Nagpur has published maps on salt-affected soils of India; soil and land use maps for districts/village level and research bulletins on geomorphology, soils and land use (http://nbsslup.nic.in/home1.htm).

Sources of Metadata

Metadata sources include dataset from Landscan and Census India. The Land Scan dataset comprises of a worldwide population database compiled on a 30" × 30" lat/long grid. Census counts (sub-national level) were apportioned to each grid cell based on likelihood coefficients, which are based on proximity to roads, slope, land cover, night time lights and other information. LandScan has been developed as part of the Oak Ridge National Laboratory (ORNL) Global Population Project for estimating ambient population at risk. The LandScan dataset files are available via the internet in ESRI grid/raster binary formats by continents and world (www.ornl.gov/sci/ land scan/index.html). The Indian census is the largest single source of statistics on the people of India. With a history of more than 125 years, this reliable, time-tested exercise has been bringing out a veritable wealth of statistics every 10 years beginning from 1872 when the first census was conducted in India, non-synchronously in different parts. For scholars/researchers in demography, economics, anthropology, sociology, statistics and many other disciplines, the Indian census is a fascinating data source. The rich diversity of the people of India is truly reflected through the decennial census, which is one of the basic tools to understand and study India. It provides information on demography, socioeconomics, population, sex, literacy, fertility/death rates, workers, nonworkers, etc., at state and district levels. Some of the information is available at www.censusindia.net.

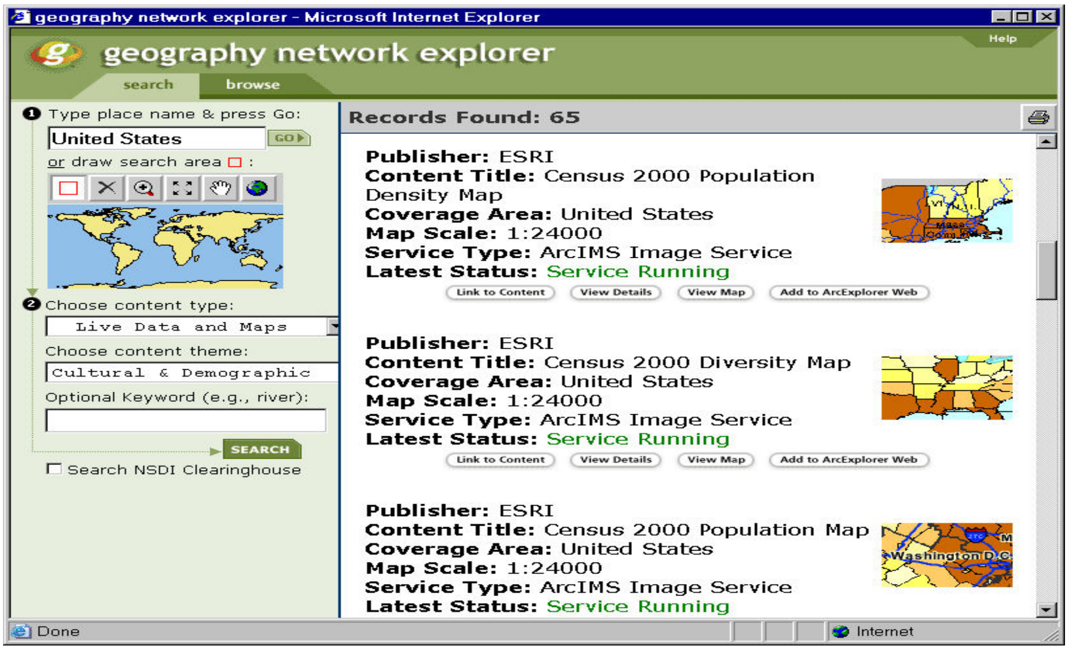


Figure 6.11: Meta Data

DATA PRODUCTS AVAILABLE BASED ON AREA COVERAGE

You will find main types of remote sensing data products based on area of coverage, as given in Table.

Table 6.1: Main Types of Remote Sensing Data Products

No	Types of Remote Sensing Products	Sensors/Satellites
1	Full Scenes-all bands	PAN from LISS-III & LISS-IV; AWIFS; TM; MLA; PLA; WIFS; OCM; MSMR; MODIS
2	Full Scenes-specified bands (3 bands for FCC products)	LISS-III, LISS-II, LISS-I, TM,
3	Full Scenes with Shift-Along Track	PAN & WIFS from LISS-III; AWIFS from LISS-IV; OCM;
4	Quadrants	LISS-III, TM, OCM
5	Geocoded Mapsheet based (15'x 15')	LISS-III, LISS-II, TM, MLA, PLA
6	Geocoded Floating (15'x 15')	LISS-III
7	Geocoded (7½'x7½') mapsheet/floating	LISS-III, LISS-IV
8	Full pass/strip data of one array	PAN, OCM, MODIS

PRODUCT CODE

In view of the large number of remote sensing data products, NRSC has prepared a unique product code in short form that fully describes and takes care of all the specifications of a desired product. If this code is mentioned in the order/indent form, it is easy for NRSC to supply the correct/desired data. The product code has nine characters. Table shows details about the product types and codes.

Product Name	Spatial Resolution	Data Availability	Sensor Used	Reference
Climate Change Initiative (CCI) LandCover V2	300 m	1992 to 2015–2016–2017–2018	MERIS Full and Reduced resolution/Spot VGT	[114]
MCD12Q1 0.5 km MODIS-based Global LandCover	500 m	2001–today	MODIS	[115]
Globeland30	30 m	2000/2010	Landsat TM, ETM7, HJ-1A/b	[116]
GLC 2000	1 km	2000	SPOT 4 VEGETATION	[117]
GlobCover 2005 V2.2 2009	300 m	2005/2009	MERIS FR	[118]
GLCNMO V.1-V.2-V3	1 km/500 m	2003/2008/2013	MODIS	[119]
GLC Share	1 km	2014	MERIS-MODIS	[120]
GLC250 m CN (2001/2010)	250 m	2001/2010	MODIS	[121]
FROM-GLC (GLC, GLC-seg, GLC-agg, GC, GLC-hierarchy)	30 m	2010	Landsat TM, ETM+	[122]
Global 30m Landsat Tree Canopy (TCC) V.4	30 m	2000, 2005, 2010, and 2015	MODIS, Landsat TM, ETM+	[123]
Global Forest Change (GFC) - GLAD (Global Land Analysis & Discovery) lab at the University of Maryland (UMD)	30 m	2000 to 2019	Landsat TM, ETM+, OLI	[80]
Copernicus Global 100 m Landcover (CGLS-LC100)	100 m	2015	PROBA-V EO and GSD	[124]
ESA-S2-LC20, 20 m (over Africa)	20 m	2016	Sentinel-2A	[125]

Table 6.2: The Product Type and Product Code

Product Type (First two characters)	
ST	Standard Product
QU	Quadrant Product
G3	Geocoded product (15'x15' of SOI map sheet)
G4	Geocoded product(7 ½'x7 ½' of SOI mapsheet)
SR	Stereo pair product
TR	Shift-Along Track product
J1	Geocoded product (1 deg.x1deg. without SOI reference)
J3	Geocoded product (15'x15' without SOI reference)
J4	Geocoded product (7 ½'x7 ½' without SOI reference)
MO	Full strip/full path
Projection Applied (Third character) Data supported include	
EV	Everest
W4	WGS -84
Resampling used (Fourth character)	
0	No sampling done
C	Cubic convolution
N	Nearest neighbour
Enhancement (Fifth and sixth character)	
00	Enhancement (mostly applicable for digital)
01	Histogram Look Table (Scene based enhancement)
YE	Yellow substance (RS-P4 OCM only)
CL	Chlorophyll map (IRS-P4 OCM only)
SE	Sediment map (IRS-P4 OCM only)
Format (Eighth character)	
5	False color composite paper print
6	Digital data on LGSOWG/Super Structured, Band interleaved (BIL)
7	Digital data on LGSOWG/Super Structured format, Band Sequential (BSQ)
B	Fast format
T	GeoTIFF (grey)
R	GeoTIFF (RGB)
H	HDF
Size capacity (Ninth character)	
5	1000 mm (only for photographic products)
J	650 MB CD-ROM
V	DVD

6.4 SUMMARY

You have learnt the following in this unit:

- There are basically two types of geospatial data, i.e., raster and vector.
- Examples of raster data type include satellite imagery, scanned photographs/maps, orthophoto and Digital Elevation Model (DEM), whereas example of vector data type include digital line graphs.
- Sources of raster, vector and metadata include various mapping agencies, internet resources and other sources from where you can either just visualise or download data and derived products with or without any cost.

6.5 GLOSSARY

- Raster Data- is any pixelated data where each pixel is associated with a specific geographical location.
- Vector Data- is represented as a collection of simple geometric objects such as points, lines, polygons.
- DEM- Digital Elevation Model
- NRSC- National Remote Sensing Centre

6.6 ANSWER TO CHECK YOUR PROGRESS

1. Give some names of Indian Agencies providing vector data.
2. From where you can precure remote sensing data.

6.7 REFERENCES

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6.8 TERMINAL QUESTIONS

1. Name some internet sources from where you can obtain raster and vector data.
2. What are the services and data provided by the Indian Portal Bhuvan related to disaster?
3. Mention the advantage of Google Earth.
4. What are primary and secondary geospatial data?

BLOCK 3 : APPLICATIONS OF GEO-INFORMATICS IN TOWN PLANNING

UNIT 7 : CONCEPT OF TOWN PLANNING, TOWN LAND USE PLANNING AND CLASSIFICATION SYSTEMS, TOWN RESOURCES INFORMATION AND INFRASTRUCTURES

7.1 OBJECTIVES

After reading this unit you should be able:

1. To understand Town Planning.
2. To explore land use and landcover mapping and planning using remote sensing and GIS.
3. To discover and map town infrastructure of cities.

7.2 INTRODUCTION

The majority of the world's population now resides in urban environments and information on the internal composition and dynamics of these environments is essential to enable maintenance of certain standards of living. The availability of urban land cover data is critical to policy makers, particularly for town planners, because of their ability to monitor impact of planning policies, the direction of urban growth and the development progress. Urban land cover in large urban centre including metropolitan areas continually changes over time and space, and local government must be able to update their database to reflect current land use. However, conventional methods of obtaining urban land cover data require a great deal of time, effort and money to meet fast growing cities. Remote sensing can provide an important source of data for urban land use/land cover mapping and environmental monitoring (Patkar, 2003). Urban land cover/use mapping has received an increasing amount of attention from urban planners and scientists including geographers. Numbers of significant studies were made for environmental quality management. Thus, various techniques have been applied for mapping urban land use/land cover. It helps in encroaching urban problems even of very small magnitude and dire. Planning is a widely accepted way to handle complex problems of resource allocation and decision-making. It involves use of collective intelligence and foresight to chart direction, order harmony and make progress in public activities relating to human environment and overall development. In order to provide more effective and meaningful direction for better planning and development necessary support of the organization has become essential. Hence the need for a suitable information system is increasingly being felt in all planning and developmental activities, whether these are for urban or rural areas. Urban areas of today are more exactly described as sprawling regions that become interconnected in a dendritic fashion (Carlson and Arthur, 2000). The positive aspects of urbanization have often been overshadowed by deterioration in the physical environment and quality of life caused by the widening gap between supply and demand for basic services and infrastructure. Urbanization is inevitable, when pressure on land is high, agriculture incomes is low and population increases are excessive, as is the case of most developing countries of the world. Urbanization has been both one of the principal manifestations as well as an engine of change. The 21st century is the century of urban transition for human society. In a way urbanization is desirable for human development. However, uncontrolled urbanization has been responsible for several problems, our cities facing today, resulting in substandard living environment, acute problems of drinking water, noise and air pollution, disposal of waste, traffic congestion etc. To minimize these environmental degradations in and around cities, the technological development in related fields have to address to these problems caused by rapid urbanization, only then the fruits of development will percolate to the most deprived ones. The modern technology of remote sensing which includes both aerial as well as satellite-based systems, allow us to collect physical data rather easily, with speed and on repetitive basis, and together with GIS helps us to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process. These information systems also offer interpretation of physical data with other socio-economic data, and thereby providing an important linkage in the total planning process and making it more effective and meaningful. Therefore, it is essential to know intensively about the characteristics and capabilities of these remote sensing data products available to the urban and regional planners.

7.3 CONCEPT OF TOWN PLANNING, TOWN LAND USE PLANNING AND CLASSIFICATION SYSTEMS, TOWN RESOURCES INFORMATION AND INFRASTRUCTURES

GEOINFORMATICS AND URBAN STUDIES

In India, the complexity of urban development is so dramatic that it demands immediate attention and perspective physical planning of the cities and towns (Sokhi and Rashid, 1999). The dynamic nature of urban environmental necessitates both macro and micro level analysis. Therefore, it is necessary for policy makers to integrate remote sensing with urban planning and management. Traditional approaches and technique designed for towns and cities may prove to be inadequate tools when dealing with metropolis. New approaches are required, and new methods must be incorporated into current practice. Until recently, maps and land survey records from 1960 to 70 were used for urban studies, but now the trend has shifted to use digital, multispectral images acquired by EOS and other sensors. The trend towards using remotely sensed data in urban studies began with first-generation satellite sensors such as Landsat MSS and was given impetus by a number of second-generation satellites: Landsat TM, ETM+ and SPOT. The recent advent of a third generation of very high spatial resolution (5m/pixel) satellite sensors is stimulating. The high-resolution PAN and LISS III merged data may be used together effectively for urban applications. Data from IRS P-6 satellites with sensors on board especially LISS IV Mono and Multispectral (MX) with 5.8 m/pixel spatial resolution is very useful for intensive urban studies.

Advancement in technology of remote sensing has brought miracle in the availability of the higher resolution satellite imageries. They are IRS-P6 Resourcesat imagery with 5.8 m resolution in multispectral mode, IRS-1D Pan image with 5.8 m resolution, Cartosat-I imagery of 2.5 m resolution with stereo capabilities, Cartosat-II with 1 m, IKONOS imageries of Space Imaging with 4 m in multispectral mode and 1 m in panchromatic mode, Quickbird imagery of Digital Globe with 61 cm resolution in panchromatic mode and so on. These high resolutions of the sensors provide a new methodology in the application with newly raised technical restrictions. Apart from cartographic applications, IRS-1D LISS IV (P-6) data will be of great use in cadastral mapping and updating terrain visualization, generation of a national topographic database, utilities planning and other GIS applications needed for urban areas. The satellite will provide cadastral level information up to a 1:5,000 scale, and will be useful for making 2-5 m contour map (NRSA, 2005). The output of a remote sensing system is usually an image representing the scene being observed. Many further steps of digital image processing and modeling are required in order to extract relevant information from the image. Suitable techniques are to be adopted for a given theme, depending on the requirement of the specific problem. Since remote sensing may not provide all the information needed for a full-fledged assessment, many other spatial attributes from various sources are needed to be integrated with remote sensing data. This integration of spatial data and their combined analysis is performed through GIS technique. It is a computer assisted system for capture, storage, retrieval, analysis and display of spatial data and nonspatial attribute data. The data can be derived from alternative sources such as survey data, geographical/topographical/aerial maps or archived data. Data can be in the form of locational data (such as latitudes/longitudes) or tabular (attribute) data. GIS techniques are playing significant role in facilitating integration of multi-layer spatial information with statistical attribute data to arrive at alternate developmental scenarios.

Remote sensing has become an important tool applicable to developing and understanding the global, physical processes affecting the earth. Recent development in the use of satellite data is to take advantage of increasing amounts of geographical data available in conjunction with GIS to assist in interpretation. GIS is an integrated system of computer hardware and software capable of capturing, storing, retrieving, manipulating, analyzing, and displaying geographically referenced (spatial) information for the purpose of aiding development-oriented management and decision-making processes. Remote sensing and GIS have covered wide range of applications in the fields of agriculture, environments, and integrated eco-environment assessment. Several researchers have focused on LU/LC studies because of their adverse effects on ecology of the area and vegetation.

India is very much dependent on photogrammetry for providing information for urban planning purposes. But since March 17, 1988 with the launch of its first satellite (IRS-1A) equipped with LISS-I sensor acquiring 72.5 m/pixel data, the application of remotely sensed data (from various sensors) in urban and regional planning processes has gained momentum. LISS-I gathered data in four spectral bands (0.45 µm - 0.86 µm) was mainly used for broad land use, land cover, and urban sprawl mapping. The IRS-1C and 1D satellites launched in 2003, carrying LISS-III and LISS-IV sensor with spatial resolutions of 23.5 m/pixel and 5.8 m/pixel using Landsat MSS optical bands (0.52 µm0.86 µm), have contributed to the effectiveness of urban planning and management. Early experiments with the first-generation satellites found the data very useful for mapping large urban parcels and urban extensions. The development of Landsat TM data with 30 m/pixel spatial resolution has helped in mapping Level-II urban land use classes. Some of the salient features of different satellite sensors and the extractable levels of urban information are summarized in Table 7.1. Cities and towns in India exhibit complex land use patterns, with the size of urban parcels varying frequently within very short distance. The extraction of urban information from remotely sensed data therefore requires higher spatial resolution.

LANDUSE/COVER MAPPING

Although the terms land cover and land use are often used interchangeably, their actual meanings are quite distinct. Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating and mapping land cover is important for global monitoring studies, resource management, and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps. Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current quantity of land is in what type of use and to identify the land use changes from year to year. This knowledge will help develop strategies to balance conservation, conflicting uses, and developmental pressures. Issues driving land use studies include the removal or disturbance of productive land, urban encroachment, and depletion of forests. It is important to distinguish this difference between land cover and land use, and the information that can be ascertained from each. The properties measured with remote sensing techniques relate to land cover, from which land use can be inferred, particularly with ancillary data or a priori knowledge. Land cover / use studies are multidisciplinary in nature, and thus the participants involved in such work are numerous and varied, ranging from international wildlife and conservation foundations, to government researchers, and forestry companies. In addition to facilitating sustainable management of the land, land cover and use information may be used for planning, monitoring, and evaluation of development, industrial activity, or reclamation. Detection of long-term changes in land cover may reveal a response to a shift in local or regional climatic conditions, the basis of terrestrial global monitoring.

Land use applications of remote sensing include the following:

- natural resource management
- wildlife habitat protection
- baseline mapping for GIS input
- urban expansion / encroachment
- routing and logistics planning for seismic / exploration / resource extraction activities
- damage delineation (tornadoes, flooding, volcanic, seismic, fire)
- legal boundaries for tax and property evaluation
- target detection - identification of landing strips, roads, clearings, bridges, land/water interface

As the Earth's population increases and national economies continue to move away from agriculture-based systems, cities will grow and spread. The urban sprawl often infringes upon viable agricultural or productive forest land, neither of which can resist or deflect the overwhelming momentum of urbanization. City growth is an indicator of industrialization (development) and generally has a negative impact on the environmental health of a region. The change in land use from rural to urban is monitored to estimate populations, predict and plan direction of urban sprawl for developers, and monitor adjacent environmentally sensitive areas or hazards. Temporary refugee settlements and tent cities can be monitored and population amounts and densities estimated. Analyzing agricultural vs. urban land use is important for ensuring that development does not encroach on valuable agricultural land, and to likewise ensure that agriculture is occurring on the most appropriate land and will not degrade due to improper adjacent development or infrastructure.

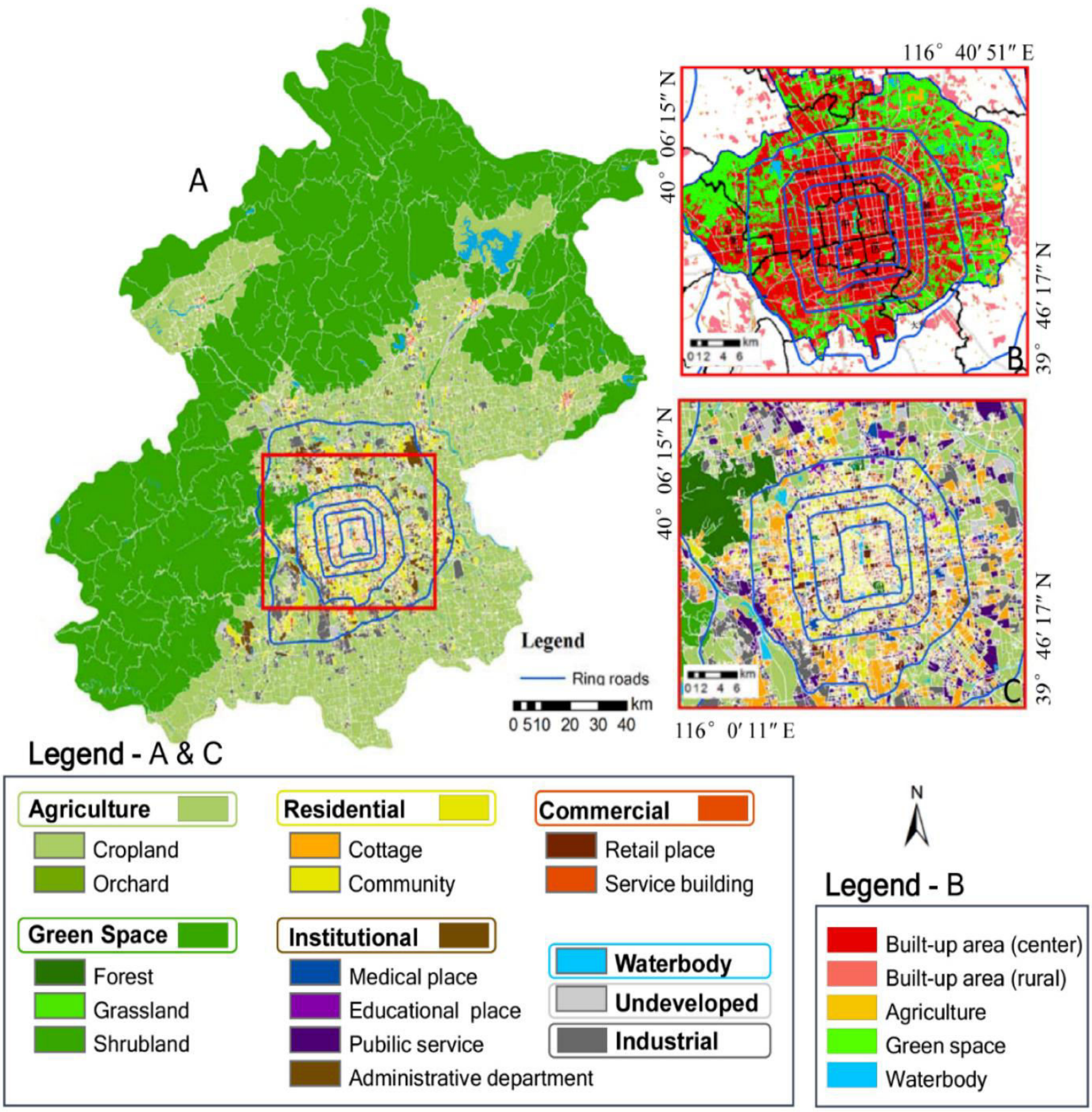


Figure 7.1: Mapping Town Land Use using Remote Sensing Data

With multi-temporal analyses, remote sensing gives a unique perspective of how cities evolve. The key element for mapping rural to urban land-use change is the ability to discriminate between rural uses (farming, pasture forests) and urban use (residential, commercial, recreational). Remote sensing methods can be employed to classify types of land use in a practical, economical and repetitive fashion, over large areas. Requirements for rural / urban change detection and mapping applications are 1) high resolution to obtain detailed information, and 2) multispectral optical data to make fine distinction among various land use classes. Sensors operating in the visible and infrared portion of the spectrum are the most useful data sources for land use analysis. While many urban features can be detected on radar and other imagery (usually because of high reflectivity), VIR data at high resolution permits fine distinction among more subtle land cover/use classes. This would permit a confident identification of the urban fringe and the transition to rural land usage. Optical imagery acquired during winter months is also useful for roughly delineating urban areas vs. non-urban. Cities appear in dramatic contrast to smooth textured snow-covered fields.

URBAN/TOWN LANDUSE DELINIATION

For most purposes, there is need to arrange detailed observations into groups, using some classification process. There is not a single ideal classification of land use and land cover. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. The following urban issues are analyzed by using this technology:

1. **Urban Land Use Inventory:** It is quite natural that population growth increases the pressure on the land, and the non-urban land is converted into urban areas. Population growth and city expansion ultimately influence the land use pattern of any urban center. Knowledge of the patterns and intensity of land use is relevant in urban planning, but the preparation of a land use inventory by conventional method is expensive and time consuming. The advantage of satellite imagery interpretation in

terms of accuracy, timeliness and cost is indisputable in comparison to conventional methods.

2. **Study of Urban Sprawl and Growth Trends:** Since satellite based remote sensing systems have unique capability to provide repetitive coverage for any pay of the world this makes it most suitable for monitoring and updating of urban expansion by using very high-resolution multi-temporal remote sensing data especially for town and country planning.
3. **Space Use in the Core Area:** From the monitoring point of view of city area, information about land use only may not be sufficient for city administrators and planners in congested core areas. The true picture may only be visualized from available information on actual space use. Space, however defined, has a location, and data necessarily refer to a point in time. In the absence of suitable large-scale maps for such detailed studies, the principal use of very high resolution IKONOS satellite data provide a base for the survey/ recording of various activities in the field. The rest were confirmed/ picked up during the field visit. Quantitative determination of space use allows in understanding the distribution pattern of various activities and functional characteristics within urban fabric, which is useful for quantifying the stress on existing infrastructure.
4. **Travel Route Pattern:** Physical infrastructure of an urban center comprises of transportation, water supply, electric power supply, sewage etc. The transportation system is one of the keys to rapid modernization, particularly in developing countries. Irrespective of whether roads act as a catalyst for development or play a more passive role in development, it is necessary to work out a judicious plan so as to avoid congestion, pollution and cost. The main objective of this type of studies using Remote Sensing and GIS techniques is to make network analysis of tourist places considering two factors: time and cost. This type of study provides a methodology for analyzing the optimum transportation network of tourist cities, and can be very helpful when planning for other cities also.

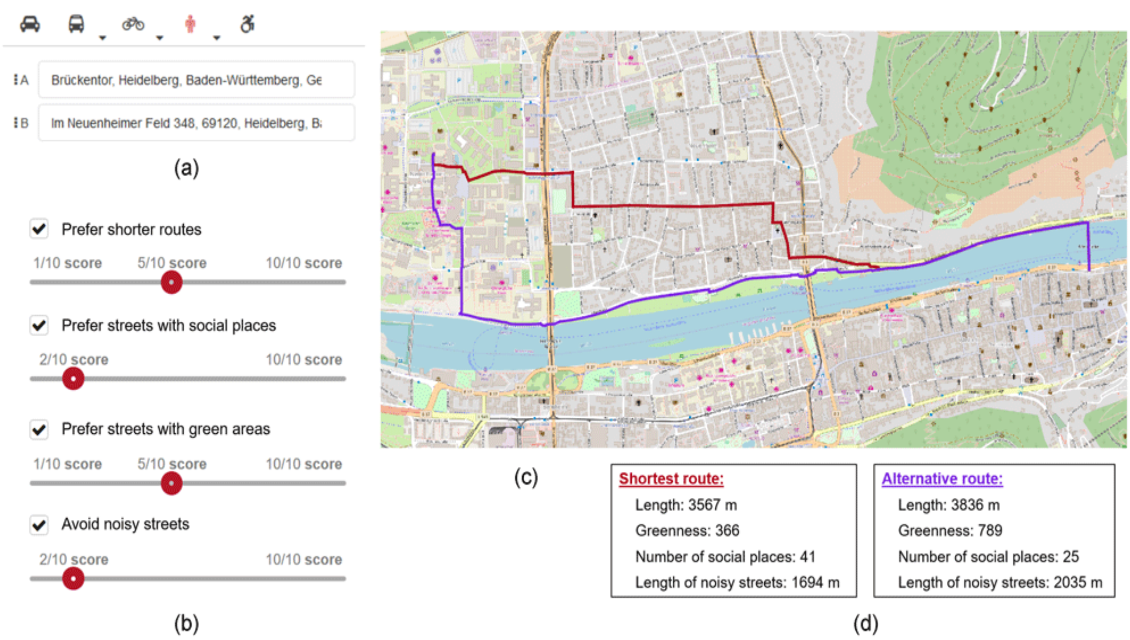
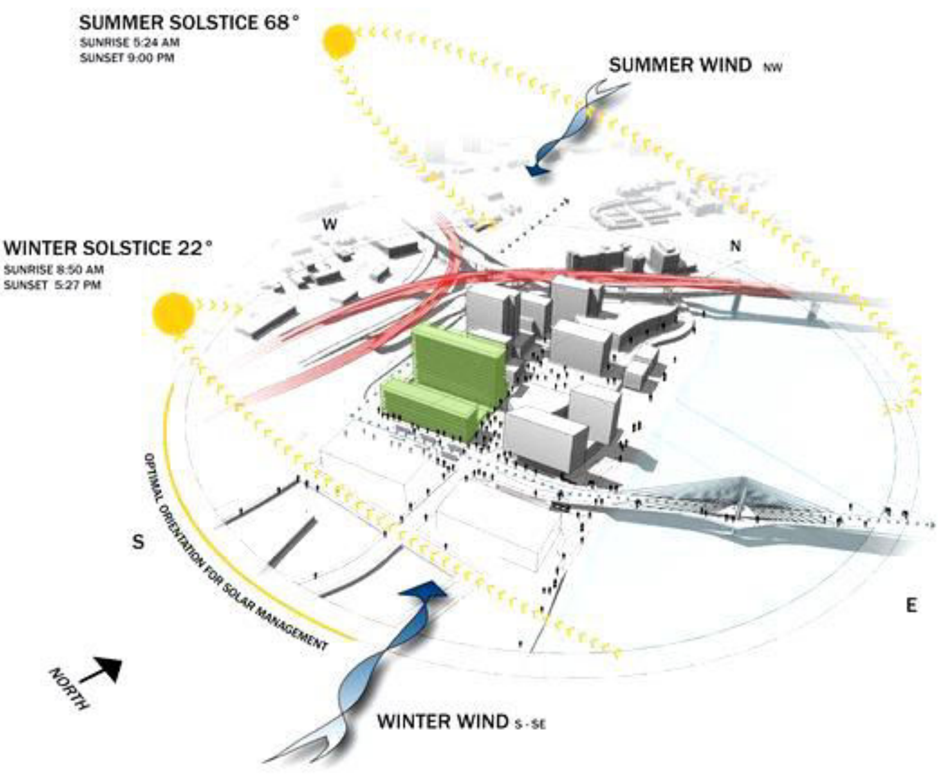


Figure 7.2: Travel Route Finding and Pleasant Route-Finding Using GIS

5. **Urban Environment Analysis:** Green spaces in cities exist mainly as semi-natural areas, managed parks and gardens, supplemented by scattered vegetated pockets associated with roads and incidental locations. Embodying the garden city concept advocated by Ebenezer Howard (1898) and the large urban park idea expounded by Frederick Law Olmsted in the US (Wilson, 1989), public green spaces have been increasingly designated in cities since the 1880s to counteract environmental impacts of urban expansion and intensification. Plants notably trees, have a wide range of environmental benefits, and urban green spaces often accommodate varied assemblages of flora and small animals, providing readily accessible site with natural ingredients. The role of remote sensing in the case of green / open spaces mapping



and analysis has become important for managing, and maintenance of old and degraded spaces. However, in a number of cases remote sensing can supplement or partially replace tedious ground survey methods. Moreover, ground methods have limitations as whole area may not be accessed in one go and information collected may not be as accurate as possible through remote sensing, aided by limited ground survey. Remote sensing not only provides spatial data but also allows us to compare temporal variations in spatial data, which is essential for green/open spaces management.

Figure 7.3: Urban Environmental Analysis using Geospatial Technologies

6. **Site Suitability Analysis:** A number of workers have identified various criteria including soils, hydrology, topography, vegetation, climate, existing built-up areas, transportation route etc. to find out suitable sites for location of development activities. The most commonly technique for suitability analysis is weighted suitability method. Weighted suitability is more complex; in order not to bias the weighting the aspect scales should first be normalized that is used in the same numerical range. The frequently used scale is in a 1-5 range: 5. Very good (much more than average) 4. Fairly good (more than average) 3. Good (average) 2. Fairly bad (less than average) 1. Very bad (much less than average) Such a scale can

accommodate qualitative and quantitative data, but the scoring of quantitative data to such a scale needs qualified professionals. The next step is assigning the weight factors. This is, of course, the critical element in this approach. Weight factors are often based on a mixture of implicit knowledge, personal experience and individual values that is usually called "professional judgment".

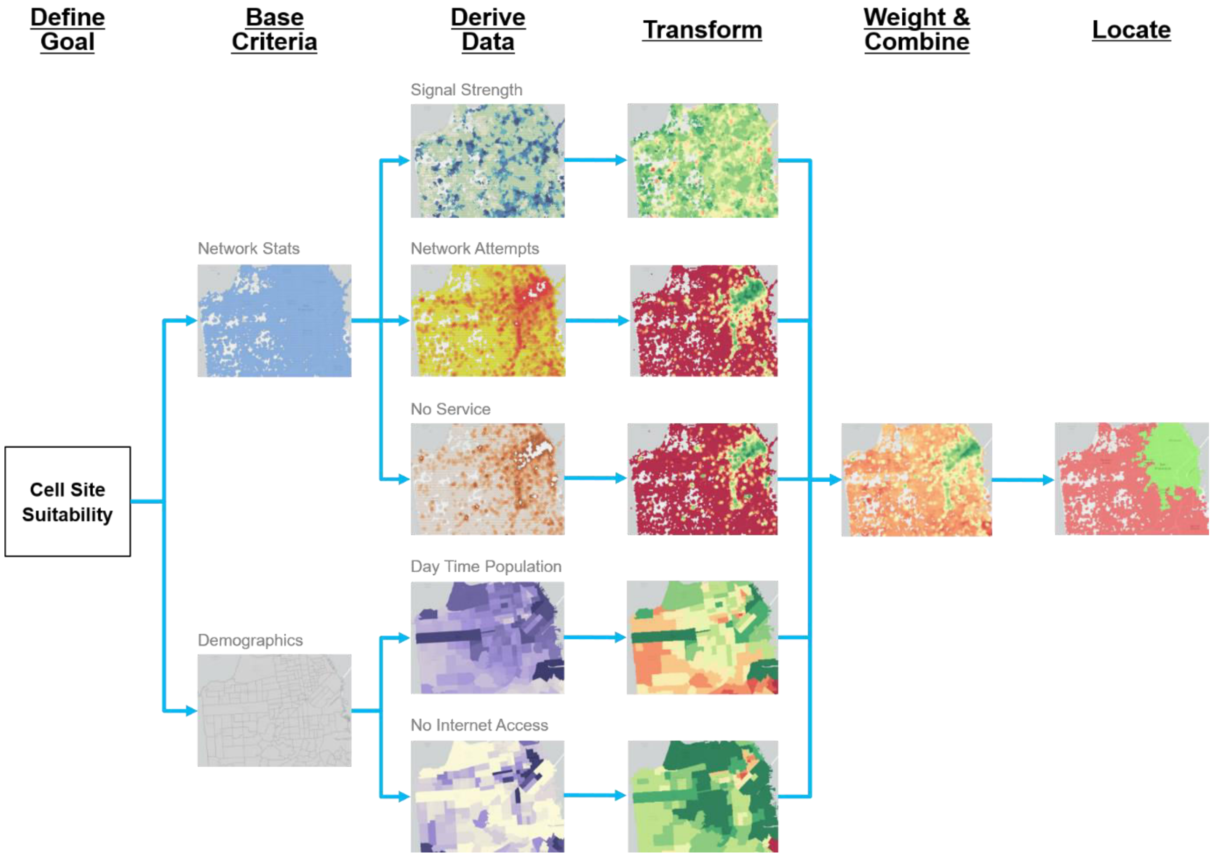


Figure 7.4: Site Suitability Analysis

7. **Social Infrastructure:** In most Indian cities, the municipal bodies have primary responsibility to cater to the basic needs of the citizen by providing required essential services and infrastructure facilities. But during the last century, cities throughout the developing world have seen an extraordinary increase in their population size, which has put tremendous strain on the delivery of the basic infrastructure services. A major concern of municipalities in developing countries is the limited access to urban services of larger parts of the city population. Equitable distribution is becoming the centre of concern in planning the infrastructure facilities. There is an urgent need to solve this problem of unbalanced distribution of infrastructure services. The social

infrastructure facilities basically include banks, post-office, schools, medical facilities, etc. For each facility the proposed indicators are: (a) Number of facility/Total population of the ward, (b) Number of facility/Total area of the ward.

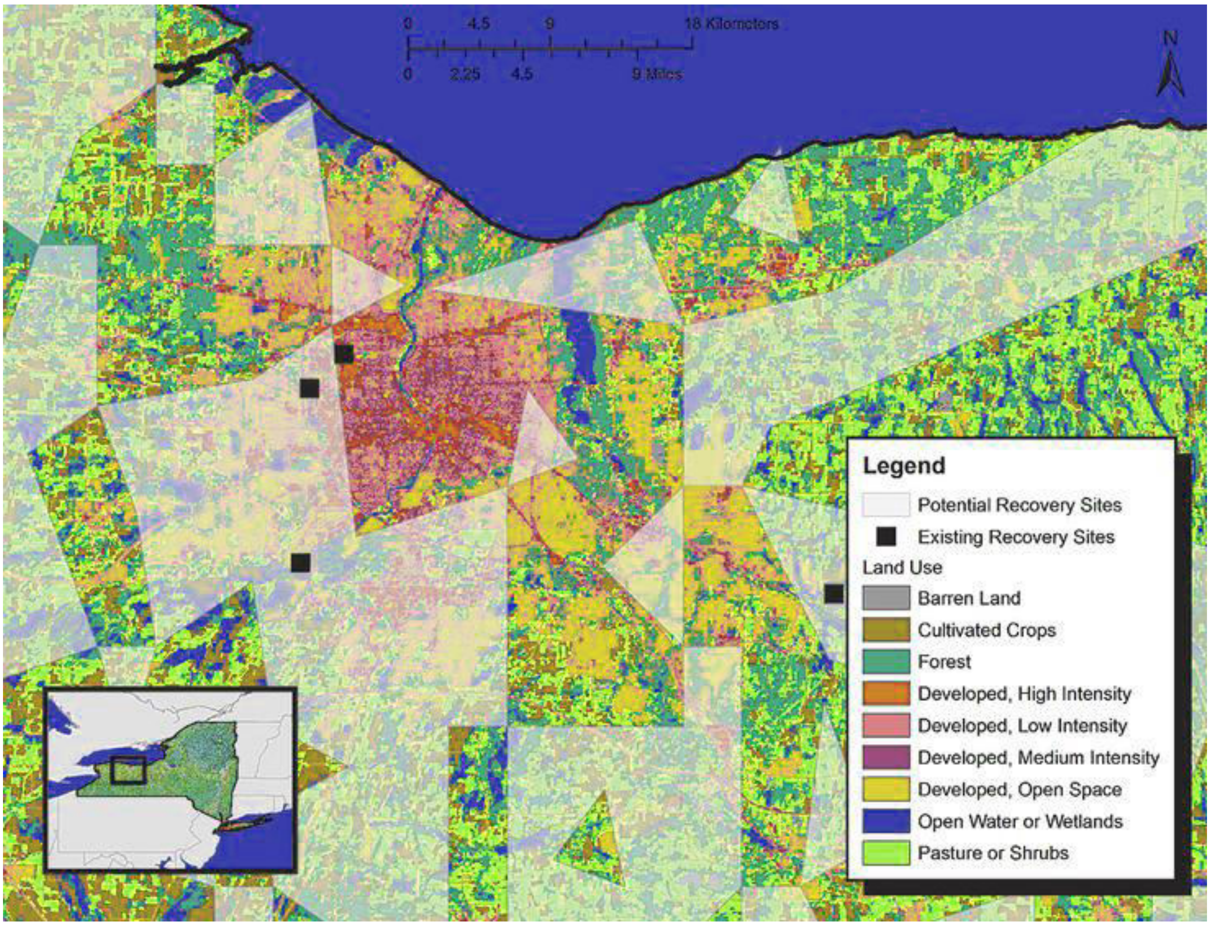
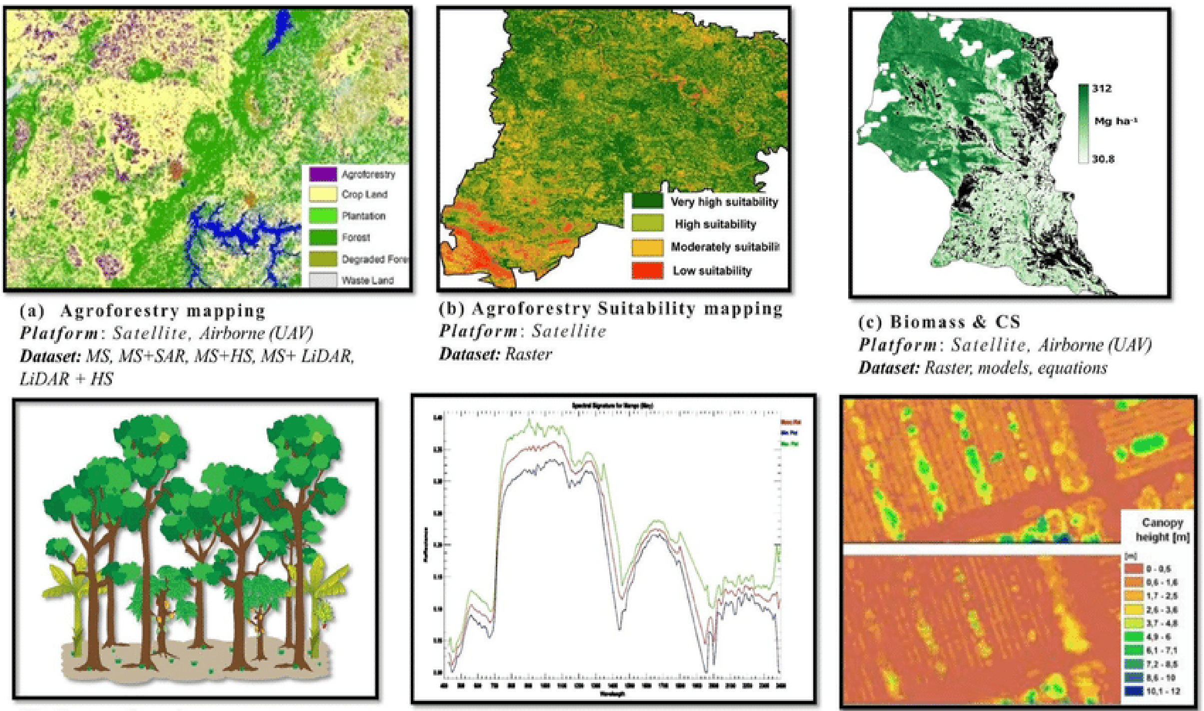


Figure 7.5: Urban Infrastructures and Geospatial Technologies

LAND COVER/BIOMASS MAPPING

Land cover mapping serves as a basic inventory of land resources for all levels of government, environmental agencies, and private industry throughout the world. Whether regional or local in scope, remote sensing offers a means of acquiring and presenting land cover data in a timely manner. Land cover includes everything from crop type, ice and snow, to major biomes including tundra, boreal or rainforest, and barren land. Regional land cover mapping is performed by almost anyone who is interested in obtaining an inventory of land resources, to be used as a baseline map for future monitoring and land management. Programs are conducted around the world to observe regional crop conditions as well as investigating climatic change on a regional level through biome monitoring. Biomass mapping provides quantifiable estimates of vegetation cover, and biophysical information such as leaf area index (LAI), net primary productivity (NPP) and total biomass accumulations (TBA) measurements - important parameters for measuring the health of our forests, for example.



(a) Agroforestry mapping
Platform: *Satellite, Airborne (UAV)*
Dataset: *MS, MS+SAR, MS+HS, MS+ LiDAR, LiDAR + HS*

(b) Agroforestry Suitability mapping
Platform: *Satellite*
Dataset: *Raster*

(c) Biomass & CS
Platform: *Satellite, Airborne (UAV)*
Dataset: *Raster, models, equations*

(d) Canopy layering
Platform: *Airborne (UAV)*
Dataset: *LiDAR, MS+ LiDAR, LiDAR + HS*

(e) Agroforestry tree signature
Platform: *Satellite, Airborne (UAV)*
Dataset: *HS*

(f) Canopy height
Platform: *Airborne (UAV)*
Dataset: *MS, MS+ LiDAR,*

Figure 7.6: Land Biomass Mapping

Remote sensing data are capable of capturing changes in plant phenology (growth) throughout the growing season, whether relating to changes in chlorophyll content (detectable with VIR) or structural changes (via radar). For regional mapping, continuous spatial coverage over large areas is required. It would be difficult to detect regional trends with point source data. Remote sensing fulfills this requirement, as well as providing multispectral, multisource, and multitemporal information for an accurate classification of land cover. The multisource example image shows the benefit of increased information content when two data sources are integrated. On the left is TM data, and on the right, it has been merged with airborne SAR. Land cover information may be time sensitive. The identification of crops, for instance canola, may require imaging on specific days of flowering, and therefore, reliable imaging is appropriate. Multitemporal data are preferred for capturing changes in phenology throughout the growing season. This information may be used in the classification process to more accurately discriminate vegetation types based on their growing characteristics. While optical data are best for land cover mapping, radar imagery is a good replacement in very cloudy areas.

LAND USE CLASSIFICATION

The growth of a society totally depends on its social and economic development. This is the basic reason why socio-economic surveys are carried out. This type of survey includes both spatial and non-spatial datasets. LULC maps play a significant and prime role in **planning, management and monitoring programmes** at local, regional and national levels. This type of information, on one hand, provides a better understanding of **land utilization aspects** and on the other hand, it plays an important role in **the formation of policies and programme required for development planning**. For ensuring sustainable development, it is necessary to **monitor the ongoing process on land use/land cover** pattern over a period of time. **In order to achieve sustainable urban development** and to **check the haphazard development** of towns and cities, it is necessary that authorities associated with the urban development generate such planning models so that every bit of available land can be used in most rational and optimal way. This requires the present and past land use/land cover information of the area. LULC maps also help us to **study the changes** that are happening in our ecosystem and environment. If we have an inch-by-inch information about Land Use/Land Cover of the study unit **we can make policies and launch programmes to save our environment.**

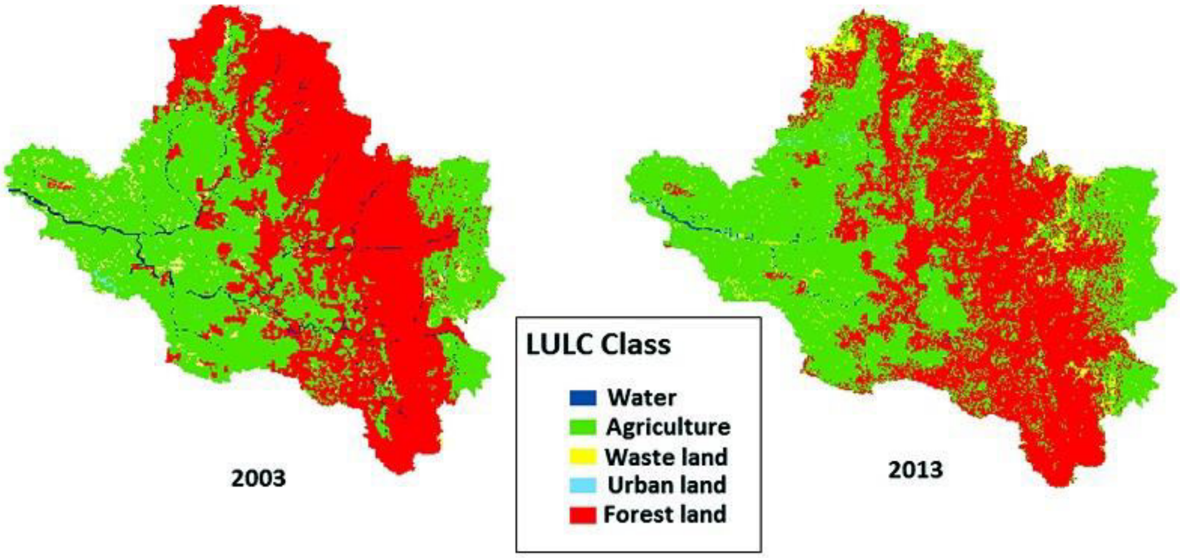


Figure 7.7: Land-use and Land Classification Mapping

LULC classification is one of the most widely used applications in remote sensing. The most commonly used approaches include:

Unsupervised classification *(calculated by software)*: This type of classification is based on the software analysis of an image without the user provided sample classes. This involves grouping of pixels with common characteristics. The computer uses techniques to determine which pixels are related and groups them into classes. The user can specify which algorithm the software will use and the desired number of output classes but otherwise does not aid in the classification process. However, the user must have knowledge of the area being classified (such as wetlands, developed areas, coniferous forests, etc.).

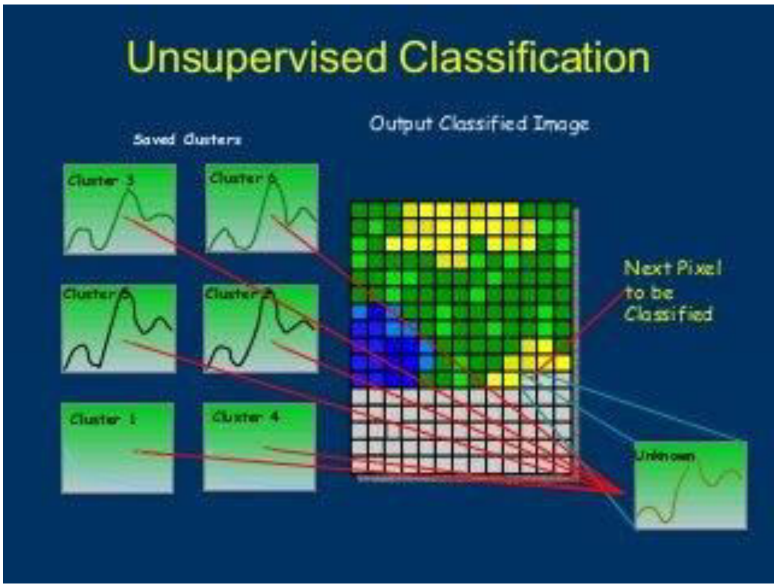


Figure 7.8: Unsupervised Classification

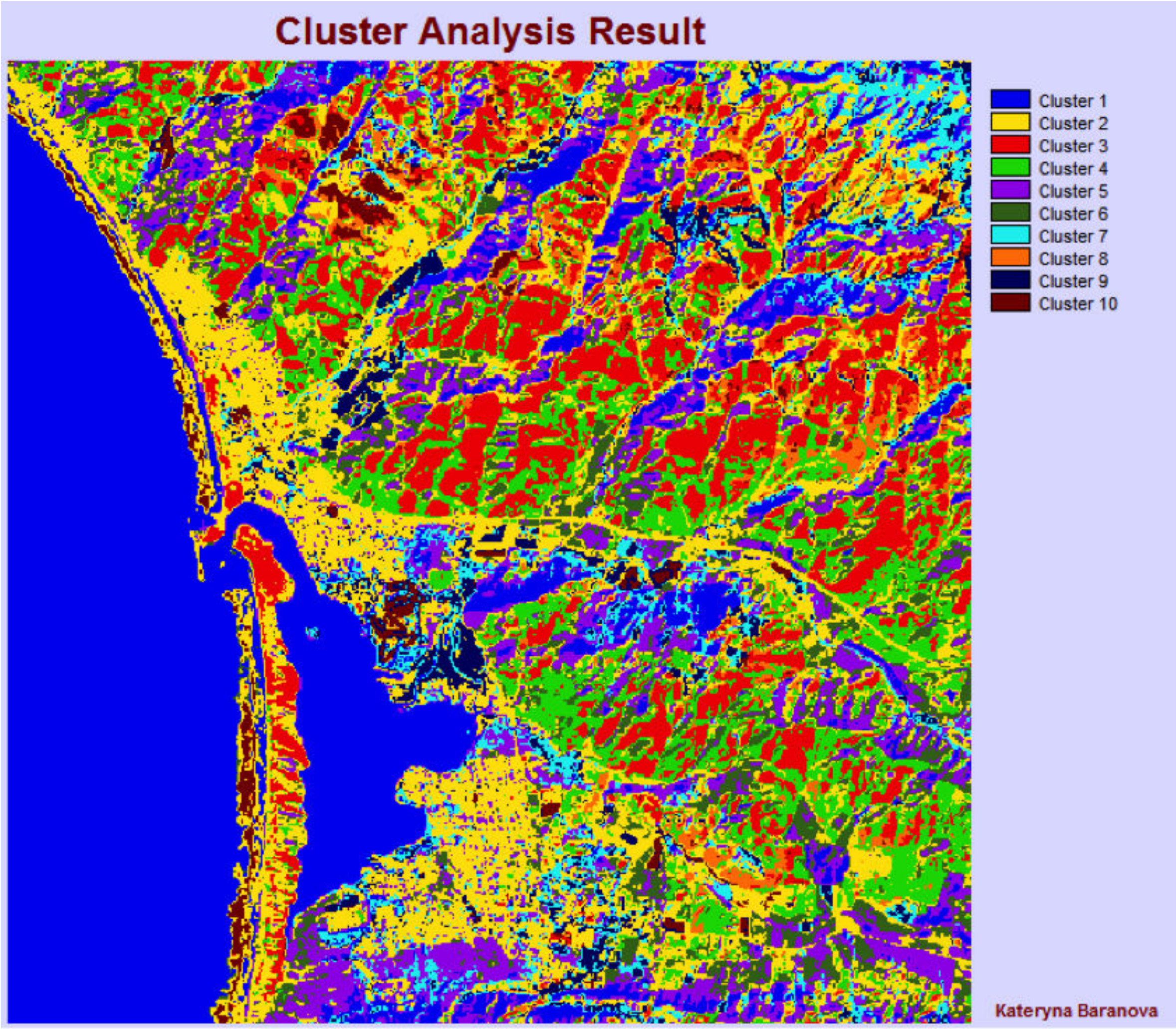
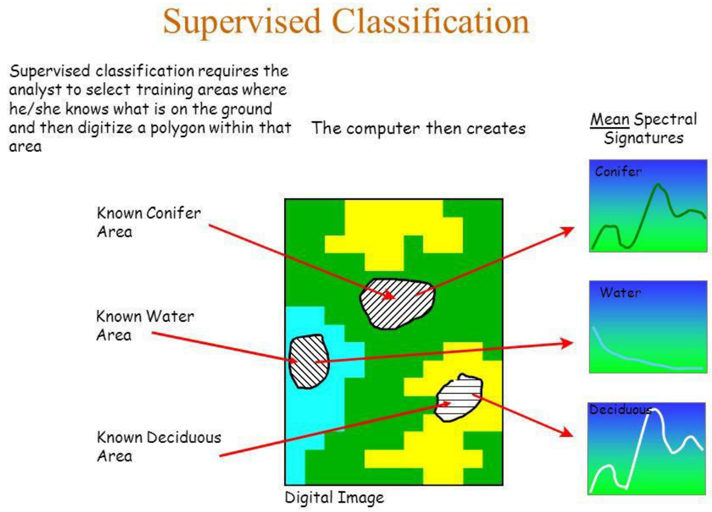


Figure 7.9: Unsupervised Classification in Remote Sensing

Supervised classification *(human guided)*: This is based on the idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together. These bounds are often set based on the spectral characteristics of the training area, plus or minus a certain increment (often based on "brightness" or strength of reflection in specific spectral bands). The user also designates the number of classes that the image is classified into.



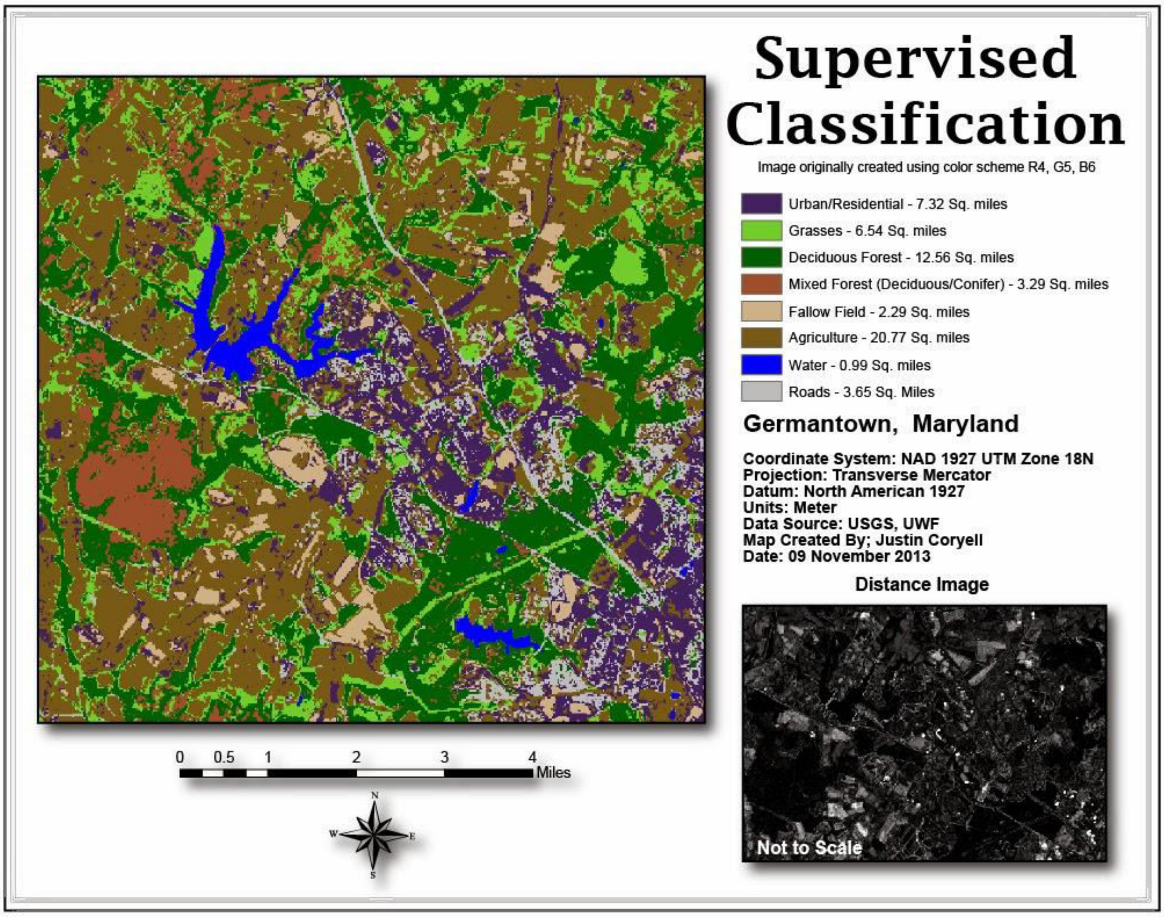


Figure 7.10: Supervised Classification

Table 7.1: Difference between Supervised and Unsupervised Classification

	Advantages	Disadvantages
Unsupervised Classification	- No prior knowledge of the region is required - Allows for minimisation of human error - Spectrally distinct areas presented which may not have been obvious to the human eye	- Spectral grouping may not correspond to information classes of interest to the analyst - Analyst has little control over the classes
Supervised Classification	- Analyst has control - Operator can often detect and rectify images	- Collecting training data is time consuming and costly - There is no way to recognise and represent categories which are not represented in the training data

Image segmentation: Image segmentation is the partition and pick-up of the homogeneous regions of the image. In the results of segmentation, the consistency of gray the smoothing of boundary and the connectivity are fulfilled. The classical method of segmentation is the spatial cleaning based on the measurement space. Image segmentation is a crucial processing procedure for the classifications and feature extraction of high-resolution remote sensing image. main image segmentation methods are:

- **Threshold based:** Threshold segmentation is the simplest method of image segmentation and also one of the most common parallel segmentation methods. It is a common segmentation algorithm which directly divides the image grey scale information processing based on the grey value of different targets.
- **Edge Detection Segmentation:** The edge of the object is in the form of discontinuous local features of the image, that is, the most significant part of the image changes in local brightness, such as the grey value of the mutation, color mutation, texture changes and so on. The use of discontinuities is to detect the edges and to achieve the purpose of image segmentation.
- **Regional Growth Segmentation:** The regional growth method is a typical serial region segmentation algorithm, and its basic idea is to have similar properties of the pixels together to form a region. The method requires first selecting a seed pixel and then merging the similar pixels around the seed pixel into the region where the seed pixel is located.

Geospatial data and Land Use Land Cover: With the advancements in remote sensing, monitoring networks, and geographic information systems (GIS), the availability of spatial data is rapidly increasing. These geospatial data include not only maps and locations of land use and land cover (LULC), but also multiple attributes of data, such as socioeconomic data from the census. Improvements in the use and accessibility of multi-temporal, satellite-derived environmental data or other thematic raster data have contributed to the growing use in environmental modelling. Remote sensing provides synoptic information on vegetation growth conditions over a large geographic area in near real-time. The vegetation growth pattern is estimated using the normalized difference vegetation index (NDVI), which is based on visible (red) (VIS) and near-infrared (NIR) band reflectance derived from the most widely used global NDVI data sets.

Applications of LULC maps

- Natural resource management
- Wildlife habitat protection
- Baseline mapping for GIS input
- Urban expansion / encroachment
- Routing and logistics planning for seismic / exploration/resource extraction activities
- Damage delineation (tornadoes, flooding, volcanic, seismic, fire)
- Legal boundaries for tax and property evaluation
- Target detection - identification of landing strips, roads, clearings, bridges, land/water interface

LAND SUITABILITY FOR URBAN DEVELOPMENT

The essence of land evaluation is to compare or match the requirements of each potential land use with the characteristics of each kind of land. The result is a measure of the suitability of each kind of land use for each kind of land. These suitability assessments are then examined in the light of economic, social and environmental considerations in order to develop an actual plan for the use of land in the area. When this has been done, development can begin. Ideas on how the land should be used are likely to exist before the formal planning process begins. These ideas, which often reflect the wishes of the local people, are usually included among the possible uses to be assessed in the evaluation and will thus influence the range of basic data that needs to be collected.

In practice it is not always possible to field the whole team at once. In this case, the physical aspects of land are usually studied and mapped first to provide a geographical framework into which the socio-economic dimensions are inserted later. A two-stage approach is obviously less well integrated and will take longer to complete. The reliability of a land evaluation can be no greater than that of the data on which it is based. Ideally, fresh data should be obtained to answer all questions raised by the study, although time and expense usually prevent this being done as thoroughly as is possible. The one really important requirement is that the evaluation process can be 'automated' and carried out quite rapidly once all the necessary data are available, by setting up a computerized data bank or geographical information system, and establishing rules or decision trees to carry out the matching process which produces the evaluation.

Stages in Land Suitability Evaluation:

Stages in Land Suitability Evaluation: Following are the different stages in Land Suitability Evaluation. - Defining objectives - Collecting the data - Identifying land uses and their classification - Identifying the physical parameters - Identifying environmental and socio-economic issues - Assessing land suitability. The new technology that is available for land evaluation consists mainly of the use of remote sensing and computers. Stereoscopic examination of paired, black and white, photographs obtained by conventional aerial photography - the best tested form of remote sensing - remains the mainstay for interpretation of landform, vegetation, land use, soils and geology, and for other purposes such as contouring.

While the newer forms of remotely sensed imagery (such as infra-red and radar) may not yet match the precision or stereoscopic capability of conventional air photography, they have other advantages. Each image sensed from space covers a comparatively large area - especially helpful in analyzing and mapping landform. Satellites return at regular intervals to obtain new imagery of the same sites, so that libraries of sequential imagery can be built up showing the changes at a single site over time. Satellites can now record at up to seven different wavelengths simultaneously. Radar wavelengths are particularly useful in the humid tropics because they can obtain images of the Earth through dense cloud. Computers can now be used to store and manipulate the huge amounts of data needed in land evaluation. Tough, portable, micro-computers are being increasingly used to record, store, interpret, test and communicate data at the survey site itself. The main impact of these new technologies has been to save time and money, and to extend the range and depth of land evaluation, allowing data a greater complexity of land-use alternatives to be collected than was possible in the past. However, many kinds of data have to be collected in traditional ways. The soil surveyor must dig or drill holes to describe the sequence of soil 'horizons' with depth. The hydro-geologist may have to drill deeper holes to prove the existence of suspected groundwater whilst hydrologists set up gauges on streams to measure surface water flow. The meteorologist has to rely on systematic measurements of change in the weather at established weather stations. Agriculturalists, economists and sociologists observe people in action in farms, villages and markets and, by means of questionnaires and other enquiries, establish the patterns of their business. These and other scientists collect the central core of basic data on land much as they have done for decades.

GEOINFORMATICS FOR URBAN PLANNERS

Main Requirements for Urban Planners Apart from topographical mapping, planners also look forward to remote sensing (data products) technology to provide them information on existing land use and their periodic updating and monitoring. In addition, with appropriate technique and methodology the same data products can be used to:

- Study urban growth/sprawl and trend of growth
- Updating and monitoring using repetitive coverage
- Study of urban morphology, population estimation and other physical aspects of urban environment
- Space use surveys in city centers
- Slum detection, monitoring and updating
- Study of transportation system and important aspects both in static and dynamic mode
- Site suitability and catchments area analysis
- Study of open/vacant space High spatial resolution satellite data are highly beneficial in the context of complex urban areas where relatively small size and complex spatial patterns of the component scene elements (e.g. buildings, roads and intra-urban open space) have restricted the use of the low-resolution space borne sensors. These new images thus increase the amount of information attainable on urban form at local level.

LAND ASSESSING SUITABILITY

Suitability is a measure of how well the characteristics of a land match the requirements of urban development. The preparation of urban development plan requires consideration of all components of the environment that exist before the new plan's creation and the environment to be created by the new development plan. The plan may not be effective if any of these components are treated separately or loosely. Therefore, the development plan should interrelate all elements that form a community. It is primarily because, the land is a concrete form and any plan must be flexible enough to change established uses either to correct mistakes or to accommodate changing needs. The steps that are followed in the preparation of development plan proceeds from deciding what land to develop to when and how to develop it. So, the development plan should encompass physical characteristics, constraints and socioeconomic possibilities. Basically, it refers to the potentiality of the land for the development. Land potentiality includes both land suitability as well as land value. The land suitability designates land according to its physical capability regardless of any planner's conceptual interest. The integration of land suitability map and land value map produces a land potential map which can be later combined with the socio-economic variables to prepare final alternative development plan.

Identification of suitable areas for urban development is, therefore, one the critical issues in the preparation of the development plan. The land suitability not only based on a set of physical parameters but also very much on socioeconomic factors. The composite effect of these parameters determines the degree of suitability and also helps in further categorizing the land into different classes of development. Also, the process of suitability assessment is very much dependent upon the prevalent conditions such as high pressure on land for development. If the pressure is on the land is too high, then it may lead to a high order of speculation and development of land which is otherwise not suitable from suitability analysis point of view. Therefore, land suitability may be viewed as prioritization of land for urban development.

TOWN INFRASTRUCTURE

In the geo-relational data model, split data system is used to store spatial and Attribute data in separate files and linked together by the feature Identification Descriptor (ID). These two sets of data files are synchronized so that both can be quarried, analyzed, and displayed. GIS role have proliferated in the construction industry in recent years. This fact is illustrated by the growing number of articles finding their way into civil engineering and Construction journals and conference proceedings, in addition to the handful of special Publications devoted to GIS. GIS can be used for:

- Progress monitoring system in construction
- 3-D data analysis
- Comparison of data

- Construction scheduling and progress control with 3-D visualization
- Government Regulations
- Infrastructure is an essential prerequisite for sustained and accelerated economic progress of any country. The wave of new technologies and methodologies has created enormous scope for infrastructural development.

Today, GIS has created a pathway for smart and sustainable infrastructure. A visualization based on GIS provides tons of information that is crucial to the success of any infrastructural project. GIS provides the central data system for the process of developing and constructing infrastructure gives the engineers a common means to communicate geospatial data, maintain current data, and allow iterative design/data collection procedures without exchanging data files of differing format, version, and content. Due to superior spatial data handling capabilities, Geographic Information System (GIS) technology is increasingly
being considered for implementation in many infrastructure projects.

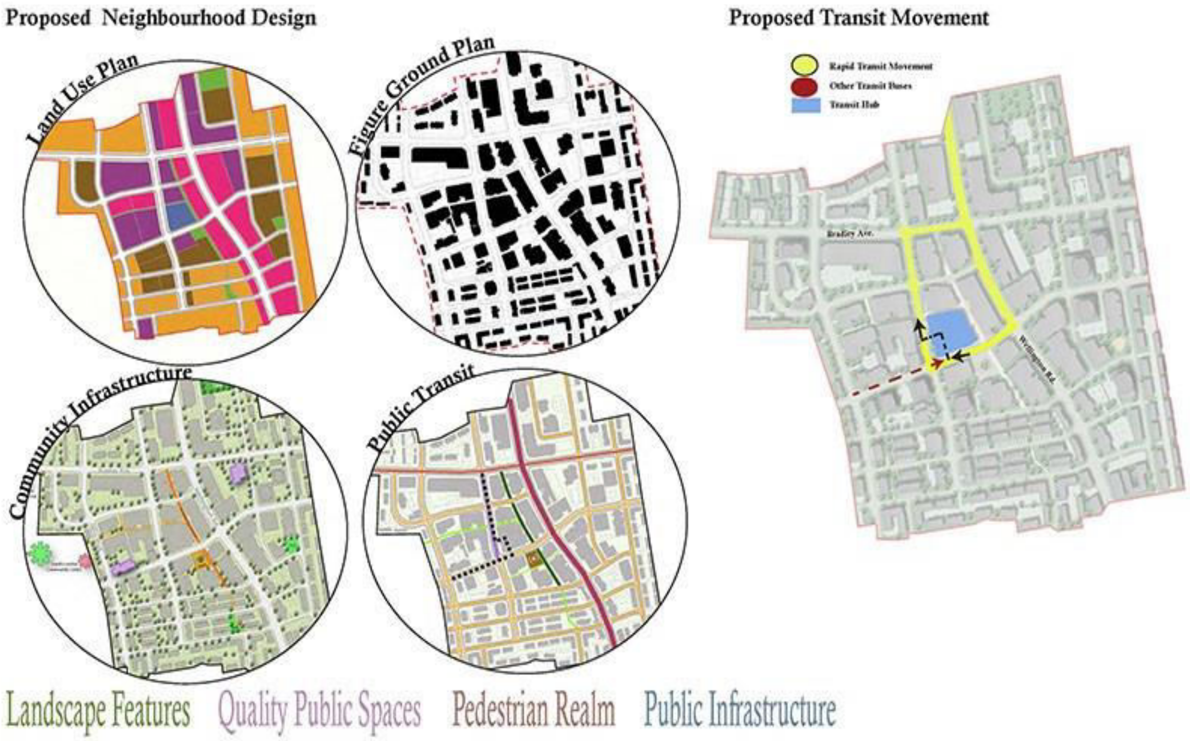


Figure 7.11: Town Infrastructures and Solution Mapping

Most of the case GIS maps of inferior quality without any documentation. Efficiency, environment protection, and supply require good quality basic data. Reliable geospatial and location information of underground utility lines is helpful for avoiding excavation damages.

The GIS-based utility mapping system is also important in the repair and replacement of utility lines because of correct locational data. GIS modelling use for certain utility management, in the future all utility plans will be GIS-based. In the GIS database, integrated information is stored, and also a database with functionalities of query making, statistical analysis with visualization capability, and geographic analysis is the advantage of GIS maps. So we can recognize that GIS mapping is beneficial in utility management and information system. Satellite images and aerial photographs (i.e. Remote sensing data) are useful for digitization, analysis of networks and utility assets. This technology is useful for the correct representation of the infrastructure as well as geospatial information used in the management system.

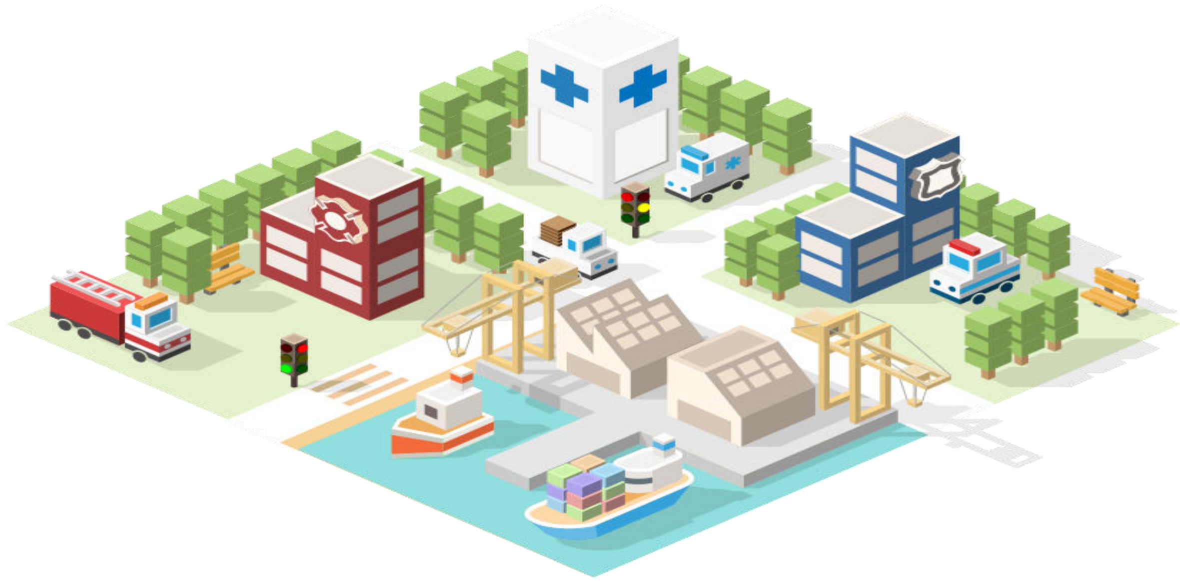


Figure 7.11: GIS in Utility Mapping

GIS techniques are ideal in terms of various aspects, representing infrastructure of utilities, problem identification with providing a solution, in maintenance, technical problems, designing efficient meter reading. Successful utility management is possible by using GIS techniques. GIS maps are important in the management of underground utilities. GIS is useful for the management of daily operations of various utilities. It is useful for modelling utility data with integration from other sources, i.e. satellite data, attribute information. GIS database with topology is beneficial in utility services as a power outage, main breaks, and service stoppages.

7.4 SUMMARY

Remote Sensing and GIS is capable of extracting urban land cover information with robust results. Satellite remote sensing with repetitive and synoptic viewing capabilities, as well as multispectral capabilities, is a powerful tool for mapping and monitoring the ecological changes in the urban core and in the peripheral land use planning, will help to reduce unplanned urban sprawl and the associated loss of natural surrounding and biodiversity. On the other hand, moving further, interfacing of urban planning models with GIS should now receive due attention. Incorporation of land use transportation models, network analysis, simulation of urban activities to evaluate different urban development alternatives in the GIS framework needs to be explored for added advantage. Land use planning, community facilities planning, transport planning, and environmental planning all can benefit from this information. Rapid development in city poses several challenges including problems associated with urbanization for urban managers and policy makers. Meeting these challenges requires access to timely and reliable information.

7.5 GLOSSARY

1. **Urban Land Use:** The land in urban areas is used for many different purposes: leisure and recreation - may include open land, e.g. parks or built facilities such as sports centres. residential - the building of houses and flats. transport - road and rail networks, stations and airports. Land use in urban areas is easily identifiable as **not rural meaning there is little agricultural land use**. (There are no farms.) Land use is often closely linked to the function. In almost all urban areas, residential is the main land use.
2. **Land Classification:** A system for determining land of the public domain into forest land, mineral land, national parks, and agricultural land based on the 1987 Constitution. In current practice, land of the public domain are classified into either forest land and alienable & disposable land. Residential. As the name suggests, residential land is a type of real estate that is meant to be used for private housing. Commercial Land and Industrial Land.
3. **Town Infrastructure:** Urban Infrastructure refers to **the physical structure present in cities and towns**. Infrastructure development has a key role to play in both economic growth and poverty reduction. Examples of essential infrastructure

are power stations and electricity supplies, sewage systems, clean drinking water systems, major transport systems (metro systems and railways) and telecommunications networks. Established cities must build, maintain, and upgrade extensive transport, power, water and telecommunication networks, in order to keep up with the demands of economic development and population growth. This infrastructure is necessary **to continue to progress societies and improve living standards**.

4. **Town Biomass Mapping:** Biomass is **renewable organic material that comes from plants and animals**. Biomass was the largest source of total annual U.S. energy consumption until the mid-1800s. Biomass continues to be an important fuel in many countries, especially for cooking and heating in developing countries. Biomass mapping **provides quantifiable estimates of vegetation cover, and biophysical information such as leaf area index (LAI), net primary productivity (NPP) and total biomass accumulations (TBA) measurements** - important parameters for measuring the health of our forests, for example.
5. **Supervised Classification:** Supervised classification is based on the idea that a user can select sample pixels in an image that. are representative of specific classes and then direct the image processing software to use these. training sites as references for the classification of all other pixels in the image. Supervised classification is the procedure most often used for **quantitative analysis of remote sensing image data**. It rests upon using suitable algorithms to label the pixels in an image as representing particular ground cover types, or classes.
6. **Unsupervised Classification:** Unsupervised classification (commonly referred to as clustering) is **an effective method of**. **partitioning remote sensor image data in multispectral feature space and extracting land-cover**. **information**. The goal of unsupervised classification is **to automatically segregate pixels of a remote sensing image into groups of similar spectral character**. Classification is done using one of several statistical routines generally called "clustering" where classes of pixels are created based on their shared spectral signatures.
7. **Site Suitability:** Site selection or suitability analysis is **a type of analysis used in GIS to determine the best place or site for something**. Potential sites used in suitability analysis can include the location of a new hospital, store or school among many others. Land Suitability Analysis (LSA) is **a GIS-based process applied to**

determine the suitability of a specific area for considered use, i. e. it reveals the suitability of an area regarding its intrinsic characteristics (suitable or unsuitable). Suitability mapping contributes to the discussion where a given crop can be best produced given prevailing biophysical conditions of soils and climate and the need to use natural resources as efficient as possible.

8. **Town Resource Information:** According to this more restrictive meaning, urban resources are the resources of the city: as we have seen, these are all the more crucial when they are the only resources available to legally, economically or socially vulnerable individuals who do not have access to public resources. Urban planning affects our transportation system, infrastructure, the layout, and prescribed densities of our residential, commercial, and industrial areas and more. Without such planning, our cities quickly become inefficient and uninviting for residents and businesses alike.
9. **Change Detection**: Change Detection can be defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times. This process is usually applied to earth surface changes at two or more times. Remote sensing change detection (RSCD) is the process of identifying changes between scenes of the same location acquired at different times. This is an active research area with a broad range of applications. In the context of remote sensing, change detection refers to the process of identifying differences in the state of land features by observing them at different times. This process can be accomplished either manually (i.e., by hand) or with the aid of remote sensing software.
10. **Town Planning:** Urban planning, also known as regional planning, town planning, city planning, or rural planning, is a technical and political process that is focused on the development and design of land use and the built environment, including air, water, and the infrastructure passing into and out of urban areas. An urban planner is someone who develops plans and programs for the use of land. They use planning to create communities, accommodate growth, or revitalize physical facilities in towns, cities, counties, and metropolitan areas. The principal phases of an urban planning process are: Preparatory / exploration phase. Feasibility / planning phase. Formal planning / zoning phase.

7.6 ANSWER TO CHECK YOUR PROGRESS

1. Discuss in brief two national agencies you think are impacting.
2. Explain how GIS can help in town Planning?

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7.8 TERMINAL QUESTIONS

3. List major application of geoinformatics in town Studies.
4. Explain about the recently launched remote sensing satellite of India, its salient features and application potential.
5. What do you think are the challenges facing geoinformatics? How it can help in town management and policy making?

UNIT 8 : REMOTE SENSING DATA AND SCALES FOR TOWN AREA ANALYSIS, TOWN SPRAWL MAPPING AND MONITORING USING REMOTE SENSING, RESIDENTIAL AREA ANALYSIS

8.1 OBJECTIVES

After reading this unit you should be able:

- To understand use of Geospatial technologies in Town Planning and Mapping.
- To get an overview of town infrastructure and facilities using remote sensing and GIS.
- To understand Slum and their management using geospatial technologies.

8.2 INTRODUCTION

Planning is important in urban areas because it helps in making informed decisions about certain areas. The main reason as to why planning is essential is that it helps in the projection of the future population and identifies the levels of economic growth. Modelling and spatial distribution has made it possible to estimate the widest range of the impacts of the existing population and record any change in both the economy and the environment. Using GIS map overlay analysis helps in identifying areas, which may be facing a crisis. Data stored in GIS, both environmental and socioeconomic have helped in the development of environmental planning models. In turn, this has helped in identifying the areas of concern and the development of the conflict. Using GIS helps in the implementation of urban plans. This is done by carrying out the assessment of the environmental impact of the proposed projects, in order to evaluate and minimize the impact of development on the environment. Different measures can be recommended to do away with the impacts. The assessment of environmental impact required the use of detailed and accurate estimations of data and effect analysis. The application of GIS in this process ensures that the desired outcome is achieved.

These results can be achieved by queries in GIS design and application: • determination for future town planning; • determination of accessibility of schools; • determination of the shortest distance between the selected places; and • determination of important and necessary places for tourism. The quality of life in the urban area largely depends on the availability of infrastructure such as water supply, waste disposal, road rail infrastructure, communication facility, house types, and availability of various other basic services, health, and education. Queries can be made on institutions concerning their accessibility from the nearest distance and mode of transport. Services provided at each site can be obtained from the tables. By clicking on several points in each site, information on the geology, planning and zoning, utility infrastructure, and other information can be obtained. In this study, two major facilities like educational facilities and hospitals were taken into account. In case of institution, the shortest route for the Vinayaka mission medical college and for the particular street address was used. The resulting map shows the shortest route. The ability of GIS to identify the geographic extent of a health facility catchment area, which corresponds to the area containing the population utilizing this facility, in case of Australia, Switzerland, and Canada. By using GIS, with the help of road network, buffer analysis and connectivity analysis, i.e. within 100 m how much area it covers, was carried out. Network analysis was carried out to find out which are the points of least connectivity.

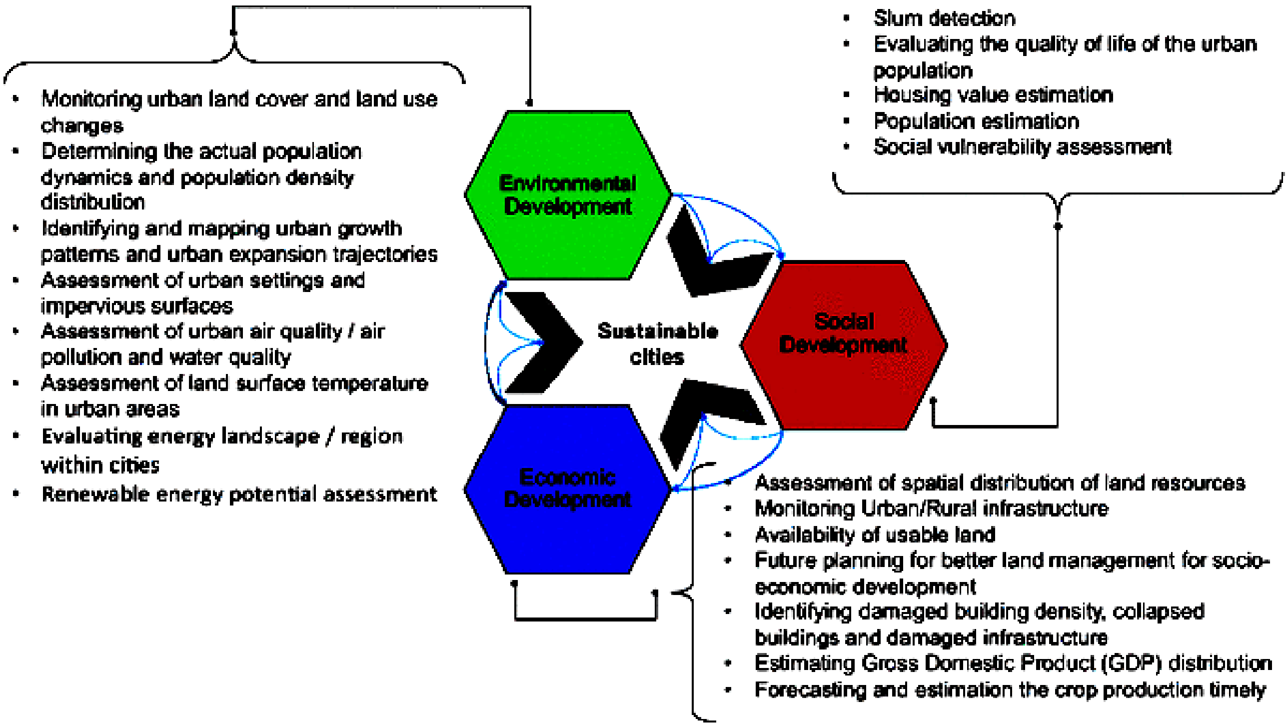

Figure 8.1: Town Planning and Geographic Information System

The quality of life in urban areas largely depends on the availability of infrastructure (such as water supply, waste disposal, road rail infrastructure, communication facility, house types, and availability of various other basic services, health, and education). Here, the study takes into account major facilities like educational facilities, hospitals, and industry. GIS can quickly analyse and display a route from a station or global positioning system (GPS) location to an emergency call. This route (depending on the sophistication of the street file) may be the shortest path (distance) or the quickest path (depending on time of day and traffic patterns). With the help of remote sensing, GPS, and GIS, one can update facility locations easily. Further, site suitability for various services, needed for planning purposes, can be carried out easily. The physical accessibility of various services can be determined in a GIS by using road network, buffer, and connectivity analysis within any specified number of km/ m. Results will also show how much area and population a service cover. One can create buffers of various distances, a feature in many GIS packages, like ArcGIS. City planners can calculate service demands for public facilities, such as schools and hospitals. Spatial connectivity analysis can be done easily (using the roadmap to locate which is the nearest facility in case of emergency). Network analysis can be carried out to see which facility is most linked as well as the points of least connectivity.

8.3 REMOTE SENSING DATA AND SCALES FOR TOWN AREA ANALYSIS, TOWN SPRAWL MAPPING AND MONITORING USING REMOTE SENSING, RESIDENTIAL AREA ANALYSIS

GEOINFORMATICS IN UTILITY SECTOR

The utility sector is one of the expanding sectors. And utility management is one of the basic needs of modern infrastructure management. The investment made on different utility supply lines ex. Water, sewage, power lines telephone lines, and gas mains. So, components of utility should be functional without any breakdown. And it very difficult to manage it manually, so geographic data provides spatial dimensions to its management. Most of the case GIS maps of inferior quality without any documentation. Efficiency, environment protection, and supply require good quality basic data. Reliable geospatial and location information of underground utility lines is helpful for avoiding excavation damages. The GIS-based utility mapping system is also important in the repair and replacement of utility lines because of correct locational data. GIS modelling use for certain utility management, in the future all utility plans will be GIS-based.

In the GIS database, integrated information is stored, and also a database with functionalities of query making, statistical analysis with visualization capability, and geographic analysis is the advantage of GIS maps. So, can recognize that GIS mapping is beneficial in utility management and information system. Satellite images and aerial photographs (i.e. Remote sensing data) are useful for digitization, analysis of networks and utility assets. This technology is useful for the correct representation of the infrastructure as well as geospatial information used in the management system.

Through GIS actual distribution of utility lines can possible to show. And it can possible to represent with roads, buildings, and land ownership boundaries.

GIS techniques are ideal in terms of various aspects, representing infrastructure of utilities, problem identification with providing a solution, in maintenance, technical problems, designing efficient meter reading. Successful utility management is possible by using GIS techniques. GIS maps are important in the management of underground utilities.

GIS is useful for the management of daily operations of various utilities. It is useful for modeling utility data with integration from other sources, i.e. satellite data, attribute information. GIS database with topology is beneficial in utility services as a power outage, main breaks, and service stoppages.

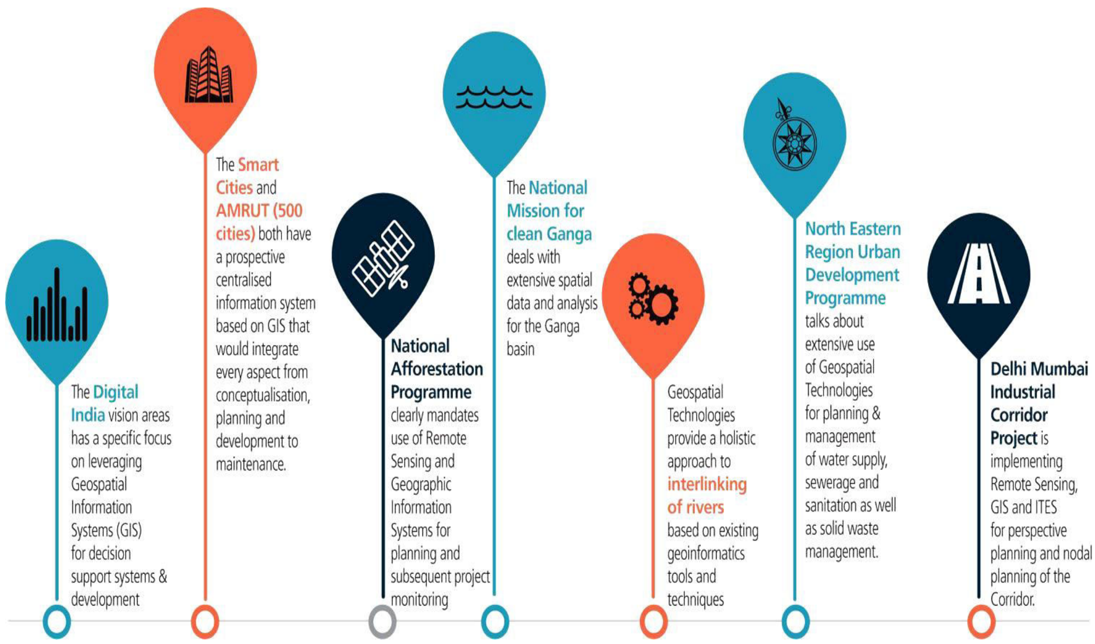

Figure 8.2: Smart Cities and Geospatial Technologies

DESIGNING AND MAPPING NEIGHBOURHOOD CITIES

Geographic Information Systems helps engineers, surveyors, and planners by providing them with tools that they require in designing and mapping their neighbourhood cities. The most frequently used GIS functions in the making of a plan include spatial analysis, visualization, and spatial modelling. Furthermore, GIS can be used in the storing, manipulation and analysis of physical data, economic and social data of a city. The existing situations in the city can be analysed through the mapping functions of Geographic Information Systems. In addition, GIS is applied in urban planning to help in the identification of the areas of conflict of land development in relation to the environment.

1. **Telecommunications:** The telecommunication industry rapidly expanding. For business growth company should know where their facilities and customers exist. Also, locational information about this data is useful. GIS database can have the potential to work on these queries.

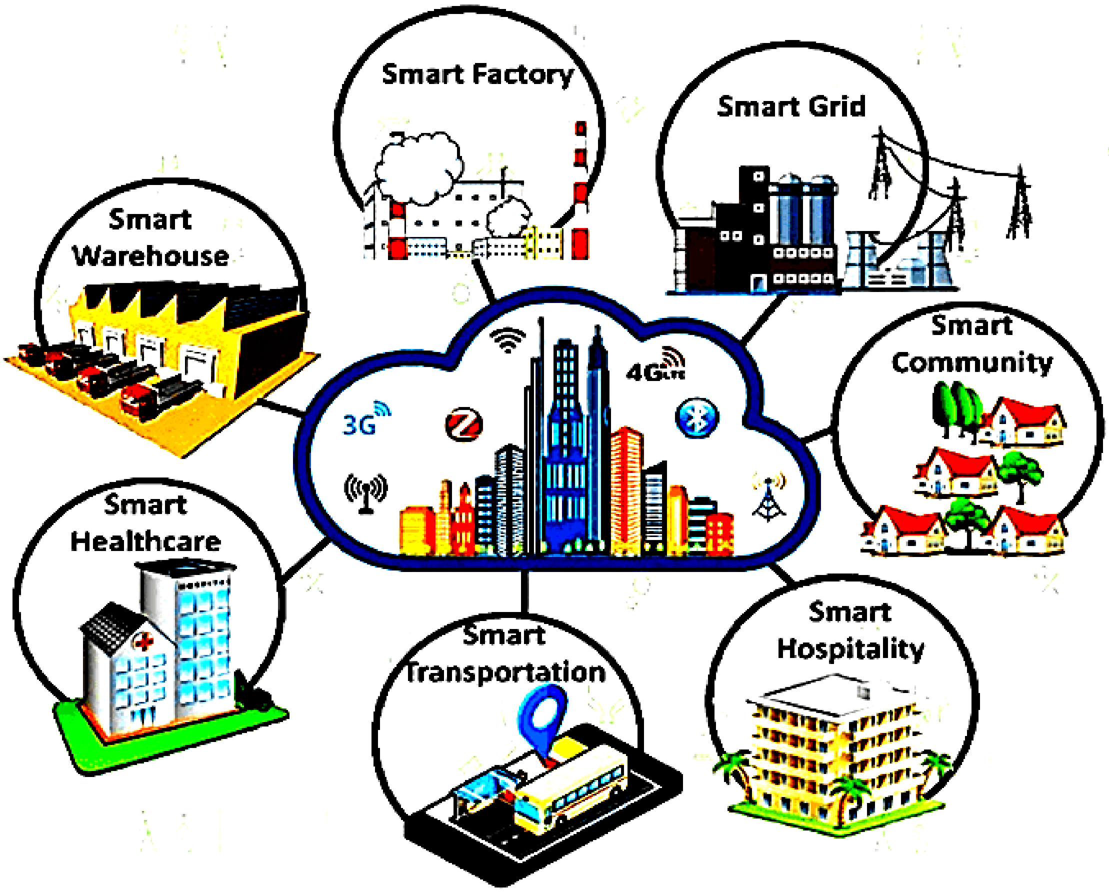

Figure 8.3: Town Infrastructure and Service

2. **Water and wastewater utilities:** Integrating data from various sources and with geospatial data one manageable system is formed by many water and wastewater utilities. This system can be beneficial for the management of the flow of wastewater to businesses and service homes by tracking the location of water and meters, hydrants, valves. In the Maharashtra government implementing Sujal and Nirmal Abhiyan Yojana, in this project consumer survey, water and energy examination, flow meter installation, hydraulic modelling, and GIS mapping components included. Water flow connectivity and associated consumers can identify through maps is an advantage of this GIS-based project.
3. **Electricity Mapping:** Geographical Information System (GIS) and Remote Sensing (RS) technologies are very important in electricity mapping projects. Restructured Accelerated Power Development & Reforms Programme **(R-APDRP)** project is a central government project implemented in the whole country. It includes preparation of Base-line data for the project area including indexing of the consumers, Mapping through **GIS**, and Metering of Distribution Transformers and Feeders. Mapping of all electricity assets and the distribution of the network over the entire assigned geography.

   Collection of geospatial data of distribution network of electricity lines **(i.e. HT-High tension line and LT-Low tension lines)** which required DGPS survey and door to door consumer survey. In this, mapping of all electrical assets with electricity network distribution information using GIS techniques. So this project useful to me for the actual location of the poles, electricity lines, and actual consumption of the electricity. So due to this utility project good revenue generated in MSEB, also gathered correct locational and actual informative data. Using modems this electricity management system application is made live application.

4. **Resource inventory**: GIS platforms, especially those used in conjunction with remote sensors, decrease time spent collecting land-use and environmental information. With remote images, urban planners can detect current land use, as well as changes to land use for an entire urban area. These images can also be used to create compelling visualizations with 3D CAD models.

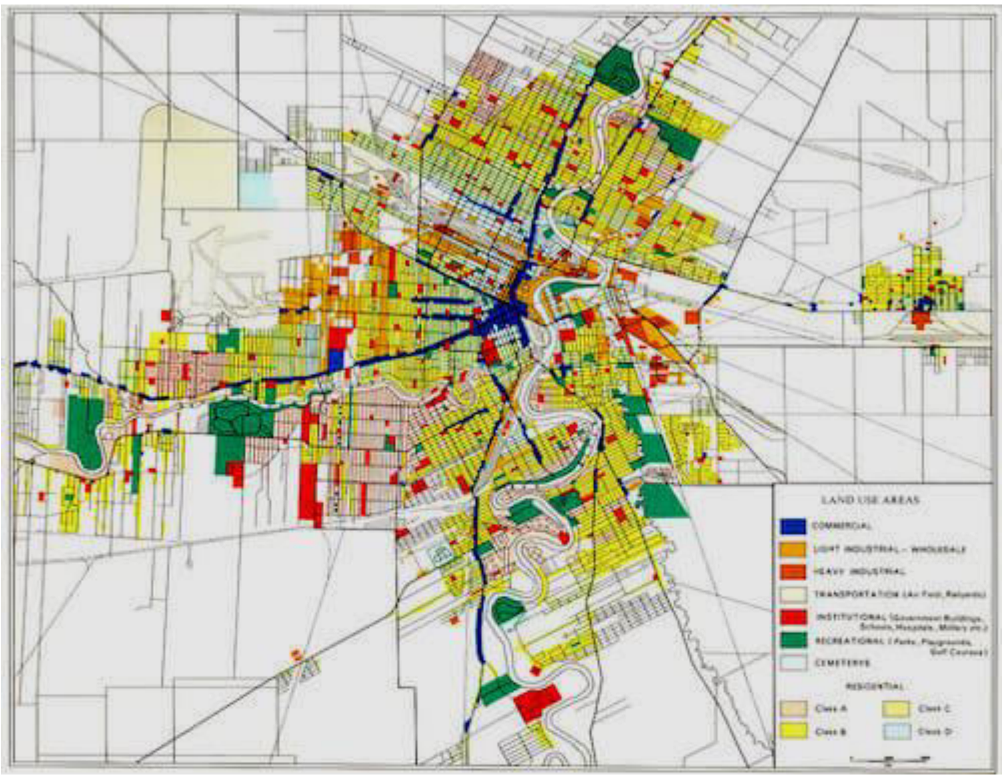

Figure 8.4: Mapping Resource Inventory for Urban Cities

5. **Creating land-use maps & plans:** Future land-use maps act as a community's guide to future infrastructure, build plans, and public spaces. These maps help ensure that a city's urban planning accounts for environmental conservation, pollution, mitigating transportation issues, and limiting urban sprawl.

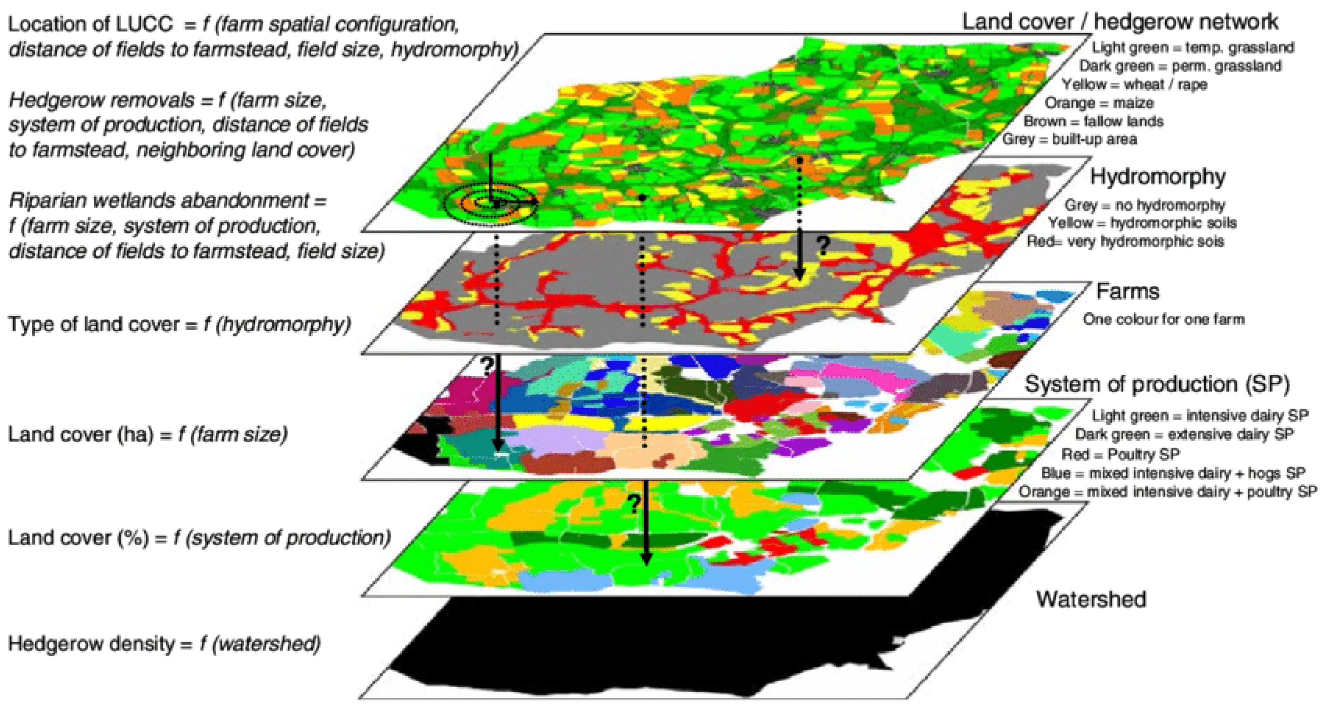

Figure 8.5: Land Use/Land Cover Mapping for Urban Planning

With GIS, urban planners can quickly create maps of the city as it is today, and then use various modelling and predictive data techniques to explore scenarios for the future. Ideally using this exercise to create a future land-use map that is thoughtful, sustainable, and sound.

Identification of Environmental Sensitive Areas

The generation of environmental sensitive areas and high-risk zones maps would very much help in planning and decision-making process as the identified areas can be avoided from being developed. If development is a "must", these maps could act as guidelines to further justify the type of development that is to be implemented together with comprehensive procedures, standards and preventive measures embedded throughout the development activities. The model for the identification of environmentally sensitive areas involved various criteria while taking into account the limitation of supporting information and database. These criteria include natural habitat which has not been interfered by human activities, natural habitat that has to be managed for human and environmental needs, natural or modified steep slopes as well as water catchment areas. The analysis was done using the GRID operation which includes the use of commands such as POLYGRID, LINEGRID, ISNULL, CON, IF, ARITHMATIC and FOCALMAJORITY (ESRI, 1995). The analysis resulted into three environmental sensitive levels namely highly sensitive, moderately sensitive and less sensitive.

TOWN PLANNING

GIS can help the government and businesses process and organize planning applications. Many GIS portals can be made public facing, which means citizens can access data such as parcel outlines and information, county/district boundaries, and area zoning. With vital information more widely available to all, government resources (which might have been spent fielding these requests and finding the data) can be put to use elsewhere. Moreover, with all the applications stored in a central database, organization, processing, and status tracking becomes much simpler.

1. **Analysing Socioeconomic & Environmental Data**: Creating future land-use maps must take into account several environmental scenarios, as well as project future demand for land resources. Modelling must include population data, economic activities, and spatial distribution. The visual component of GIS makes analysing **location-based data** (like socioeconomic and environmental trends) simpler and more effective. GIS enables the creation of thematic maps i.e. maps that combine data and location in order to explore correlation and display trends. With the various data sets stored in the GIS database, users can create layered images that include topography, street maps, thematic maps, and more - helping to easily identify ideal spaces, as well as areas of potential conflict.
2. **Land Suitability Analysis/site Selection**: GIS tools like map overlay enable urban planners to conduct land suitability analysis, an important step in site selection. Remote sensing, spatial queries, and environmental data analysis help urban planners find areas of environmental sensitivity. By overlaying existing land development on land suitability maps, they can identify any areas of conflict between the environment and potential development.
3. **Measuring Connectivity**: GIS geoprocessing functions like map overlay, buffering, and spatial analysis help urban planners to conduct connectivity measurement. Connectivity refers to how easy it is to walk or bike in a given city. A highly-connected area will give its residents numerous options to get from A to B quickly.
4. **Impact Assessments**: An environmental impact assessment can be conducted to evaluate the potential effects urban development will have on the environment. If issues are found, the urban planner can then recommend ways to alleviate or mitigate negative outcomes.
5. **Evaluation, Monitoring, & Feedback**: GIS tools can help evaluate a building plan, monitor the project after completion, and even gather feedback to help make improvements.

Together with remote sensing, GIS can help planners to track if development is following the area's land use plan. It can also help them evaluate impact and suggest adjustments - if required.

GEOINFORMATICS AND TOWN CONSTRUCTION MONITORING:

Planning and managing infrastructure projects can be a daunting job. Geoinformatics can help infrastructure companies in asset management to model an entire virtual city, public transport for route optimization, traffic management, security, and citizen management. When integrated with construction management and financial software, GIS can help track the performance of one or multiple infrastructure projects. GIS makes a wealth of information, such as schedules, estimates, and contracts, easily available from a spatial interface. For project tracking, GIS can help organize all relevant information, from survey data, soils, and geotechnical studies to planning, environmental studies, and engineering drawings. Having quick and easy access to data during construction can greatly increase efficiency and reduce time spent searching for needed information.

Figure 8.6: Indian States embrace GIS tools for Infrastructure Development

- **Asset and Maintenance Management:** GIS integrates asset mapping with project management and budgeting tools so that construction and maintenance expenses can be accounted for and centrally managed. A GIS-based maintenance management system promotes efficient scheduling of activities and tracking of work tasks, personnel, equipment, and material usage so managers can track and report maintenance activities. Simultaneously, field-workers can record information, perform inspections, and locate assets with GIS-equipped mobile devices. Deficiencies identified in the field during inspections can automatically prompt the GIS to generate new work orders for maintenance and repair.
- **Security Management:** Comprehensive transportation facility protection requires the cooperation and close coordination of various agencies and the integration of different technologies and information sources. GIS integrates multiple sources of information, displays them on a map or satellite image, and delivers the resultant situational awareness on a secure network. You can combine real-time tracking of assets and vehicles with sources such as live closed-circuit television cameras to deliver a real-time security view of your transportation facilities. These capabilities make GIS an essential technology for managing a transportation security framework.

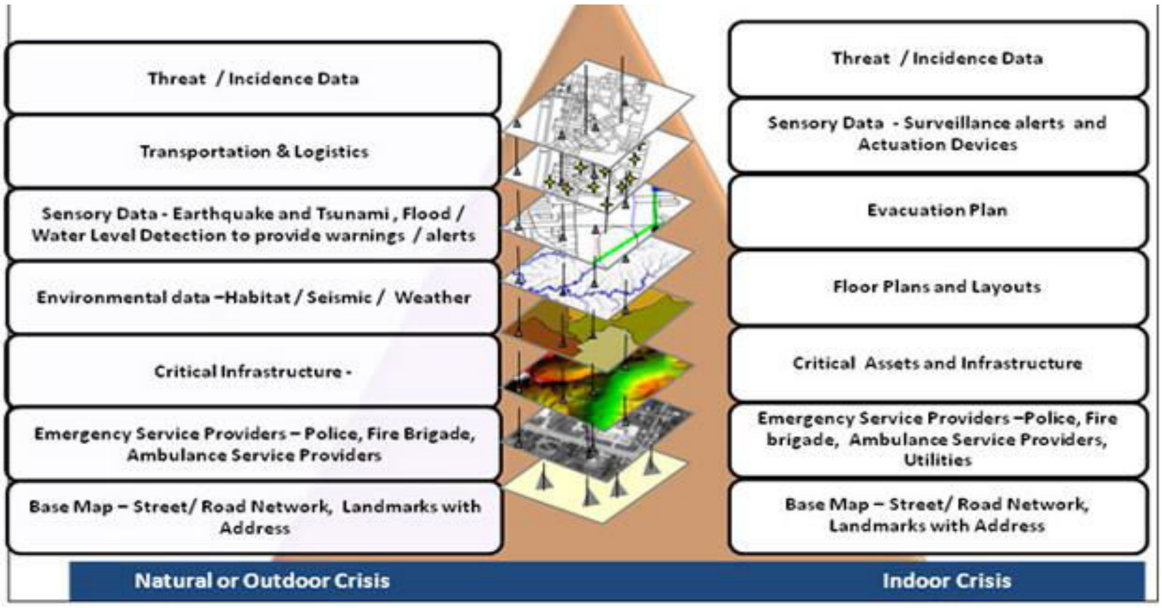

Figure 8.8: Geospatial Technologies for Town Development

- **Operations:** The demand for operational efficiency and increased safety in modern transportation systems requires access to detailed and real-time information. GIS provides management solutions that integrate data from all aspects of your operations. GIS can track and analyze assets over space and time and provide insight through visualization of information via maps and easy-to-understand reports. GIS gives you the ability to integrate disparate information sources into a common operational picture of all your facilities and transportation systems, with greater power to control your operations and positively impact your bottom line.
- **Safety Management** Accurate records of accident locations frequently hold the key to improving safety for motorists, freight carriers, railways, and pedestrians. GIS maps can display crash records paired with spatial analysis of congestion, construction zones, and weather, making obvious what can easily be missed in simple tabular data. Spatial analysis, combined with statistical and business intelligence tools, can help pinpoint the root causes of accidents and determine effective countermeasures. Departments of transportation can identify trends, such as increases in oversized vehicle traffic, permit violations, and general commercial traffic route information, using GIS tools—all leading to significant improvements in transportation safety.

Figure 8.9: Airport Integrated Spatial Management System

GEOINFORMATICS AND AIRPORT DEVELOPMENT

Airports today are tasked with catering to the needs of an ever-growing traveller lists, so the system needs to be fast, efficient and secure. Geoinformatics helps in planning an airport's layout and facilitate airspace efficiency through airspace planning and routing, flight monitoring, and real-time flight tracking.

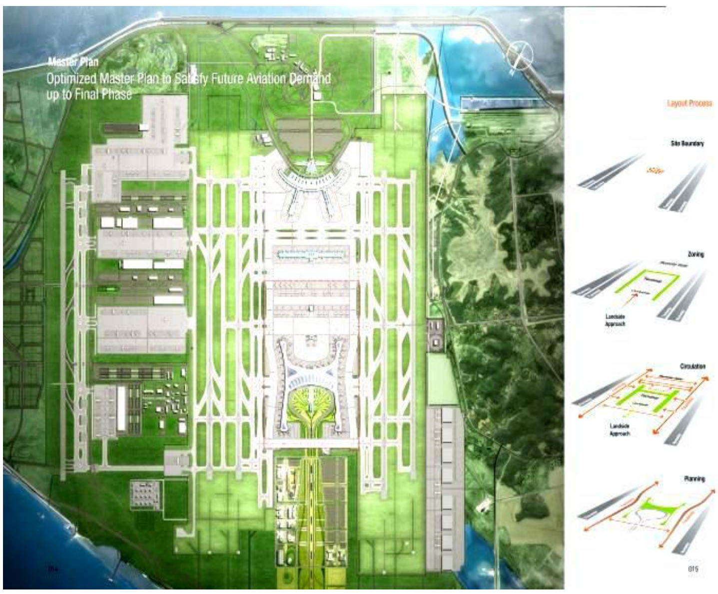

Figure 8.10: Airport Mapping and Master Plan Using Geospatial Technologies

GEOINFORMATICS AND SUPPLY CHAIN

We help companies visualize factories, suppliers, stores and distributions. Trace all the complex network connections and track and analyse the gaps to look for opportunities.

GEOINFORMATICS AND TRANSPORT INFRASTRUTURES

Throughout the transportation infrastructure life cycle, GIS technology helps you create a seamless flow of information from one stage to the next. With GIS, information from your planning process can be brought into the design process and easily carried over into other areas such as as-built drawings, operations, and maintenance. Gains in both employee productivity and transportation system performance are made possible by the unique ability of GIS to integrate with a wide variety of technologies. Transportation organizations benefit by making use of the resultant information throughout their enterprise for better decision making.

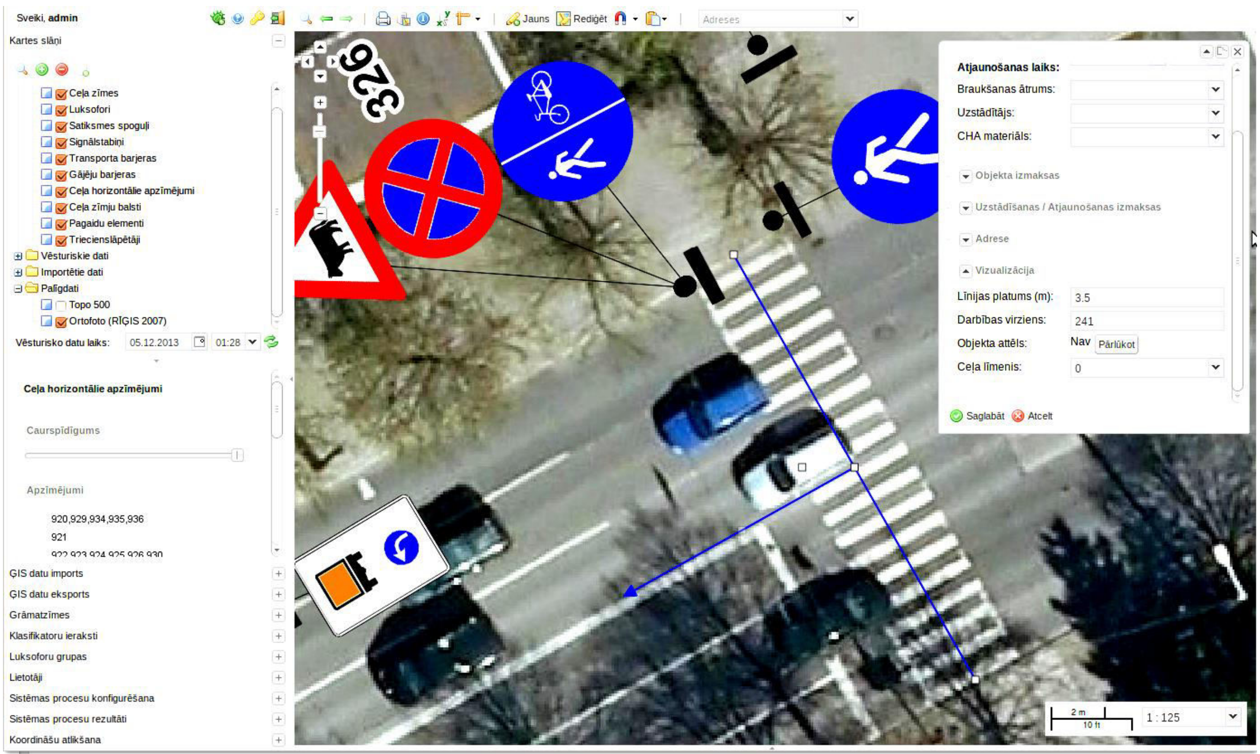

Figure 8.11: GIS in Transportation for Better Management

Transportation agencies face an enormous challenge in keeping their infrastructure operating smoothly and efficiently. The world's leading travel demand forecasting packages are integrated with GIS technology, helping transportation professionals conduct the complex analyses required to plan the transportation systems of the future. Increasingly, transportation planners are integrating land-use, environmental, and greenhouse gas considerations, along with energy consumption factors, into their planning processes. In doing so, they have discovered that GIS can bring all these factors together in the type of comprehensive planning models that will be required to help effectively plan the future.

Figure 8.12: GIS in Transportation Infrastructure Management

GEOINFORMATICS IN SMART CITY DEVELOPMENT

Smart cities are the future, however, developing them is a big challenge. We make low-cost GIS platforms to improve transparency between departments like Utilities Management and Operations (Water, Electricity, and Gas) through a map-based interface. The smart city concept is developing very quickly around the world, because it provides a comprehensive digital environment that improves the efficiency and security of urban systems and reinforces the involvement of citizens in urban development. This concept is based on the use of geospatial data concerning the urban built environment, the natural environment and urban services. The successful implementation of a smart city project requires the development of a digital system that can manage and visualise the geospatial data in a user-friendly environment. The geographic information system (GIS) offers advanced and user-friendly capabilities for smart city projects. This article shows how a GIS could help in the implementation of smart city projects and describes its use in the construction of a large-scale model of the smart city.

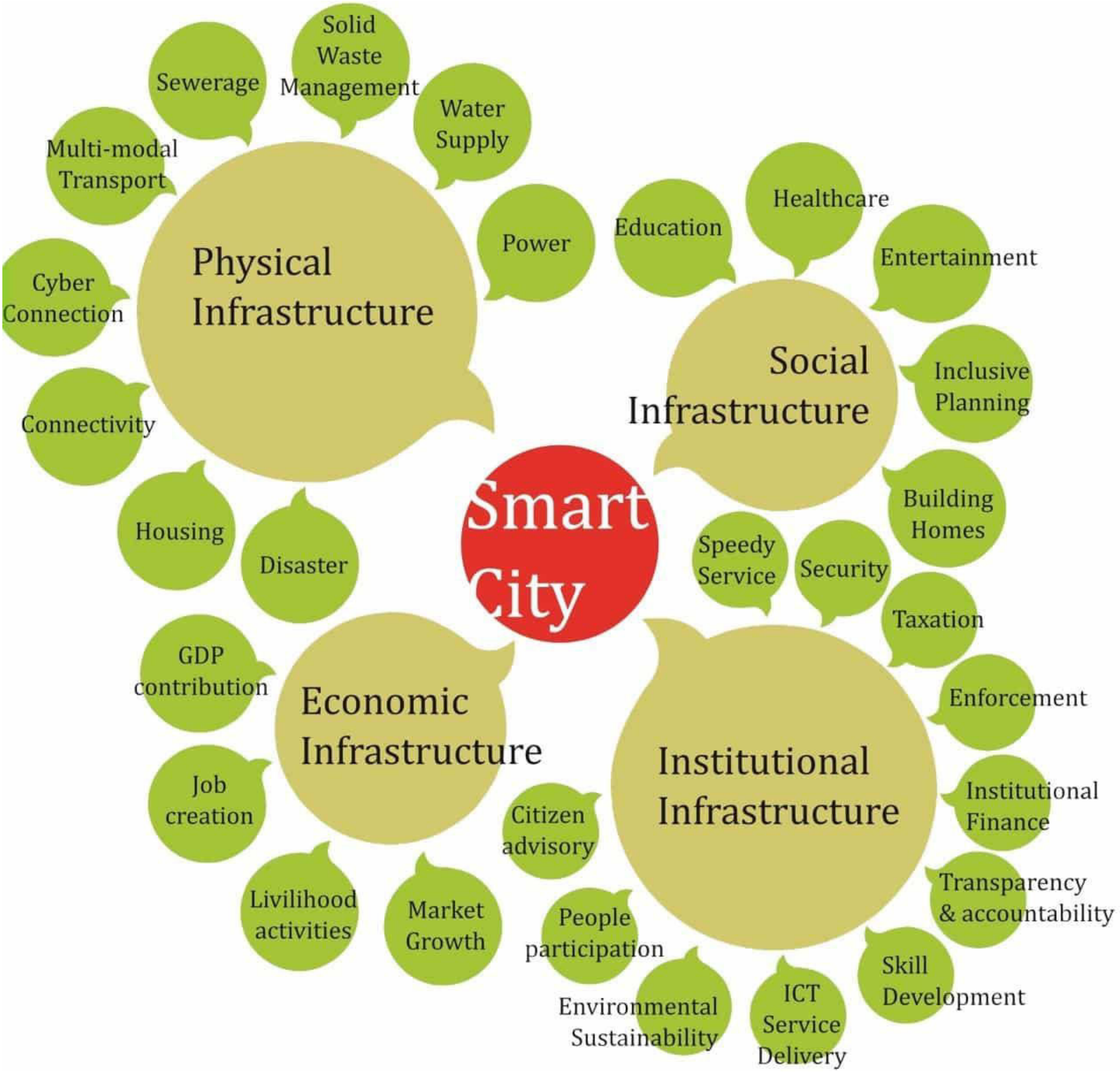

Figure 8.13: Smart City Planning using Geospatial Technology

The 'smart city' concept aims at developing a comprehensive system that uses geospatial data to enhance the understanding of complex urban systems and to improve the efficiency and security of these systems. This geospatial data concerns (i) the urban built environment such as infrastructure, buildings and public spaces, (ii) the natural environment such as biodiversity, green spaces, air quality, soil and water, and (iii) urban services such as transport, municipal waste, water, energy, health and education. The smart city concept also aims at transforming the 'silo-based' management of cities into a 'shared' system that involves urban stakeholders in the design, realization and evaluation of urban projects.

Figure 8.14: Smart City and Geographic Information System

Benefits of GIS in Urban Planning

GIS in urban planning is becoming increasingly useful over time.

Initially, the high costs of installation and operation stunted the adoption of GIS in urban planning. However, as **GIS hardware** became less expensive and **GIS software** became more user-friendly - adoption has increased. There are numerous benefits of using GIS in urban planning, but here are the top five.

1. Improved mapping - With a single repository for current and historical data and maps, GIS can **improve map currency** (whether or not a map is up-to-date), increase the efficacy of thematic mapping, and lower expenditures for data storage

2. Increased access to vital information - Desktop GIS makes it easier to store, manage, and access data from a variety of sources. **Cloud GIS** offers that same benefit, while enabling access from any device.

3. Improved communication - With a unified system for data storage and management, internal parties can access the information they need immediately - rather than sifting through documents, hard drives, or trying to track down data across departments.

4. Increased quality and efficiency for public services - GIS can be used to create a public facing portal (like **this one**), opening the flow of information between government organizations and the public. Government officials can share information quickly, while members of the public have self-serve access to the information they need.

5. Increased support for strategic decision making - With speedier access to a wider ranger of important geographic information, planners can create informed strategies more effectively. More than that, they can explore a wider range of **'what-if' scenarios** - ideally leading to stronger, more effective long-term strategies.

GIS AS TOOL FOR TOWN PLANNING

GIS platforms have a variety of capabilities that can be applied to urban planning. Database management, visualization, spatial analysis, and spatial modelling are among the most widely employed. Let's take a quick look at each.

1. **Database management**: Database management is the process of creation, import, maintenance, and use of all data traveling in and out of a GIS platform. For urban planning, this involves the storage of environmental data, socioeconomic data, land use maps and plans, and planning applications. As you can imagine, cities produce huge quantities of data in many different formats. GIS provides a single database where all that data can be stored and easily organized. Once data has been added to the database, urban planners can use spatial queries to quickly access the information.
2. **Visualization**: In the context of urban planning, visualization often refers to maps. Desktop GIS offers powerful mapping visualization tools, enabling planners to create maps (sometimes even in 3D). Environmental and socioeconomic data can be used to help create these maps, or added after the fact as a secondary data source. Digital maps make it easier for urban planners to make decisions and explore solutions. For example, identifying an ideal location for a new park or public space.
3. **Spatial analysis & modelling**: GIS in urban planning enables spatial analysis and modelling, which can contribute to a variety of important urban planning tasks. These tasks include site selection, land suitability analysis, land use and transport modelling, the identification of planning action areas, and impact assessments. GIS functionality such as interpolation, buffering, map overlay, and connectivity measurement help urban planners to achieve these tasks.
4. **Assessing Squatters Resettlement Programmes and Supply of Low -Cost Housing**: The distribution, characteristics and associated problems were analysed to assign alternative solutions to be undertaken in solving the problems of squatter settlements. The analysis carried out was able to categorise squatters to three level of action to be taken namely 'Immediate Resettlement', 'Upgrading' and 'No immediate action'. The distribution and particularly development status (Occupied, Ready but unoccupied and Under Construction) of low cost housing in area was also monitored. Apart from assessing the development status, the quantity and distribution of the low cost housing is essential in evaluating its supply and demand based on population needs and to cater for resettlement of squatters wherever necessary.

5. **Development of the Planning Analysis Model and Planning Evaluation Model:** The analysis process needs a critical and relative action to acknowledge certain situation and comprehend the collected data (Wahab, 1991). In defining the analysis model, a few questions need to be asked in order to obtain rational results. Selection of the right model will lead to integrated and sustainable development in the future. The consequence due to failure in choosing the appropriate model will be worst if decision-makers are not well informed where planning is concerned. Evaluation is an essential in the planning process especially in selecting the appropriate alternative development scenario to be implemented. Among the usual evaluation method employed include the cost-benefit analysis, the development goal achievement matrix analysis, the policy achievement and development strategy analysis, and some others. As such, in this phase, it is necessary for decisionmakers to define the suitable planning evaluation model so that the alternative development scenario chosen could cater for future planning and its implementation is beneficial to the public. In defining the planning evaluation model, the development scenario alternatives should satisfy various criteria such as taking into consideration the planning objectives proposed and measuring all the costs and benefits for every sector.
6. **Organisational Issues and Integration of information from multi-sector planning:** One of the biggest challenges in the development and operation of GIS is the adaptation of the organisation to the new technology. This is not to say that the organisation should be technology driven, but that some new organisational structure and operation may be required to take fullest advantage of the benefits that GIS can offer. Lack of trained personnel, finance and political consideration may cause changes in public organisation difficult to be accomplished (Yaakup, 1993a). Data management is most important for an organization so that the information can be shared with other related agencies. Most data for planning and management purposes does not possess the appropriate quality for GIS application. Data from multiple agencies consist of different levels of accuracy and is not systematically organised. The issue of data sharing will remain unsolved as data is not easily provided by some agencies due to its confidential status and too sensitive to be shared. Nevertheless, Masser (1998) pointed out that the question of digital data availability was much more a question of central and local government attitudes towards the management of information, rather than a matter of information rich verses information poor. Countries with relatively low levels of digital data availability and GIS diffusion also tend to be countries where there had been a fragmentation of data sources in the absence of central or local government coordination. While countries where government had created a framework in terms of responsibilities, resources and standards for the collection and management of geographic information also tended to be those with relatively high levels of digital data availability and GIS diffusion.

SLUM MONITORING AND MANAGEMENT

A slum according to UN-HABITAT (2007) is an area that combines, to various extents, the following characteristics: inadequate access to safe water, inadequate access to sanitation and other infrastructure, poor structural quality of housing, overcrowding and insecure residential status. These characteristics are being proposed because they are largely quantifiable and can be used to measure progress toward the Millennium Development Goal to significantly improve the lives of at least 100 million slum dwellers by 2020 (UN-HABITAT, 2007). Slums manifest in different ways and vary from country to country. Two major ones have been identified. These are slums of hope or progressing settlements and slums of despair or declining neighbourhoods. The first is made of 'old' city centre slums and 'new' slum estates whilst the latter is made of squatter settlements and semi-legal sub-divisions (UN-Habitat, 2003). These two major ones are sub divided into four categories of slums. These are inner city slums; slum estates, squatter settlements and illegal sub-divisions which differ in terms of their formation, condition and extent of deprivation.

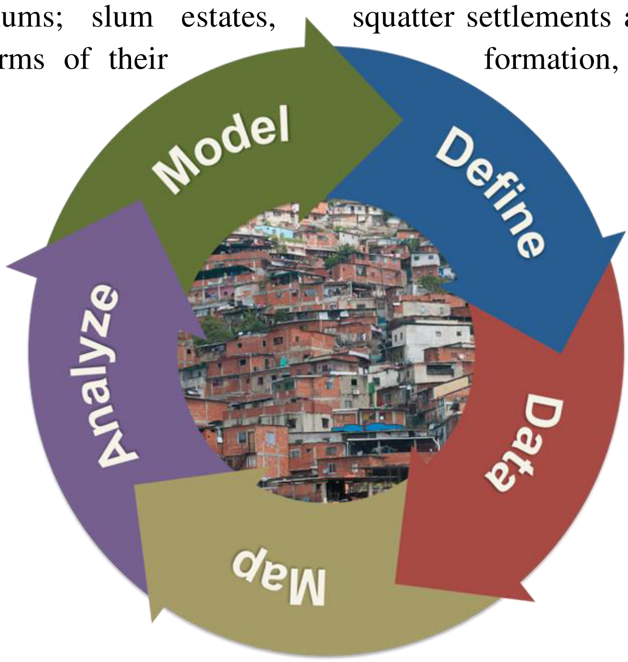

Figure 8.15: Mapping and Monitoring of Slum in Given 5 Steps

Remote Sensing and GIS has been applied severally for change detection of informal settlements and exploiting spatial patterns (Hurskainen & Pellikka, 2004; Stasolla & Gamba, 2007; Abbott, 2003; Sartori, Nembrini & Stauffer, 2002). The Object-based Image Classification (OBIA) approach has been employed for detecting and mapping slum settlements through the integration of semantic information (Benz et al., 2004; Hofmann, 2001; Nobrega, Quintanilha & Ohara, 2006).

The slum level information is categorized into thematic like slum extent, infrastructure (roads, street lights, proposed water and sewer network, hand pumps, wells) and natural features (trees, water ponds). In all these thematic, user can toggle houses (parcels) to understand the trend, pattern and connect. The slum improvement plan for a specific slum settlement depends on indicators like existing condition of housing (typology distribution, building use, plot size, number of families residing), socio-economic profile (water connection, water source, connection charges, lake water usage, toile type use, houses from where children go to school, type of schools they prefer, health facilities used, availability of electricity connections), and demographic (caste, below poverty, number of males and females). fusion of traditional with emerging open data sources and data mining tools to identify additional indicators that can be used to detect and map the presence of slums, map their footprint, and map their evolution. Towards this goal, we develop an indicator database for slums using open sources of physical and socio-economic data that can be used to characterize slum settlements. Using this database, we then leverage data mining techniques to identify the most suitable combination of these indicators for mapping slums.

Urban Poverty Mapping In principal, there are three different methodologies of poverty mapping depending on the availability of data.

1. Full data coverage (case study Nairobi). When a complete, recent census dataset is available covering all the required indicators and the corresponding maps exist, the program can focus on data analysis, mapping and follow-up (policy support). In case a reliable, recent census is available these data are very useful. The crucial question is whether the variables included in the census are covering the information required for the specific needs of an urban inequity study or poverty study. In many cases, e.g. income data will not be available.
2. Sample Household Surveys (case study Addis Ababa). In case auxiliary data (such as old census data, social welfare records, municipal population registration, large demographic and health surveys) are available, these can be related to data obtained through a specifically designed sample household survey. By developing a model to identify the relationship between the survey and the auxiliary data more reliable estimates can be made and it is possible to extrapolate the information to areas not covered by the household survey.
3. Qualitative and secondary data. In case there is no capability / resources available for a household survey and there is neither an up-to-date census, alternatives are required for an urban inequities study. A possibility is to use a combination of local expert knowledge, high resolution images and local records. This is sometimes referred to as the development of 'participatory poverty profiles'. Thematic layers (land use, location of slums, hazard zones, water coverage) can be developed using specific local knowledge supported by good base maps (or recent high-resolution images). An additional layer is the boundaries of administrative areas (enumeration areas, neighbourhoods) with local available records. The combination of these data sets in a GIS can generate a wealth of information on urban inequities and can easily deals with the so-called modifiable areal unit problem. The advantage that is locally generated, and thus easier for institutional embedding.
4. mapping of the spatial variations in living conditions is a powerful tool to visualise urban inequalities, or, in a more programmatic language, urban inequities. GIS communicates this message in a convincing way, which is easy to understand for an audience of mostly non-technical decision-makers at the local level. Especially in combination with high-resolution satellite images as an objective medium (what the sensor sees is what you get), GIS maps as a communication tool are very convincing. Other useful opportunities for this combination lie in e.g. the verification of other data sources or using it as a data source itself (counting of buildings, population estimation). There are two important actions to be taken: the first one is that actions need to be undertaken to improve the living conditions of slum dwellers. These strategic actions plans need to be developed not only at the sector level (e.g. water)

but preferable at the district or neighbourhood level (e.g. the subcities and kebeles of Addis Ababa) with a variety of stakeholders including the residents themselves. The second action is that GIS should not be seen as a project or product ("project GIS") but be part of an incremental development process, in which spatial databases are developed gradually across different institutions ("community GIS"). The improved quality (up-to-date, compatibility, accuracy) of such an inter-institutional spatial data infrastructure will allow the institutionalisation of the monitoring activities described in this paper without exorbitant costs. Since a number of years, the Global Urban Observatory Section at UN-HABITAT has assisted governments and local authorities to monitoring human settlements at country and city level. Now, increasingly support is giving to local level partners (so-called local urban observatories) to monitor the impact of policy and development intervention on the living conditions at the intra-city level using GIS. The challenge ahead is to embed GIS within local communities and institutions, generate genuine interest of politicians, and support this development with effective actions. We do hope that the availability of GIS software through an ESRI grant to UN-HABITAT partners (1000 Cities GIS Programme) will serve as a stimulation to our partners, and help them to address the urgent problems at hand rather than creating databases, only. In that respect, the introduction of monitoring systems and community GIS is a first step towards developing targeted, evidence-based proposals to improve the living conditions of the one billion slum dwellers worldwide.

SITE SUITABILITY

Determination of appropriate site location for urban development is critical issue. GIS in urban planning enables spatial analysis and modelling, which can contribute to a variety of important urban planning tasks. These tasks include **site selection, land suitability analysis, land use and transport modelling, the identification of planning action areas, and impact assessments**. The goal of land-use suitability assessment is to determine the suitability of a specific area for particular land use and to estimate the potential of land for alternative land uses considering a wide range of criteria based on environmental, social, and economic factors.

Remote sensing has been recognized worldwide as an effective technology for the monitoring and mapping the urban growth and environmental change. The main advantage of satellite remote sensing is its repetitive and synoptic coverage that is very much useful for the study of urban area.

How do you do a suitability analysis in GIS?

1. Open the Make Suitability Analysis Layer tool.
2. From Input Features, you have the option to select a feature layer from your project or browse for hosted or shared content. Click the browse button. ...
3. Type Market Suitability Candidates in the Layer Name text box.
4. Click Run.

Site suitability is the process of **selecting the best location for a particular purpose based on specified criteria**. Criteria may have any number from one to hundreds. The entire suitability of land structure thus depends upon four major elements • Geological information of study area. • Road proximity. • Land use/ Land cover (LC/LU). • Slope, Aspect ratio. The selection of suitable sites is based on upon a specific set of local criteria. The characteristics of a site (e.g. present landuse, slopes, water availability, distance to employment, development coast, geology, geomorphology etc.) influence its suitability for a specific land use type. To assess the overall suitability a scoring and weighting system is applied to the various aspects of suitability. Site suitability is the process of understanding existing site qualities and factors, which will determine the location of a particular activity. The purpose of selecting potential areas for residential development depends upon the relationship of different factors, like location of available sites, extent of the area, accessibility etc. and site association factors like slope, soil etc. the analysis may also determine how those factors will fit into the design process to evaluate site suitability.

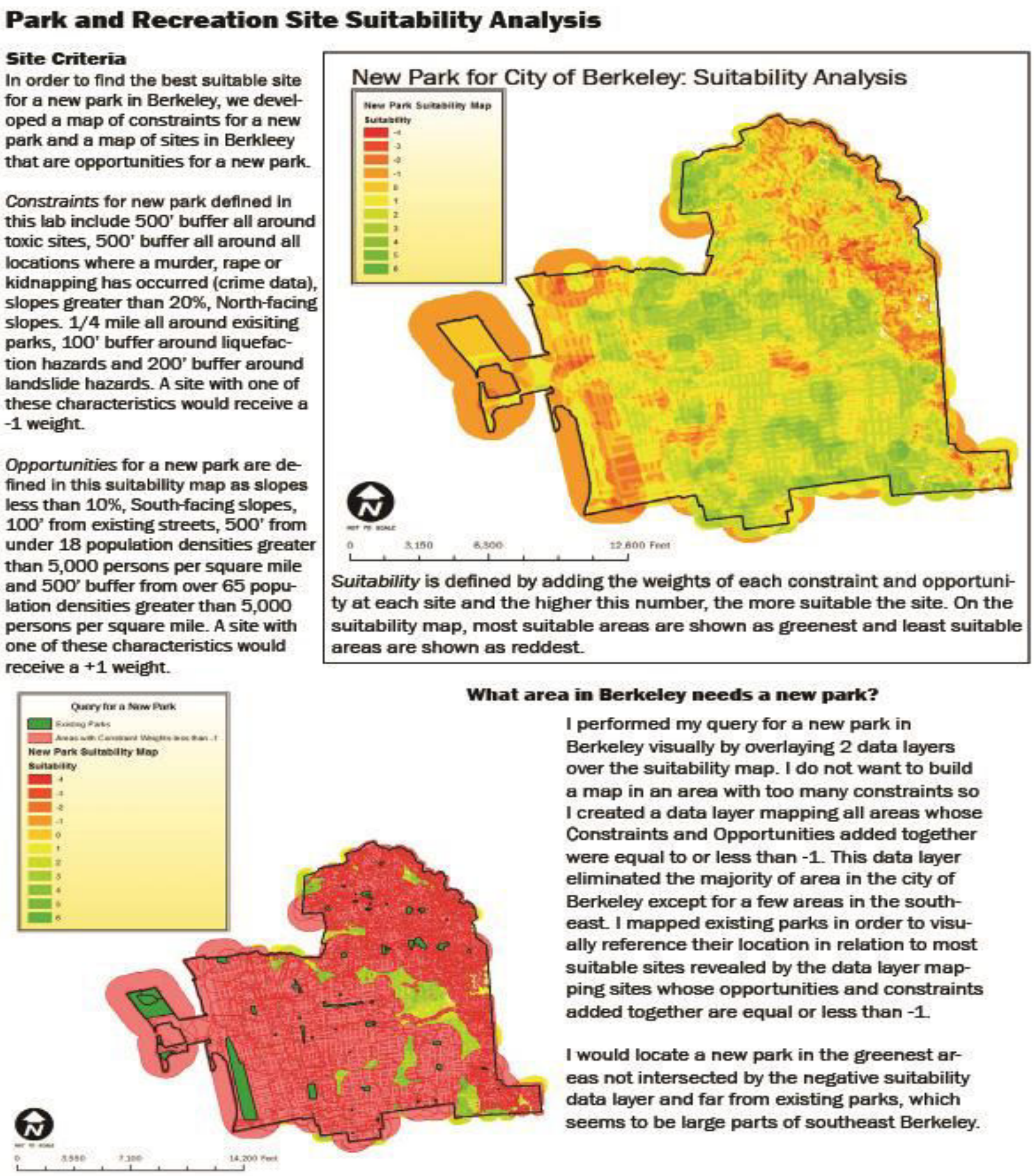

Figure 8.16: Site Suitability in Town Planning

For any suitability analysis, appropriate base data is required (generally satellite data or air photos, topographic maps and thematic maps and field data). The different land qualities, which can be considered for suitability modelling are, present land use/land cover, slope, proximity of transportation network, flood hazard, ground water condition etc. the characteristics of a site (e.g. present land use, water availability, road accessibility, flood hazard etc.) influence its suitability for further urban development. To assess the overall suitability a scoring and weighting system is applied to the various aspects of suitability. Suitable sites are found out by adding all layers which are affecting site suitability. The suitability scoring used in study for each of the map and their category at 10-point scale. All the thematic maps have been converted in raster form, so that for each pixel, a score can be determined. These maps are then combined into a composite map by simple addition of recorded maps with weight system. A suitability map has been prepared finally by applying the scoring using GIS software. The final output of raster layers having particular suitability score. Land suitability analysis for urban development is necessary to overcome the problem with limited land availability against drastic growth of urbanization.

LAND SUITABILITY FOR TOWN DEVELOPMENT

The essence of land evaluation is to compare or match the requirements of each potential land use with the characteristics of each kind of land. The result is a measure of the suitability of each kind of land use for each kind of land. These suitability assessments are then examined in the light of economic, social and environmental considerations in order to develop an actual plan for the use of land in the area. When this has been done, development can begin. Ideas on how the land should be used are likely to exist before the formal planning process begins. These ideas, which often reflect the wishes of the local people, are usually included among the possible uses to be assessed in the evaluation and will thus influence the range of basic data that needs to be collected. A wide range of specialist knowledge is needed to collect and analyse all the data relevant to land evaluation. The work is best undertaken by a multidisciplinary team that includes social and economic expertise as well as biophysical scientists. Ideally, such a team should work together throughout the study so that each member can influence the others with his or her special knowledge and viewpoint. In practice it is not always possible to field the whole team at once. In this case, the physical aspects of land are usually studied and mapped first to provide a geographical framework into which the socio-economic dimensions are inserted later. A two-stage approach is obviously less well integrated and will take longer to complete. The reliability of a land evaluation can be no greater than that of the data on which it is based. Ideally, fresh data should be obtained to answer all questions raised by the study, although time and expense usually prevent this being done as thoroughly as is possible. The one really important requirement is that the evaluation process can be 'automated' and carried out quite rapidly once all the necessary data are available, by setting up a computerized data bank or geographical information system, and establishing rules or decision trees to carry out the matching process which produces the evaluation.

Stages in Land Suitability Evaluation: Following are the different stages in Land Suitability Evaluation.

- Defining objectives
- Collecting the data
- Identifying land uses and their classification
- Identifying the physical parameters
- Identifying environmental and socio-economic issues
- Assessing land suitability

Identifying environmental and socio- Identifying environmental and socio-economic issues: The land suitability not only is based on a set of physical parameters but also very much dependent on the socioeconomic factors. Before a land use can be recommended in a development plan, its environmental and socioeconomic implications must be evaluated further. A new or improved land use can succeed only if it can be adapted to fit local social and economic conditions. Socio-economic investigations are therefore a vital part of land evaluation, starting with the initial formulation of the study's objectives. Attention needs to be given to markets (local, national and perhaps even international), population levels and growth rates, the availability of skilled and unskilled labour, transport of products and inputs, availability of building materials etc. Local religions and cultures may be important. Political circumstances cannot be ignored, and any analysis should take account of the needs of all members of the population, including minority groups.

Assessing suitability: Suitability is a measure of how well the characteristics of a land match the requirements of urban development. The preparation of urban development plan requires consideration of all components of the environment that exist before the new plan's creation and the environment to be created by the new development plan. The plan may not be effective if any of these components are treated separately or loosely. Therefore, the development plan should interrelate all elements that form a community. It is primarily because, the land is a concrete form and any plan must be flexible enough to change established uses either to correct mistakes or to accommodate changing needs. The steps that are followed in the preparation of development plan proceeds from deciding what land to develop to when and how to develop it. So, the development plan should encompass physical characteristics, constraints and socioeconomic possibilities. Basically, it refers to the potentiality of the land for the development. Land potentiality includes both land suitability as well as land value. The land suitability designates land according to its physical capability regardless of any planner's conceptual interest. The integration of land suitability map and land value map produces a land potential map which can be later combined with the socio-economic variables to prepare final alternative development plan.

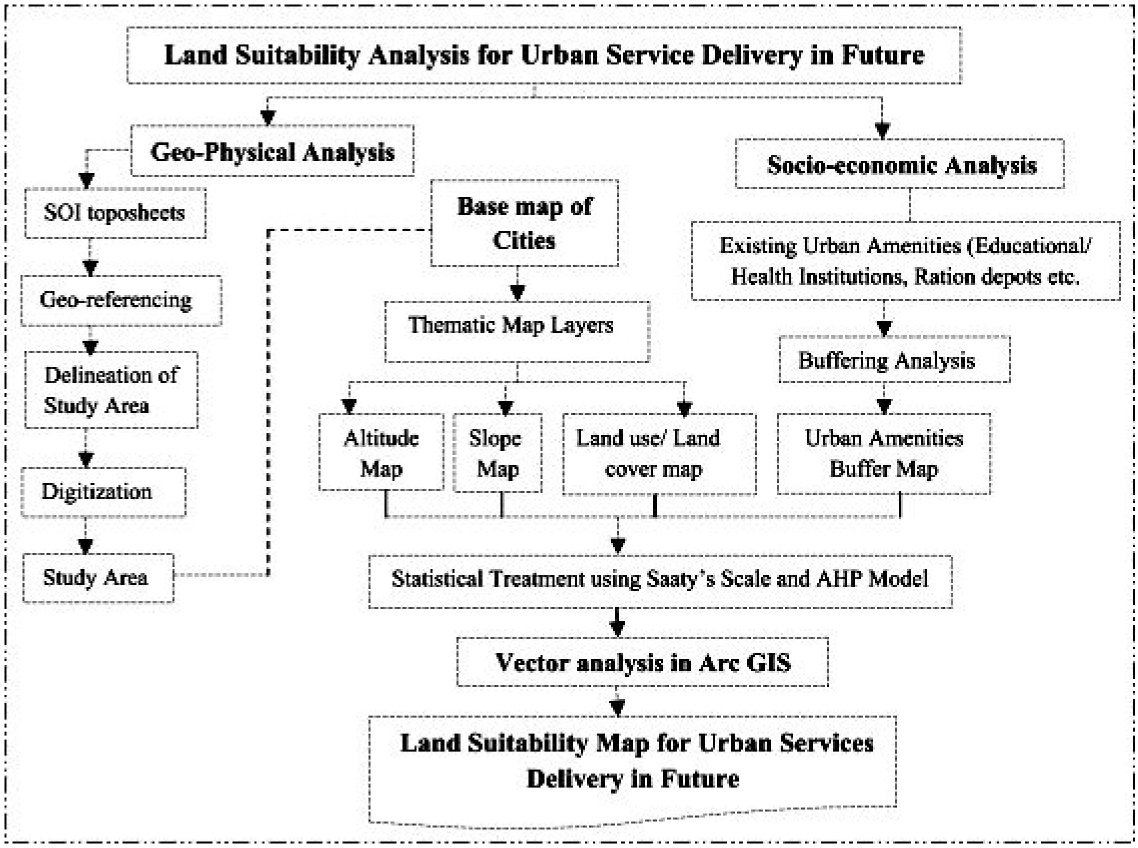

Figure 8.17: Land Suitability Analysis Model for Town Development

Identification of suitable areas for urban development is, therefore, one the critical issues in the preparation of the development plan. The land suitability not only based on a set of physical parameters but also very much on socioeconomic factors. The composite effect of these parameters determines the degree of suitability and also helps in further categorizing the land into different classes of development. Also, the process of suitability assessment is very much dependent upon the prevalent conditions such as high pressure on land for development. If the pressure is on the land is too high, then it may lead to a high order of speculation and development of land which is otherwise not suitable from suitability analysis point of view. Therefore, land suitability may be viewed as prioritization of land for urban development.

8.4 SUMMARY

Although the GIS was successfully implemented, this raised several issues that have to be solved. Some of these are difficulty in translating all the user requirement; difficulty in integrating the data sets as they are available in different forms, formats and characteristics; difficulty in getting full cooperation from various agencies which hold the data and lacking of clear work procedures and methods of analysis as being practiced in the present system. The challenge that remains is updating and maintaining the database and utilising every potential of the system mainly as a decision support tool in planning and monitoring of urban development of the region. A sustainable planning approach inevitably needs a support

system that can support the monitoring process to derive at a better decision. The emergence of GIS supported by the 'What if?' software provides an opportunity for its use as an essential tool in urban and regional planning and management activities. The capabilities of GIS can in time be enhanced and updated while collaboration with outside package such as the 'What if?' software will hopefully enable ARCGIS to be an effective and comprehensive planning support system, taking into account the land use regulations such as physical characteristics, transportation and environmental impact of the growth scenarios. However, related technical, organizational, statutory and human issues need to be countered before GIS can really be applied for planning and management purposes. Hence, planning strategies play an important role in defining the success of a GIS development. Subsequently, effective implementation of the PSS technology very much depends on an overall management strategy based on the needs of users in the organisation.

In this study, optimum planning for site management decisions and geographical data query were carried out to obtain both visual and detailed information and network analysis applications. However, this study on GIS design and application for cultural heritage sites and network analysis reveals important considerations to help users make decisions for future town planning. The advantage for making decisions based on the overall data from this system could provide spur economic revitalization, enhanced city planning, economic development, and preserve important cultural and heritage sites and buildings. Moreover, users appear to save time via GIS design and enhanced decision-making. The applicability of the GIS database has far-reaching potential in making effective decisions in town planning. The GIS is served in this study as an "intelligent" database. GIS is used to provide a compact space where all sorts of data relevant to Karaikal Town area can be stored in digital format, including images, maps, documents, and photographs. Data have been already arranged so that it can be incorporated into displays like maps, charts, and tables, and queried in the service of sophisticated analytical procedures. Future analyses will be the basis for future planning, design, and site management decisions. The list of queries is endless, and unique to every potential user. A successful plan and implementation will provide an opportunity to local decision-makers to provide a synoptic and detailed planning of the town.

8.5 GLOSSARY

- Socioeconomic- relating to or concerned with the interaction of social and economic factors.
- Implementation- the process of putting a decision or plan into effect; execution.
- Database- a structured set of data held in a computer, especially one that is accessible in various ways.
- Synoptic- outline of the contents
- Buffering- Buffer is a region of memory used to temporarily hold data while it is being moved from one place to another.
- Map Overlay- Map overlay is a procedure for combining the attributes of intersecting features that are represented in two or more geo registered data layers.

- Slum- a densely populated usually urban area marked
- Geospatial technologies- Geospatial Technology is an emerging field of study that includes Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System.

8.6 ANSWER TO CHECK YOUR PROGRESS

- Define slum.
- Define Geospatial technologies.
- Define Assessing suitability.
- Define site suitability.
- Write a short note on Land Suitability Analysis.

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8.8 TERMINAL QUESTIONS

1. Explain GIS application in the field of town planning.
2. What do you understand by Slum. Describe GIS applicability in planning and management of slum.
3. How Geospatial technologies are helpful in Town Infrastructure and Facility management.
4. Define Utilities management with suitable examples in any selected town of your choice.
5. Enlighten the problems faced by cities in India with its possible solutions using Geospatial technologies.

UNIT 9 : OVERVIEW OF TOWN INFRASTRUCTURE, FACILITIES AND SERVICES, SLUM AND SQUATTER SETTLEMENT AND THEIR IDENTIFICATION TOWN SERVICES AND FACILITIES ANALYSIS, LAND SUITABILITY ANALYSIS FOR TOWN AREA DEVELOPMENT

9.1 OBJECTIVES

After reading this unit you should be able:

1. To understand the remote sensing and Town infrastructure and facility analysis.
2. To know application of Geospatial technology in town monitoring.
3. To describe residential area analysis and town area development using Geospatial Technologies.

9.2 INTRODUCTION

Humans have influenced the Earth environment by changing the dynamics of land use/land cover. In the last five decades, human activities around the world negatively affected most of land use land cover (LULC) categories. The land has become scarce because of the enormous agricultural and population pressure. The farmland displacement, urban sprawl, and deforestation, which leads to habitat destruction, loss of arable land, and to the decline of natural greenery areas are characteristics of rapid land cover change. LULC rapid change is attributed to several direct and potential sprawling factors. Direct factors would involve the infrastructure construction, settlement expansion, and industry development factors, whereas potential factors include technology, economy, population, policies, wars, and natural factors. On the other hand, another relevant factor that supports growth and development in cities is the transportation infrastructure of primary and secondary road networks that show the spatial structure of population distribution. Consequently, urban expansion and transportation are essentially interrelated. These landscape dynamics can be well understood using multi-temporal satellite imagery for digital change detection techniques. Satellite images are significant source for land use/land cover information as they offer rapid, periodic and accurate data acquisition from RS system. Landsat data are widely used in the study of the LULC change. Information on LULC change and urban growth study is essential for urban planners and local governments futuristic plans for sustainable development in any area. Landsat TM, ETM+ and LOL, Satellite Pour'Observation de la Terre (SPOT), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Ikonos (Pereiraa and Caetanoa,), Pleiades, Worldview, and aerial photographs have been employed in the mapping analysis of land use classes and in the monitoring of their changes.

9.3 OVERVIEW OF TOWN INFRASTRUCTURE, FACILITIES AND SERVICES, SLUM AND SQUATTER SETTLEMENT AND THEIR IDENTIFICATION TOWN SERVICES AND FACILITIES ANALYSIS, LAND SUITABILITY ANALYSIS FOR TOWN AREA DEVELOPMENT.

REMOTE SENSING DATA AND IMAGES

Geospatial Technology is an emerging field of study that includes Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS). Geospatial technology **enables us to acquire data that is referenced to the earth and use it for analysis, modeling, simulations, and visualization**. Geospatial technology is used **to collect, analyze and store geographic information**. It uses software to map geographic locations while analyzing the impact of human activity. Geographic Information System (GIS) uses digital software to combine maps and datasets about environmental events and socioeconomic trends.

Geospatial data is information that describes objects, events or other features with a location on or near the surface of the earth. Geospatial data typically combines location information (usually coordinates on the earth) and attribute information (the characteristics of the object, event or phenomena concerned) with temporal information (the time or life span at which the location and attributes exist). The location provided may be static in the short term (for example, the location of a piece of equipment, an earthquake event, children living in poverty) or dynamic (for example, a moving vehicle or pedestrian, the spread of an infectious disease).

Geospatial data typically involves large sets of spatial data gleaned from many diverse sources in varying formats and can include information such as census data, satellite imagery, weather data, cell phone data, drawn images and social media data. Geospatial data is most useful when it can be discovered, shared, analysed and used in combination with traditional business data.

Geospatial analytics is used to add timing and location to traditional types of data and to build data visualizations. These visualizations can include maps, graphs, statistics and cartograms that show historical changes and current shifts. This additional context allows for a more complete picture of events. Insights that might be overlooked in a massive spreadsheet are revealed in easy-to-recognize visual patterns and images. This can make predictions faster, easier and more accurate. **Geospatial information systems (GIS)** relate specifically to the physical mapping of data within a visual representation. For example, when a hurricane map (which shows location and time) is overlaid with another layer showing potential areas for lightning strikes, you're seeing GIS in action.

Types of geospatial data

Geospatial data is information recorded in conjunction with a geographic indicator of some type. There are two primary forms of geospatial data: vector data and raster data. Vector data is data in which points, lines and polygons represent features such as properties, cities, roads, mountains and bodies of water. For example, a visual representation using vector data might include houses represented by points, roads represented by lines and entire towns represented by polygons.

Raster data is pixelated or gridded cells which are identified according to row and column. Raster data creates imagery that's substantially more complex, such as photographs and satellite images.

Examples of geospatial data

Examples of geospatial data include:

- **Vectors and attributes:** Descriptive information about a location such as points, lines and polygons
- **Point clouds:** A collection of co-located charted points that can be recontextured as 3D models
- **Raster and satellite imagery:** High-resolution images of our world, taken from above
- **Census data:** Released census data tied to specific geographic areas, for the study of community trends
- **Cell phone data**: Calls routed by satellite, based on GPS location coordinates
- **Drawn images**: CAD images of buildings or other structures, delivering geographic information as well as architectural data
- **Social media data:** Social media posts that data scientists can study to identify emerging trends.

Geospatial technology

Geospatial technology refers to all the technology required for the collecting, storing and organizing of geographic information. It includes the satellite technology which allowed for the geographic mapping and analysis of Earth. Geospatial technology can be found in several related technologies, such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), geofencing and remote sensing.

Geospatial technology and Python

The popular programming language Python is well suited to working with geospatial data and is capable of accommodating both vector data and raster data, the two ways in which geospatial data are typically represented. Vector data can be worked with by using programs such as Fiona and GeoPandas. Raster data can be worked with by using a program such as xarray.

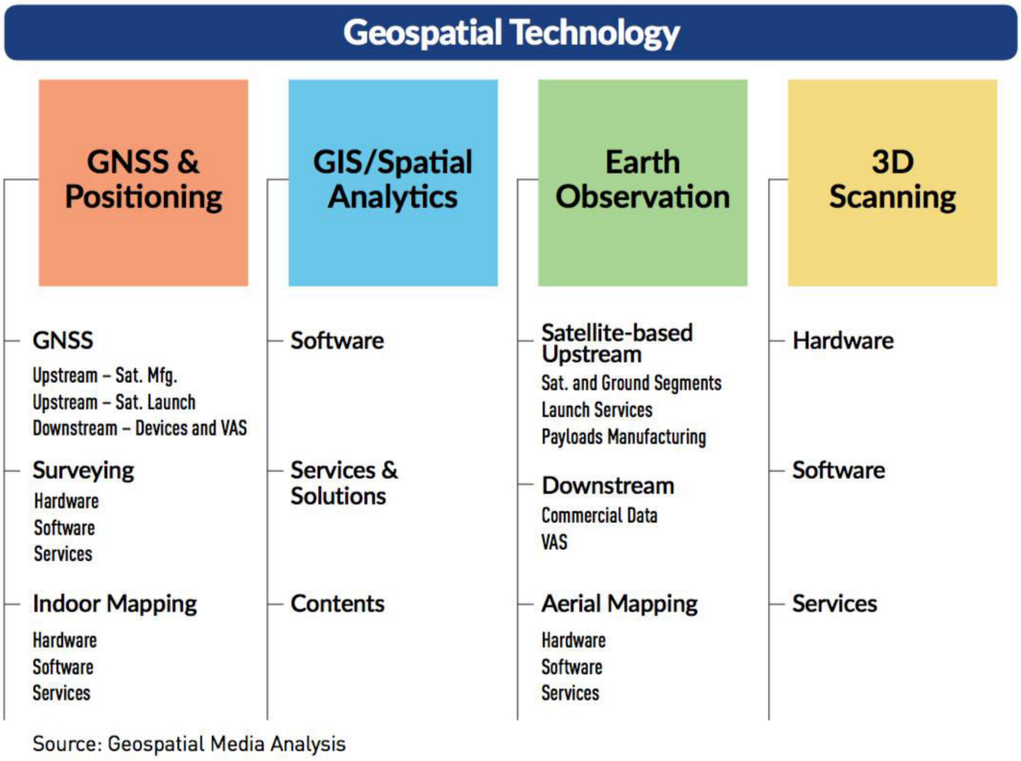

Figure 9.1: Geospatial Technology

REMOTE SENSING DATA AND TOWN PLANNING

In India, the complexity of urban development is so dramatic that it demands immediate attention and perspective physical planning of the cities and towns. The dynamic nature of urban environmental necessitates both macro and micro level analysis. Therefore, it is necessary for policy makers to integrate remote sensing with urban planning and management. Traditional approaches and technique designed for towns and cities may prove to be inadequate tools when dealing with metropolis. New approaches are required, and new methods must be incorporated into current practice. Until recently, maps and land survey records from 1960 to 70 were used for urban studies, but now the trend has shifted to use digital, multispectral images acquired by EOS and other sensors. The trend towards using remotely sensed data in urban studies began with first-generation satellite sensors such as Landsat MSS and was given impetus by a number of second-generation satellites: Landsat TM, ETM+ and SPOT. The recent advent of a third generation of very high spatial resolution (5m/pixel) satellite sensors is stimulating. The high-resolution PAN and LISS III merged data may be used together effectively for urban applications. Data from IRS P-6 satellites with sensors on board especially LISS IV Mono and Multispectral (MX) with 5.8 m/pixel spatial resolution is very useful for intensive urban studies.

Advancement in technology of remote sensing has brought miracle in the availability of the higher resolution satellite imageries. They are IRS-P6 Resourcesat imagery with 5.8 m resolution in multispectral mode, IRS-1D Pan image with 5.8 m resolution, Cartosat-I imagery of 2.5 m resolution with stereo capabilities, Cartosat-II with 1 m, IKONOS imageries of Space Imaging with 4 m in multispectral mode and 1 m in panchromatic mode, Quickbird imagery of Digital Globe with 61 cm resolution in panchromatic mode and so on. These high resolutions of the sensors provide a new methodology in the application with newly raised technical restrictions. Apart from cartographic applications, IRS-1D LISS IV (P-6) data will be of great use in cadastral mapping and updating terrain visualization, generation of a national topographic database, utilities planning and other GIS applications needed for urban areas. The satellite will provide cadastral level information up to a 1:5,000 scale, and will be useful for making 2-5 m contour map (NRSA, 2005). The output of a remote sensing system is usually an image representing the scene being observed. Many further steps of digital image processing and modeling are required in order to extract relevant information from the image. Suitable techniques are to be adopted for a given theme, depending on the requirement of the specific problem. Since remote sensing may not provide all the information needed for a full fledged assessment, many other spatial attributes from various sources are needed to be integrated with remote sensing data. This integration of spatial data and their combined analysis is performed through GIS technique. It is a computer assisted system for capture, storage, retrieval, analysis and display of spatial data and nonspatial attribute data. The data can be derived from alternative sources such as survey data, geographical/topographical/aerial maps or archived data. Data can be in the form of locational data (such as latitudes/longitudes) or tabular (attribute) data. GIS techniques are playing significant role in facilitating integration of multi-layer spatial information with statistical attribute data to arrive at alternate developmental scenarios.

Main Requirements for Urban Planners Apart from topographical mapping, planners also look forward to remote sensing (data products) technology to provide them information on existing landuse and their periodic updating and monitoring. In addition, with appropriate technique and methodology the same data products can be used to:

- Study urban growth/sprawl and trend of growth
- Updating and monitoring using repetitive coverage
- Study of urban morphology, population estimation and other physical aspects of urban environment
- Space use surveys in city centers
- Slum detection, monitoring and updating
- Study of transportation system and important aspects both in static and dynamic mode
- Site suitability and catchments area analysis
- Study of open/vacant space High spatial resolution satellite data are highly beneficial in the context of complex urban areas where relatively small size and complex spatial patterns of the component scene elements (e.g. buildings, roads and intra-urban open space) have restricted the use of the low-resolution space borne sensors.

These new images thus increase the amount of information attainable on urban form at local level.

Importance of GIS and Remote Sensing in Urban Planning: -

1. The spatial depiction of the public amenities and infrastructural facilities can be made quite user friendly with application of GIS.
2. Also, GIS can help determine spatial and temporal distribution of natural resources and type of activities that are damaging the natural wealth of the nation. With this information the authorities can take pre-emptive steps in specific regions to promote the cause of conservation of natural resources.
3. GIS can also be applied to the relatively newer concept of multilevel parking needs in the developing nation.
4. GIS can help in providing information about crime rate and types of crime in the various city-sectors and in different cities.
5. GIS and remote sensing techniques can also help in tackling problems related to traffic, encroachments, air and noise pollution water and power supply etc.

One of the reasons why GIS is important in urban planning is the ability to better understand current needs for a city, and then design to fulfill those needs. By processing geospatial data from satellite imaging, aerial photography and remote sensors, users gain a detailed perspective on land and infrastructure. As urban populations grow and spread, the importance of GIS lies in its ability to pull together the vast amounts of information necessary to balance competing priorities and solve complicated problems, such as optimizing new building placement or determining the feasibility of a waste disposal site. These powerful tools help planners understand the needs of densely populated areas, but they also adapt to examining smaller towns and even informal settlements. The ability to run a variety of queries and analytics on GIS data means experts can evaluate how new construction will fit in with existing infrastructure and meet regulatory demands. Users may spot opportunities for improved resource use, identifying the best locations to harvest solar, wind or geothermal energy. GIS technology empowers urban planners with enhanced visibility into data. They monitor fluctuations over time, evaluate the feasibility of proposed projects and predict their effects on the environment. GIS software can also show all relevant stakeholders exactly what the changes on the ground will look like to help them make better decisions. For example, GIS software may generate visualizations of an area's current environmental conditions and allow users to draw comparisons between the anticipated results of proposed development plans.

Urban planners in both the public and private sector employ data-driven methods to address a wide array of issues that have long-term implications for communities and the surrounding landscape.

Some of the common applications for GIS include:

- Review and analysis of plans for development.
- Checks on regulatory compliance.
- Review of environmental impact.
- Preservation of historic sites.
- Regional planning beyond the borders of a city or town.
- Mapping the delivery of utilities and planning for service interruptions.

By performing land use analyses, planners can guide new developments to areas that are less prone to damage from natural disasters. Synthesizing geographic information with financial data might lead to revitalizing an urban area in need of new businesses.

For example, GIS software allowed the City of San Antonio Planning Department to collaborate with other stakeholders in the initial stages of the ongoing efforts to redevelop the Broadway Corridor. GIS offers the means to synthesize information from a diverse set of sources, model the outcomes of multiple courses of action and share data among the San Antonio Public Works Department, the Alamo Area Council of Governments, a group of architects and Environmental Protection Agency staff in Dallas and Washington, D.C. Experts from many different disciplines found common ground and created actionable plans for making services and amenities more accessible and travel easier for bikers and pedestrians.

REMOTE SENSING IN TOWN INFRASTRUCTURE AND SPRAWL

Urban sprawling refers to the growth of urban areas resulting from uncontrolled, uncoordinated and unplanned growth. In most cities around the world, the urban growth phenomena have become unsustainable in many respects. Moreover, urbanization itself is a common concern throughout the world where people leave rural areas and accumulate in major cities.

Sprawl is a term that is often used to describe perceived inefficiencies of development, including disproportionate growth of urban areas and excessive leapfrog development. Sprawl is accumulative result of many individual decisions and it requires not only an understanding of the factors that motivate an individual landowner to convert land, but also an understanding of how these factors and individual land use decisions aggregate over space. Some of the causes of the sprawl include - population growth, economy and proximity to resources and basic amenities. Many studies indicate that urban sprawl is the pattern, density, and rate of new urban growth that create the appearance of sprawl. Population dynamics are often cited as a driving force behind urban sprawl. Population increases and the consequences of unplanned urbanization are directly related to recent growth management practices that seek to influence the way in which built-up land can proliferate. The pattern, density, and rate at which built-up land develops are the basis for one contemporary debate: urban sprawl versus urban growth. As a contemporary planning issue, the debate over sprawl is framed by different disciplines and their understanding of how and why urban areas grow. Although urban sprawl is a type of urban growth, sprawl is dependent on the way in which development occurs.

In recent times, the spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data along with conventional ground data. In recent times, the spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data along with conventional ground data. In India, unprecedented population growth coupled with unplanned developmental activities has led to urbanization, which lacks infrastructure facilities. This also has posed serious implications on the resource base of the region. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways, or surrounding the city and in rural countryside is often referred as sprawl. Some of the causes of the sprawl include - population growth, economy and proximity to resources and basic amenities. Patterns of infrastructure initiatives like the construction of roads and service facilities (such as hotels, etc.) also often encourage the regional development, which eventually lead to urbanization. The direct implication of such urban sprawl is the change in land use and land cover of the region. The ability to service and develop land heavily influences the economic and environmental quality of life in towns. Identification of the patterns of sprawl and analyses of spatial and temporal changes would help immensely in the planning for proper infrastructure facilities.

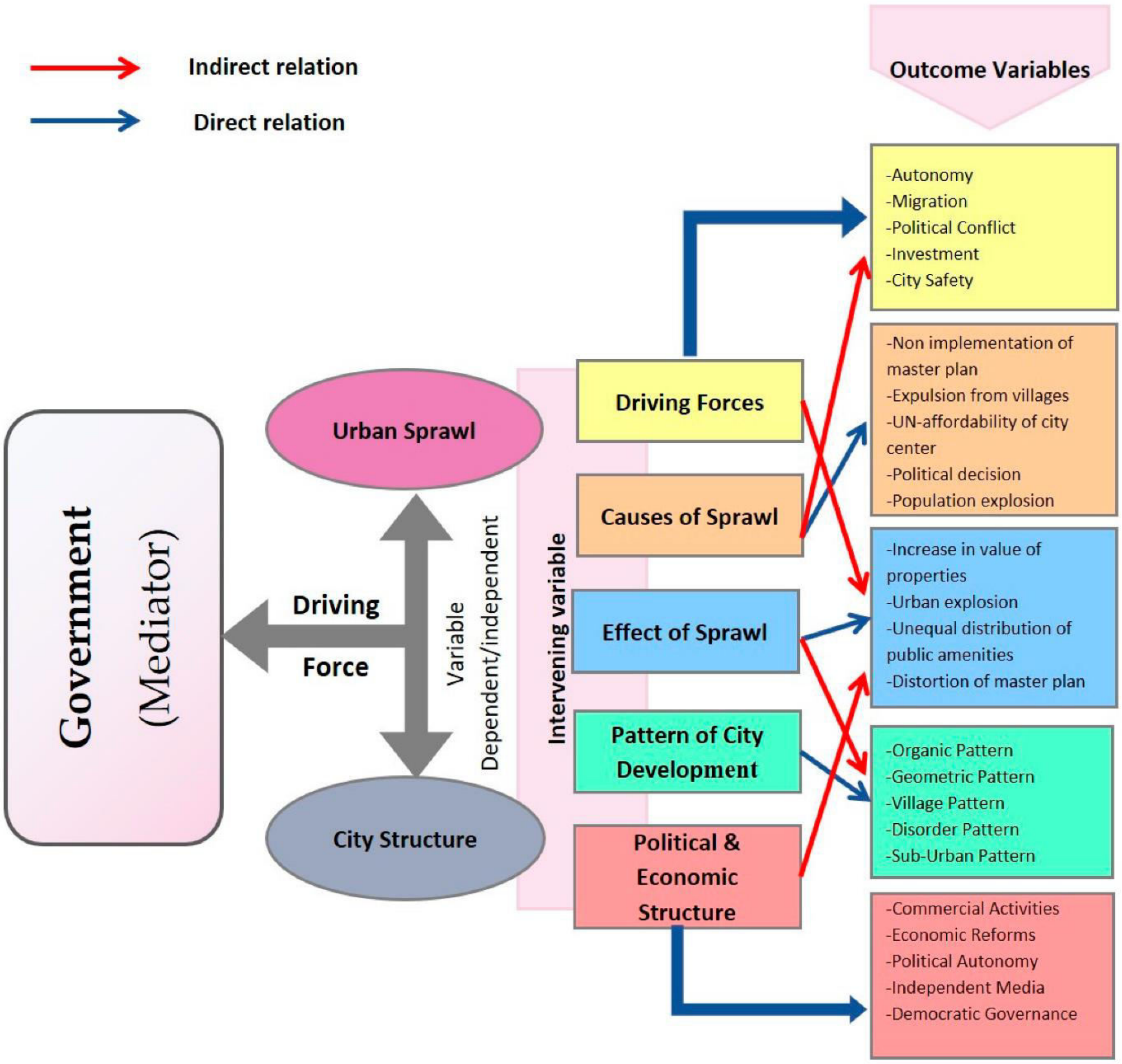

Figure 9.2: Town Sprawl and Urbanization Monitoring

Patterns of sprawl and analyses of spatial and temporal changes could be done cost effectively and efficiently with the help of spatial and temporal technologies such as Geographic Information System (GIS) and Remote Sensing (RS) along with collateral data (such as Survey of India maps, etc.). GIS and remote sensing are land related technologies and are therefore very useful in the formulation and implementation of the land related component of the sustainable development strategy. The different stages in the formulation and implementation of a sustainable regional development strategy can be generalized as determination of objectives, resource inventory, analyses of the existing situation, modeling and projection, development of planning options, selection of planning options, plan implementation, and plan evaluation, monitoring and feedback (Yeh and Xia, 1996). GIS and remote sensing techniques are developed and operational to implement such a proposed strategy.

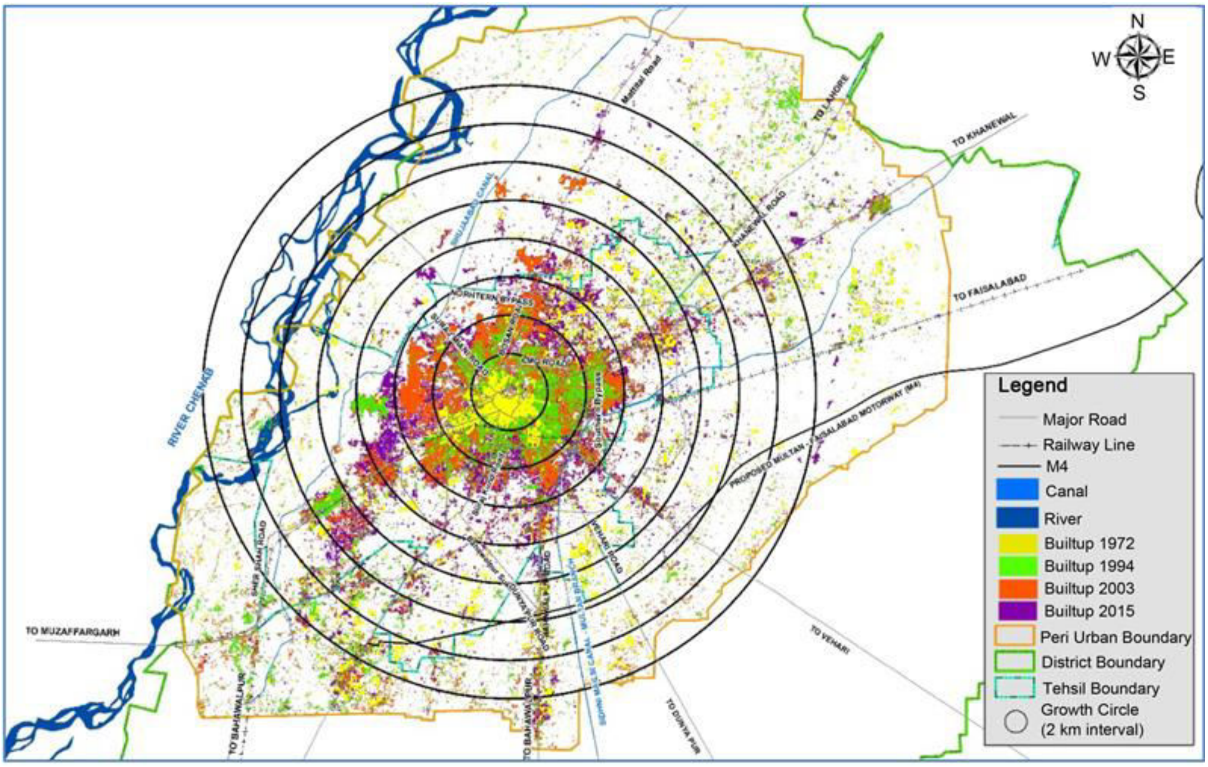

Figure 9.3: Geo-spatial Technology and Mapping Town Growth

The spatial patterns of urban sprawl over different time periods, can be systematically mapped, monitored and accurately assessed from satellite data (remotely sensed data) along with conventional ground data (Lata et al., 2001). Mapping urban sprawl provides a "picture" of where this type of growth is occurring, helps to identify the environmental and natural resources threatened by such sprawls, and to suggest the likely future directions and patterns of sprawling growth. Ultimately the power to manage sprawl resides with local municipal governments that vary considerably in terms of will and ability to address sprawl issues.

Remote sensing and GIS can be used separately or in combination for application in studies of urban sprawl. In the case of a combined application, an efficient, even though more complex approach is the integration of remote sensing data processing, GIS analyses, database manipulation and models into a single analyses system (Michael and Gabriela, 1996). Such an integrated analyses, monitoring and forecasting system based on GIS and database management system technologies requires an understanding of the problem and the application of available technologies. The integration of GIS and remote sensing with the aid of models and additional database management systems (DBMS) is the technically most advanced and applicable approach today.

Remote sensing applications are growing very rapidly with the availability of high-resolution data from the state-of-the-art satellites like IRS-1C/1D/P4 and LANDSAT. The advancement in computer hardware and software in the area of remote sensing also enhances the remote sensing applications. IRS-1C/1D/P4 provides data with good spectral resolution (LISS data) and the spatial resolution of 5.6 m in panchromatic mode. The remote sensing satellites with high-resolution sensors and wide coverage capabilities provides data with better resolution, coverage and revisit to meet the growing applications needs. The image processing techniques are also quite effective in identifying the urban growth pattern from the spatial and temporal data captured by the remote sensing techniques. These aid in delineating the specific growth patterns of sprawl which could be linear or radial or both.

The physical expressions and patterns of sprawl on landscapes can be detected, mapped, and analyzed using remote sensing and geographical information system (GIS) (Barnes et al., 2001) with image processing and classification. The patterns of sprawl are being described using a variety of metrics and through visual interpretation techniques. Characterization of urbanized landscapes over time and computation of spatial indices that measure dimensions such as contagion, the patchiness of landscapes, fractal dimension, and patch shape complexity are done statistically by Northeast Applications of Useable Technology In Land Use Planning for Urban Sprawl (Hurd et al., 2001; NAUTILUS, 2001). Epstein et al. (2002) bring out the techniques for mapping suburban sprawl. They evaluate the traditional unsupervised classification and proposed GIS buffering approach for mapping the suburban sprawl. They also discuss the problems associated with the classification of urban classes (built-up) in comparison with rural and urban centres.

Visualizing urban sprawl

Before the introduction of Geographic Information Systems, mapping any phenomenon took an extremely long time. Maps produced through manual cartography for comparison were planned well in advance of a due date. Computer aided maps without GIS were very rudimentary and were not very aesthetically pleasing to say the least. The availability of different types of spatial data allows a GIS user to map virtually any phenomena with a geographic dimension applied to it. In addition, large amounts of data are processed before the creation of a map with much less work than with manual cartographic techniques. With a GIS, maps can be compared in a fraction of the time and can be done at variable scales with ease.

Measuring Sprawl

To understand the complexity of a dynamic phenomenon such as urban sprawl; land use change analyses, urban sprawl pattern and computation of sprawl indicator indices were determined.

The characteristics of land use / land cover, drainage network, roads and railway network and the administrative boundaries from the toposheets were digitised. Individual layers for each character were digitized. The highway passing between the two cities was digitized separately and a buffer region of 4 km around this was created using MAPINFO 5.5. This buffer region demarcates the study region around the highway.

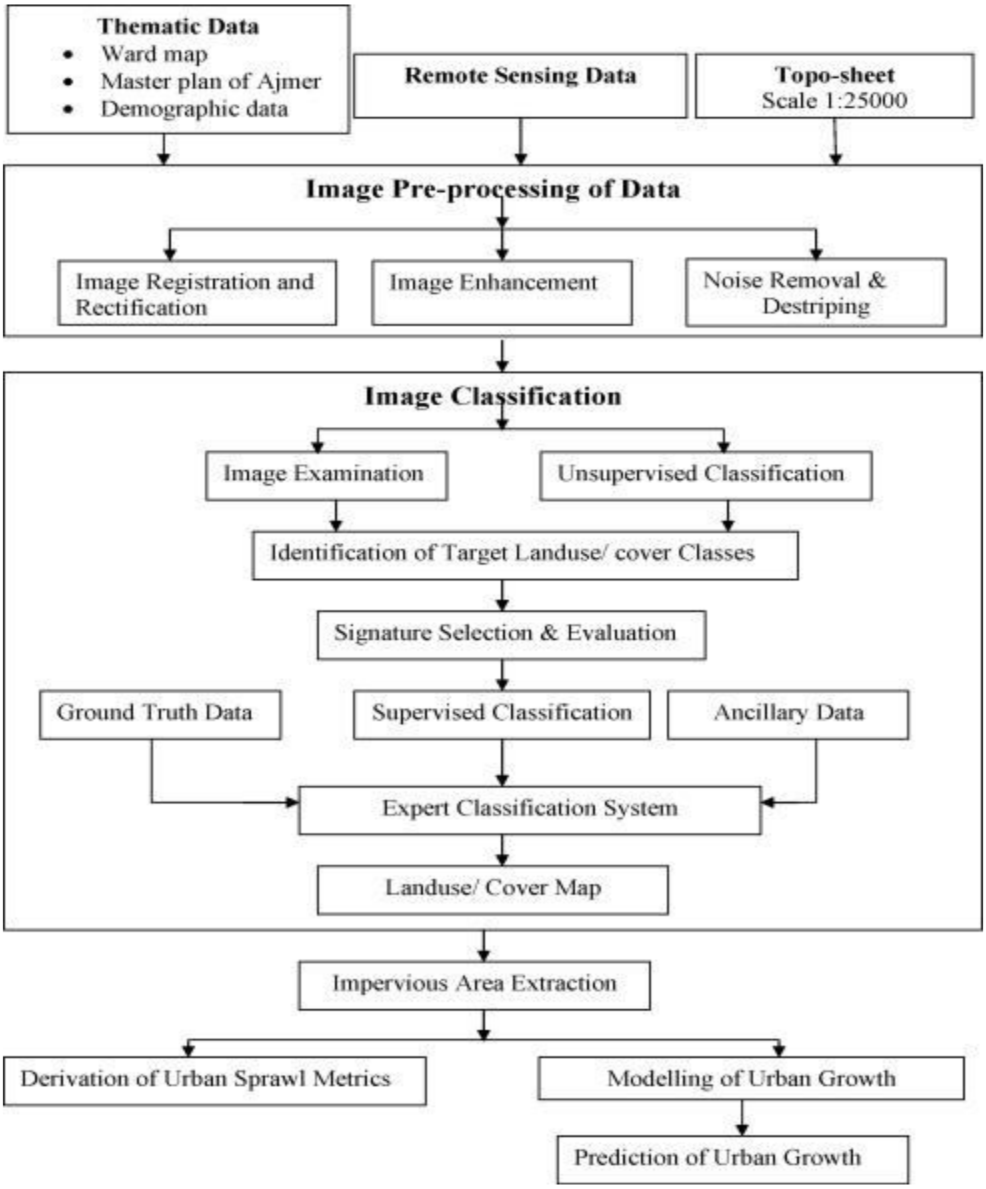

Figure 9.4: Monitoring and Measuring Sprawl using Remote Sensing and GIS

Urban sprawl over the period of three decades (1972-99) was determined by computing the area of all the settlements from the digitized toposheets of 1971-72 and comparing it with the area obtained from the classified satellite imagery for the built-up theme. The vector layers were digitized from the toposheets of 1972, included themes as; highway in the buffer region, built-up area, drainage (sea, rivers, streams and water bodies), administrative boundaries, and road network.

The toposheets, were first geo-registered. Since urban sprawl is a process, which can affect even the smallest of villages, each and every village was analyzed. Details of villages like taluk it belongs to, village name, population density, distance to the cities, were extracted from census books of 1971 & 1981 and were added to the attribute database. The area under built-up (for 1972) was later added to this attribute database after digitization of the toposheets for the built-up feature for each village. Satellite image - IRS data for Path 97 and Row 67 dated 29th March 1999 was procured from NRSA, Hyderabad. From the LISS imagery available the analysis for 1999 was undertaken using Idrisi 32.

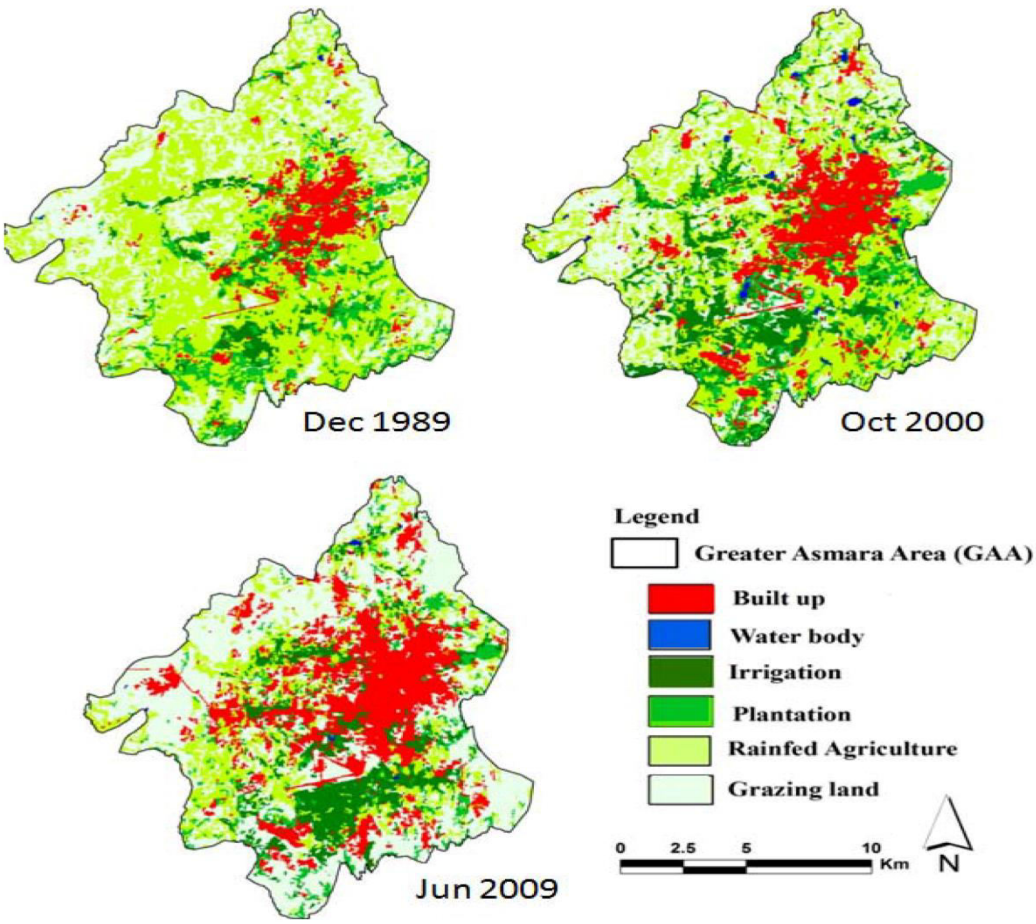

Figure 9.5: Sprawl Analysis and Modelling

The standard processes for the analyses of satellite imagery such as extraction, restoration, classification, and enhancement were applied for the current study. The Maximum Likelihood Classifier (MLC) was employed for the image classification. The original classification of land-use of 16 categories was aggregated to vegetation, built-up (residential & commercial), agricultural lands & open, and water bodies. Area under built-up theme was recognized and the whole built-up theme from that imagery was digitized; this vector layer gave the urban area of 1999. Further, by applying vector analyses, the built-up area under each village was calculated.

Built-up area as an indicator of town sprawl

The percentage of an area covered by impervious surfaces such as asphalt and concrete is a straightforward measure of development (Barnes et al, 2001). It can be safely considered that developed areas have greater proportions of impervious surfaces, i.e. the built-up areas as compared to the lesser-developed areas. Further, the population in the region also influences sprawl. The proportion of the total population in a region to the total built-up of the region is a measure of quantifying sprawl. Considering the built-up area as a potential and fairly accurate parameter of urban sprawl has resulted in making considerable hypothesis on this phenomenon. Since the sprawl is characterized by an increase in the built-up area along the urban and rural fringe, this attribute gives considerable information for understanding the behaviour of such sprawls. This is also influenced by parameters such as, population density, population growth rate, etc. Pattern recognition helps in finding meaningful patterns in data, which can be extracted through classification. Digital image processing through spectral pattern recognition wherein the spectral characteristics of all pixels in an image were analysed. By spatially enhancing an image, pattern recognition can also be performed by visual interpretation.

One of the most relevant factors that relates to RS is classification. Certain types of algorithms are used to provide suitable classification accuracy. Maximum likelihood classification (MLC), the most commonly supervised method, was used. In this context, the training areas are used in supervised technique. The mapping of LULC can be delineated from fine and coarse resolutions. Landsat TM, ETM+ and LOL, Satellite Pour l'Observation de la Terre (SPOT), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Ikonos (Pereiraa and Caetanoa, Pleiades, Worldview, and aerial photographs have been employed in the mapping analysis of land use classes and in the monitoring of their changes.

A map provides the visual aspect from which studies on urban sprawl can begin in relation to urban growth. A Geographic Information System is useful for mapping the spatial distribution of urban areas. Unlike traditional cartographic methods, GIS allows for the manipulation of different types of data in one map frame. Mapping urban phenomena is a crucial part of quantifying urban sprawl. While many layers of data are used to create a map of urban growth, ultimately it is the map that tells the story about the level of urban sprawl over a given landscape. This type of mapping involves a temporal signature in which two or more time periods are used for comparing amounts of urbanization. One base map shows urban or built-up land in a starting year and another map shows the developed land from the end year. Therefore, mapping the extent of urbanization over a given period of time is an essential part of understanding urban sprawl.

If we consider the definition of local economic development to be the improvement of land and infrastructure for the benefit of the community as a whole, it is clear that GIS have a key role to play. GIS are now used extensively in government, business, and research for a wide range of applications including environmental resource analysis, land use planning, locational analysis, tax appraisal, utility and infrastructure planning, real estate analysis, marketing and demographic analysis, habitat studies, and archaeological analysis.

GIS can better understand all the information on one-way and becomes a guide for the best choice of urban traffic. It also allows to update the dynamic that know the ways in urban areas as new development will be done automatically updated in the information system, more specifically, it leads to: Mapping networks (urban transport, water, sanitation, electricity, etc.), Monitoring urban expansion, create zoning regulations to provide for the possible extension of the city, with services that must accompany it; Monitor extension possible nuisances (noise, pollution). Although traffic safety is a concern to many urban residents, the role of urban design on crash incidence is typically not considered as part of the transportation planning and design process. To better account for the effects of urban design on crash incidence, the authors recently sought to develop a GIS. This technique will assist planners and urban designers in systematically evaluating the effects of community design on traffic safety. GIS have become increasingly important in the transport sector.

The few examples where GIS can be effectively used are in Environmental planning, Ground water contamination, Fresh water and saltwater interface, Water quality, Solid waste and Waste water management, Air & Water pollution, Natural Hazards and their mitigation etc. GIS can: Monitor land use; Cross the information collected with statements operators (political, agricultural and common); Diagnose the specific needs of certain operations and practice a less polluting agriculture (precision farming).

One of the prerequisites for understanding urban sprawl is successful land use change detection. This is made possible by accurate registration of the satellite imageries so that the overhead pixels represent the same location. There is a wide range of techniques used for land use change detection to study urban sprawl. Some of the major techniques include composite image, image comparison, comparison of classified images, combination of classified images, and radar classification and so on. One of these techniques is based on the comparison of the classified images. Remote Sensing is the science of making inferences about objects from measurements, made at a distance, without coming into physical contact with the objects under study Remote sensing means sensing of the earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resource management, land use and the protection of the environment.'

GEOSPATIAL TECHNOLOGY AND RESIDENTIAL AREA DEVELOPMENT

1. GIS provides the platform for the development of place-based data systems to measure the impact of federally supported housing programs and support housing policy decision-making, Up-to-date, accurate information is needed for analyzing issues and trends, for examining the impact of programs, and to support nation-wide analysis.
2. GIS provides the platform to conduct spatial analysis research to support policy making and impact assessment. Coupled with the growing availability of spatial analytical tools, GIS permits advanced spatial queries to inform policy making (e.g., "Show me all the housing units with children within 5 miles of a toxic waste site").
3. GIS provides a platform for collaboration among researchers, practitioners, and policy makers. GIS is a powerful visualization and communication tool that presents data in a map-like form that people can relate to and offers opportunity for collaborative work on interdisciplinary housing policy questions.
4. GIS for Housing and Urban Development. Washington, DC: The National Academies Press. https://doi.org/10.17226/10674.GIS provides the technology to develop Internet-based tools to support housing decisions for low-income households. Information tools are currently available to higher income households. For example "realtor.com" provides detailed property and neighbourhood information for houses

available for sale in the private market. Johnson (2002) describes a prototype Internet-based GIS program designed to allow Section 8 participants to identify preferred communities.

IMPORTANCE OF GIS IN TOWN PLANNING

The spatial depiction of the public amenities and infrastructural facilities can be made quite user friendly with application of GIS. This also holds true for the private organizations as they can chalk out the consumer load, the paying capacity of the consumers in different region and develop the organization accordingly. GIS can also be applied to the relatively newer concept of multilevel parking needs in the developing nation. This is important because even relatively smaller urban centers are experiencing severe parking pressure in certain areas, forcing the consumers to walk for kilometers, in turn hurting business and increasing pedestrian accidents.

GIS can help in providing information about crime rate and types of crime in the various city-sectors and in different cities. This information should be mapped and made available on the internet. This would make people aware and help them take judicious decisions about their movement across different parts of the nation. Several cities across US provide regional crime database to citizens. Making such information publicly available also promotes competition among the authorities of different cities, because best talent and companies would like to establish themselves in the safest cities. GIS and remote sensing techniques can also help in tackling problems related to traffic, encroachments, air and noise pollution water and power supply etc. If the relevant spatial information is made available to the planners, they can take much better and fine-grained policy decisions to solve these problems.

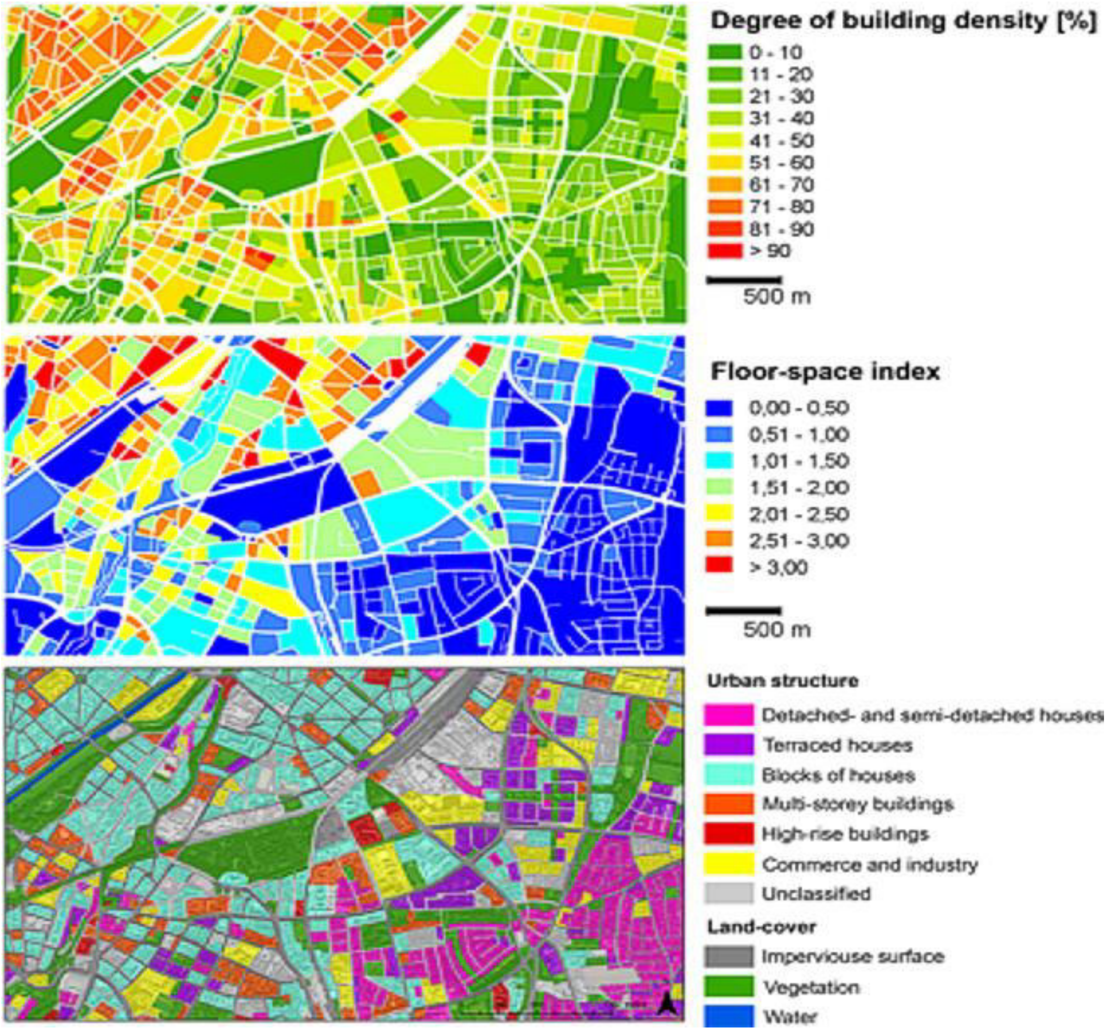

Figure 9.6: Remote Sensing and Town Planning

One of the prerequisites for understanding urban sprawl is successful land use change detection. Spatial analysis is done using GIS to chalk out the potentials and restraints of the region. This is made possible by accurate registration of the satellite imagery so that the overhead pixels represent the same location as the base map. There is a wide range of techniques used for land use change detection to study urban sprawl. The growth and trend of urban sprawl is analyzed with help of change in the percent of various land use categories during the period.

Land suitability was performed to develop a plan that would make this city sustainable. Land suitability analysis was carried out using Arcview GIS Spatial Analyst. This suitability analysis was based on three major parameters namely, slope of the region, stream buffer zones and the existing land use (Figure 4). Prospective growth sectors are determined by overlaying these major parameters and other socio-economic infrastructural data of the region.

The data is loaded as themes which were converted into discrete grids. The land suitability was derived using weighted overlay technique whereby land use was given fifty percent weight, slope thirty percent and stream buffer twenty percent weight inferences. The land use was categorized into barren land, crop land, built up area, water and forest and scrub land. The scale was predefined at one to five with land suitability decreasing as we go from one to five.

The region with moderate land suitability lies at the base of the high hills and can be developed as recreational centers, for trekking, mountaineering and sports tourism. Protected forest areas are mostly the areas which have been conserved on high slopes to enrich the scenic beauty of the region, enhance the tourism prospects and develop greener sustainable city. Looking into the cultural factors influencing the pace and trend of urban development it is found that generally the larger settlements with high population have stronger attraction forces of land suitability and urban development.

This depicts the process and pattern of urban sprawl. When such study is incorporated with the infrastructural developments and amenities of the city using GIS, urban planners can extrapolate the growth patterns several years in the future. The urban quality of life and facilities management in urban area is one of the major concerns that unplanned urbanization has created across the globe. The world is well aware of the harmful implications of urbanization. It is the need of the hour that the developed nations and developing nations move hand in hand to tackle this issue and successful developmental models are followed across suitable urban centers.

Implementing a web-based GIS database is the best way to improve access to the GIS data. Also better training and networking among GIS professionals would encourage the sharing of high quality spatial data. Insufficient user support, lack of proper hardware and software, unavailability of GIS professionals, unreliable power supply, and slow and limited internet access are the major hurdles prohibiting widespread use of GIS technology especially in developing nations.

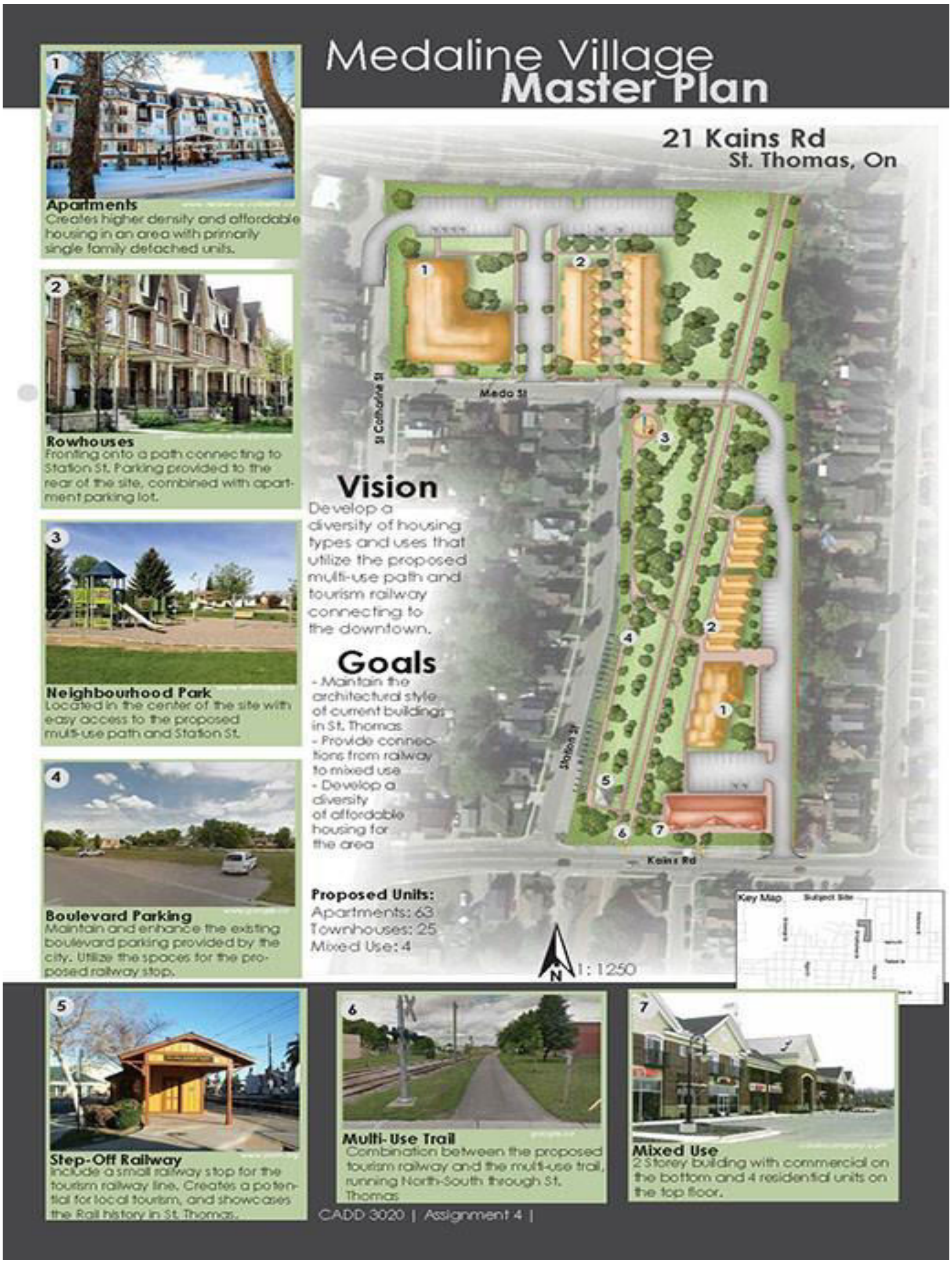

Figure 9.7: GIS and Town Planning

TOWN EXPANSION

The GIS help to brought out significant urban expansion of the city for the period 1998–2018. Hence, the built-up land has expanded more than threefold during the last 20 years from 4.51 to 14.93 km^2 showing a positive trend over time. However, the barren land is under stress due to population pressure and the associated demand for urban expansion. In order to identify, describe, and quantify differences between images of the same scene at different times, a GIS has been used to integrate urban/built-up areas class for the three images and generate a thematic map to examine dynamics of urban expansion. This analysis allowed to identify several changes occurring in different classes of the land use. The classified land use maps of built-up area and their spatial distributions for years 1998, 2008 and 2018. During the three periods, the encroachment of urban/built-up areas occurred to the direction of SE from the center of district since 1998, where the classified results indicate that the city is expanding and fanning out in the SE, NE and SW parts of the city. These areas are less hilly with no agricultural activities.

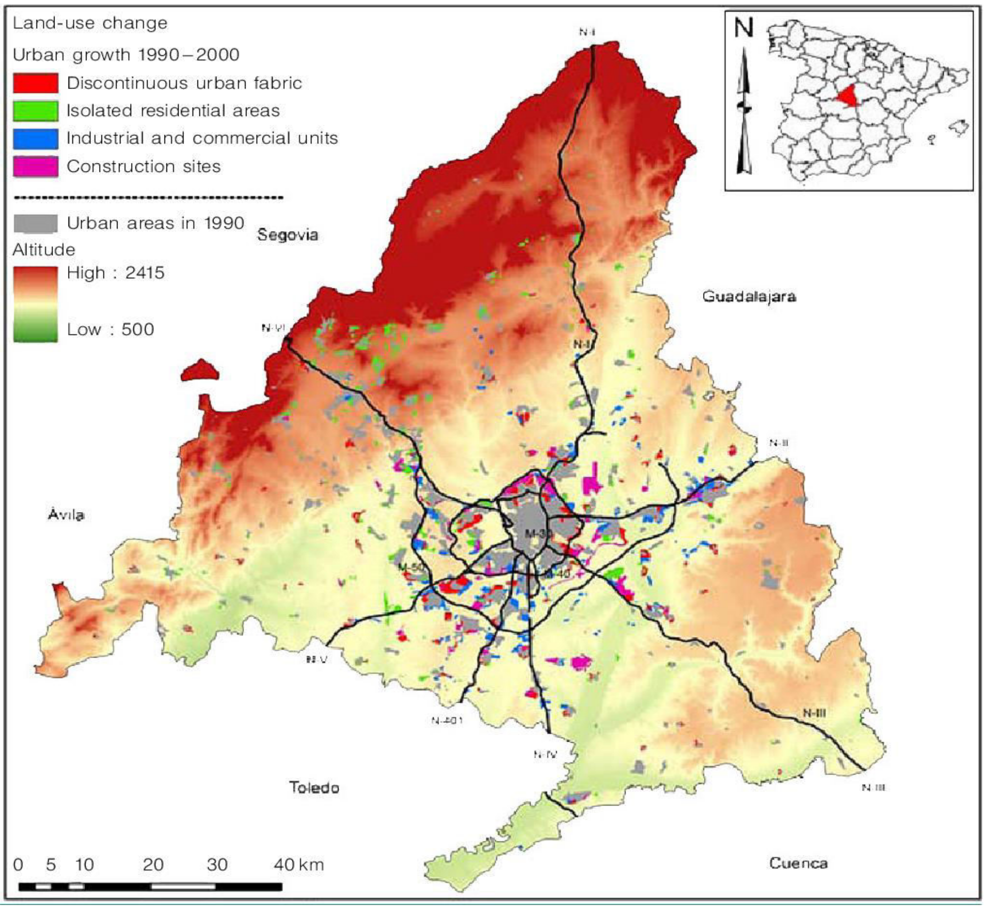

Figure 9.8: Urban Expansion and Mapping Using GIS

Urban expansion in district during last 20 years effected the land resources, as well as a potential decrease in water quantity and quality in the town. It has pointed out that district has experienced substantial changes in land cover and land use since the end of 1990s. These changes are induced by upgrading of many urban roads or construction of new road linked structures. Furthermore, the sprawl in district particularly in the north and NE part occurs in disorderly and unplanned patterns, influenced by the proximity of villages and land rents. Further research is encouraged to use proper measures in accordance with scientific planning for the urban expansion of the city in the future.

GIS FOR BUILDING SMART CITIES

GIS is only a piece of the puzzle when it comes to making our cities more sustainable, but it can be a powerful tool when used together with the right resources. For example, GIS can help planners create more sustainable communities by identifying where new development should be built to meet the needs of future residents and businesses. The technology can also help identify areas that need to be preserved due to environmental concerns and provide details about potential issues such as flooding, air quality, traffic, and more. GIS can also help urban planners find the right balance between development, manufacturing and food production, housing, services, and income inequality. As urban regions grow, planners can use GIS to help them track assets, determine equity and evaluate development needs.

Figure 9.9: GIS AS PLATFORM FOR SMART CITIES

GIS is used by city planners, policymakers, and public works teams to create better communities through its actionable insights. Using a mix of technology and data, GIS is changing how we look at urban development. It provides a detailed look at the city as a whole, not just the individual parts spread out across a city. To that end, here are some real-world examples of GIS at work in cities:

1. Population tracking (migration, demographics);
2. Planning for new development or redevelopment;
3. Identification of natural or man-made disasters;
4. Examination of land use and zoning;
5. Examination of growth patterns;
6. Assets management and determination of how they are being used;
7. Assets management and examination of capacity issues;
8. Mapping of city infrastructure;
9. Mapping of community assets;
10. Mapping of community risks;
11. Combining the layers of data to determine socioeconomic status demographic and other factors that affect growth;
12. Identification of issues such as crime, infrastructure, and other city problems.

APPLICATION OF REMOTE SENSING AND GIS TECHNOLOGY

GIS in urban planning enables spatial analysis and modelling, which can contribute to a variety of important urban planning tasks. These tasks include site selection, land suitability analysis, land use and transport modelling, the identification of planning action areas, and impact assessments. GIS functionality such as interpolation, buffering, map overlay, and connectivity measurement help urban planners to achieve these tasks which further help a lot in planning. GIS platforms, especially those used in conjunction with remote sensors, decrease time spent collecting land-use and environmental information. With remote images, urban planners can detect current land use, as well as changes to land use for an entire urban area. These images can also be used to create compelling visualizations with 3D CAD models which gives very decent look to people. Together with remote sensing, GIS can help planners to track if development is following the area's land use plan. It can also help them to evaluate, impact and suggest adjustments - if required. Therefore, we have seen the great role of GIS in urban planning. My observation and review of literature were totally based on Delhi NCR urban planning. Before moving further defining the term REMOTE SENSING, it's a type of sensor which senses any distinct object without physical touch. Application of Remote Sensing technology can lead to innovation in the planning process in various ways: -

1. Digitisation of planning base maps and various layout plans has facilitated updating of base maps wherever changes have taken place in terms of land development etc. Digital maps provide flexibility as digital maps are scale free. Superimposition of any two digital maps which are on two different scales is feasible. This capability of digital maps facilitates insertion of fresh survey or modified maps into existing basemaps. Similarly, superimposition of revenue maps on basemaps with reasonable accuracy is great advantage compared to manually done jobs.
2. Since information and maps are available in digital format, correlating various layers of information about a feature from satellite imagery, planning maps and revenue maps is feasible with the help of image processing software like ERDAS Imagine, ENVI and PCI Geomatica, ILWIS. Such superimposed maps in GIS software like Map info, Geomedia, Arc View, AutoCAD Map and ArcGIS provide valuable information for planning, implementing and management in urban areas.
3. Remote Sensing techniques are extremely useful for change detection analysis and selection of sites for specific facilities, such as hospitals, restaurants, solid waste disposal and industry. Aerial photography and satellite data in urban studies Aerial photographs have long been employed as a tool in urban analysis (Jensen 1983, and Garry, 1992).

9.4 SUMMARY

The representation of geographic phenomena in digital databases is one of the most central and fundamental issues in Geographic Information System. This paper uses Geographic Information Systems (GIS) mapping and Remote Sensing data to measure sprawl. It is important to note a few of the definitions from different time periods. Here the paper was presented those definitions in a chronological manner in order to show a progression in the concept of urban sprawl. The advancement of GIS data models to allow the effective utilization of very large heterogeneous geographic databases requires a new approach that incorporates models of human cognition. The use of Geographic Information Systems modelling has become quite prevalent within the field of urban sprawl research. This paper has attempted to define GIS and its features and identify how GIS plays a key role in delivering the information needed to support the urban sprawl program. Illustrative examples

of GIS were presented to show how the use of GIS technology facilitates the process of presenting spatial planning and urban dynamics. GIS is becoming more suitable for emergency operations and is integrating tools that allow real-time display of information. The GIS allows, in many respects, the enhancement of technical capacity and decision making in the territorial management.

Figure 9.10: Smart Cities and GIS

Finally, and in a sense reversing the previous section, there is much to be gained by looking for applications of GIS and Remote Sensing imagery developments in other fields. The problems of representation of moving objects are not unique to urban sprawl, but are motivated by similar issues in wildlife management, health, and many other areas. GIS and Remote Sensing are a generic technology, designed to provide useful functions across a range of application areas. Similarly, GIS and Remote Sensing are most productive when their developments and principles are generic, motivated perhaps by a single field but with implications for many other fields. The final challenge is to find fields that are substantively analogous to urban sprawl application, and to make research advances by taking advantage of a broadly conceived approach that sees the parallels between widely disparate applications.16 Uses of GIS and Remote Sensing imagery range from indigenous people, communities, research institutions, environmental scientists, health organizations, land use planners, businesses, and government agencies at all levels. Uses range from information storage;

spatial pattern identification; visual presentation of spatial relationships; remote sensing - all sometimes made available through internet web interfaces, involving large numbers of users, data collectors, specialists and/or community participants. Some examples include: GIS Application in crime, history, hydrology, indigenous, public, transportation engineering. Other applications include the use of GIS techniques for water, wastewater and stormwater systems, and in solid waste management. The combined use of remotely-sensed images and vector GIS data has received considerable interest in recent years. The benefits of integration to users of both GIS and remote sensing for various applications are reviewed and some thoughts are given on terminology and future directions in this field.

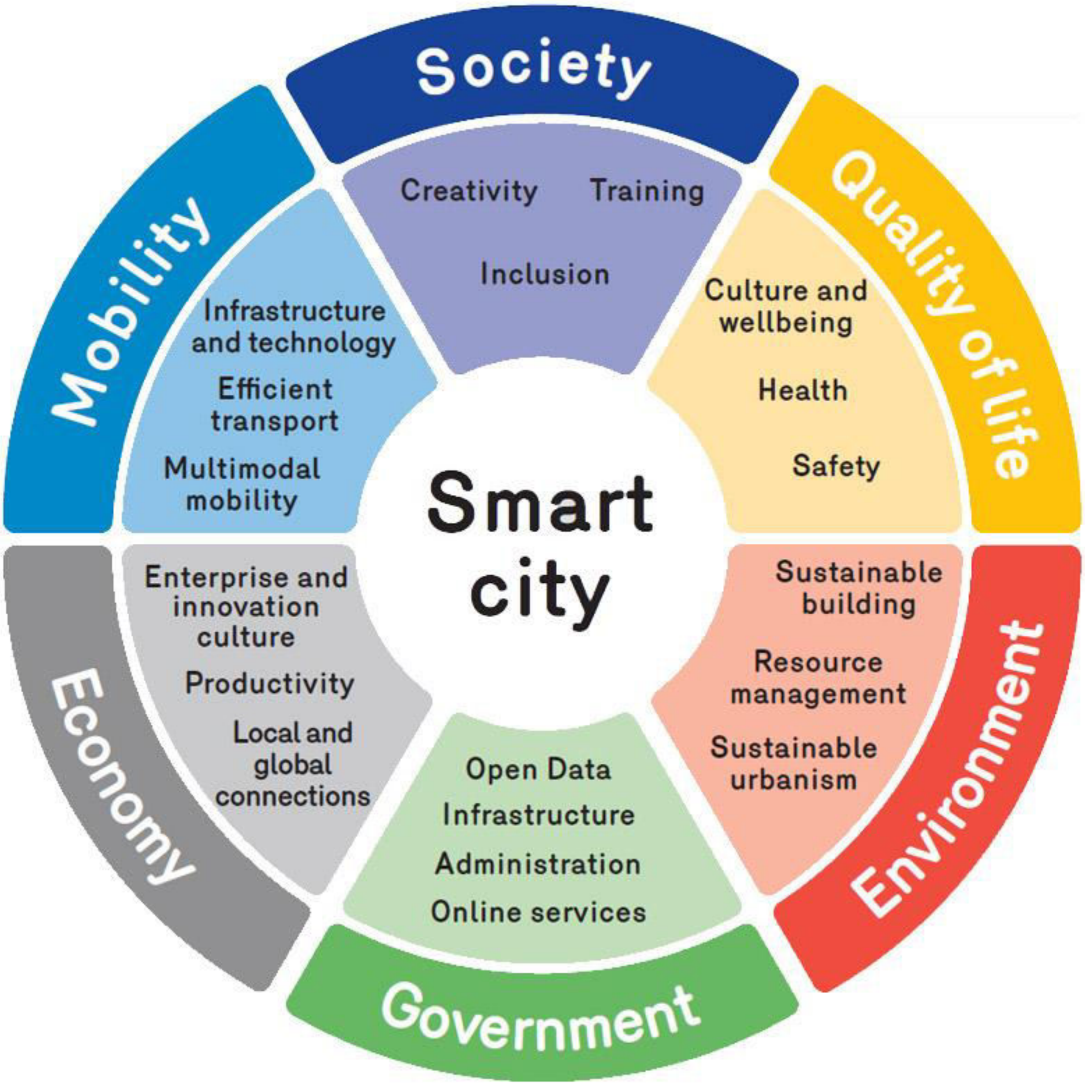

Figure 9.11: Smart City and Planning at Various Stages

The future of cities is bright, and these improvements will help urban planners create better communities by finding the right balance between development, manufacturing, cities and food production, housing, services, and income inequality. In that regard, GIS serves as the heart that makes it possible to create a living for all people from different walks of life. Ellipsis Drive helps organizations be more successful in using, producing, and sharing spatial data. Our drives help you manage and deliver geospatial data, commercialize spatial analytics, manage spatial administration, monitor your environment, and more.

9.5 GLOSSARY

1. **Geospatial Technology:** Geospatial Technology is an emerging field of study that includes Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS). Geospatial technology enables us to acquire data that is referenced to the earth and use it for analysis, modelling, simulations, and visualization.
2. **Urban Sprawl:** urban sprawl, also called sprawl or suburban sprawl, the rapid expansion of the geographic extent of cities and towns, often characterized by low-density residential housing, single-use zoning, and increased reliance on the private automobile for transportation.
3. **Urban Planning:** Urban planning, also known as regional planning, town planning, city planning, or rural planning, is a technical and political process that is focused on the development and design of land use and the built environment, including air, water, and the infrastructure passing into and out of urban areas.
4. **Smart Cities:** A smart city uses information and communication technology (ICT) to improve operational efficiency, share information with the public and provide a better quality of government service and citizen welfare.
5. **Geographic Information System:** A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map, such as streets, buildings, and vegetation. This enables people to more easily see, analyze, and understand patterns and relationships.
6. **Remote Sensing:** Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a

distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth.

9.6 ANSWER TO CHECK YOUR PROGRESS

- Define Remote Sensing.
- Define Smart Cities.
- Define Urban Sprawl.
- Define Geospatial Technology.

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9.8 TERMINAL QUESTIONS

1. What do you understand by Geospatial Technology? Describe various types of geospatial data for town planning.
2. Define urban expansion. Explain town expansion using remote sensing.

3. Describe important application of geoinformatics in town planning with suitable examples.
4. Why GIS is important in town planning and how?
5. Define sprawl? How town sprawling can be monitored by GIS.
6. Integration of geospatial technologies is necessary for town planning and land suitability management. Evaluate?