GIS-603

M.A. Geo-informatics

APPLICATIONS OF GEOINFORMATICS PART-IV

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

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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
1.2 INTRODUCTION
1.3 INTRODUCTION AND DISTRIBUTION OF FORESTS TYPES IN INDIA
1.4 SUMMARY
1.5 GLOSSARY
1.6 ANSWER TO CHECK YOUR PROGRESS
1.7 REFERENCES
1.8 TERMINAL QUESTIONS

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

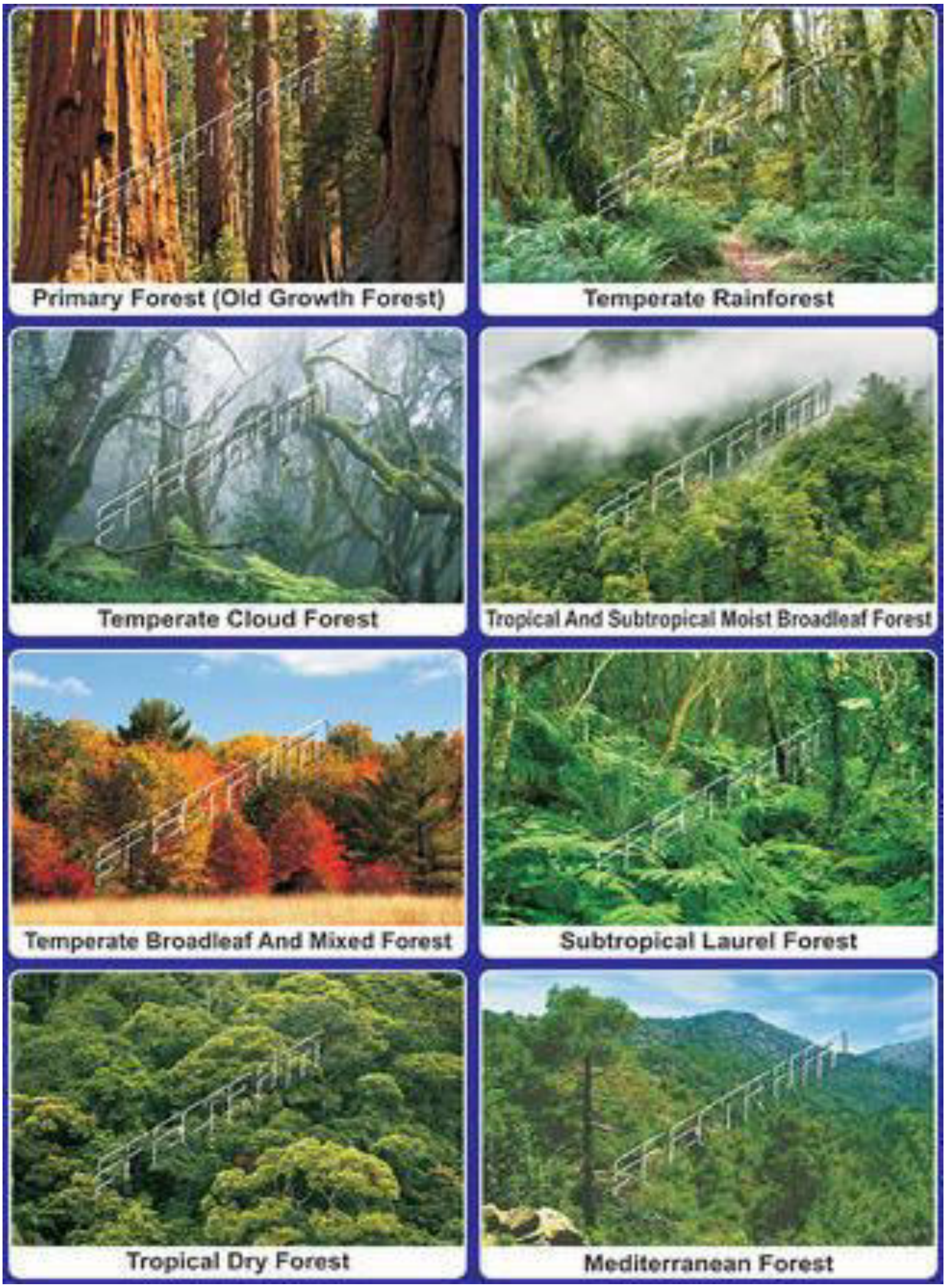
Forests in India are very diverse in their composition with a long evolutionary and geological history, occurring under diverse climatic and edaphic conditions. The forests represent a very unique assemblage of both Indo-Malayan and Australian species indicating the geological and paleo-botanical value 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 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 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,	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 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

Kerala are characterized by high proportion of Mesua ferrea, Palaquium ellipticum, Cullenia sp., and Calophyllum elatum.	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.

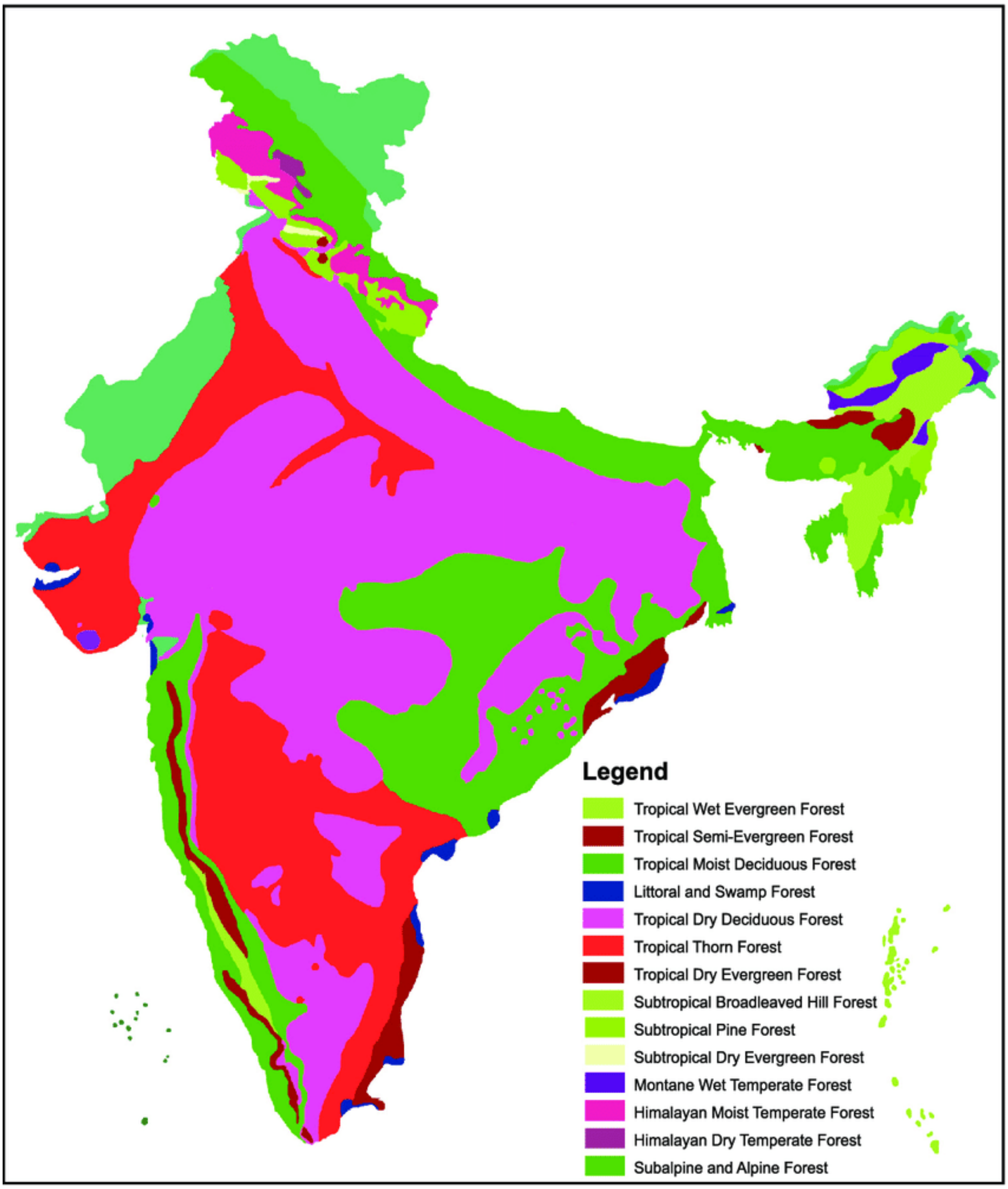


Figure 1.5: Distribution of Forest in India

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

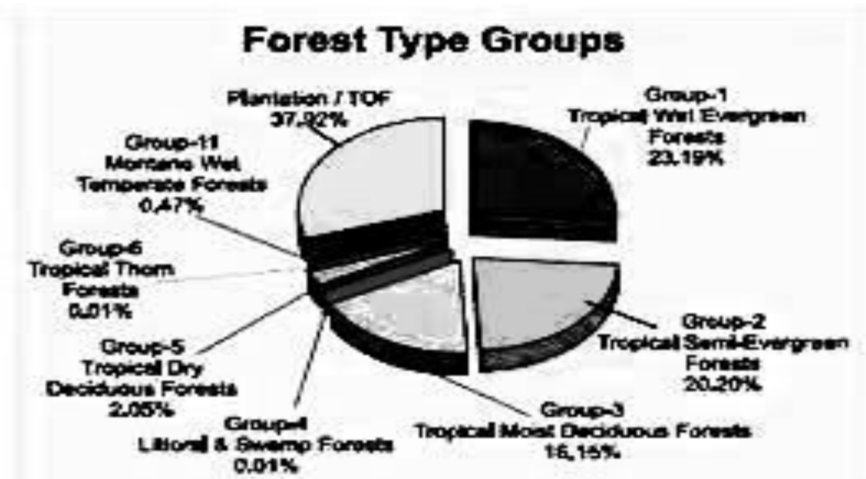


Figure 1.6: Forest percentage Distribution according to Group
Source: Google

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

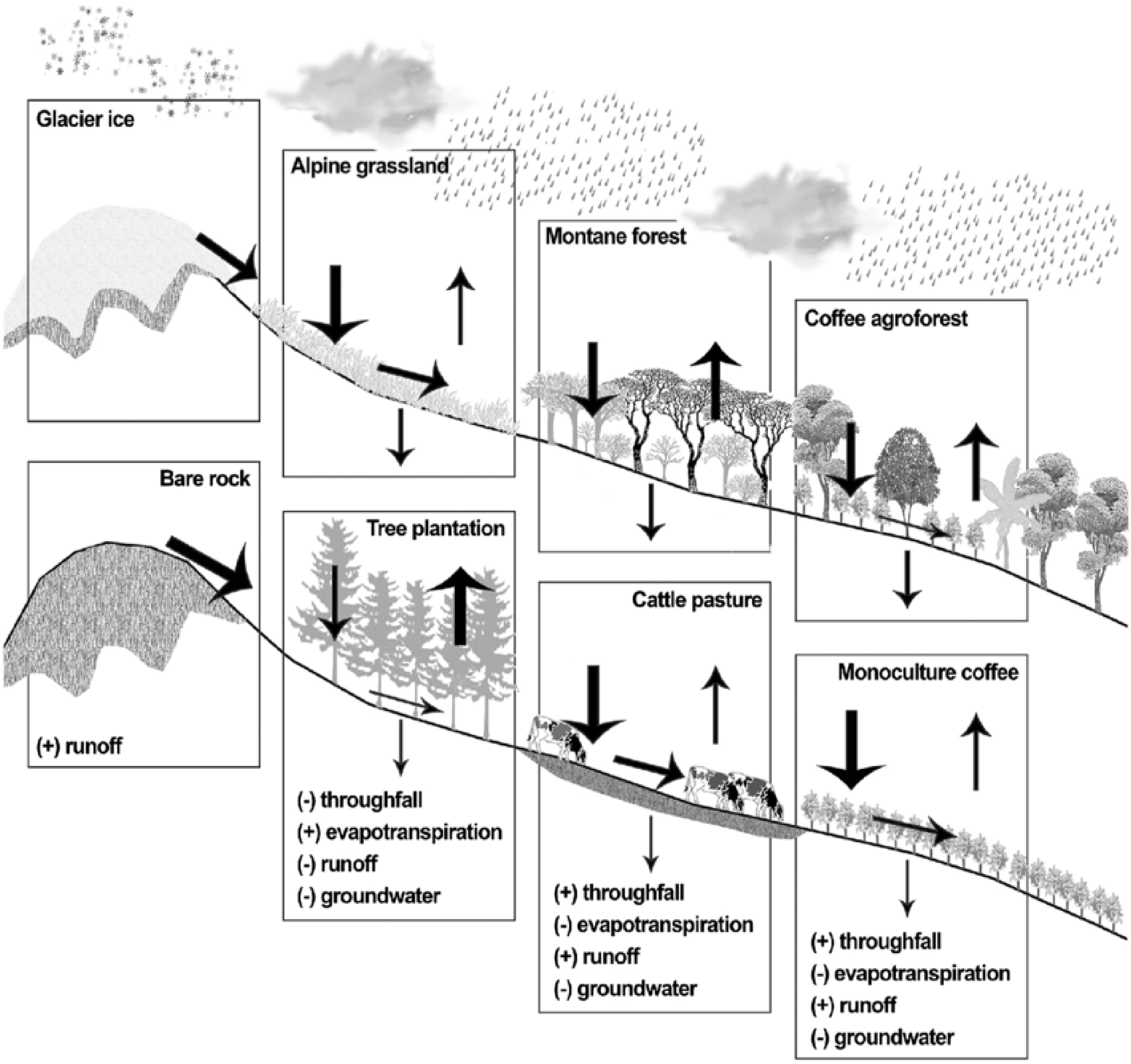
Forests The forests are restricted in distribution to Karnataka coast, also reported from the east coast in AP. These are low growing forests; trees are of 9-12 m height, and form a complete canopy. Most conspicuous trees are Manilkara hexandra, Memecylon edule along with Diaspyros, Eugenia, Chloroxylon,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

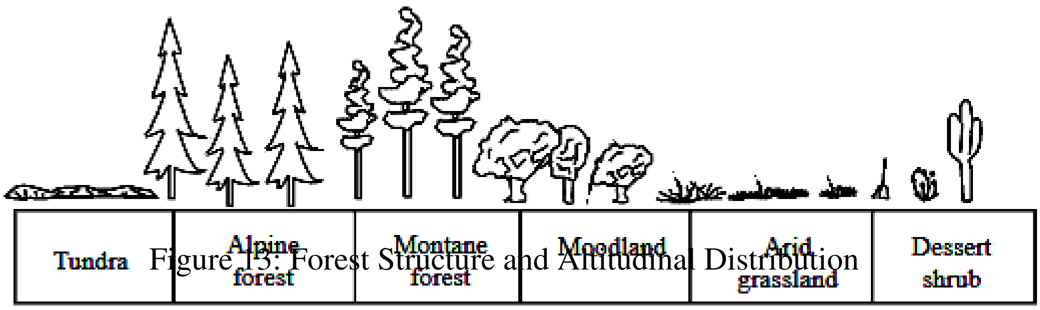
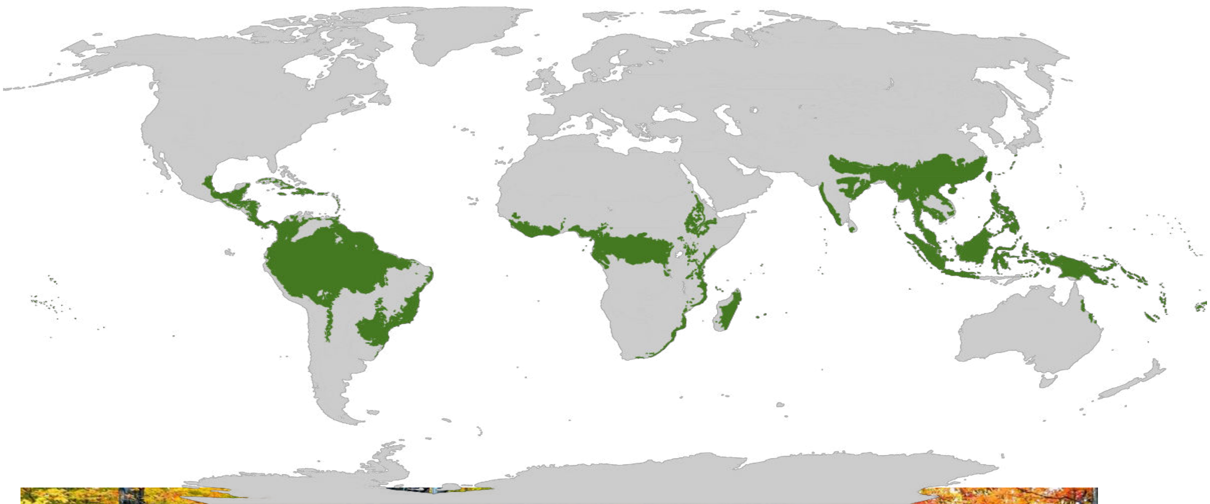


Figure 13: Forest Structure and Altitudinal Distribution



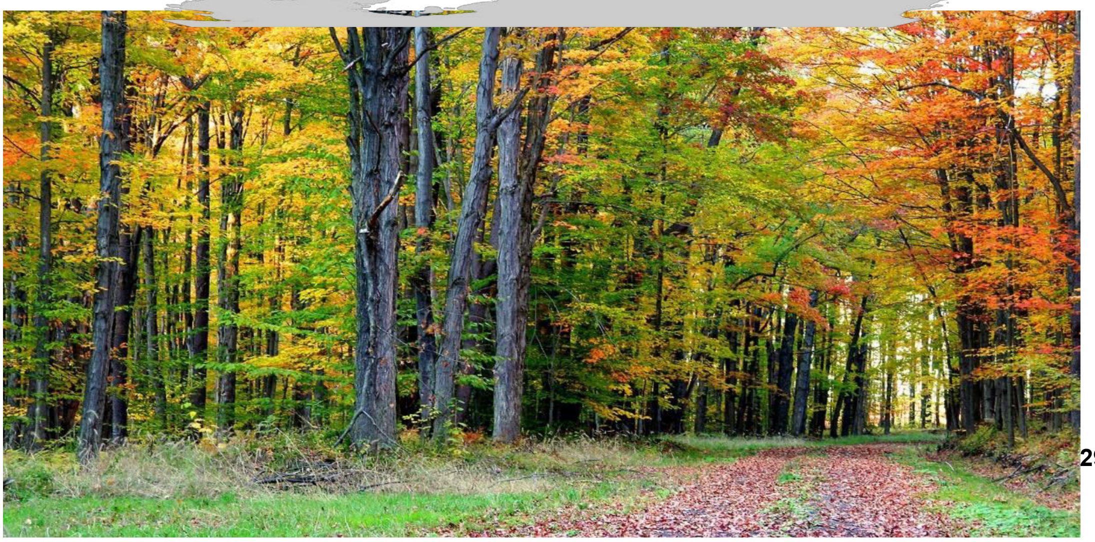


Figure 1.14 Broad Leaved Hill Forest
Source: Google

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.

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

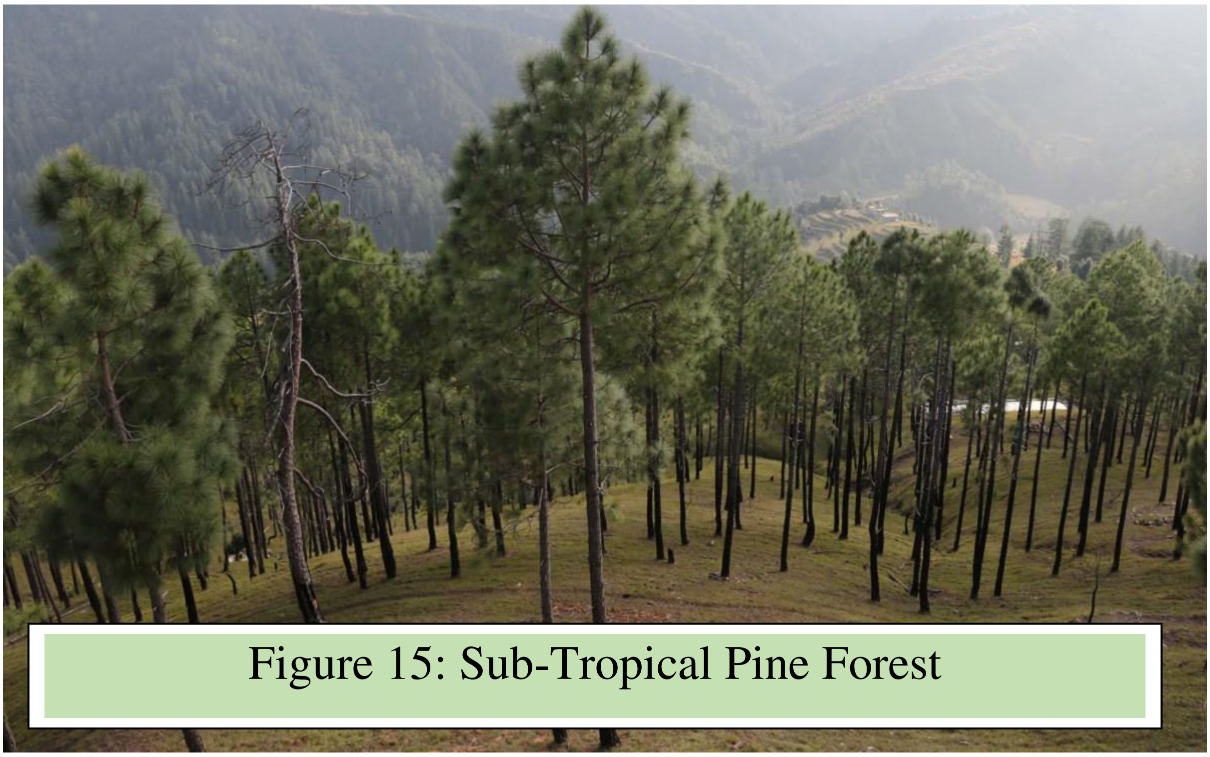


Figure 15: Sub-Tropical Pine Forest

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.

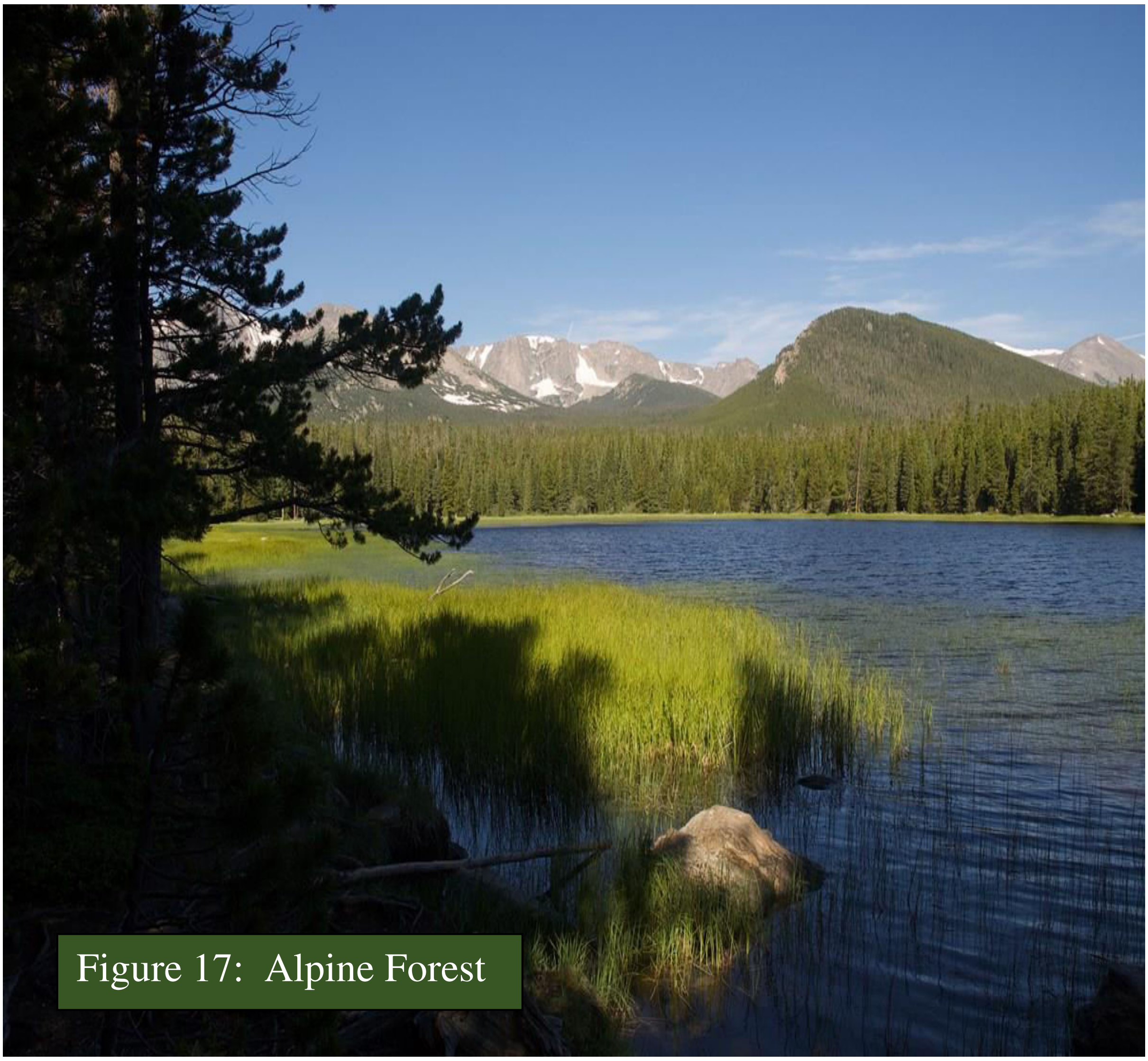


Figure: 1.17 Alpine Forest
Source: Google

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	1549.5053	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
2.2 INTRODUCTION
2.3 INTERACTION OF EMR WITH VEGETATION, SPECTRAL AND TEMPORAL CHARACTERISTICS OF VEGETATION.
2.4 SUMMARY
2.5 GLOSSARY
2.6 ANSWER TO CHECK YOUR PROGRESS
2.7 REFERENCES
2.8 TERMINAL QUESTIONS

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.

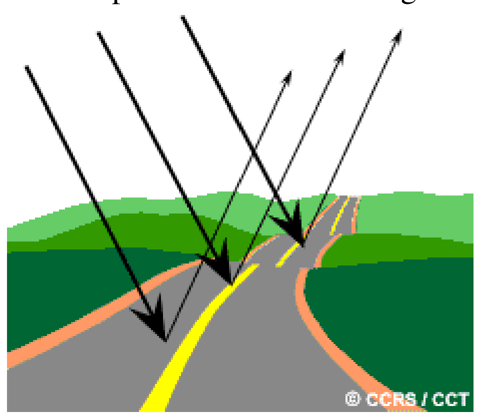

Figure 2.2: Specular Reflection

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.

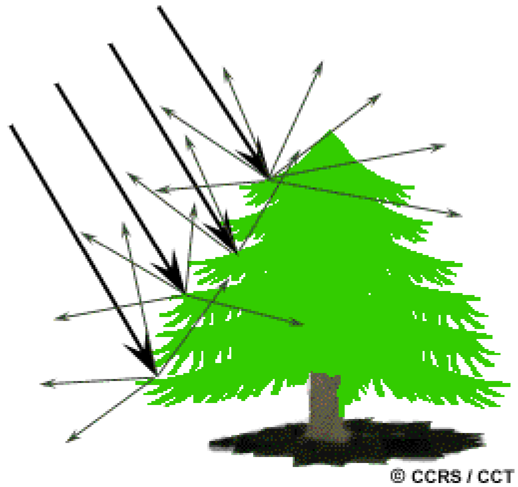

Figure 2.3: Diffuse Reflection

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.

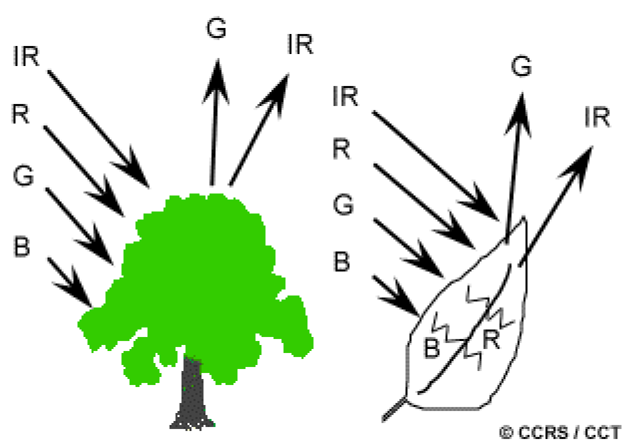

Figure 2.4: Chlorophyll of tree leaves strongly absorbs radiation in the red (R) and blue (B) Wavelengths but reflects green wavelengths. IR reflectance from tree leaves is Directly related to health and amount of chlorophyll content

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.

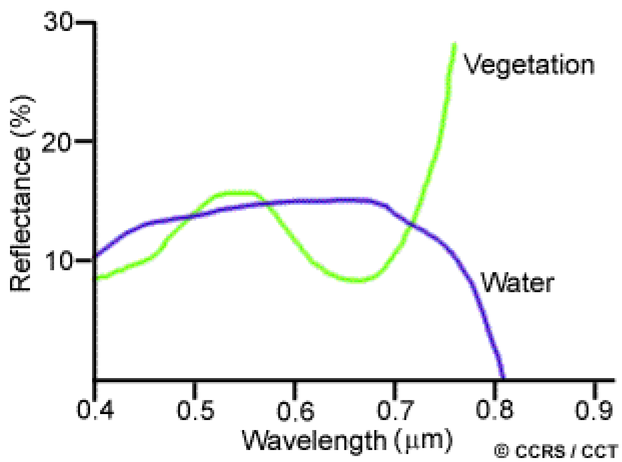

Figure 2.5: Spectral curve of water and vegetation reflectance within visible and IR band

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

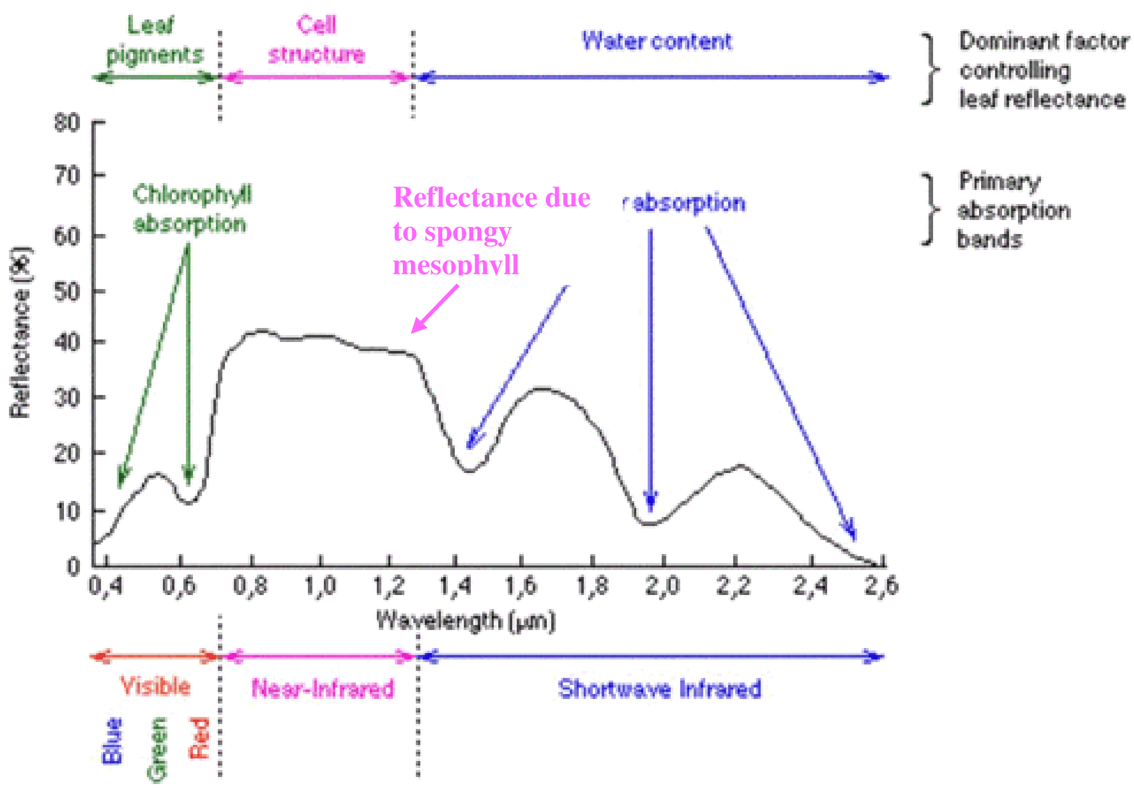

Figure 2.6: Spectral characteristics for green vegetation within the wavelength range of 0.4–2.6 µm.

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).

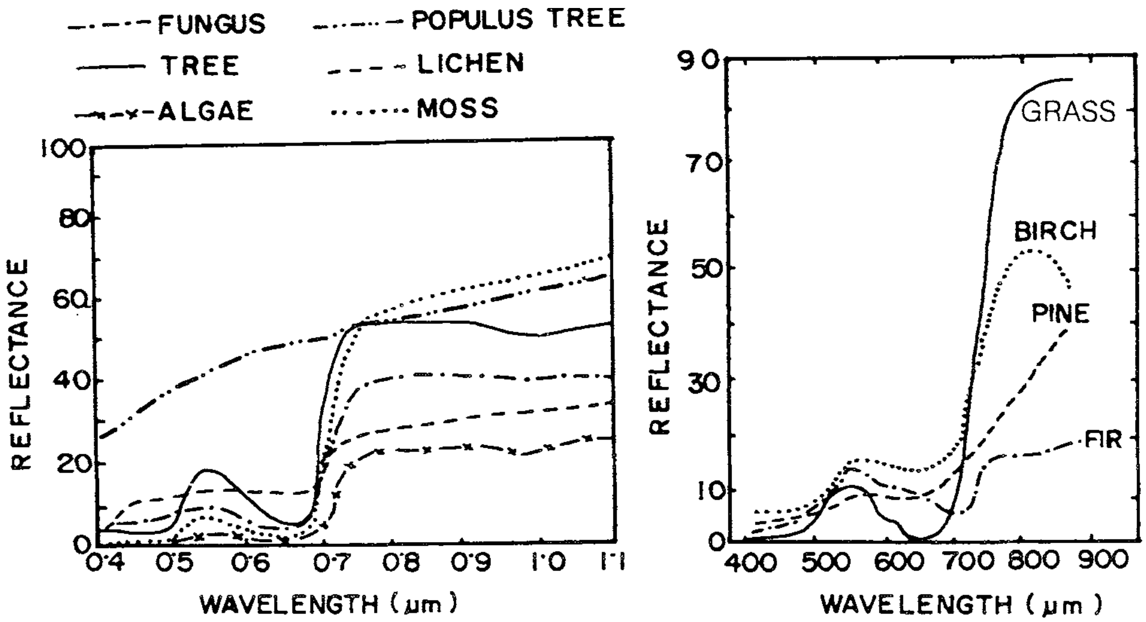

Figure 2.7: Spectral Reflectance of Species of Plants Belonging to Various Groups

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.

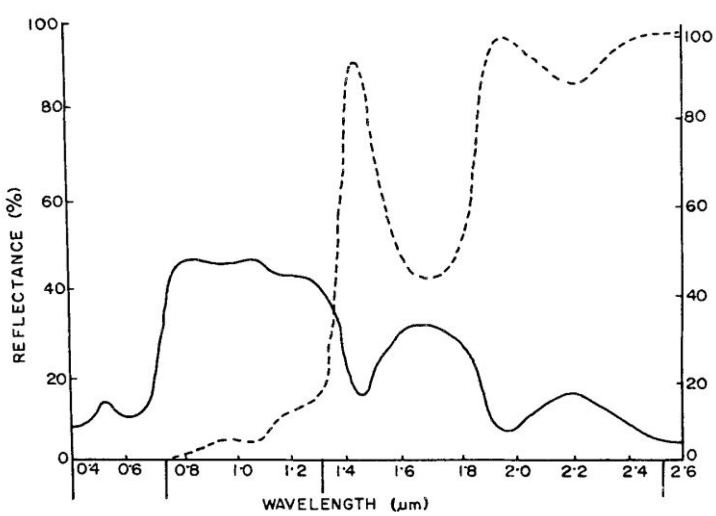

Figure 2.8. Spectral response of typical vegetation

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).

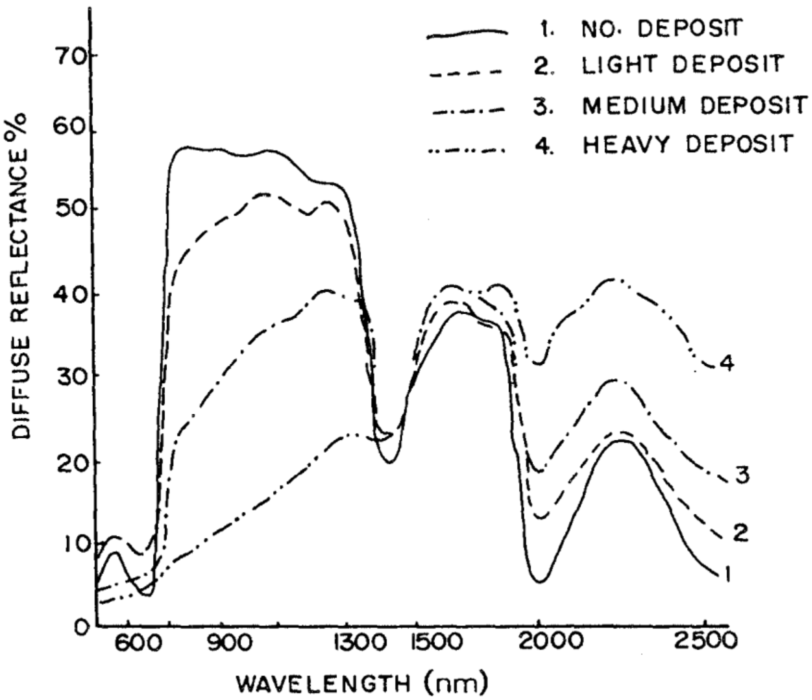

Figure 2.9. Spectral response of leaves of Citrus affected by fungus (*Capnodium citri*)

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 vacuolarpigments 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

1. Define Vegetation Reflectance?
2. Write a note on factors affecting Spectral Reflectance of Vegetation?

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- Google(For Images)

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

3.2 INTRODUCTION

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

3.4 SUMMARY

3.5 GLOSSARY

3.6 ANSWER TO CHECK YOUR PROGRESS

3.7 REFERENCES

3.8 TERMINAL QUESTIONS

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.

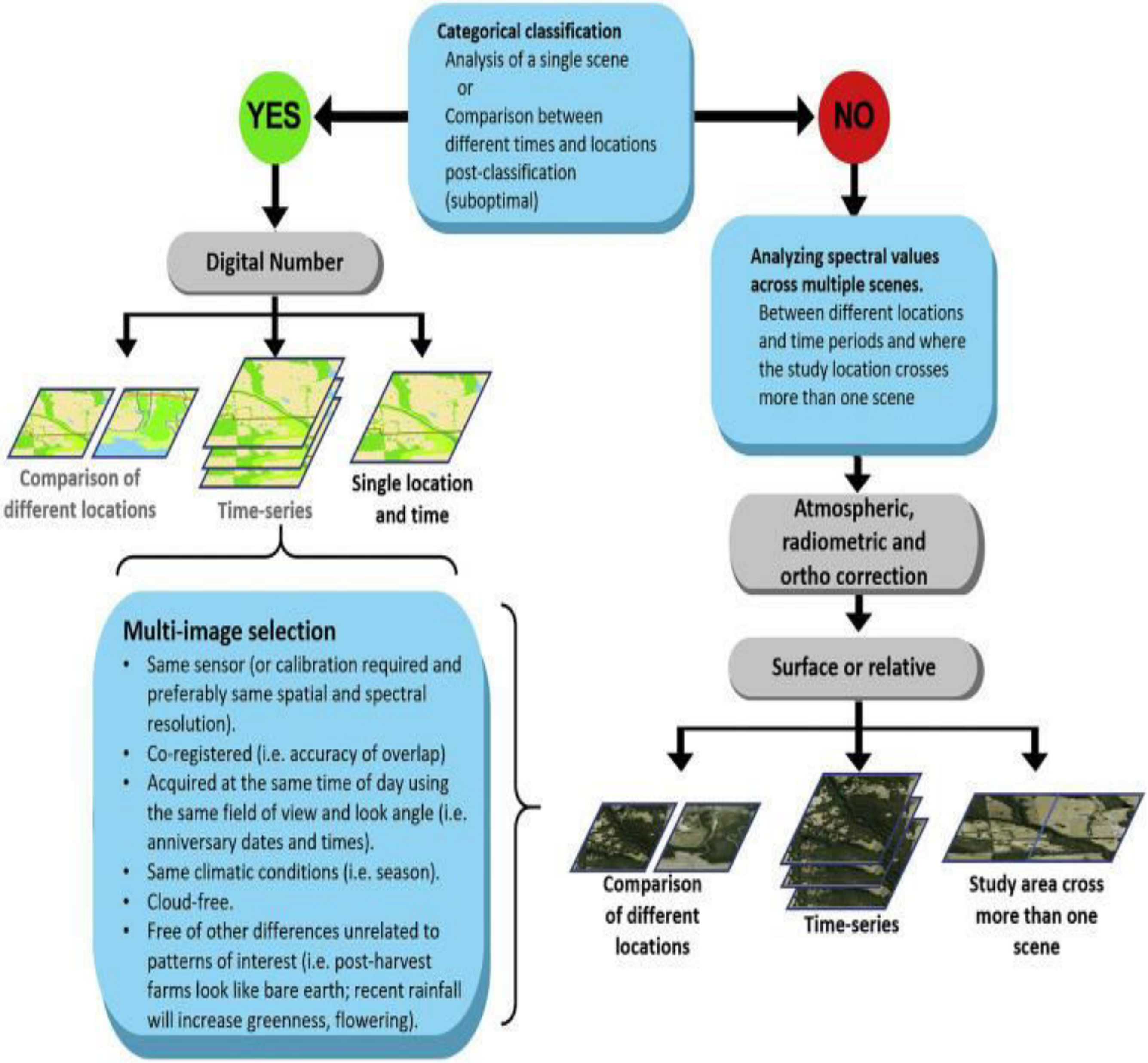


Figure 3.1: Remote Sensing and Forestry
Source: Google

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.

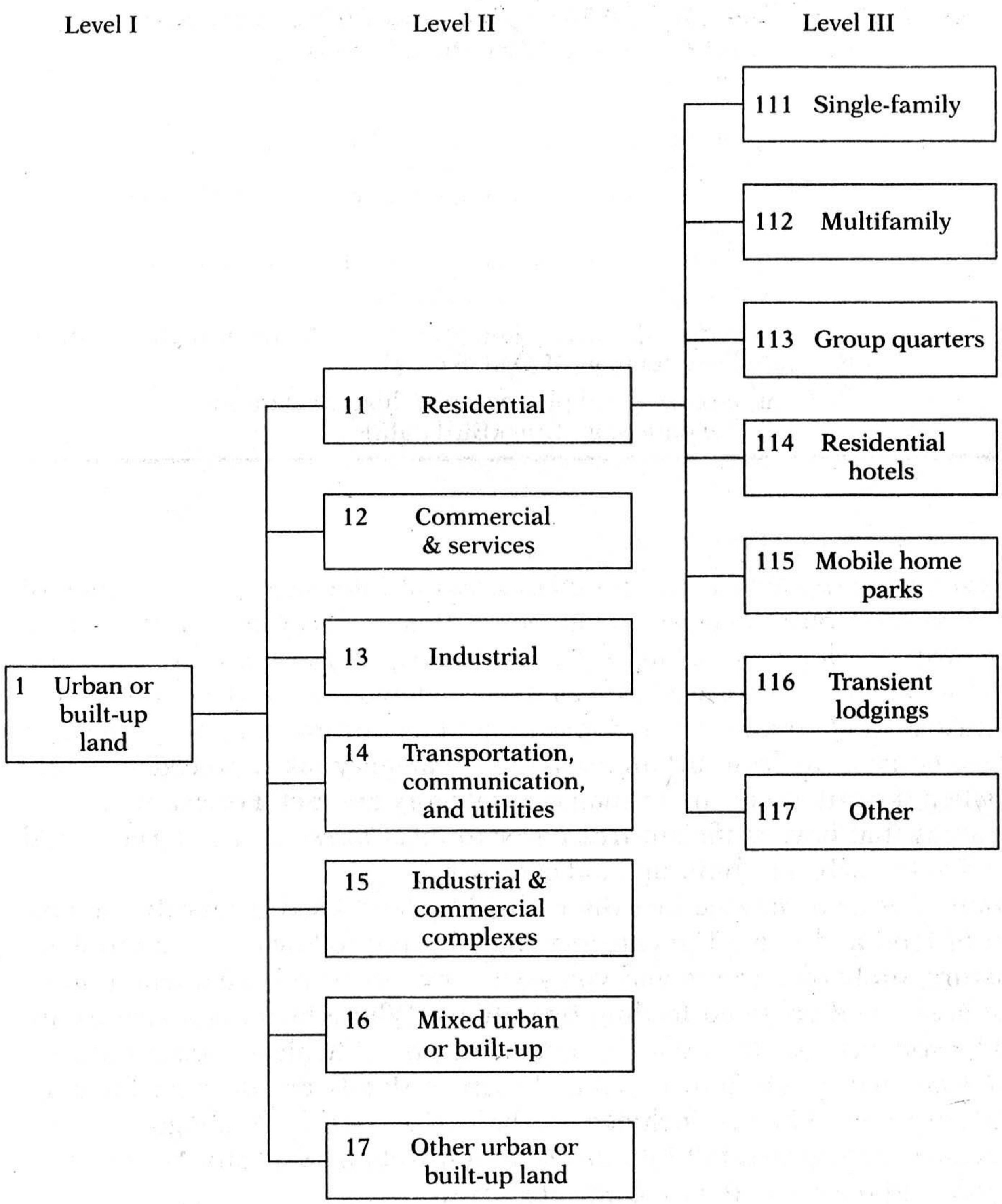


Figure 3.2: Land use Classification on Various Level

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.

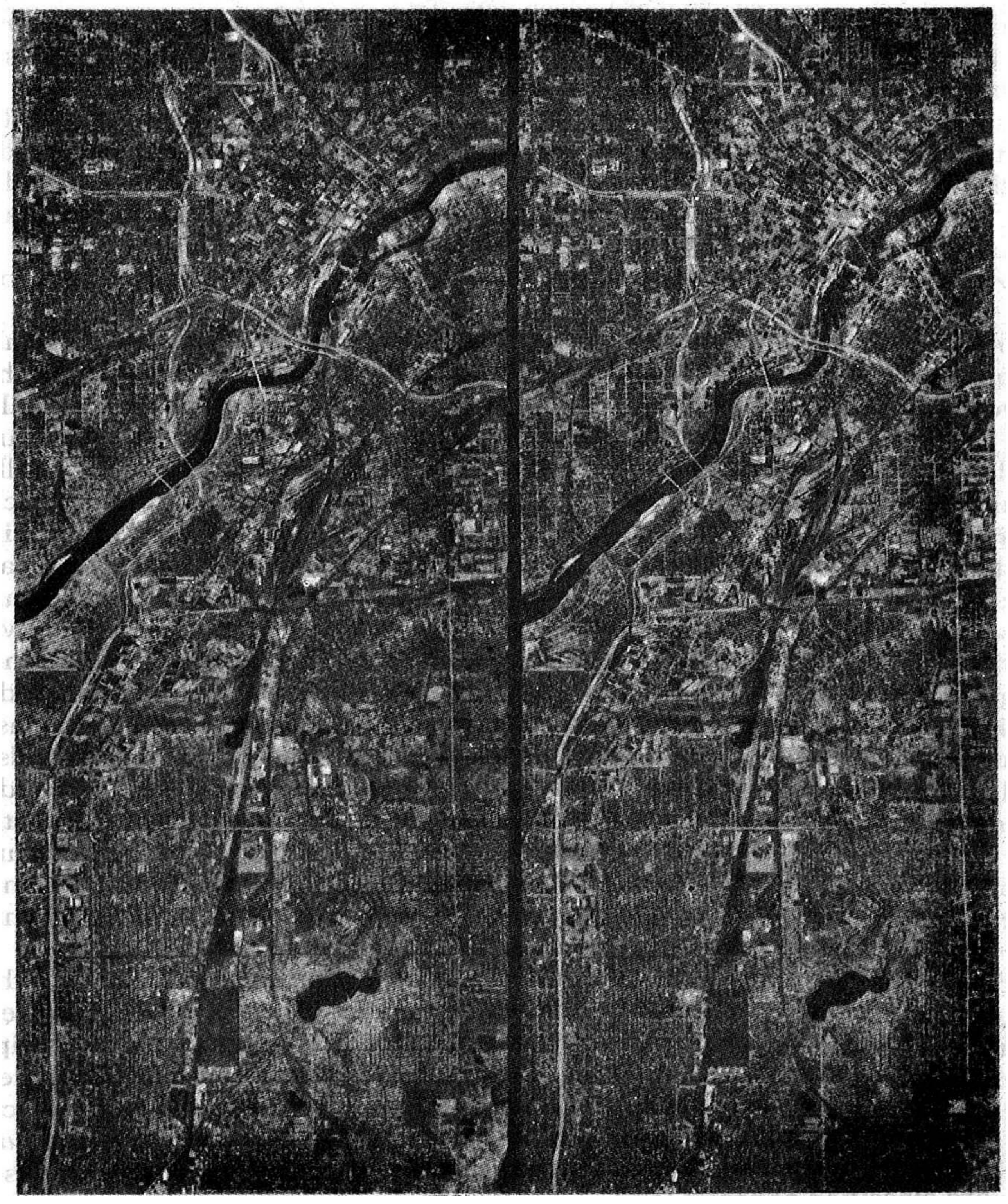


Figure 3.3: Remote Sensing and Land Use Classification

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

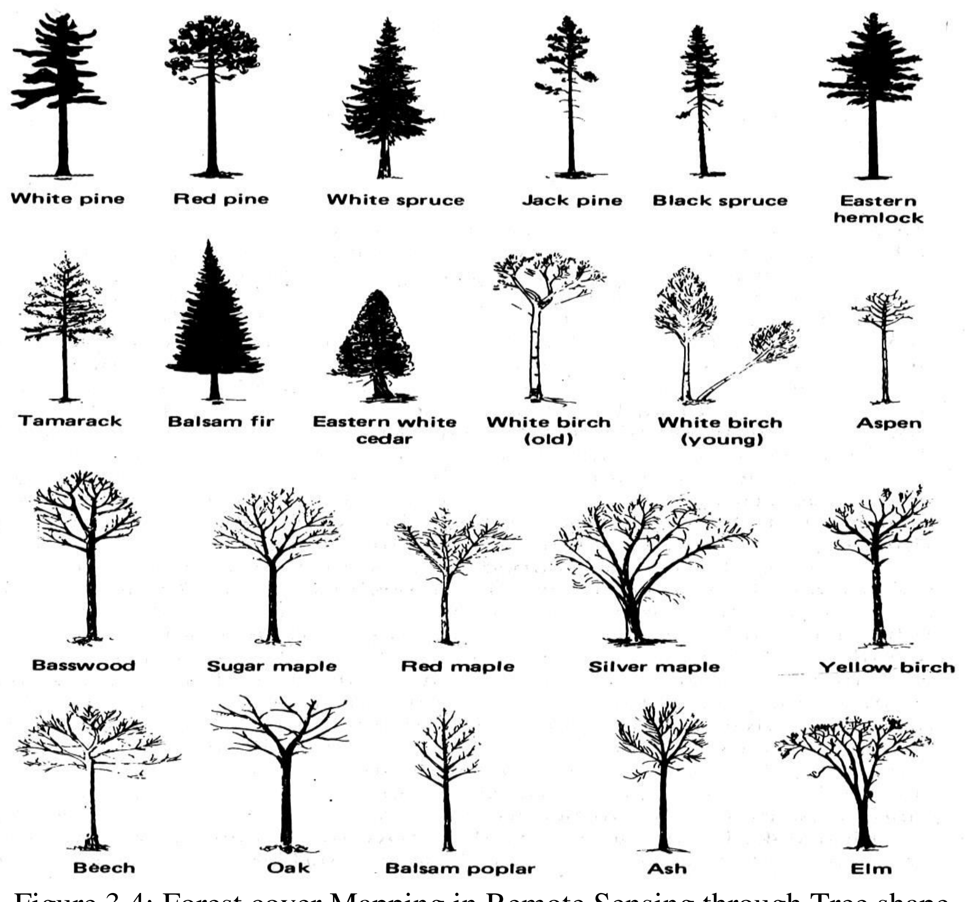
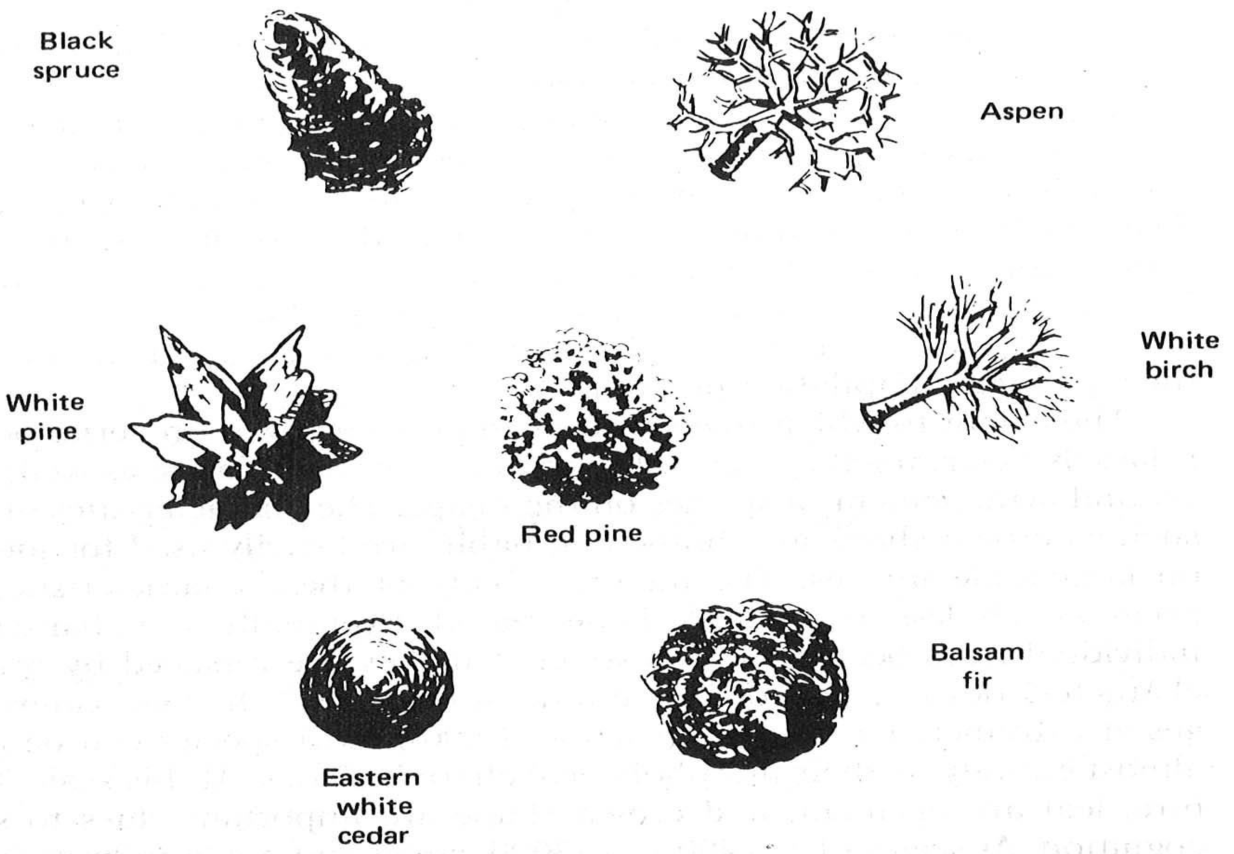


Figure 3.4: Forest cover Mapping in Remote Sensing through Tree shape



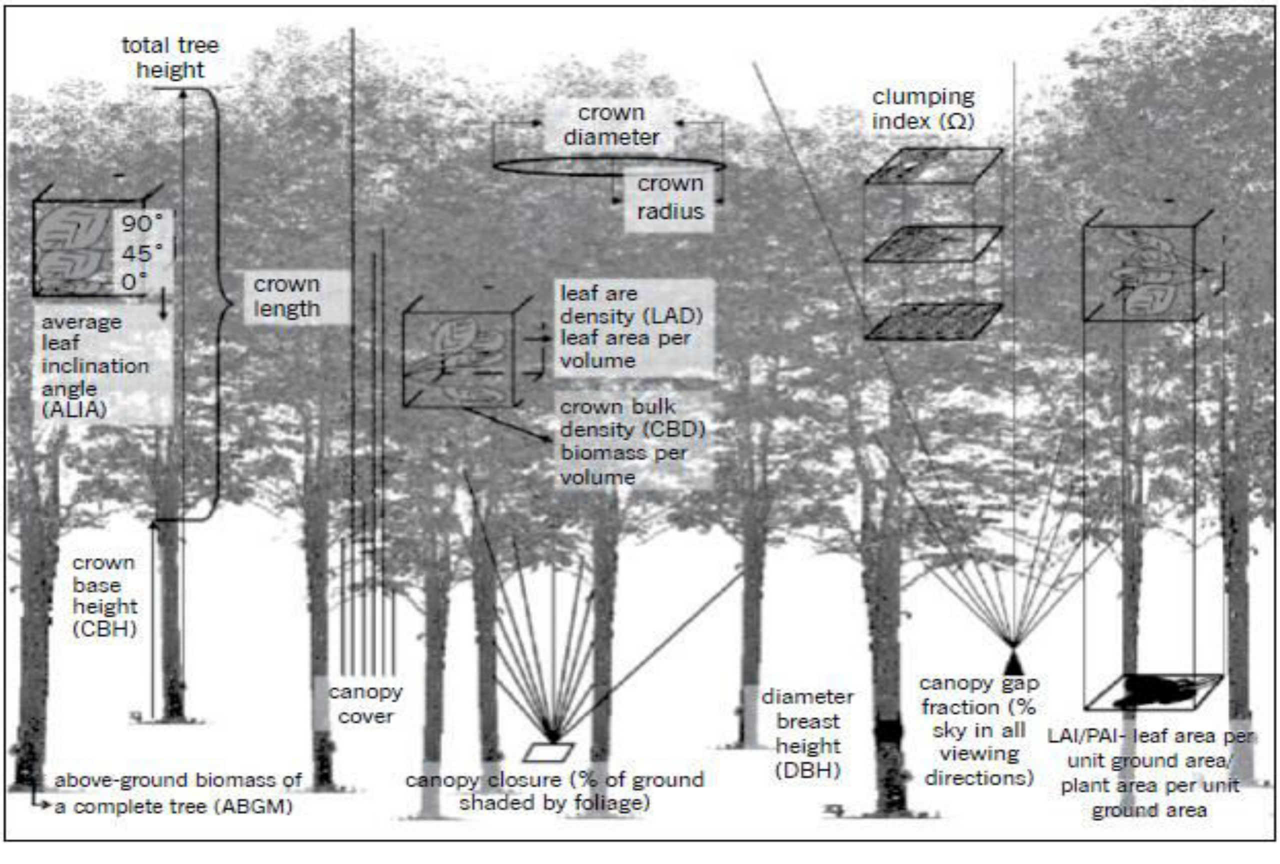


Figure 3.5: Major Structural Characteristics of Forest Canopy

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.

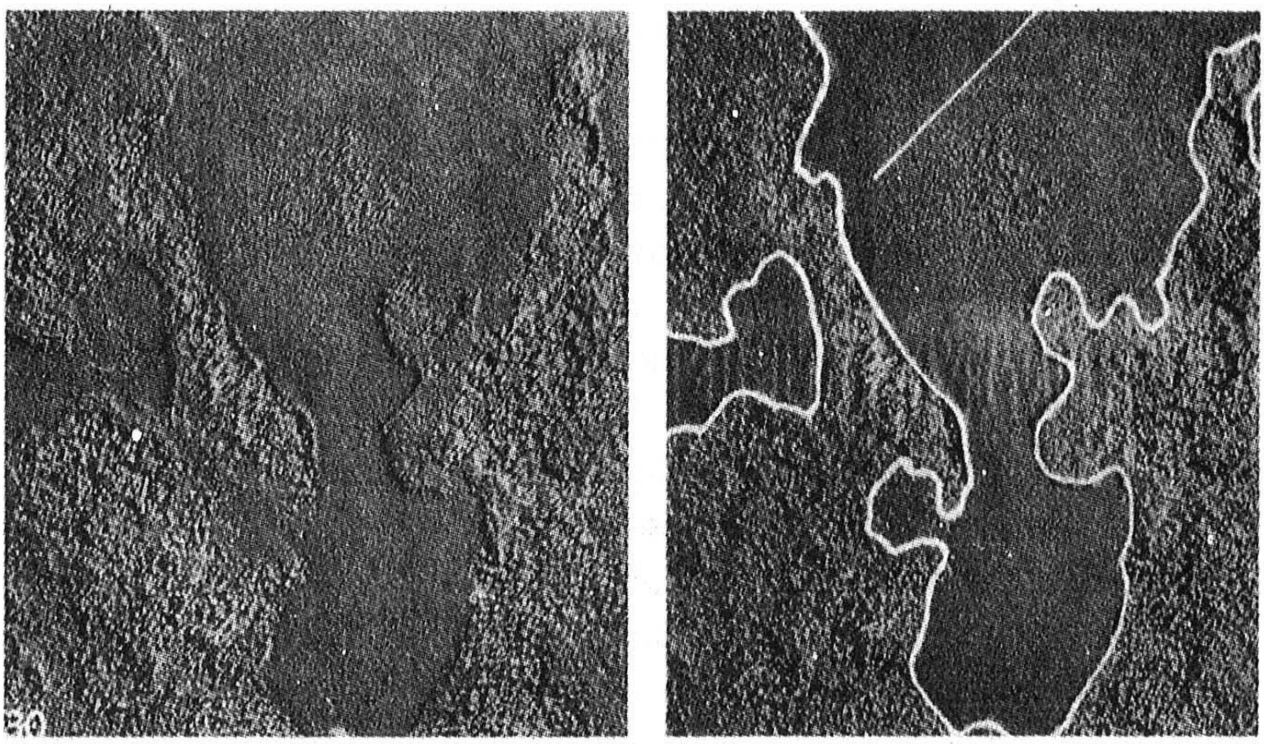


Figure 3.6: Different Image Texture of Various Variety of Tres Species

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.

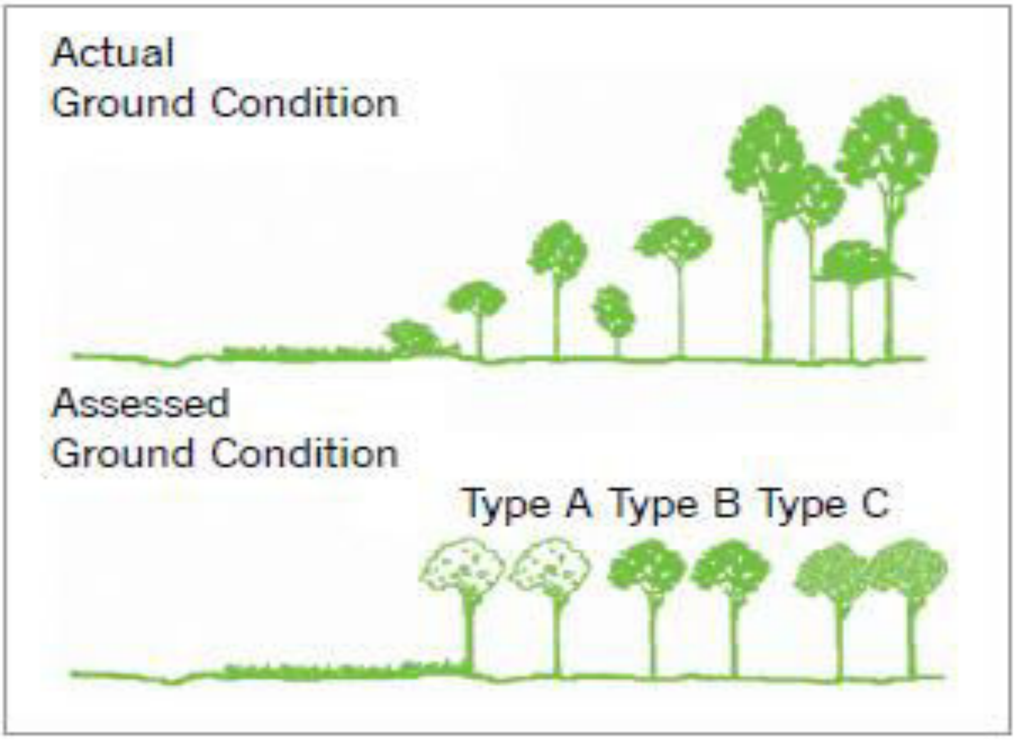


Figure 3.7: Canopy Cover on Ground and assessed using Remote Sensing

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.

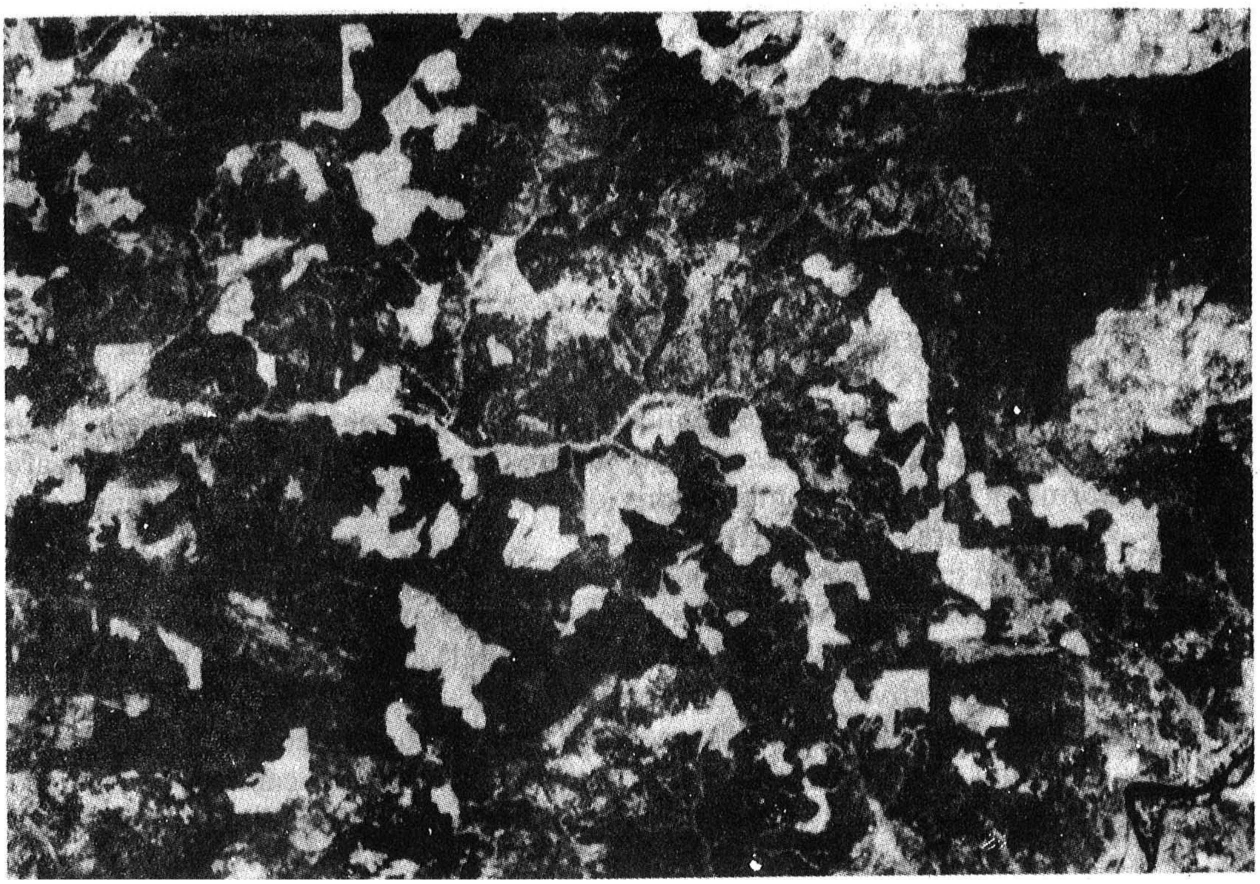


Figure 3.8: Satellite Image showing Timber

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.

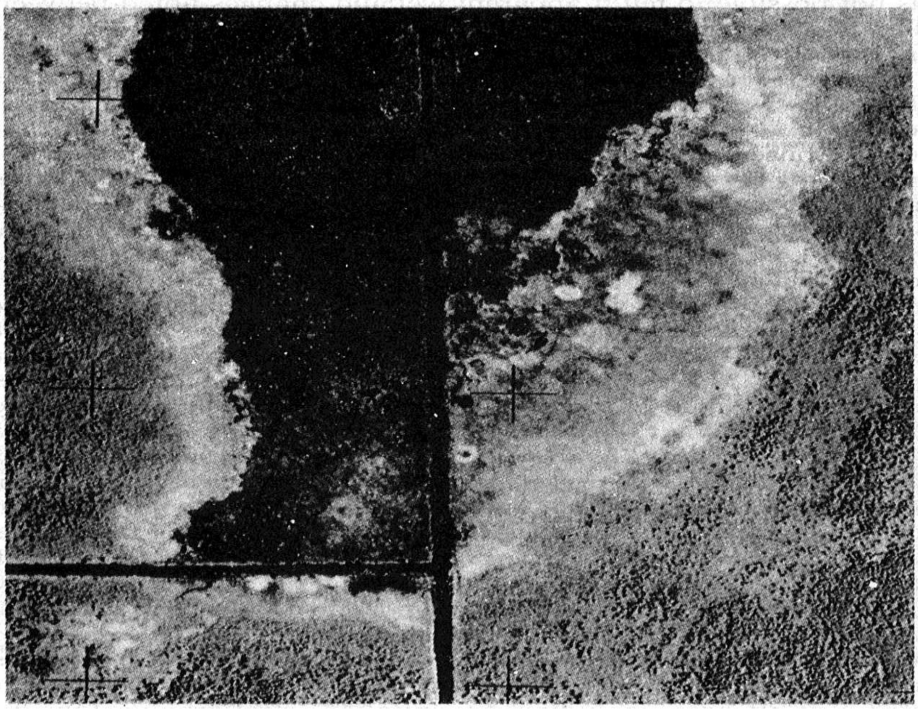


Figure 3.7: Wetland Mapping though Remote Sensing

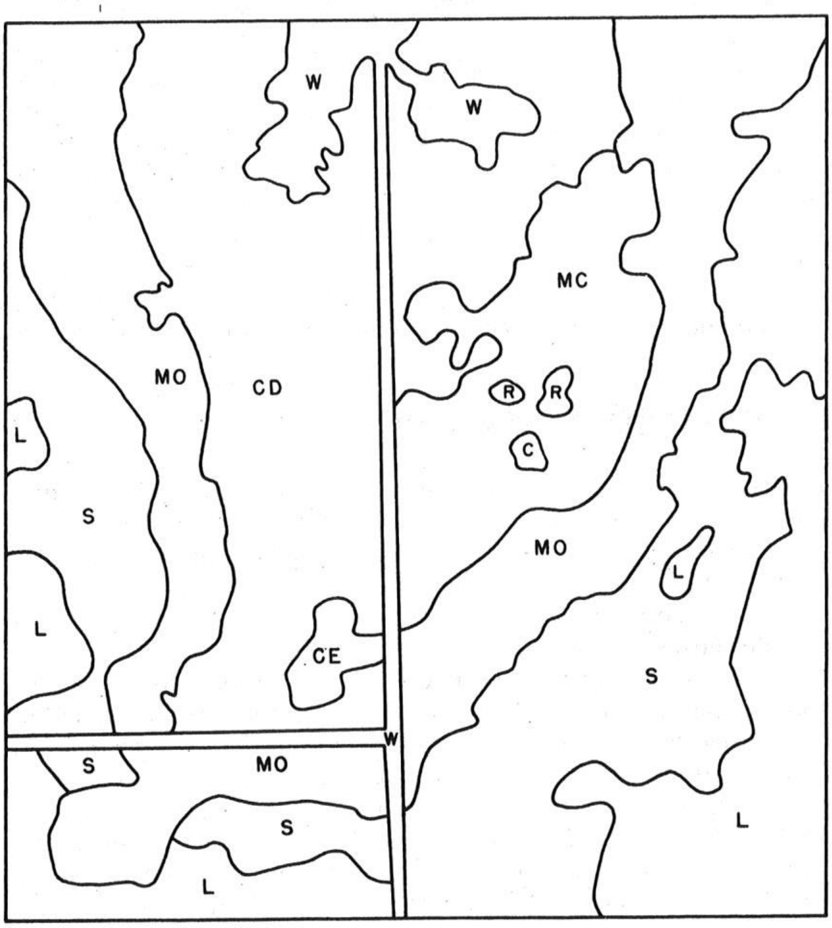


Figure 3.8: Wetland Categorization and Mapping

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.

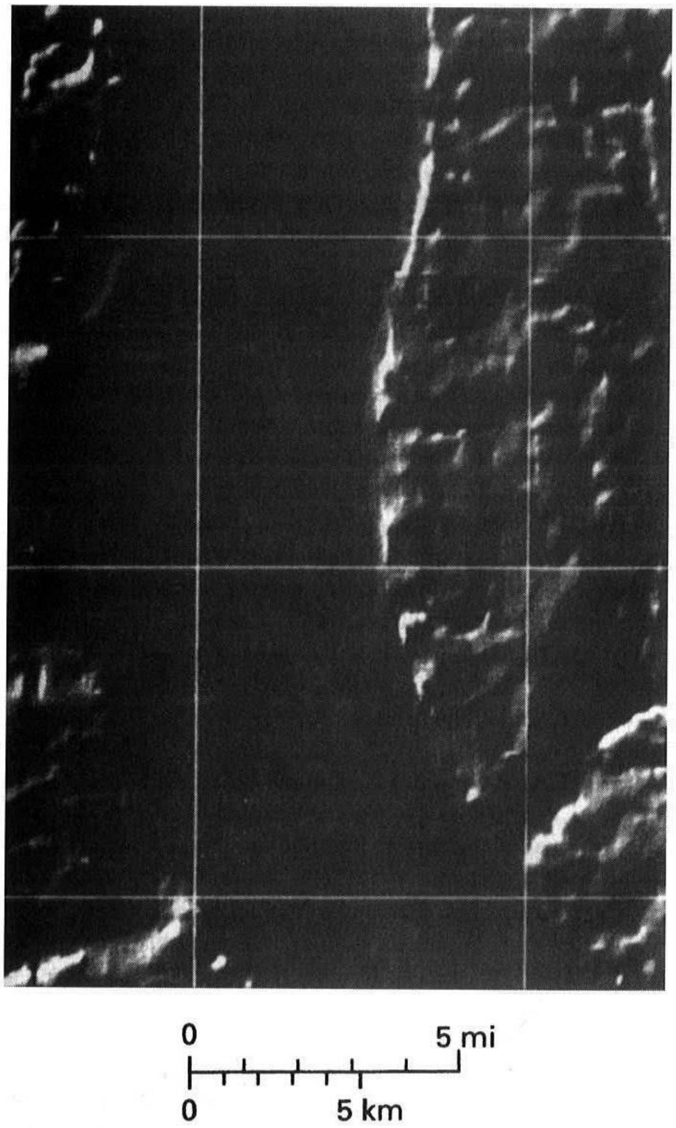


Figure 3.9: Satellite Image

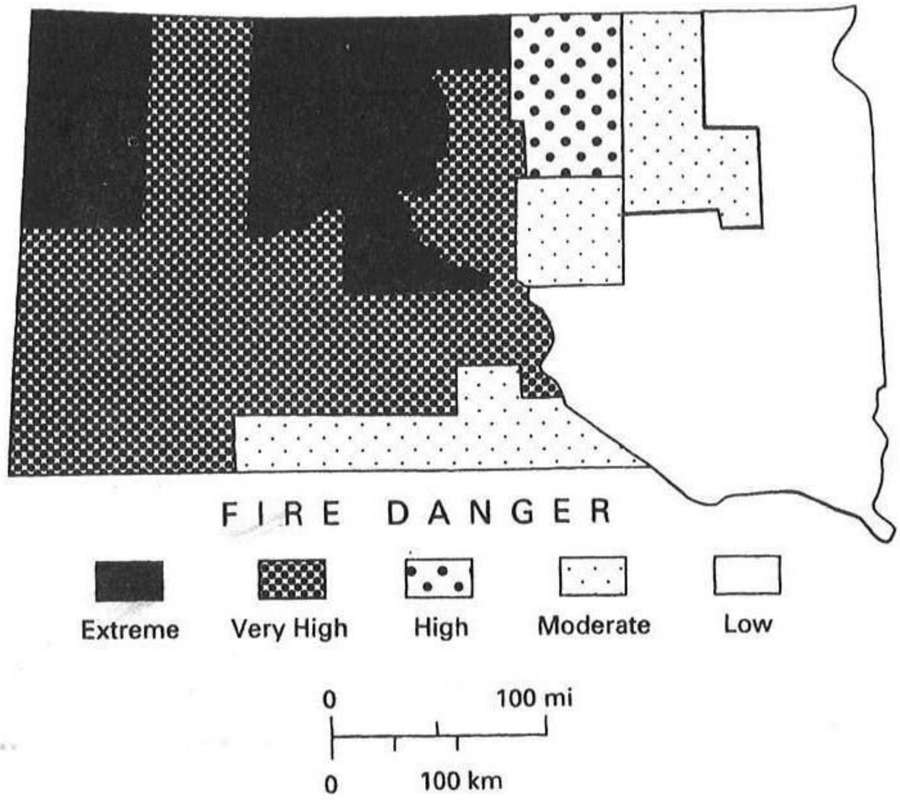


Figure 3.10: Forest Fire Mapping

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.

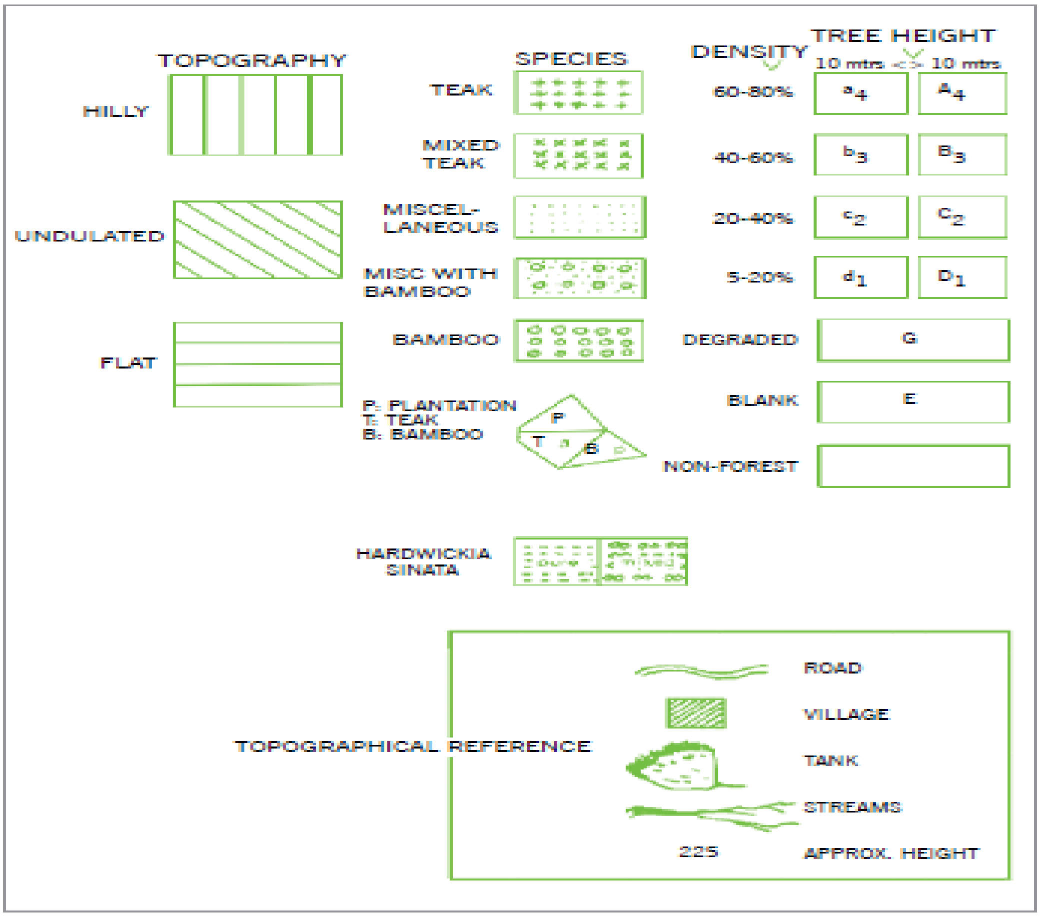


Figure 3.10: Forest Mapping

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 3.11: 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.

3.5 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 DISASTER RISK MANAGEMENT

UNIT 4 - OVERVIEW OF DISASTERS, MEANING, DEFINITION AND CLASSIFICATION OF DISASTERS, IMPORTANCE OF REMOTE SENSING & GIS IN DISASTER MANAGEMENT- RECONNAISSANCE, FORECAST, FOREWARNING SYSTEMS, DISASTER PREPAREDNESS WITH RESPECT TO DIFFERENT DISASTERS

4.1 OBJECTIVES
4.2 INTRODUCTION
4.3 OVERVIEW OF DISASTERS, MEANING, DEFINITION AND CLASSIFICATION OF DISASTERS, IMPORTANCE OF REMOTE SENSING & GIS IN DISASTER MANAGEMENT- RECONNAISSANCE, FORECAST, FOREWARNING SYSTEMS, DISASTER PREPAREDNESS WITH RESPECT TO DIFFERENT DISASTERS
4.4 SUMMARY
4.5 GLOSSARY
4.6 ANSWER TO CHECK YOUR PROGRESS
4.7 REFERENCES
4.8 TERMINAL QUESTIONS

4.1 OBJECTIVES

After reading this unit you should be able to:

- Define Disasters
- Explain the types of Disasters
- Gain knowledge about the importance of Remote sensing & GIS in Disaster Management.

4.2 INTRODUCTION

The impact of natural disasters can be reduced through a proper disaster management, including disaster prevention (hazard and risk assessment, land use planning and legislation, building codes), disaster preparedness (forecasts, warning, prediction) and rapid and adequate disaster relief (OAS, 1990; UNDRO, 1991). Mitigation of natural disasters can be successful only when adequate knowledge is obtained about the expected frequency, character, and magnitude of hazardous events. Some types of disasters, like, floods or earthquakes may originate very rapidly and may affect large areas. The use of synoptic earth observation methods has proven to be especially suitable in the field of disaster management. In a number of countries, where warning systems and building codes are more advanced, remote sensing of the earth has been found successful to predict the occurrence of disastrous phenomena and to warn people on time.

4.3 OVERVIEW OF DISASTERS, MEANING, DEFINITION AND CLASSIFICATION OF DISASTERS, IMPORTANCE OF REMOTE SENSING & GIS IN DISASTER MANAGEMENT-RECONNAISSANCE, FORECAST, FOREWARNING SYSTEMS, DISASTER PREPAREDNESS WITH RESPECT TO DIFFERENT DISASTERS

Disasters are serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources. Disasters can be caused by natural, man-made and technological hazards, as well as various factors that influence the exposure and vulnerability of a community.

The term “DISASTER” owes its origin to French word “Disastre”, a combination of two words “Des” meaning “Bad” and “Aster” meaning “Star” thus the term Disaster refers to “Bad or Evil Star”. The term can be used for personal tragedies also, as they may cause emotional and financial sufferings. Disasters, however, are the catastrophic events resulting in heavy losses in terms of human, animal and plant lives, injuries and disabilities and damage to property and environment. In contemporary academia, disasters are seen as the consequence of inappropriately managed risk. These risks are the product of hazards and vulnerability. Hazards that strike in areas with low vulnerability are not considered a disaster, as is the case in uninhabited regions. Disaster occurs when a hazard impacts on or strikes a vulnerable community with low capacity resulting in damages, loss and serious disruption of community functioning. The widespread human, material and environmental losses exceed the community's ability to cope using its own resources. The World Health Organization (WHO) defines a disaster as “a sudden ecological phenomenon of sufficient magnitude to require external assistance”. It is also defined as any event, typically occurring suddenly, that causes damage, ecological disruption, loss of human life, deterioration of health and health services, and which exceeds the capacity of the affected community on a scale sufficient to require outside assistance (Landsman, 2001). Disasters are events that occur when significant numbers of people are exposed to extreme events to which they are vulnerable, with resulting injury and loss of life, often combined with damage to property and livelihoods. Disasters, commonly leading to emergency situations, occur in diverse situations in all parts of the world, in both sparsely populated rural and densely populated urban regions, as well as in situations involving natural and man-made hazards. Disasters are often classified according to their speed of onset (sudden or slow), their cause (natural or man-made), or their scale (major or minor).

DEFINITIONS OF DISASTER

- A disaster is defined as a "sudden or great misfortune" or simply "any unfortunate event." More precisely, a disaster is "an event whose timing is unexpected and whose consequences are seriously destructive."
- A disaster is defined as a sudden, destructive occurrence that disrupts a community's or society's functioning and causes human, environmental damage, economic and material losses. It is greater than the community's or society's capacity to cope with using its resources. While often caused by nature, disasters may have human causes. In today's academia, disasters are viewed as the result of ineffective risk management. These challenges are the result of a confluence of hazards and vulnerabilities. Hazards that occur in low-vulnerability areas will never become disasters, as they do in uninhabited regions.

(VULNERABILITY+ HAZARD) / CAPACITY = DISASTER

Across all of history, natural disasters and military conflict have already marked human life and triggered peaks in mortality and morbidity.

TYPES OF DISASTER

There are mainly two types of disaster:

1. Natural Disaster
2. Man-made Disaster

NATURAL DISASTER

A natural disaster is a natural process or occurrence that can lead to property harm, injury or other health effects, loss of livelihoods, loss of life, environmental damage, and economic disruption. These types of disasters are as follows:

- Earthquakes
- Floods

- Drought
- Wildfires
- Cyclone
- Tornadoes and Severe Storms

According to the International Federation of Red Cross, natural physical events are caused either by fast or slow accidents that directly impact human health and cause more death and misery. The United Nations Office for Disaster Risk Reduction characterizes natural disasters in terms of magnitude or severity, onset speed, length, and area of magnitude. For example, earthquakes are a short time of duration and typically affect relatively small regions, while droughts are slow to grow and fade and often affect large areas.

MAN-MADE DISASTER

Technological or human faults cause Man-made disasters. Man-made disasters include stamping, oil spills, burning, industrial accidents, nuclear explosions/radiation, and transport incidents. Battle and deliberate attacks can also be included in this group. As with natural threats, man-made hazards are occurrences that have not existed, such as terrorism. Man-made disasters are examples of particular situations in which man-made threats have become a fact in an event.

COMPLEX EMERGENCIES

Some disasters are caused by a combination of natural and man-made disasters, including a robbery, breakdown of authority, and attacks on strategic facilities, like conflict situations and war. There are various complex emergencies given below:

- Epidemics
- Displaced Populations
- Food Insecurity
- Armed Conflicts
- Extensive Violence
- Displacement of populations

PANDEMIC EMERGENCIES

The pandemic is an infectious disease outbreak that has spread to a wide area that can impact the human or animal population and affect health and interrupt services, resulting in economic and social costs. It may be an unexpected rise in the number of infectious diseases that already occur in a particular region or population. It may also apply to the emergence of many cases of an infectious disease in an area or population that is usually disease-free. Pandemic emergencies can arise as a result of natural or man-made disasters. Some Pandemic emergencies are as follows:

- Coronavirus Disease (Covid-19)

- Malaria
- Dengue fever
- Zika
- Yellow Fever
- Avian Flu

The impact of natural disasters can be reduced through a proper disaster management, including disaster prevention (hazard and risk assessment, land use planning and legislation, building codes), disaster preparedness (forecasts, warning, prediction) and rapid and adequate disaster relief (OAS, 1990; UNDRO, 1991). Mitigation of natural disasters can be successful only when adequate knowledge is obtained about the expected frequency, character, and magnitude of hazardous events. Some types of disasters, like, floods or earthquakes may originate very rapidly and may affect large areas. The use of synoptic earth observation methods has proven to be especially suitable in the field of disaster management. In a number of countries, where warning systems and building codes are more advanced, remote sensing of the earth has been found successful to predict the occurrence of disastrous phenomena and to warn people on time.

EARTHQUAKES

Remote sensing techniques can the information available through seismic techniques. Generally, the faults associated with earthquakes can be identified on good resolution satellite imagery, whereas the volcanic related earthquakes are not all that obvious (Richards, 1982). For this purpose, land use and geological maps can give vital pointers towards potential earthquake zones. Satellite sensors that are active in the visible 35 and near infrared spectral band would be useful. Conventionally, aerial remote sensing (airborne radar) would be thought as more effective to delineate unconsolidated deposits sitting on fault zones, upon which most of the destruction occurs, and to identify areas where an earthquake can trigger landslides but now with 1m resolution satellite imageries professionals are very hopeful to apply more and more of remote sensing techniques.

It is one of the oldest enemies of humankind and now it is possible to map and analyse earthquakes in a detailed manner. GIS supports national, regional, and local emergency organizations in planning and managing preparatory programs. The GIS-based Urban Information Systems is used to analyse demographic data and infrastructure locations.

Remote sensing and GIS Technology provides the exact position of the spatial data of historical sites. The vision of remote sensing and GIS technology is to visualize the critical vulnerabilities & damages and reduce the impact of the disaster. The GIS Technology results could be responded to quickly during the disaster.

Experience has shown that earthquake deaths can increase due to secondary disasters such as tsunamis and fires. Buffer analysis serves as a good remedy to reduce vulnerabilities to predict the damage that could be caused by a tsunami. The GIS-based Network analysis tool is used to identify the location and routes that provide the fastest response to emergency needs like a hospital, fire station, and so on.

The real-time location tracking platform or web/mobile GIS-based applications are enabled to interact with the maps which contain the details of the earthquake location & its intensity, health facility, nearby base camp information, and Damage assessment. The GIS-based application also acts as a collective platform for data gathering around the incident of infrastructure damage or fire and information dissemination to relief teams involved in providing aid to those affected by the disasters.

VOLCANIC ERUPTIONS

Volcano monitoring is important simply because an unexpected-ted awakening can imperil thousands of lives over a wide area. Remote sensing techniques can play an important role by providing the vital information with only limited fieldwork, which saves effort and money. Thermal infrared (TIR) imagery can capture the volcanic heat provided the spatial resolution is high enough. Also, PAN stereo-pair imagery, due to its 3-D capabilities, of moderate resolution would serve the purpose of finding out the evidence of hazardous activities. An IR pattern of geothermal heat in the vicinity of a volcano is an indication of thermal activity, which many inactive volcanoes display. Many volcanoes thought to be extinct may have to be reclassified if regular monitoring discovered any abnormally high IR emissions from either the summit craters or the flanks. Changes in thermal patterns can be obtained for a volcano only through periodic IR imageries of very high resolution, like that of IKONOS, taken under similar conditions of data acquisition. The temperature and gas emission changes, however, can be monitored, through a geostationary satellite, at ideal locations identified on the thermal imagery.

TSUNAMIS

Tsunamis are water waves or seismic sea waves caused by large-scale sudden movement of the sea floor (due to earthquakes; landslides; volcanic eruptions or man-made explosions). With increasing population and development along most coastlines, there is a corresponding increase in tsunami disaster risk in recent years. Tsunamis differ from other earthquake hazards in that they can cause serious damage thousands of kilometers from the causative faults. Once they are generated, they are nearly imperceptible in mid- 41 ocean, where their surface height is less than a meter. They travel at incredible speeds, as much as 900 km/hr, and the distance between wave crests can be as much as 500 km. As the waves approach shallow water, a tsunami's speed decreases and the energy is transformed into wave height, sometimes reaching as high as 25 m, but the interval of time between successive waves remains unchanged, usually between 20 and 40 minutes. When tsunamis near the coastline, the sea recedes, often to levels much lower than low tide, and then rises as a giant wave.

These large-scale low-pressure systems occur throughout the world over zones referred to as "tropical cyclone basins" (www.oas.org/usde/). The determination of past hurricane paths for the region can be derived from remotely sensed data from the U.S. National Oceanographic and Atmospheric Administration (NOAA) satellite sensors designed and operated for meteorological purposes. The Tropical Analysis and Forecast Branch of the

Tropical Prediction Center (TPC) provides year-round products involving marine forecasts, aviation forecasts and warnings (SIGMETs), and surface analyses. The unit also provides satellite interpretation and satellite rainfall estimates for the international community. The Technical Support Branch provides support for satellite data processing. One of the key lessons NASA learned during Hurricane Andrew was that it is critical to select appropriate data and put it together to make informed decisions. Due to the lengthy process required to gather the data, it was suggested that communities not wait until a disaster happens to do so. Imagery is an important aspect of a community's database.

The next generation of satellites such as Earthwatch's Early Birds and Astrovision will significantly enhance the remote sensing capabilities

LANDSLIDES

An area with a potential landslide hazard usually has some evidence of previous occurrences. An examination of stream traces frequently shows deflections of the bed course due to landslides. Typical features that signify the occurrence of landslides include, chaotic blocks of bedrock whose only source appears to be upslope, crescentic scarps or scars whose horns point downward on a normal-looking slope, abnormal bulges with disturbed vegetation at the base of the slope, large intact beds of competent sedimentary or other layered rock displaced down dip with no obvious tectonic relationship and mudflow tongues stretching outward from the base of an obviously eroded scar of relatively unconsolidated material .

FLOODS

Scientists and researchers have been investing valuable hours and funds in finding out more accurate and faster methodologies to predict and estimate flood depth and extent. Satellite imagery can be very effective for flood management in the following way:

• Detailed mapping that is required for the production of hazard assessment maps and for input to various types of hydrological models;

• Developing a larger scale view of the general flood situation within a river catchment or coastal belt with the aim of identifying areas at greatest risk and in the need of immediate assistance; and

• Monitoring land use/cover changes over the years to quantify prominent changes in land use/cover in general and extent of impervious area in particular.

With the help of Remote Sensing & GIS techniques, floods can be predicted. National Disaster Management Authority (NDMA) & State Disaster Management Authority (SDMA) utilized remote sensing techniques in combination with GIS/Photogrammetric technology for Effective & Economic way management of disasters. GIS technology plays a key role in identifying flood-affected locations and providing shelter for affected people. In addition to that, the suitable places for constructing the retaining wall structures and an alternate route for draining the stormwater. This process also helps to create different levels of vulnerability maps which indicate the areas that are frequently affected by floods and base maps (Gram Panchayat, District) to show the location and setup of boats and the rescue team's plans. The 3-Dimensional of Flood simulation results will give more strong information to understanding the disaster impacts quickly.

4.4 SUMMARY

- GIS technology helps identify disasters before they occur, using forecasts or risk zone maps.
- Remote sensing and GIS technology for Disaster Management create an emergency database for people in need of all assistance in the event of a disaster.
- The emergency database contains information about nearby hospitals, emergency shelters, and more. Disaster risk or impact maps focus on taking corrective action against disasters.
- The GIS Technology is combined with Global Positioning System (GPS), which will help to receive/update the help from disaster rescue teams.

- GIS for Disaster Management uses remote sensing data to forecast climate conditions and climate anomalies at any given point by latitude-longitude coordinates.
- The alternate routes can be created by using Disaster Management technology i.e., GIS for rescuing from disasters.
  The details of the disaster like the occurred place, severity level, and how many areas are affected & disaster directions all will be mapped using GIS Technology.
- The GIS Maps will give also historical/past disaster events details, from this disaster management action will be taken more strongly.
- The Risk zone map of disasters may reduce the vulnerability of the disasters.
- In the event of a disaster or post-disaster emergency, GIS technology uses a combination of GPS & 5G to enhance assistance.
- Remote Sensing and GIS technology have strong essence to provide the solution to all types of disasters but only the method, and consideration of the factors are different.
- So, disasters occur naturally or accidentally and cannot be stopped, but technology can be used to minimize the impact and damage.

4.5 GLOSSARY

- Natural Disasters-Natural disasters are catastrophic events with atmospheric, geological, and hydrological origins (e.g., droughts, earthquakes, floods, hurricanes, landslides) that can cause fatalities, property damage and social environmental disruption.
- Man made Disasters- Man-made disasters have an element of human intent, negligence, or error involving a failure of a man-made system, as opposed to natural disasters resulting from natural hazards. Such man-made disasters are crime, arson, civil disorder, terrorism, war, biological/chemical threat, cyber-attacks, etc.
- Floods-a large amount of water that has spread from a river, the sea, etc.
- Earthquakes-An earthquake is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves.
- Landslides-the sudden fall of a mass of earth, rocks, etc. down the side of a mountain.
- Tsunamis- a very large wave in the sea which destroys things when it reaches the land, and is often caused by movements under the surface of the earth (an earthquake)

4.6 ANSWER TO CHECK YOUR PROGRESS

- Define Tsunami?
- Define Landslides?
- Define Earthquakes?
- Define Floods?

4.7 REFERENCES

- https://www.ifrc.org/our-work/disasters-climate-andcrises/what disaster#:~:text=Disasters%20are%20serious%20disruptions%20to,and%20vulnerability%20of%20a%20community.
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4.8 TERMINAL QUESTIONS

1- What do you mean by disasters? Explain the types of disaster.
2- Explain the role of Remote sensing and GIS in Flood management.
3- Explain the role of Remote sensing and GIS in Landslides disaster management.
4- Explain the role of Remote sensing and GIS in disaster management.
5- Explain the role of Remote sensing and GIS in Tsunamis disaster management.

UNIT 5 - EARTHQUAKE: MEANING, CAUSES, PREDICTION OF EARTHQUAKE, GEOMATICS IN EARTHQUAKE MITIGATION, SEISMIC DAMAGE AND LOSS ESTIMATION, QUAKE REHABILITATION AND EARTHQUAKE DISASTER MANAGEMENT. LANDSLIDE: MEANING, CAUSES, TYPES AND MITIGATION MEASURES, LANDSLIDE MONITORING AND LANDSLIDE ZONATION; FLOODS: MEANING, TYPES AND MITIGATION MEASURES, FLOOD POTENTIAL ZONATION MAPPING, FLOOD HAZARD AND RISK ANALYSIS USING RS & GIS, FLOOD DISASTER MONITORING AND REPORTING SYSTEM

5.1 OBJECTIVES
5.2 INTRODUCTION
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5.1 OBJECTIVES

After reading this unit you should be able:

- To study the various types of disaster and the application of remote sensing and GIS in their management.
- To study earthquake disaster, their types, impacts and their management though geospatial technologies.
- To study landslide disaster, their types, impacts and their management though geospatial technologies.
- To study flood disaster, their types, impacts and their management though geospatial technologies.
- To explore various types of geospatial technologies in disaster management.

5.2 INTRODUCTION

Natural disasters are sudden unexpected events that cause environmental, financial and human loss. These events include avalanches, blizzards, drought, earthquakes, extreme heat or cold, hurricanes, landslides, tornadoes, volcano eruptions, and wildfires. Their detrimental effects can be thwarted or minimized if the public is sufficiently prepared. Geographic Information Systems (GIS) offer valuable spatial data to emergency management response units during and following natural disasters. GIS is a valuable tool in addressing natural disaster management processes. The program is designed to provide succinct, up-to-date information particularly to managers and first responders in their assessment of the natural disaster, at any stage. Emergency response professionals can combine road, population and land data into a clear map format prior to a natural disaster. The events may be natural but rebuilding after the wake of destruction becomes the responsibility of the victims. GIS can alleviate some of the surprise and fear associated with sudden natural disasters by combining today's technology with emergency management knowledge. Since there are often several agencies or organizations working together during emergencies, using GIS allows trained responders to quickly upload and share information between command centers across town or across the world. When a disaster hits, time means lives. Having access to valuable information instantly is what will provide the basis for future GIS processes.

Emergency management has three main objectives "protecting life, property and the environment". GIS can be an invaluable resource in meeting these requirements through the emergency management cycle that includes planning, mitigation, preparedness, response and recovery stages. Each of the phases overlap one another and using GIS, prior to a natural disaster, to analyze spatial data creates a broad framework for emergency managers. In the planning stage, GIS can be used to identify future hazards in the event of a natural disaster such as a potential flood zone. With this information, the rest of the emergency planning process can begin to solidify. Areas that are highly vulnerable during an emergency can be identified through GIS data and proper mitigation proceedings can take place to ensure safety. Mitigation refers to the phase when actions are taken to avoid or reduce the likelihood of a natural disaster. This may include implementing management plans in vulnerable areas, such as building restrictions in areas prone to floods. Locations that are particularly susceptible to natural disasters may execute more comprehensive plans to avoid detrimental effects from unavoidable events. Preparation is a vital part of emergency management; GIS can provide information that is valuable during real emergencies. Several "what if?" questions can be answered through preparedness training like what homeowners should do in the event of a flood or how vulnerable are they to rising waters. When responders complete GIS training sessions, response times will increase and second-guessing should be eliminated. Having capable emergency response teams prepared prior to an event will minimize confusion during an actual crisis situation. Following a natural disaster, response teams only have a short time to react. Quick reaction times are imperative for natural disaster management. Responders will be able to determine the quickest way to their destination according to route identified in the planning stages prior to a flood using GIS TIGER (road) data. If additional support is needed, GIS can provide location information to the new arrivals. GIS can assist in natural disaster severity assessment. This valuable information determines the type of recovery efforts needed. Recovery is an extremely important phase. After a natural disaster, the public safety is a primary concern and the goal becomes restoring the impacted areas back to normal. This can either be a short-term recovery process, which simply involves returning vital needs or it may be a long-term recovery commitment that can take several years, in some circumstances. GIS data can be used in this capacity to identify the vital areas that require immediate repair in order to restore some normalcy to the area. The extent and gravity of a disaster will dictate the recovery efforts. GIS can likely never eliminate the threat of these events but high-risk areas may be better prepared for if and when events do occur. Despite the noted advantages of utilizing GIS during a natural disaster, there are also limitations. These include the possibility of insufficient data, lack of organization, difficulty- recognizing deficiencies in models, problems with software and the inability to recognize needs of end users. The deficiencies in the system may be rectified with further investment in the preparation process. Management professionals need to maximize the capabilities of the program with additional training and research concerning its potential. Since natural disasters can change the structure of a city in moments, having comprehensive base data is imperative to saving lives and the surrounding environment. As cities, states and the federal government expand their GIS capacities, further solutions can be identified for the aforementioned limitations.

MITIGATION, SEISMIC DAMAGE AND LOSS ESTIMATION, QUAKE REHABILITATION AND EARTHQUAKE DISASTER MANAGEMENT. LANDSLIDE: MEANING, CAUSES, TYPES AND MITIGATION MEASURES, LANDSLIDE MONITORING AND LANDSLIDE ZONATION; FLOODS: MEANING, TYPES AND MITIGATION MEASURES, FLOOD POTENTIAL ZONATION MAPPING, FLOOD HAZARD AND RISK ANALYSIS USING RS & GIS, FLOOD DISASTER MONITORING AND REPORTING SYSTEM

An earthquake can be defined as the shaking or trembling of the ground caused by a sudden release of energy inside the earth, usually associated with faulting or breaking of rocks. The general mode of occurrence of an earthquake is a simple sliding of a block of rock mass over another along a plane. The point inside the earth from where seismic waves initiate is called the focus or hypocenter and its vertical projection on the earth's surface is called the epicenter (figure 5.1).

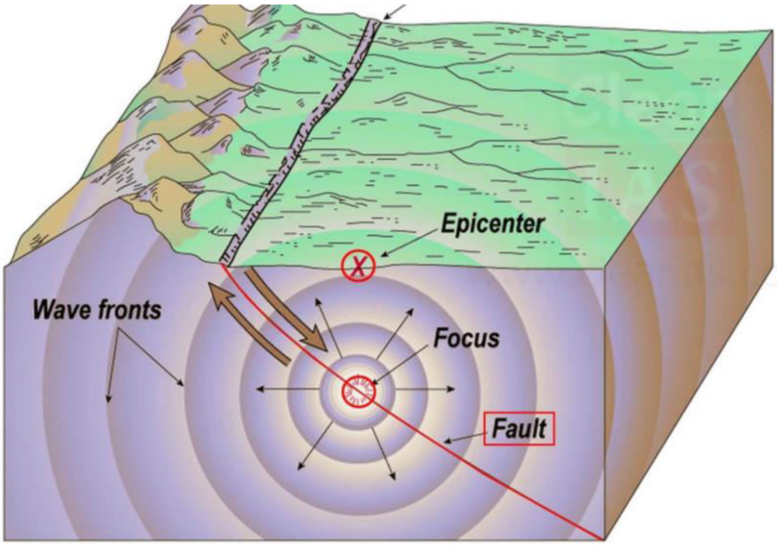


Figure 5.1: Earthquake Epicenter and Focus

Most earthquakes are caused by geological or tectonic causes, and are referred as tectonic earthquakes. Another type of earthquakes is those due to volcanic activity although in conjunction with tectonic forces, which are called volcanic earthquakes. There are two other types of earthquakes which are isotropic in nature which means that they radiate energy uniformly in all directions. The first one is the collapse earthquake which is a small earthquake occurring in underground caverns and mines due to roof collapse. The other is the explosion earthquake similar to a chemical or a nuclear blast. For centuries earthquakes were regarded as an expression of fury of the nature. With the development of science this myth was broken and a new branch of Earth Sciences emerged which was called Seismology. It is

defined as the study of earthquakes and seismic waves that travel through the earth. A seismologist is a scientist who studies earthquakes and analyses seismic waves. Every day there are about fifty earthquakes worldwide that are strong enough to be felt locally, and every few days an earthquake occurs that is capable of damaging structures. Each earthquake radiates seismic waves in all directions which propagate through the earth, and several earthquakes per day produce distant ground motions which although too weak to be felt, can be detected by sensitive instruments all over the world. Seismic waves can also be used to study the structure of the earth apart from understanding the physics of earthquake processes. This is very similar to the way in which doctors scan the human body to elucidate detailed structure or anomalies in the body parts. Seismology has been the main source of information about the earth's deep interior, where direct measurements are impossible, and has provided many important discoveries regarding the structure and nature of our planet earth.
Seismology occupies an important position in the field of Geophysics and in Earth Sciences in general. It comprises a wide range of studies of the earth's structure ranging from thousands of kilometers below the surface, to a detailed mapping of very shallow structure to help locate minerals and ore deposits. Incidentally, this is the most important tool used by the oil industry to detect petroleum deposits inside the earth. On the societal front, it plays an important role in understanding the physical processes that cause earthquakes and seeking ways to reduce their destructive impacts on structures and human beings.

What are Seismic waves?

The energy released during an earthquake travels as seismic waves in all directions through the earth's layers, reflecting and refracting at each interface. These waves are of two types - Body waves and Surface waves. Body waves can travel through the earth's inner layers, but surface waves can move only along the surface of the earth like ripples of water waves. Earthquakes radiate seismic energy as both body and surface waves.

Body Waves: There are two types of body waves as described below.

P Waves (Primary Waves): The first type of body wave is the P wave or Primary wave (figure 5.2). This is the fastest kind of seismic wave that travels with a velocity of about 6 km/s. The P wave can move through solid rock and fluids, like water or the water filled layers of the Earth. It pushes and pulls the medium that it moves through, since it is longitudinal in nature like the sound waves.

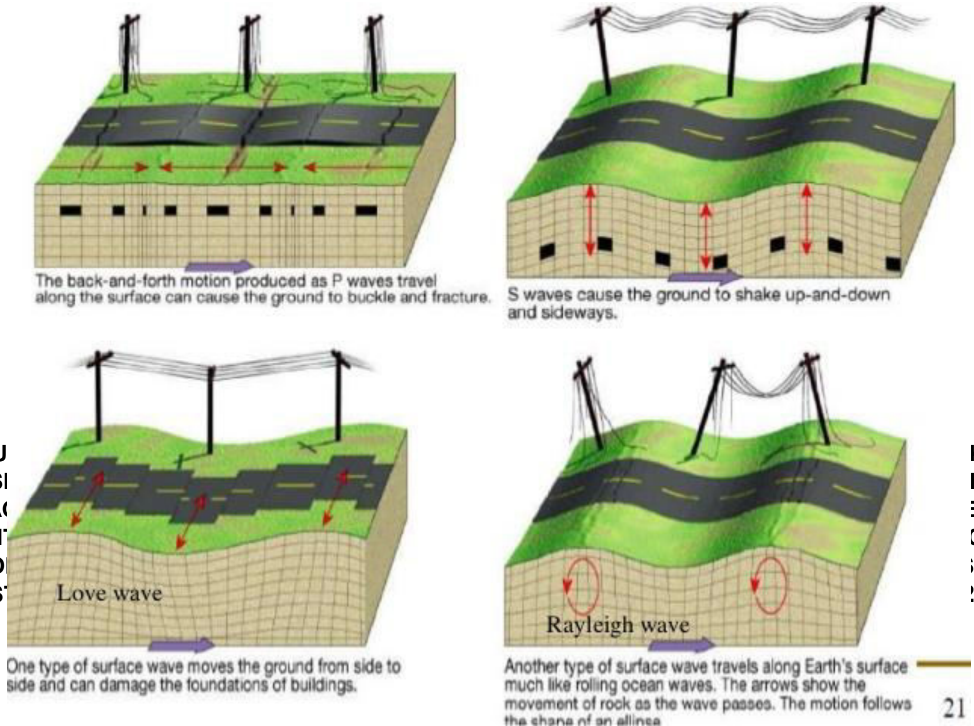


Figure 5.2: Types of Waves in Earthquake Process

S Waves (Secondary Waves): The second type of body wave is the S wave or Secondary wave (figure 5.2), which travels slower than the P wave, with a velocity of about 3.5 km/s. The S wave is transverse in nature like the light waves, and cannot move through a liquid medium.

Surface Waves: These are the waves that travel along the earth's surface and are the most damaging ones, having the largest amplitudes. These are of two types as described below

- **Love Waves:** The first kind of surface wave is the Love wave, named after A.E.H. Love, a British mathematician who worked out the mathematical formulation for this type of wave in 1911. It is the fastest surface wave and moves the ground from side-to-side (figure 3). It is a little slower than the S wave and hence arrives after the P and S waves.
- **Rayleigh Waves:** The other type of surface wave is the Rayleigh wave, named after Lord Rayleigh, who mathematically demonstrated the existence of such waves in 1885. This wave rolls along the ground like a wave rolls across a lake or an ocean. Hence, it moves the ground up and down and side-to side in the same direction as that of the wave propagation (figure 5.3). Most of the ground shaking during an earthquake is due to the Rayleigh waves, which can be the largest waves.

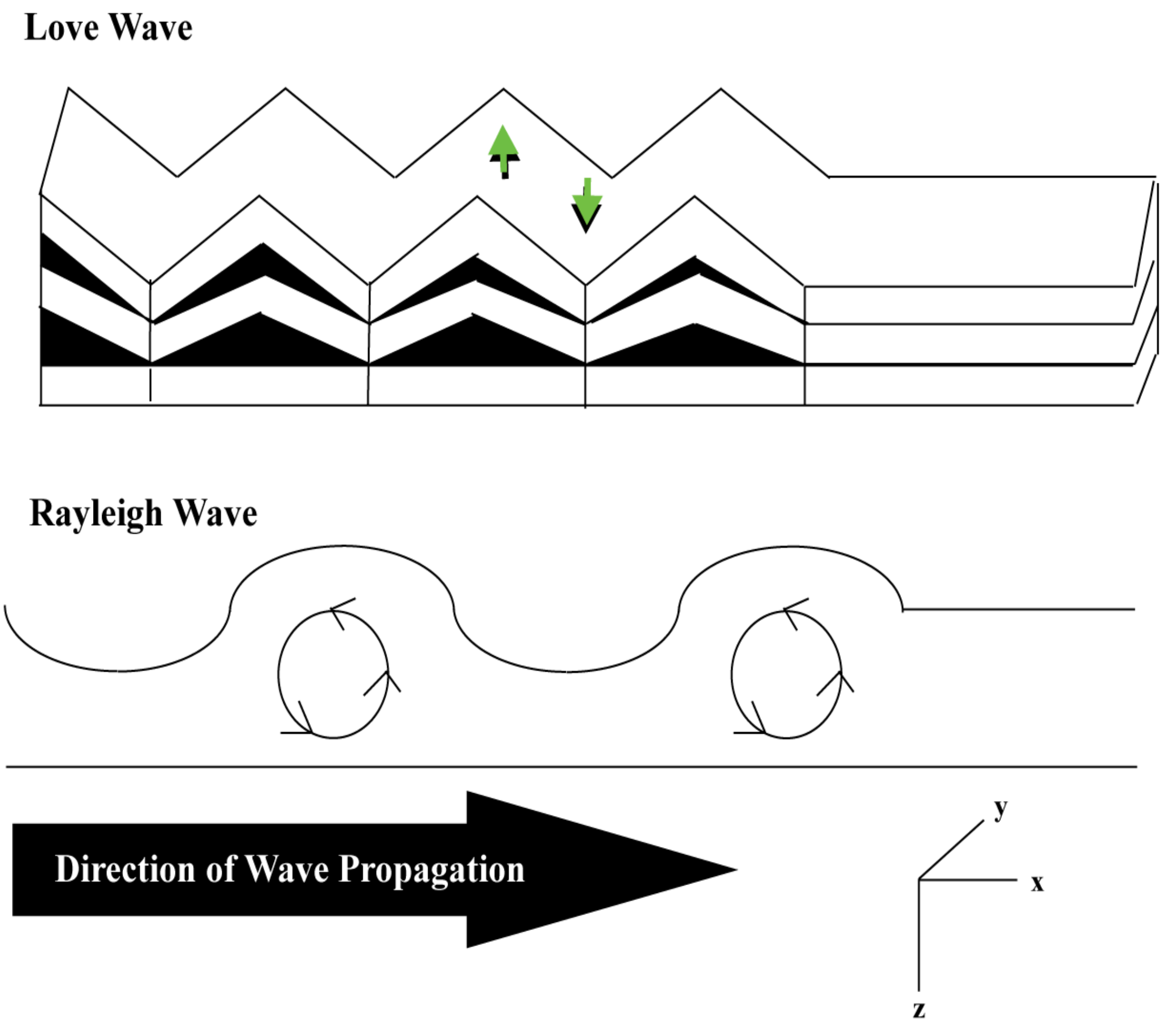


Figure 5.3: How Surface Waves Behaves under Earth

What are Tectonics Plates?

The crust and the upper-most mantle constituting the hard and rigid outer layer of the Earth, is referred as the Lithosphere which moves on the lower mantle medium which is in a fluid state called the Asthenosphere (figure 5.4). The lithosphere of the earth is broken into broadly 13 pieces called the Plates which are in constant motion with respect to each other (figure 5.5). The plate motions are due to convective currents in the lower mantle due to temperature gradients, which are the main cause driving plate tectonics. Sometimes plates collide and converge, resulting in mountain building, like in the Himalayas. On the other hand, hot molten magma comes out with high pressure at zones with thin and weak lithosphere, usually in the middle of Oceans, resulting in creation of two plates which start moving away from one another. Such regions are called mid-oceanic ridges which comprise diverging plate boundaries. In another type of plate boundary, two plates can move side-by-side, as in the case of the San Andreas Fault in the United States.

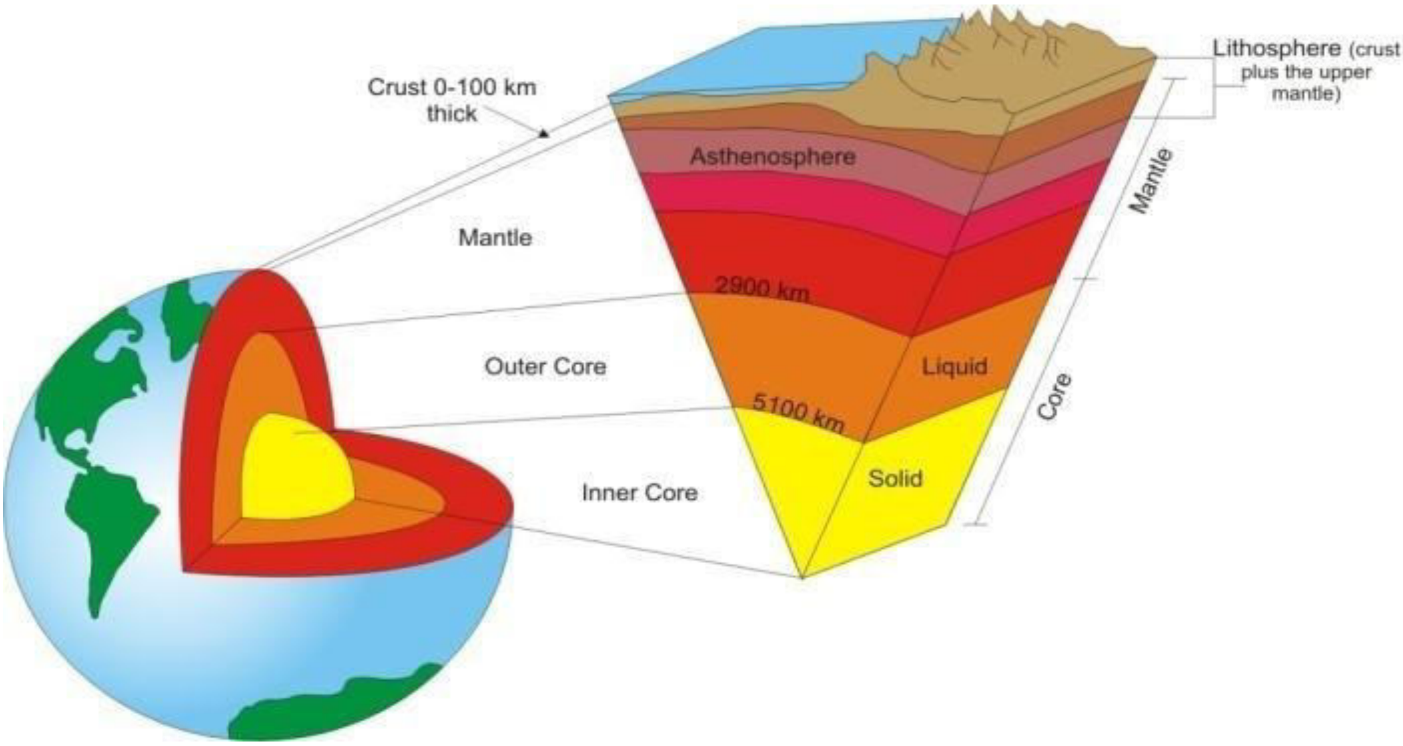


Figure 5.4: Interior Structure of Earth

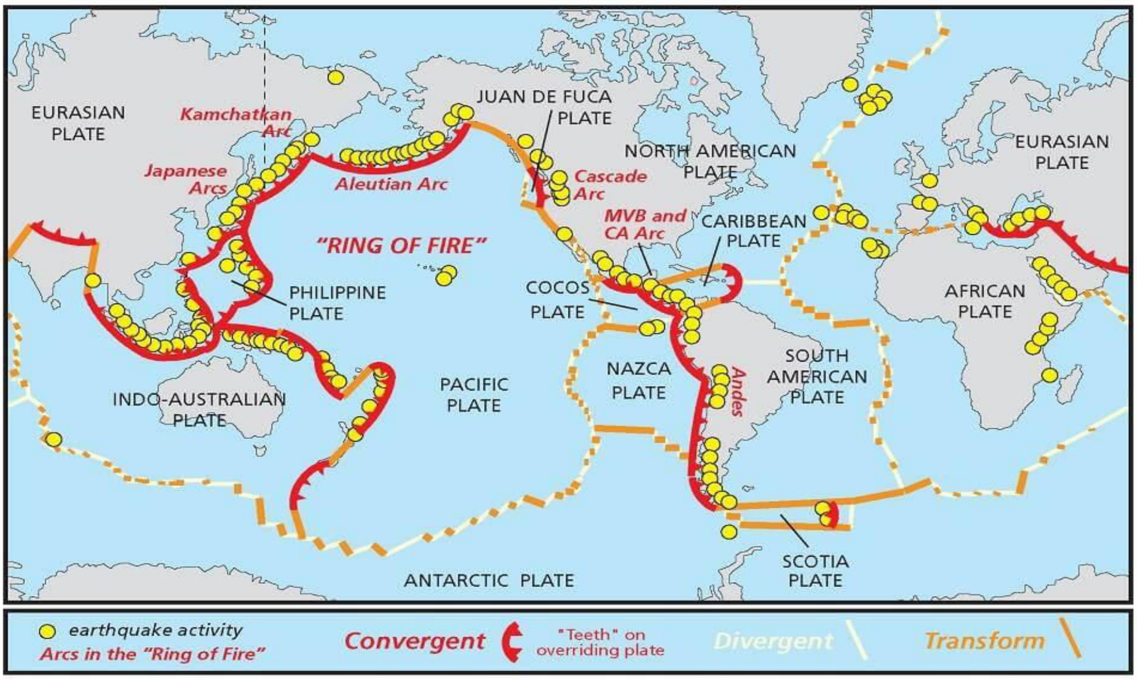


Figure 5.5: Plate Tectonics

These three types of plate interactions are called convergent, divergent and transform plate boundaries, respectively. In a convergent zone one of the plates, usually the denser one dives beneath the other. Such a plate boundary is called a subduction zone. However, a convergent boundary can sometimes be a collision zone, like the Himalayas, where there is an equal tussle between colliding plates. The relative movement of plate boundaries varies across the earth. On an average, it is of the order of a few cm per year. Depending on the movement between the plates or blocks adjacent to the faults, earthquakes are classified into three types - Thrust, Normal, and Strike-Slip corresponding to the three types of plate movements.

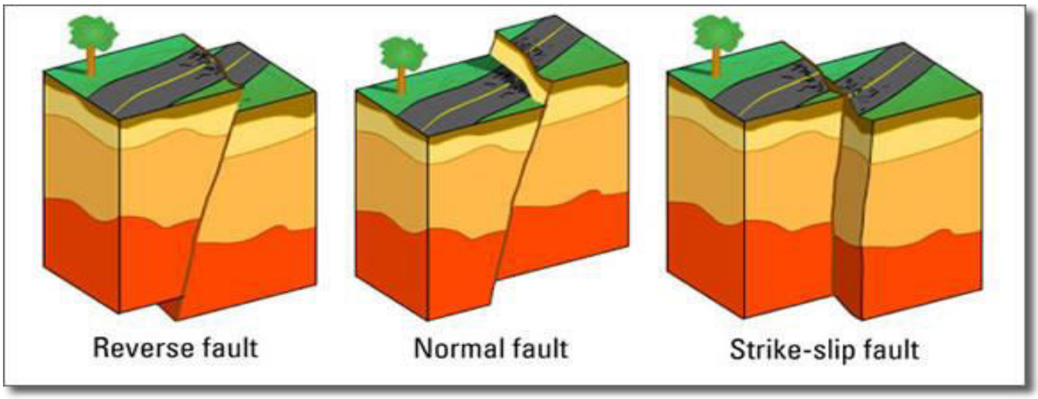


Figure 5.6: Fault and Plate Tectonics

Where do Earthquakes occur?

Earthquakes occur at all times, all over the globe. However, about 90% of the energy is released along the plate boundaries. The world seismicity map (figure 5.7) clearly shows that the seismicity distribution is not random but follows a trend along the major plate boundary zones. One of the most prominent belts is the circum-pacific belt, also referred as the Ring of Fire, which is an area where a large number of earthquakes and volcanic eruptions occur along the border of the Pacific Ocean.

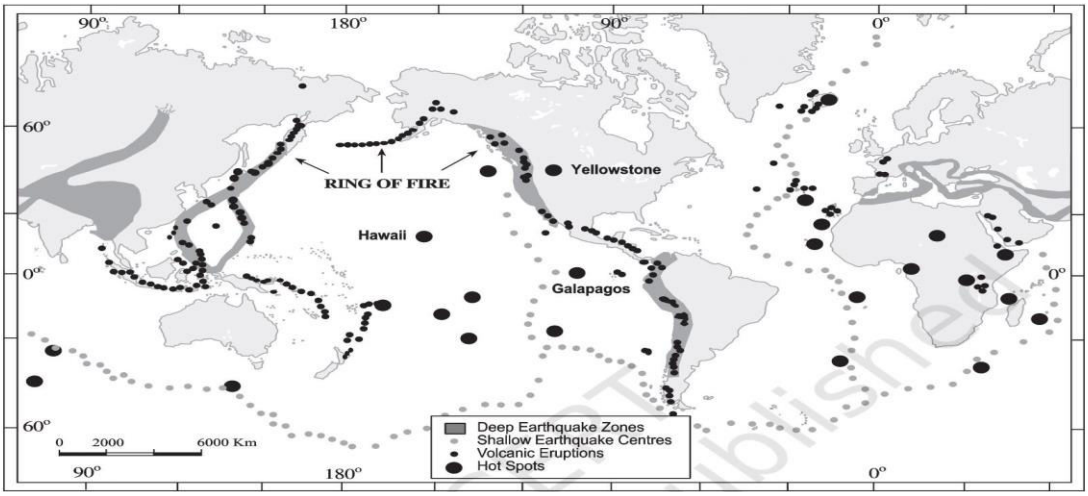


Figure 5.7: Seismicity and Earthquake

It is associated with a nearly continuous series of oceanic trenches and volcanic arcs. The next most seismically active region including 17% of the world's largest earthquakes is the Alpide belt, which extends from Java to Sumatra through the Himalayas, the Mediterranean, and out into the Atlantic. The Mid-Atlantic Ridge is the third most prominent earthquake belt.

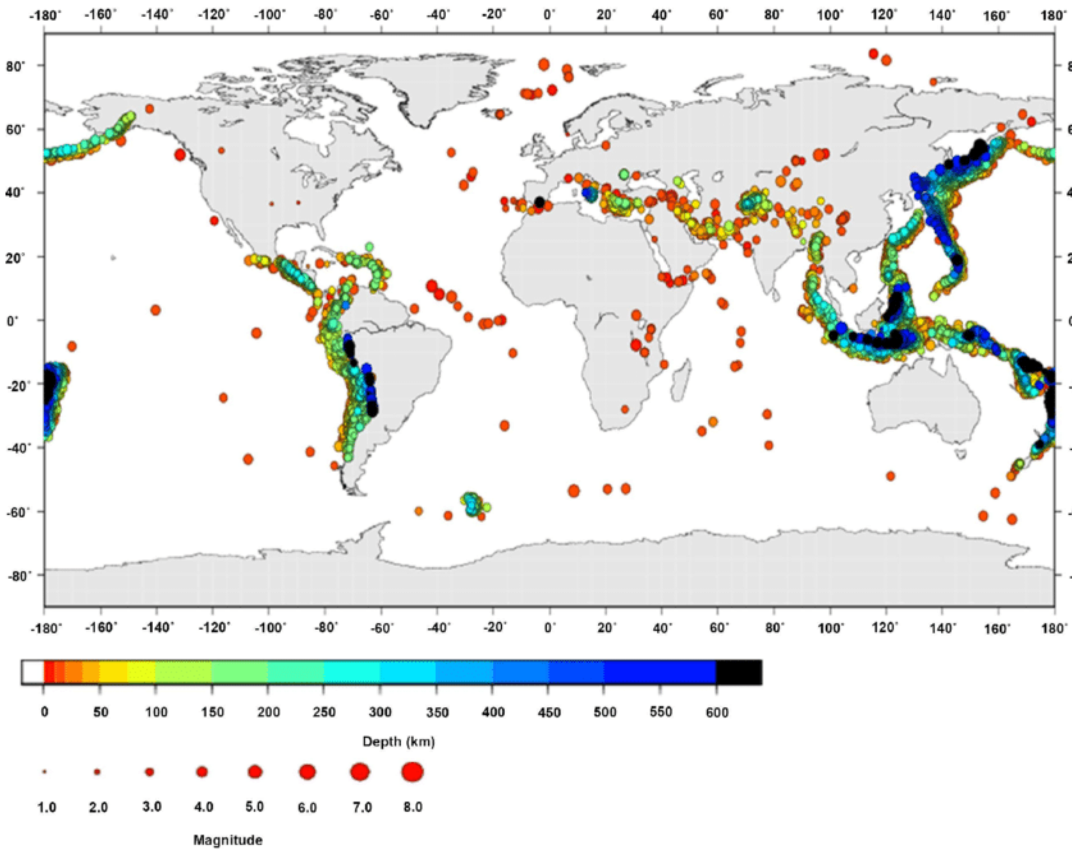


Figure 5.8: Earthquake Distribution and Hotspots

A second belt, known as the Alpide Belt, passes through the Mediterranean region eastward through Asia and joins the Circum-Pacific Belt in the East Indies. The energy released in earthquakes from this belt is about 15 percent of the world total. There also are striking connected belts of seismic activity, mainly along oceanic ridges—including those in the Arctic Ocean, the Atlantic Ocean, and the western Indian Ocean—and along the rift valleys of East Africa. This global seismicity distribution is best understood in terms of its plate tectonic setting.

Natural forces: Earthquakes are caused by the sudden release of energy within some limited region of the rocks of the Earth. The energy can be released by elastic strain, gravity, chemical reactions, or even the motion of massive bodies. Of all these the release of elastic strain is the most important cause, because this form of energy is the only kind that can be stored in sufficient quantity in the Earth to produce major disturbances. Earthquakes associated with this type of energy release are called tectonic earthquakes.

Tectonics: Tectonic earthquakes are explained by the so-called elastic rebound theory, formulated by the American geologist Harry Fielding Reid after the San Andreas Fault ruptured in 1906, generating the great San Francisco earthquake. According to the theory, a tectonic earthquake occurs when strains in rock masses have accumulated to a point where the resulting stresses exceed the strength of the rocks, and sudden fracturing results. The fractures propagate rapidly through the rock, usually tending in the same direction and sometimes extending many kilometres along a local zone of weakness. In 1906, for instance, the San Andreas Fault slipped along a plane 430 km (270 miles) long. Along this line the ground was displaced horizontally as much as 6 metres (20 feet).

As a fault rupture progresses along or up the fault, rock masses are flung in opposite directions and thus spring back to a position where there is less strain. At any one point this movement may take place not at once but rather in irregular steps; these sudden slowings and restartings give rise to the vibrations that propagate as seismic waves. Such irregular properties of fault rupture is now included in the modeling of earthquake sources, both physically and mathematically. Roughnesses along the fault are referred to as asperities, and places where the rupture slows or stops are said to be fault barriers. Fault rupture starts at the earthquake focus, a spot that in many cases is close to 5–15 km under the surface. The rupture propagates in one or both directions over the fault plane until stopped or slowed at a barrier. Sometimes, instead of being stopped at the barrier, the fault rupture recommences on the far side; at other times the stresses in the rocks break the barrier, and the rupture continues.

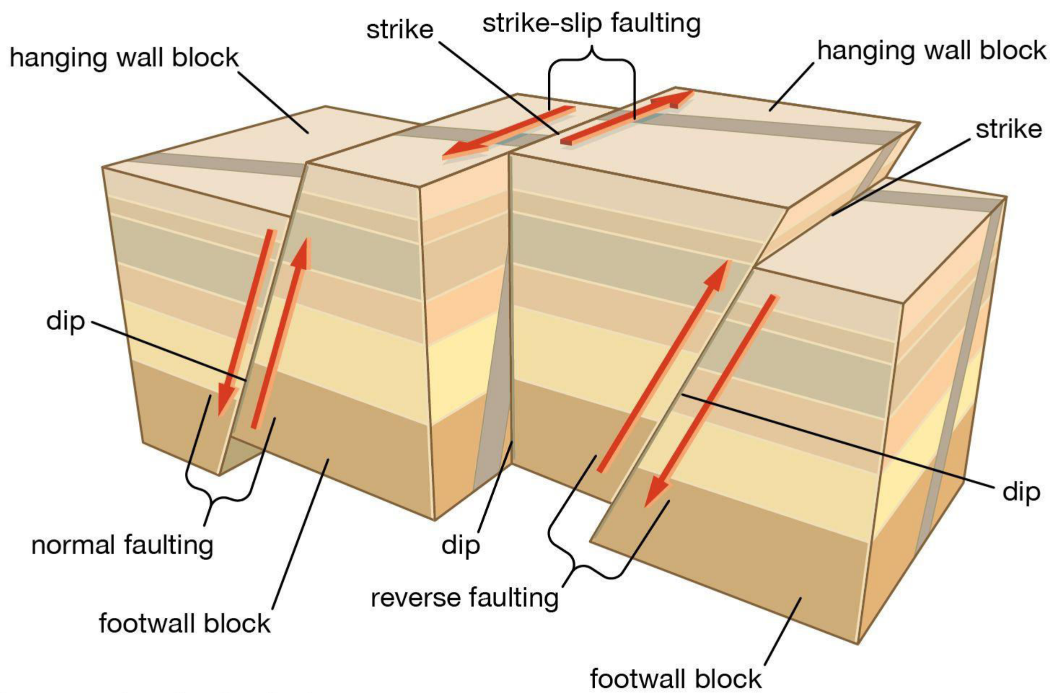


Figure 5.9: Movement in Earth Surface

Earthquakes have different properties depending on the type of fault slip that causes them (as shown in the figure). The usual fault model has a "strike" (that is, the direction from north taken by a horizontal line in the fault plane) and a "dip" (the angle from the horizontal shown by the steepest slope in the fault). The lower wall of an inclined fault is called the footwall. Lying over the footwall is the hanging wall. When rock masses slip past each other parallel to

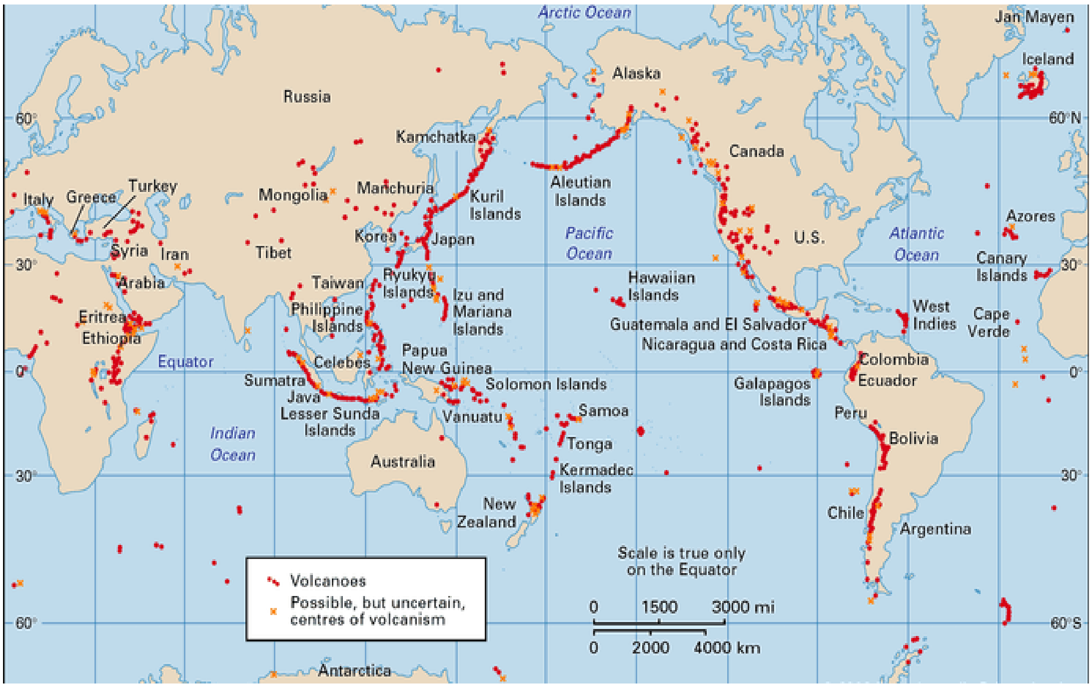


Figure 5.10: Volcanic Distribution in World

the strike, the movement is known as strike-slip faulting. Movement parallel to the dip is called dip-slip faulting. Strike-slip faults are right lateral or left lateral, depending on whether the block on the opposite side of the fault from an observer has moved to the right or left. In dip-slip faults, if the hanging-wall block moves downward relative to the footwall block, it is called "normal" faulting; the opposite motion, with the hanging wall moving upward relative to the footwall, produces reverse or thrust faulting. All known faults are assumed to have been the seat of one or more earthquakes in the past, though tectonic movements along faults are often slow, and most geologically ancient faults are now aseismic (that is, they no longer cause earthquakes). The actual faulting associated with an earthquake may be complex, and it is often not clear whether in a particular earthquake the total energy issue from a single fault plane.

Volcanism: A separate type of earthquake is associated with volcanic activity and is called a volcanic earthquake. Yet it is likely that even in such cases the disturbance is the result of a sudden slip of rock masses adjacent to the volcano and the consequent release of elastic strain energy. The stored energy, however, may in part be of hydrodynamic origin due to heat provided by magma moving in reservoirs beneath the volcano or to the release of gas under pressure. There is a clear correspondence between the geographic distribution of volcanoes and major earthquakes, particularly in the Circum-Pacific Belt and along oceanic ridges. Volcanic vents, however, are generally several hundred kilometres from the epicentres of most major shallow earthquakes, and many earthquake sources occur nowhere near active volcanoes. Even in cases where an earthquake's focus occurs directly below structures marked by volcanic vents, there is probably no immediate causal connection between the two activities; most likely both are the result of the same tectonic processes.

Artificial Induction: Earthquakes are sometimes caused by human activities, including the injection of fluids into deep wells, the detonation of large underground nuclear explosions, the excavation of mines, and the filling of large reservoirs. In the case of deep mining, the removal of rock produces changes in the strain around the tunnels. Slip on adjacent, preexisting faults or outward shattering of rock into the new cavities may occur. In fluid injection, the slip is thought to be induced by premature release of elastic strain, as in the case of tectonic earthquakes, after fault surfaces are lubricated by the liquid. Large underground nuclear explosions have been known to produce slip on already strained faults in the vicinity of the test devices.

Reservoir Induction: Of the various earthquake-causing activities cited above, the filling of large reservoirs is among the most important. More than 20 significant cases have been documented in which local seismicity has increased following the impounding of water behind high dams. Often, causality cannot be substantiated, because no data exists to allow comparison of earthquake occurrence before and after the reservoir was filled. Reservoir-induction effects are most marked for reservoirs exceeding 100 metres (330 feet) in depth and 1 cubic km (0.24 cubic mile) in volume. Three sites where such connections have very probably occurred are the Hoover Dam in the United States, the Aswan High Dam in Egypt, and the Kariba Dam on the border between Zimbabwe and Zambia. The most generally accepted explanation for earthquake occurrence in such cases assumes that rocks near the reservoir are already strained from regional tectonic forces to a point where nearby faults are almost ready to slip. Water in the reservoir adds a pressure perturbation that triggers the fault rupture. The pressure effect is perhaps enhanced by the fact that the rocks along the fault have lower strength because of increased water-pore pressure. These factors notwithstanding, the filling of most large reservoirs has not produced earthquakes large enough to be a hazard. The specific seismic source mechanisms associated with reservoir induction have been established in a few cases. For the main shock at the Koyna Dam and Reservoir in India (1967), the evidence favours strike-slip faulting motion. At both the Kremasta Dam in Greece (1965) and the Kariba Dam in Zimbabwe-Zambia (1961), the generating mechanism was dip-slip on normal faults. By contrast, thrust mechanisms have been determined for sources of earthquakes at the lake behind Nurek Dam in Tajikistan. More than 1,800 earthquakes occurred during the first nine years after water was impounded in this 317-metre-deep reservoir in 1972, a rate amounting to four times the average number of shocks in the region prior to filling.

Seismology and Nuclear Explosion: In 1958 representatives from several countries, including the United States and the Soviet Union, met to discuss the technical basis for a nuclear test-ban treaty. Among the matters considered was the feasibility of developing effective means with which to detect underground nuclear explosions and to distinguish them seismically from earthquakes. After that conference, much special research was directed to seismology, leading to major advances in seismic signal detection and analysis. Recent seismological work on treaty verification has involved using high-resolution seismographs in a worldwide network, estimating the yield of explosions, studying wave attenuation in the Earth, determining wave amplitude and frequency spectra discriminants, and applying seismic arrays. The findings of such research have shown that underground nuclear explosions, compared with natural earthquakes, usually generate seismic waves through the body of the Earth that are of much larger amplitude than the surface waves. This telltale difference along with other types of seismic evidence suggest that an international monitoring network of 270 seismographic stations could detect and locate all seismic events over the globe of magnitude 4 and above (corresponding to an explosive yield of about 100 tons of TNT).

Effects of Earthquake: Sudden changes on or near the earth's surface result from earthquakes and may include:

Ground Shaking: Rapid horizontal movements associated with earthquakes may shift homes off their foundations and cause tall buildings to collapse or "pancake" as floors collapse down onto one another. Shaking is exaggerated in areas where the underlying sediment is weak or saturated with water.

Fault Rupture and Uplift: Break of the ground surface by the fault plane may form a step in the surface known as a fault scarp. Large sections of Earth's surface may change elevation as a result of uplift on an earthquake fault. Mountain's east of Los Angeles was uplifted 0.3 meters (1 foot) by the 1994 Northridge earthquake.

Liquefaction: Liquefaction occurs when water-saturated sediment is reorganized because of violent shaking. The sediment collapses, expelling the water, and causing the ground surface to subside. **Landslides:** Earthquakes are often associated with mountains formed along convergent plate boundaries. The steep slopes present in these environments are prone to landslides when shaken. Landslides are common following earthquakes in California.

Tsunamis: Giant Sea waves are generated by submarine earthquakes, especially noted from the Pacific Ocean. Tsunamis caused by earthquakes around the ocean's perimeter may travel thousands of miles to destroy coastal property in Hawaii. Tsunami waves may reach heights of 15 meters (50 feet) near shore and travel at speeds up to 960 km/hr (600 mph). Many casualties associated with the 1964 Alaska earthquake resulted from tsunamis.

Magnitude and Intensity of Earthquake?

Magnitude is a measure of the size of an earthquake while the damage effect of an earthquake at various places around the epicenter is termed as Intensity. The Magnitude is a quantitative measure of the amount of energy released at the hypocenter during an earthquake. Hence, for a given earthquake the magnitude value is fixed whereas the intensity values vary from place to place, usually decreasing as we move away from the epicenter. There are different types of magnitude scales, but the standard one which has been most widely used is the Richter Scale or the Local Magnitude (ML), which was proposed by Charles Richter in 1934. There are other types of magnitude scales like Body wave magnitude (mb) which uses the amplitude of the initial P wave. However, this magnitude scale saturates at higher values beyond 6 to 6.5, which means it tends to remain same even for larger earthquakes. Hence, another scale called the Surface wave magnitude (Ms) was defined in 1950 based on amplitude of the Rayleigh wave. Modern Seismology uses a better scale called the Moment Magnitude (Mw), which is based on analysis of digital waveform data using the Seismic Moment. The earthquake magnitude is on a logarithmic scale to base 10, and is expressed as a relative amplitude of the seismic wave with respect to a smaller reference amplitude value. Hence, magnitude is simply a ratio, and is given as a number without units. The size of the earthquake does not increase linearly with magnitude. For instance, an earthquake of magnitude 6 has 10 times the amplitude of ground shaking compared to that of magnitude 5. The energy release of the former is however, 31.6 times more than the latter. The average rate of occurrence of earthquakes globally, is given below.

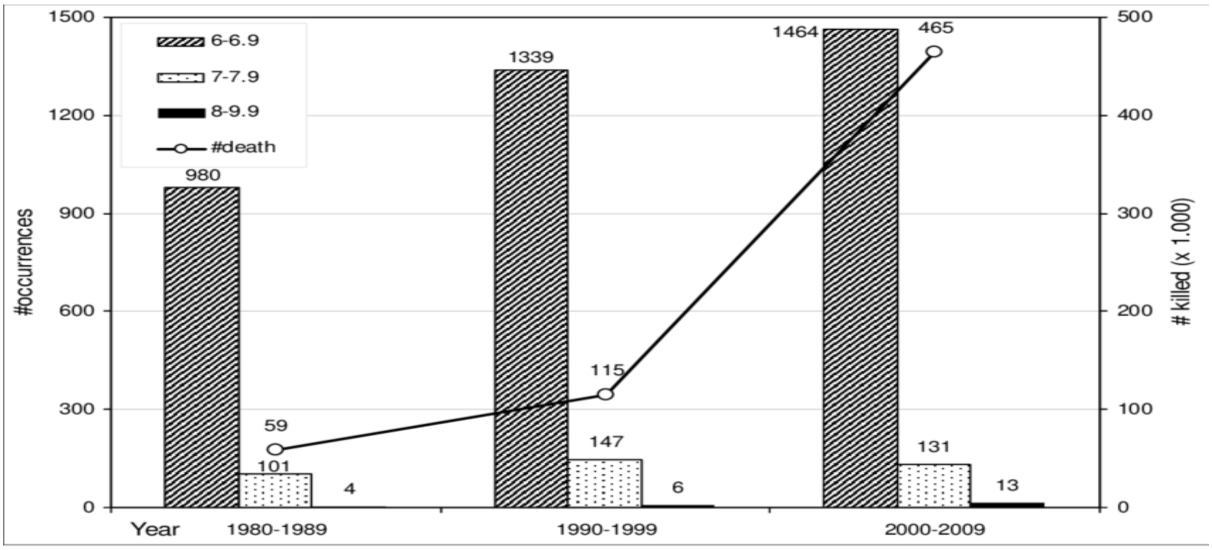


Figure 5.11: Frequency and Occurrence of Earthquake

Descriptor	Magnitude	Average Annually
Great	8 and higher	1 [1]
Major	7 - 7.9	17 [2]
Strong	6 - 6.9	134 [2]
Moderate	5 - 5.9	1319 [2]
Light	4 - 4.9	13,000 (estimated)
Minor	3 - 3.9	130,000 (estimated)
Very Minor	2 - 2.9	1,300,000 (estimated)
[1] Based on observations since 1900. [2] Based on observations since 1990.		

Table 5.1: Major Earthquake Disaster in World with their Impacts and Devastations

Year	Location	Death Toll	Injury	Damage	Structure
1985	Mexico City	9,500	30,000–100,000	3 – 4 billion US Dollar	412 buildings collapsed 3124 buildings damaged
1990 (M 7.8)	Philippians (Luzond Island)				190+ 54 buildings were affected
1995 (M 6.8)	Great Hanshin (City of Kobe)	6,000	35,000	US$61 – 70 billion	55,000 houses collapsed, 32,000 houses damaged in Kobe, 500,000 persons lost their houses
1999	Taiwan (Chi-Chi)	2,415	1441	US$9.2 billion	41,336 houses damaged
2001	India (Gujarat)	15,000 – 20,000		US$5.5 billion	50 multistory buildings collapsed
2004	Japan (Nigata-Chuetsu)	-	3,000	-	-
2004 (M 9.1)	Indian Ocean (Indonesia, Sri Lamka, India and Thailand)	1,000,000	-	-	-
2009 (M 7.5)	Indonesia (Mentawi Islands)	1,000,000	-	-	-
2010 (M 7.0)	Haiti	230,000	300,000	-	1,000,000 people homeless, 250,000 residence + 30,000 commercial buildings collapsed

Source: Noji (2008): Earthquake Statistics http://neic.usgs.gov/neis/eqlists/eqstats.html

Can we predict earthquakes?

Earthquake forecasting and prediction is an active topic of geological research. Geoscientists are able to identify particular areas of risk and, if there is sufficient information, to make probabilistic forecasts about the likelihood of earthquakes happening in a specified area over a specified period. These forecasts are based on data gathered through global seismic monitoring networks, high density local monitoring in known risk areas, and geological field work, as well as from historical records. Forecasts are improved as our theoretical understanding of earthquakes grows, and geological models are tested against observation. Long-term forecasts (years to decades) are currently much more reliable than short to medium-term forecasts (days to months). It is not currently possible to make deterministic predictions of when and where earthquakes will happen. For this to be possible, it would be necessary to identify a 'diagnostic precursor' – a characteristic pattern of seismic activity or some other physical, chemical or biological change, which would indicate a high probability of an earthquake happening in a small window of space and time. So far, the search for diagnostic precursors has been unsuccessful. Most geoscientists do not believe that there is a realistic prospect of accurate prediction in the foreseeable future, and the principal focus of research is on improving the forecasting of earthquakes.

Why are earthquakes difficult to predict?

Most earthquakes result from the sudden release of stress in the earth's crust, which has built up gradually due to tectonic movement, usually along an existing geological fault. The crust's response to changing stress is not linear (that is, it is not directly proportional, making prediction of behaviour more difficult), and is dependent on the crust's complex and highly variable geology. As a result, it is very difficult to build accurate simulations which predict tectonic events. Laboratory experiments which attempt to reproduce these physical processes can add to our understanding, but cannot accurately reflect the complexities of real-world geological settings. A further difficulty is that earthquakes originate beneath the ground, often many kilometres down, so data gathering depends on remote observation techniques and measuring effects at the surface. Even measuring the prevailing stress in the crust is challenging, as it requires drilling several kilometres into the ground. Earthquakes tend to occur as sequences or clusters in close spatial and temporal proximity, but the pattern of these varies greatly. Large earthquakes are sometimes preceded by a series of smaller ones. However, a series of small seismic events does not always prefigure a large one – 'swarms' of small earthquakes are common. Patterns of small earthquakes therefore do not provide a diagnostic precursor. (Almost all big earthquakes are followed by smaller ones called aftershocks, and it may be possible to forecast these more accurately.) Some have suggested that other factors such as increased levels of radon, changes in the water table, variation in the electrical properties of rock or the behaviour of animals may be diagnostic precursors. These have been the subject of research over several decades, and none has been found to be a good indicator, as they can all occur without being followed by an earthquake.

GEOINFORMATICS AND EARTHQUAKE DISASTER

Emergency management professionals are responsible for assessing risks and hazards and identifying potential emergencies and disasters. Emergency operations personnel recommend appropriate prevention or mitigation strategies that can reduce the impact of potential emergencies. Large, complex emergencies such as earthquakes often affect multiple departments or multiple agencies and require data to be collected and assembled from a variety of locations quickly under adverse conditions. Part of the Emergency Operations Center (EOC) role is to understand the details of the emergency, order the required response resources, coordinate with adjoining agencies, and determine the immediate actions necessary to contain the incident. Emergency personnel use GIS to help manage the impact of earthquakes and other disasters by Assessing risk and hazard locations in relation to populations, property, and natural resources Integrating data and enabling understanding of the scope of an emergency to manage an incident Recommending preventive and mitigating solutions Determining how and where scarce resources should be assigned Prioritizing search and rescue tasks Identifying staging area locations, operational branches and divisions, and other important incident management needs Assessing short- and long-term recovery operations.

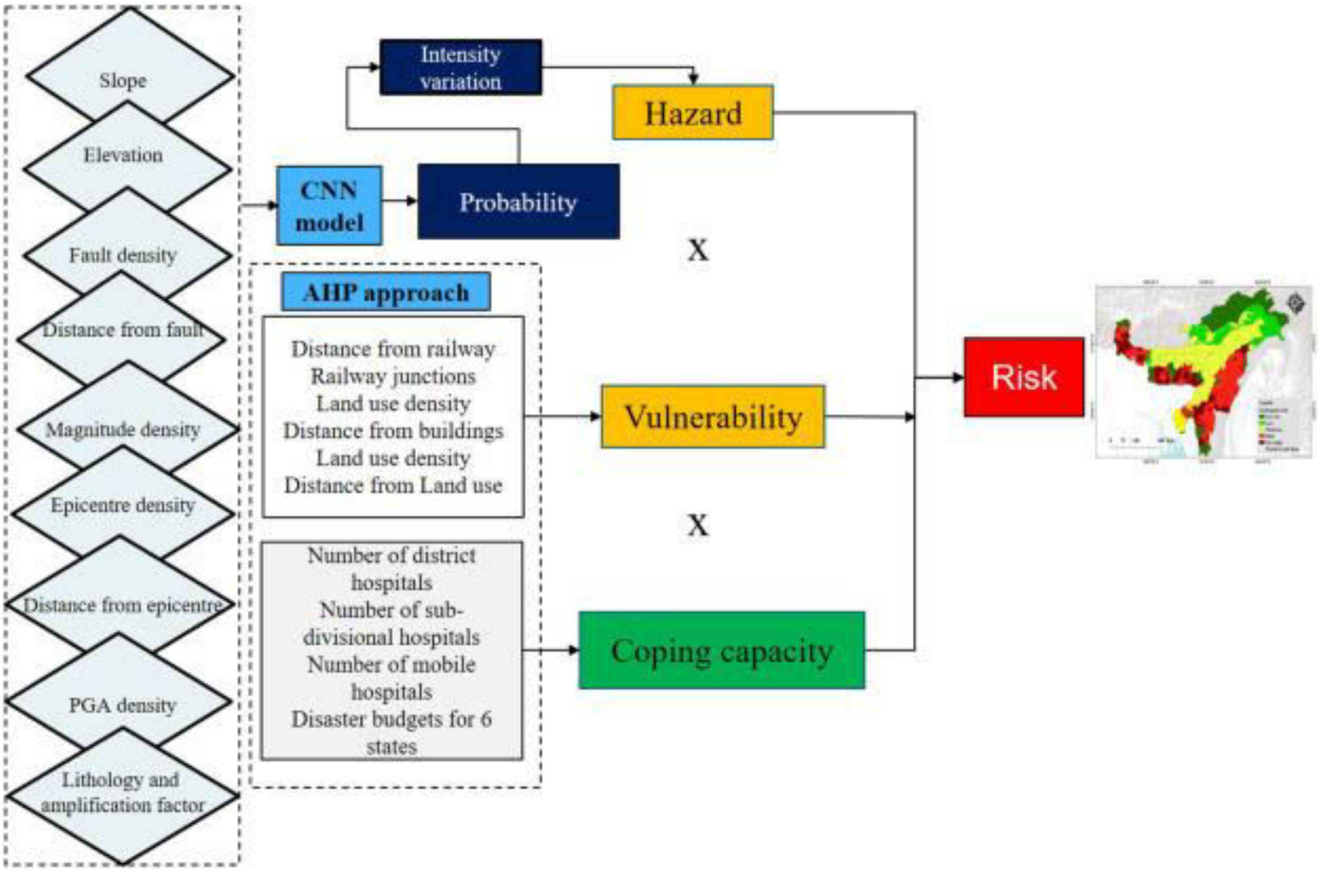


Figure 5.12: Earthquake Hazard Mapping and Assessment using GIS

Damage Assessment

This GIS portal project had great significance because it gathered various organizations from the national, local, educational, and private domains together and built a framework in which geographic information could be shared in real time to support disaster response activities. The establishment of the project initiated a foundation that would be carried on and utilized in future disaster events.

- The following summarizes the benefits of utilizing ArcPad for damage assessment: The results are calculated automatically and entered on-site, avoiding errors associated with manual data entry (miscalculation, etc.). Also, the assessment results are properly linked to the corresponding buildings. One of the biggest issues the team had to resolve in developing the database for damage certificates was the large number of mismatches that occurred between the results and building polygons. This problem arose mainly because a parcel with a single address would often contain multiple buildings (house, garage, warehouse, workshop, etc.), and it was difficult to identify the correct building for the assessment once the survey was completed. However, once the team began using the ArcPad PDA solution, it didn't have such problems because the results were entered into the correct polygon at the time of the assessment.
- A great number of investigators were out-of-town volunteers and not familiar with the city. Furthermore, they often had to go to places where there were neither street signs nor nameplates. However, the PDAs with GPS devices attached allowed ArcPad to automatically zoom in to the point so the investigators knew exactly where they were. Damage certificates are issued to victims of a disaster to officially acknowledge their losses. These certificates determine eligibility for receiving various kinds of relief measures, such as distribution of relief money, tax exemptions, and a reduction on their national health insurance premiums, so it was important to process the assessment results as quickly and correctly as possible. Early on, it was decided to digitize the assessment results from paper survey sheets into a database where the information could be managed and retrieved accurately and efficiently. Once the base datasets were prepared, the damage assessment results were linked to the building footprints of the Property Tax layer, and photographs of the damage were linked to the building polygons.

Figure 5.13: GIS Mapping with Hazard Intensity

The system meets the following goals: Develop the applications based on the specific needs of the damage so city personnel can perform their tasks effectively. Design a user interface that is as simple as possible so city personnel can access the necessary functions as quickly as possible (Arc-Objects was used for customization), since most city personnel had never used GIS before. Make the system as simple as possible. The team was given less than one week to develop the whole system, so it was particularly important to make the development work uncomplicated. It was also important to make the system straightforward and trouble free so the tasks could be carried out successfully. It was essential to develop the system on a server/client configuration so the same information could be shared among everyone, and any edits that were made could be reflected in real time (ArcEditor, ArcSDE, and Oracle9i were used to support this).

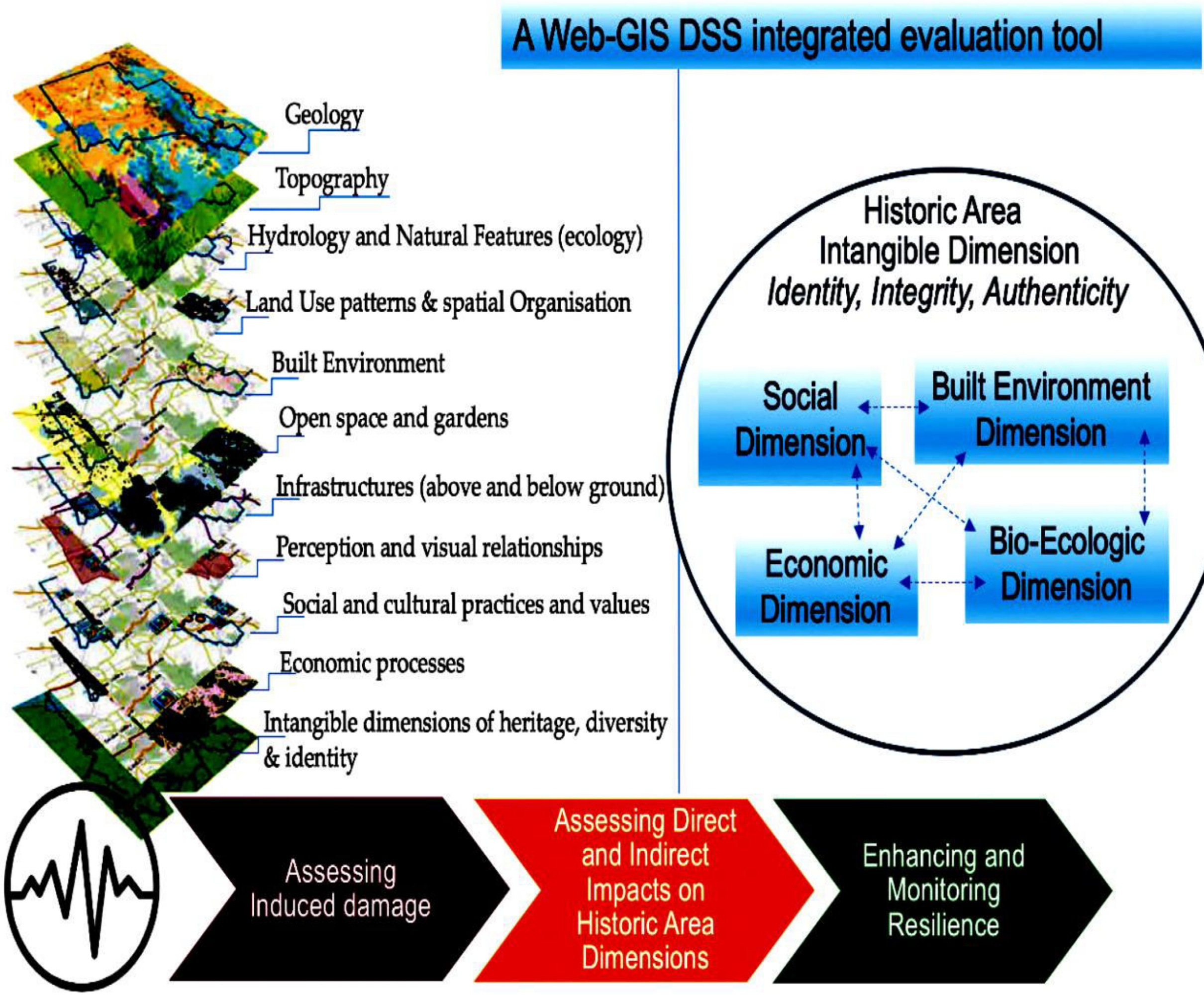


Figure 5.14: Geospatial Technology and Damage Assessment

Application to seismic ground motion evaluation

In the aseismic design and earthquake disaster prevention, the evaluation of the seismicity and the seismic ground motion is the most fundamental. In the evaluation of seismicity, the engineer should make the synthetic judgment based on the survey of various fault parameters of historical earthquake such as magnitude & hypocenter, and activity and histeresis of existing active fault. In the estimation of earthquake ground motion, the following items should be considered. These are

(1) the specification of earthquake considered in aseismic design and damage estimation.
(2) the level evaluation of the earthquake ground motion based on seismic risk analysis,
(3) the prediction of ground motion at bedrock,
(4) the grasp of soil amplification based on the earthquake response analysis of subsurface subsoil, and
(5) the evaluation of surface ground motion.

Since the existing knowledge and data on the ground motion evaluation are enormous, their appropriate synthesis contributes to accuracy improvement of estimated result. Here, GIS named 'QuSE' to evaluate earthquake ground motion is constructed, where the user can visually experience the fluctuation of the result due to the change of method and data. The user can select various parameters and evaluation techniques furnished in the system though the consultation of reference box, where the various information on seismic source data and knowledge on method applicability is provided. The system is composed of three subsystems as shown in figure 5.14, which are (1) the listing and evaluation of the active faults and historical earthquake which affect the site, (2) the deterministic evaluation of ground motion for the inland active fault and inter-plate earthquake, and (3) the stochastic evaluation of the seismic risk. This system also promotes the education of the expertise related to the evaluation of seismic ground motion through the use of the system.

Application to soil modeling

GIS named 'SMACS' to estimate dynamic soil model in Nagoya urban area is constructed, which conjugates maximally all the existing limited subsurface exploration data. As shown in fig. 5.6, the system estimates the soil velocity & density layering structure at arbitrary site and evaluates the soil amplification. Basic policies to make the dynamic soil model are as follows. (1) PS logging data is prior utilized. There exists about hundred data with average depth of 57m and average bedrock shear wave velocity of 400m/s. (2) When the data of standard penetration test exists near the site, shear wave velocity and density are estimated using the regression formula, which derived by us using N value, depth, geological age and soil classification. In the city, there exists 4,200 data with average depth of 25m, which covers 20% of city area as 125m mesh data. (3) In the area lacking for sufficient boring data, the depth of each stratum at arbitrary point is estimated by interpolating depth contour line for each geological age. The shear wave velocity and density are estimated from the regression formula based on geological age and depth. (4) The deep soil structure is modeled by interpolating shear wave contour line of the same velocity, which is estimated based on the seismic refraction survey, gravity prospecting and deep well survey. (5) Using above estimated shear wave velocity and density, the soil amplification is calculated by one dimensional wave propagation analysis. (6) At the place where lacks for soil data, the soil amplification is estimated based on the regression formula using the digital national land information.

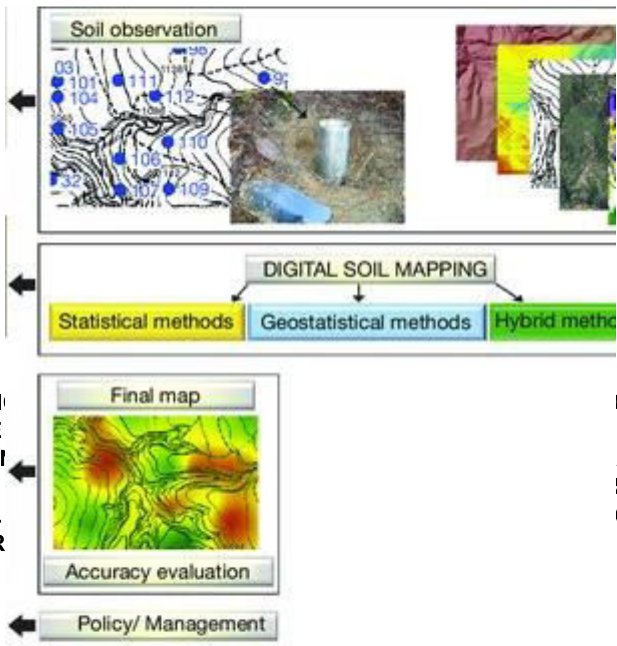


Figure 5.15: Soil Mapping and Monitoring using GIS

Application to seismic damage estimation

GIS named 'SDES' to estimate building damage for arbitrary earthquake can be constructed by combining the above GIS's 'SMACS' and 'QuSE' with the building information of urban area and the vulnerability function. Building number of each structural type and building age in each region is calculated on the basis of the taxation ledger. Then, the number of damaged building in each region is estimated using the vulnerability function for each structural type, building age and damage level which was derived from the analysis on damage and ground motion intensity in Kobe. Since the damage for arbitrary earthquake can be interactively grasped, it becomes possible to select the earthquake to be assumed, to specify the disaster weak region, and to investigate the cause of weakness. The system may offer effective information to make disaster prevention measure by adding human and social/economic point of view.

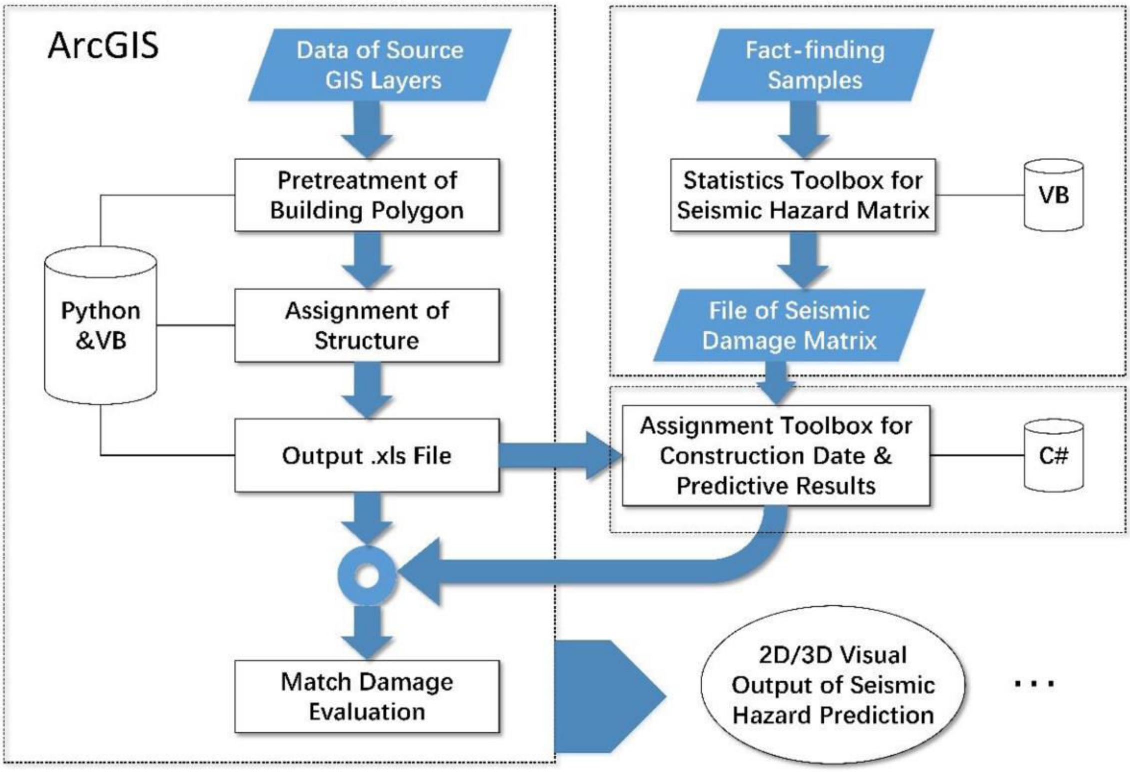


Figure 5.16: GIS and Seismic Hazards Estimation and Mapping

By installing 16 seismometers in 3 campuses of Nagoya Univ. and by combining this seismic observation system with the above GIS, the early damage estimation system named 'EMA' can be constructed. The features of this system are in integrating seismic observation network system and damage estimation system 'SDES' by use of Internet and engineering workstation (EWS). The basic idea is to connect the seismometers via Internet with LAN interfaces, which are note type personal computers mounted to the hard disk of EWS. By this, it is possible to transmit the strong-motion records into EWS immediately, and to combine them with the various databases and damage estimation system 'SDES' constructed on EWS. In the system, just after the quake, first the hypocenter and magnitude is automatically determined, then the ground motion is estimated using attenuation curves and pre-calculated soil amplification, and finally the building damage is predicted using building database and vulnerability curves. Since using the Internet and EWS, the data transfer is robust and high-speed. The extension of seismic network and the immediate offer of the strong-motion record and damage prediction result through the web are also technically easy to realize.

Urban Information System for Earthquake Resistant Cities

Current, accurate information assists decision makers in normal planning and monitoring tasks. For emergency planning and response, this type of dynamic information is even more important. The information gathered during the hours, days, months, and years following a disaster can lead to improved policies and practices that reduce risks and enhance the effectiveness of emergency planning, awareness, preparedness, and recovery. Earthquakes, one of the oldest enemies of mankind, can now be mapped and analyzed. GIS helps national, regional, and local emergency organizations plan and manage preparedness programs. Urban information systems, a subspecialty of GIS, are used to analyze the location of both populations and infrastructure. This article, describing an earthquake-preparedness study of a district in Istanbul, Turkey, illustrates how the effects of earthquakes can be minimized, emergency response planned, and an urban inventory created using GIS.

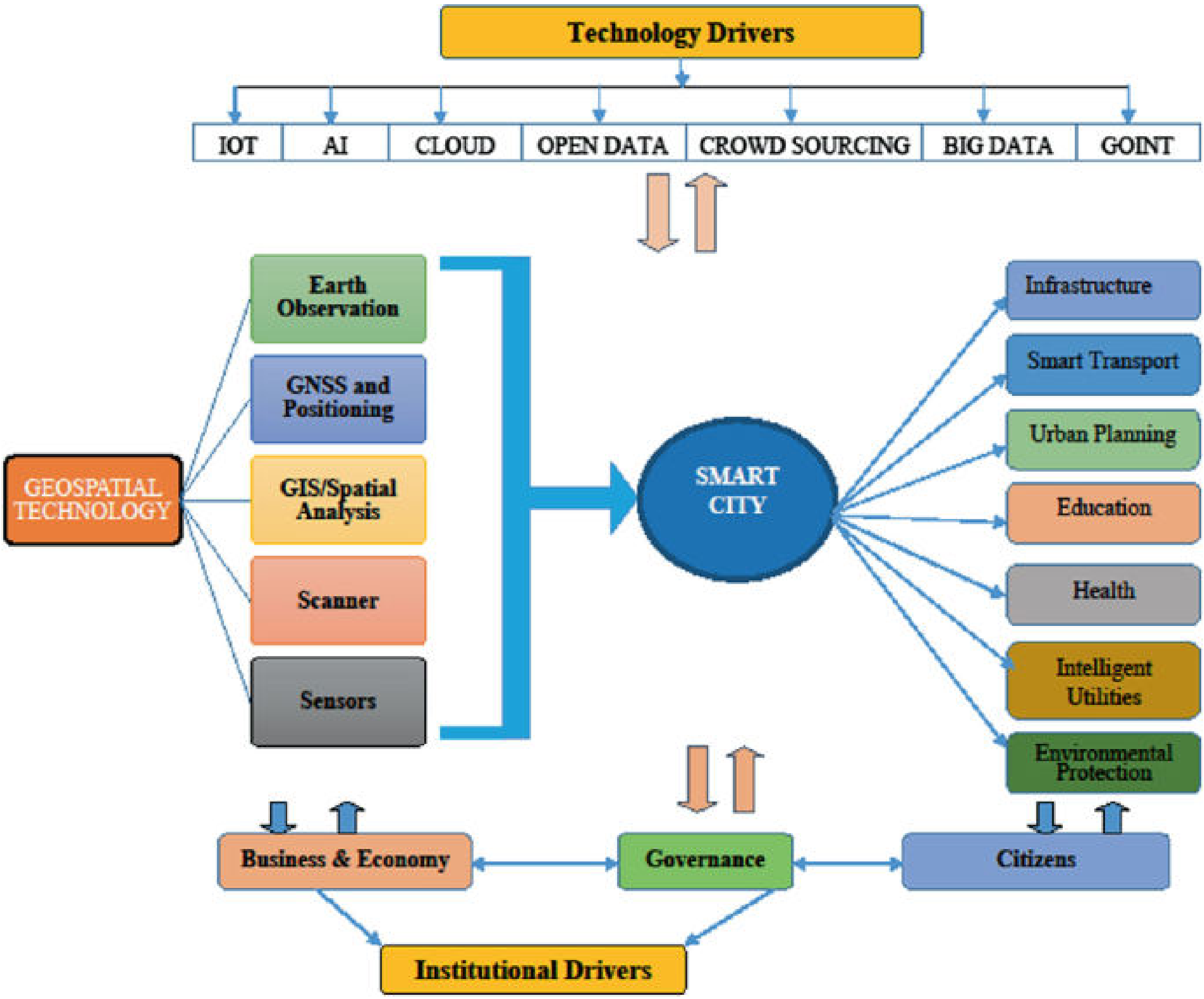
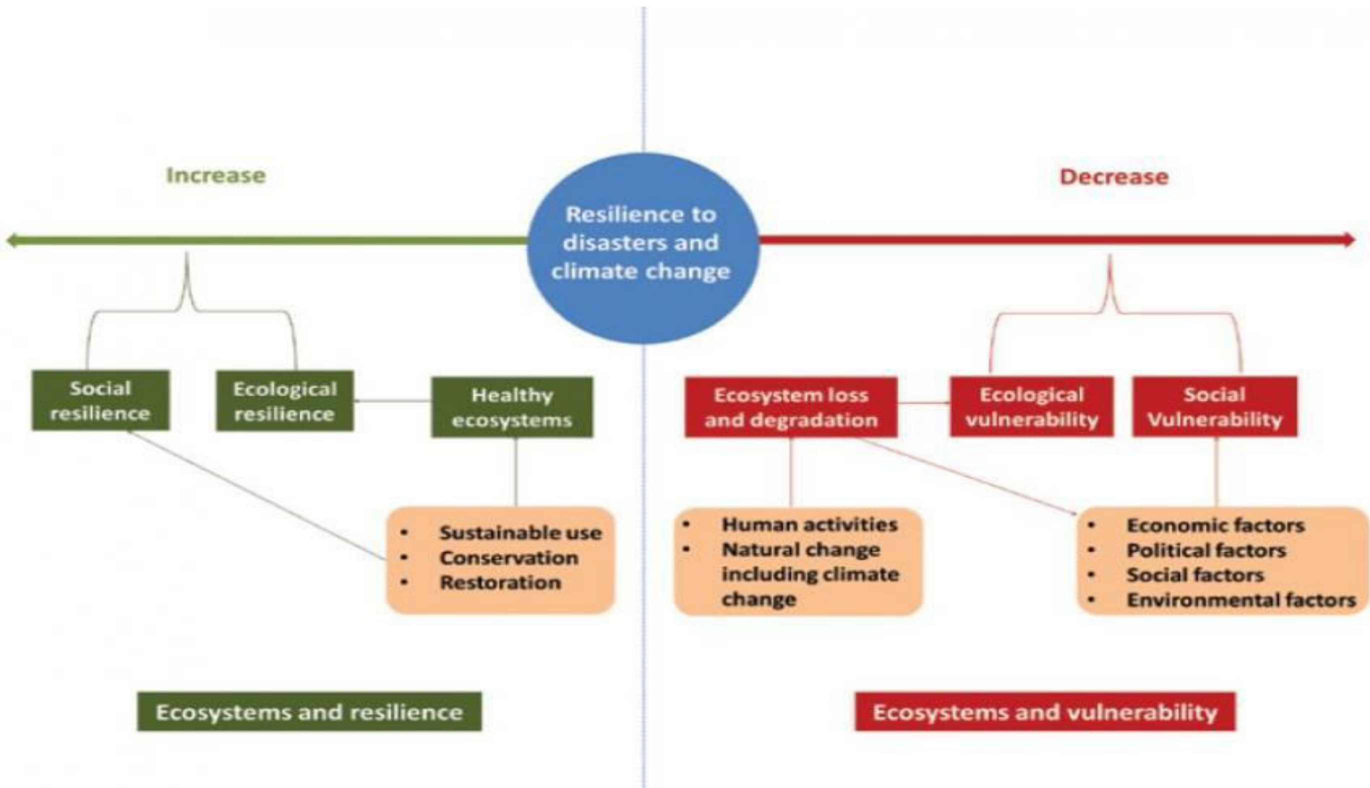


Figure 5.17: Smart Cities and Earthquake Management

GIS has proved a powerful tool for assessing the risk and prioritizing needs in Pendik. ArcView, versions 3.2 and 8.1, were used to produce detailed risk maps, perform queries, and generate analytical reports. After collecting the municipal data describing the district's land, residents, and infrastructure, digitizing and editing were done using ESRI products. After preparations were completed, thematic maps could be created for the Pendik Urban Inventory. Data for hospitals and health centers, schools, governmental buildings, police and fi re stations, industrial buildings, and gas stations was created as separate themes. Geological maps and infrastructure maps were produced. Chart maps produced in ArcView were used to make comparisons between neighborhoods and identify areas where earthquake preparedness could be improved. Mapping and spatial analysis have helped authorities make better decisions and formulate more effective policies for local emergency bureaus. Working with geographic data can answer questions such as "where is...?", "what intersects...?", and "what if...?" Analyzing the location of various structures in relation to hazardous conditions highlighted significant dangers. Querying the building theme to fi nd all buildings located on earthquake faults identified 255 such buildings. Many residential buildings and industrial plants are located on alluvial ground. [Loose soils amplify and prolong shaking.] Thirteen schools are located on unstable land. Potentially explosive natural gas main pipes and tanks as well as 56 companies that produce hazardous materials and 76 gas stations are located on unstable land. Several unauthorized buildings are located under high voltage power lines. GIS was also used for other emergency preparedness activities. Experience has shown that an earthquake's death toll can be multiplied by follow-on disasters such as tsunamis and fires. To predict the damage that might result from a tsunami, a buffer analysis was made along the coast initially using a 50-meter buffer and then creating additional 100-meter buffers farther inland. Service area analyses of hospitals and fi re stations identified routes that provided the quickest response. "What-if" scenarios were used to predict the effect of road and highway closures. Using ArcView Network Analyst, alternate routes were generated. ArcView 3D Analyst was used to extrude buildings for a three-dimensional view of the pilot study area. Buildings with more than five stories, buildings situated on alluvial land, and wooden and masonry buildings are most vulnerable to earthquakes.

Figure 5.18: Disaster Resilience Cities Management System

These structures were located by query and mapped. Buildings with mixed commercial and residential use (i.e., commercial facility on ground floor with many flats on the upper floors) are at greater risk for floor collapse and evacuation problems. Strategic databases, such as a pharmacy database for medical supplies, were created. Urban information systems help automate analysis, share information, and encourage teamwork. By visually displaying information, GIS enhances risk evaluation and performs analyses that would not otherwise be possible. Real-time information updates in GIS support better decision making and improve earthquake management. Creating an urban inventory, thematic maps, and queries also helped identify Pendik's most vulnerable areas. With SCEMD selecting earthquake size and epicenter location, the software provides results geographically on a map as well as in tabular



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lists and text descriptions. Results include estimates of

Number of buildings damaged

Number of casualties

Degree of damage to transportation

Disruption of power and water

Number of people displaced from homes

Cost to repair damage

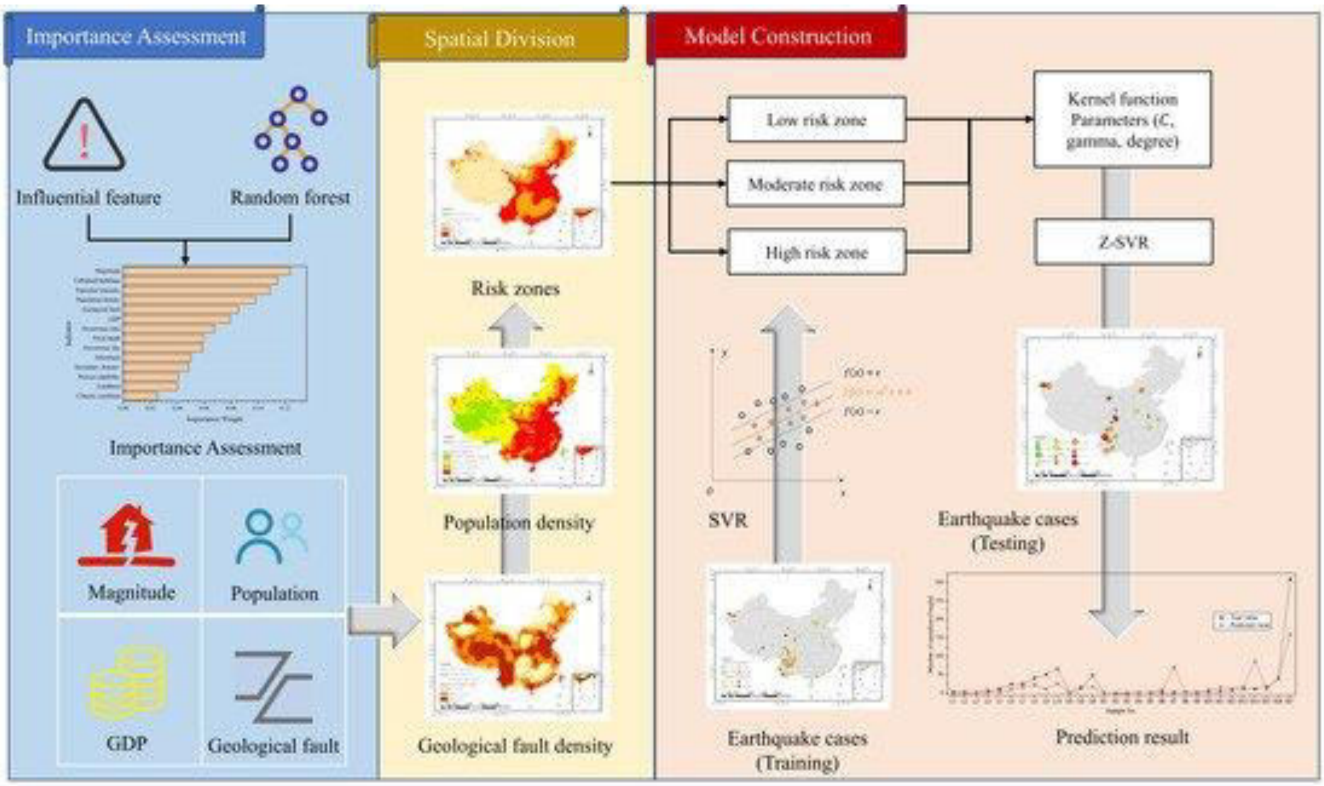


Figure 5.19: Earthquake Causality Prediction Modelling in GIS

Geoinformatics and Disaster Relief

Disasters in the form of earthquakes, fi res, floods, hurricanes, and tornadoes severely impact communities economically, financially, and socially. Most disasters are characterized by short reaction/response times, overwhelming devastation to infrastructure, and a strain on the tangible and intangible resources of the affected community. Decision makers at local, state, and federal levels are expected to quickly implement plans to restore order and mitigate the aftermath of the disaster. When properly trained, emergency planners and geospatial analysts can take advantage of GIS to aid in tasks such as establishing communications sites, restoring electrical power, and routing emergency supplies to critical facilities. However, in many cases specific datasets will not be available to accommodate every possible contingency that may arise in these operations. Based on inputs of recent data on area building uses, occupancy classes, and construction type, the analysts estimated 69,000 homes would be uninhabitable, 30 of 108 hospitals would be too damaged to operate, and more than 25 percent of schools and 34 percent of fire stations would be closed by damage. Unreinforced masonry buildings would be hit hardest. For geospatial analysts, the challenge is to quickly gather data and accurately fuse it together to support emergency planners. ArcGIS is a powerful mechanism available to emergency planners for collecting, storing, analyzing, and sharing the geospatial information needed by agencies to effectively support operations and restore disaster-affected communities in a relatively efficient manner. For emergency planners, GIS can facilitate critical decision making before a disaster strikes and in the crucial early stages of disaster relief operations. Geospatial products can provide important information such as locations of critical facilities (e.g., hospitals, water plants), transportation routes (e.g., major highways, harbor charts), and areas affected by follow-on events such as flooding. These products can be used in every stage of a disaster relief operation, but it is necessary to have an existing GIS, a well-trained analyst, and access to credible data sources.

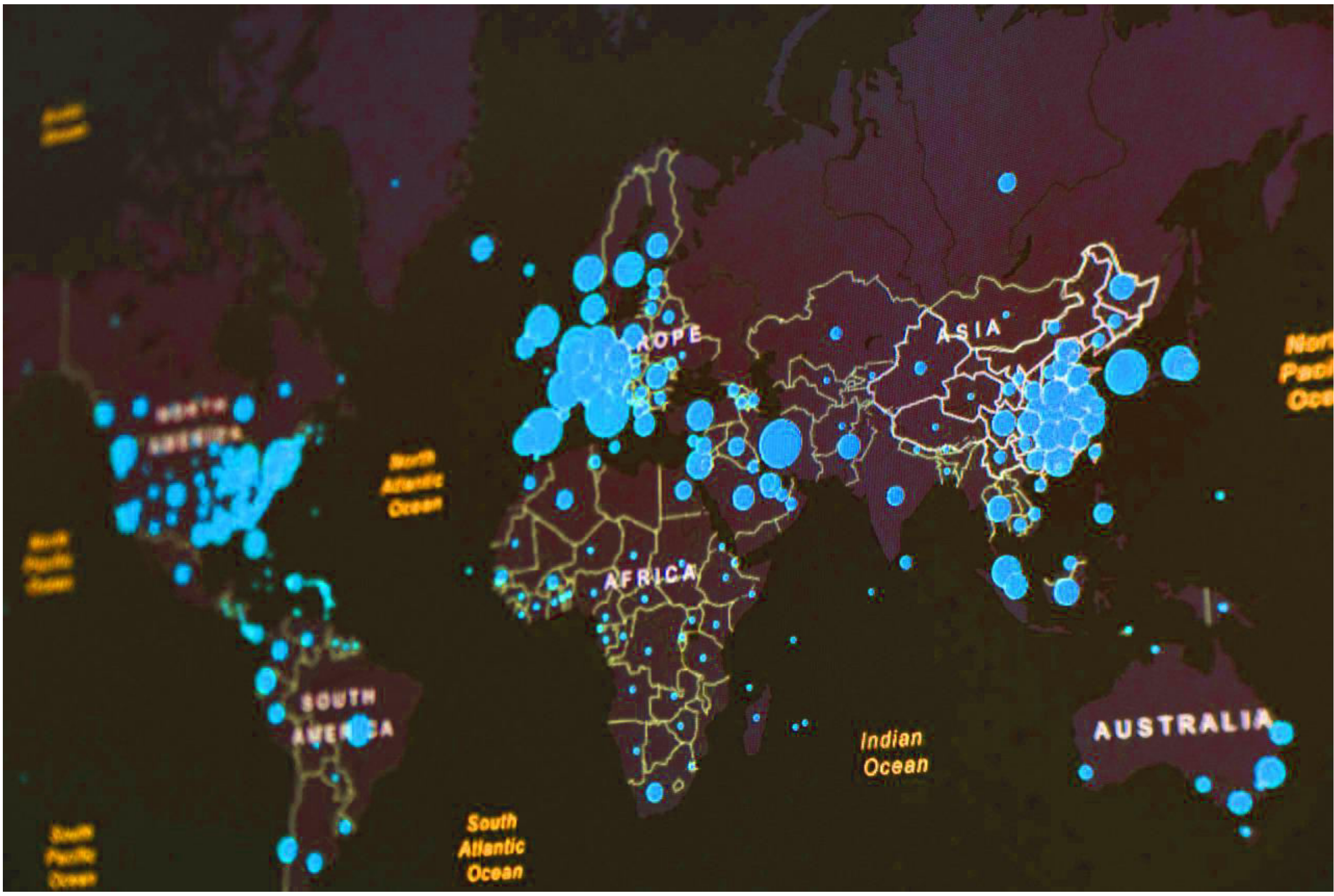


Figure 5.20: Real-Time Monitoring and Mapping using Geospatial Technology

Fusing geospatial products, such as remotely sensed imagery with a digital topographic map, can aid response to a tornado by helping determine tornado destruction paths and allocate debris-clearing resources. Vector data can be fused to this product for network analysis to determine the best route to haul generators from a staging area to power up critical facilities. In addition, this product can be fused later with elevation data derived from Light Detection and Ranging (LIDAR) to identify low-lying areas and create image-based flood maps for post-disaster insurance claims. Geospatial analysts trained for disaster relief operations can provide these types of products to emergency planners before (if possible), during, and after disasters have impacted an area.

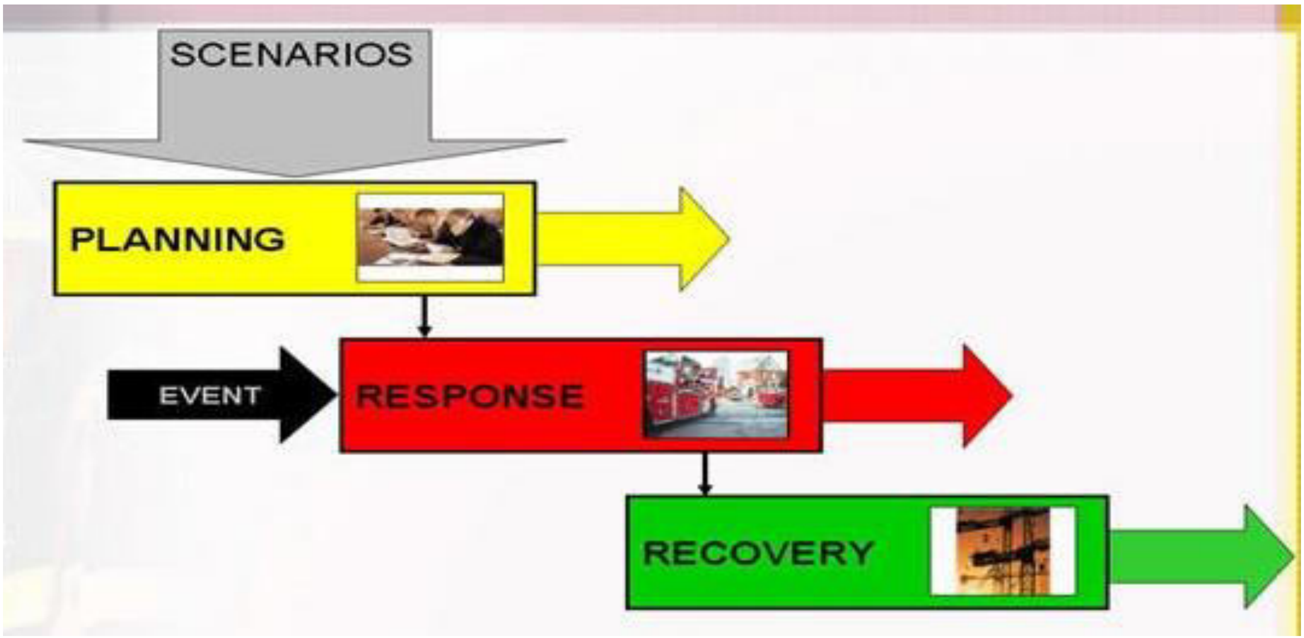


Figure 5.21: Disaster Emergency Planning

To be able to create products and formulate analysis, it is critical that geospatial analysts Have access to a GIS, preferably one using a powerful GIS software package with a full range of functionality such as ArcGIS. Understand data mining and what data will best support a particular disaster relief operation. Understand that data integrity includes data sources, data structure/format, and spatial and/or spectral accuracy. Understand the types of products that will need to be produced for decision makers during various stages of the disaster relief operation. The goal is to develop timely, accurate, and relevant geospatial information that can be easily interpreted by a plethora of end users for a wide range of disaster relief functions. Moreover, the geospatial information must be measurable quantitatively and qualitatively to assure the credibility and integrity of the products produced in support of the disaster relief effort.

Geospatial Modelling

Nationwide databases built into HAZUS-MH include data sets on demographics, building stock, essential facilities, transportation, utilities, and facilities with a high potential for loss. The FEBRUARY 2007 36 GIS FOR EARTHQUAKES software can estimate losses from earthquakes, hurricane winds, and floods. Updated hazard models supplement these new features: Earthquake Model—This model provides estimates of damage and loss to buildings, essential facilities, transportation and utility lifelines, and population based on scenario or probabilistic earthquakes. In addition to estimating direct damage, the new model addresses debris generation, fires, casualties, and shelter requirements.

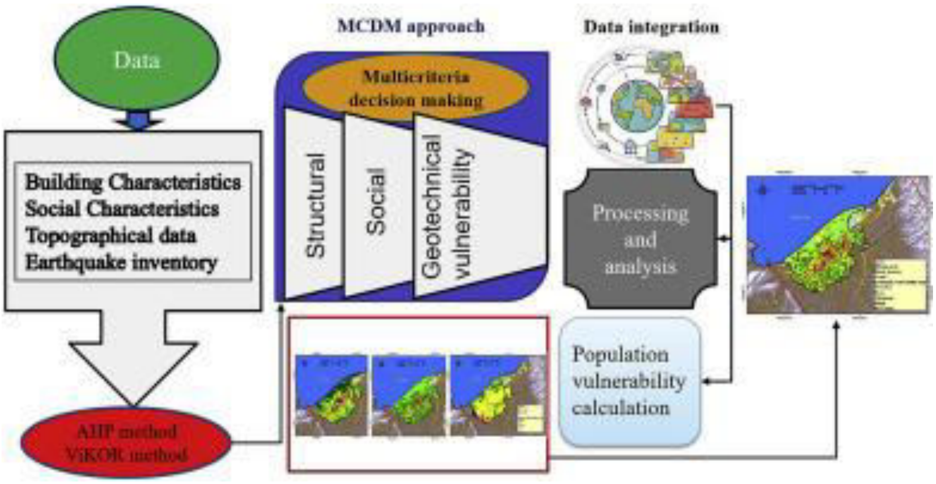
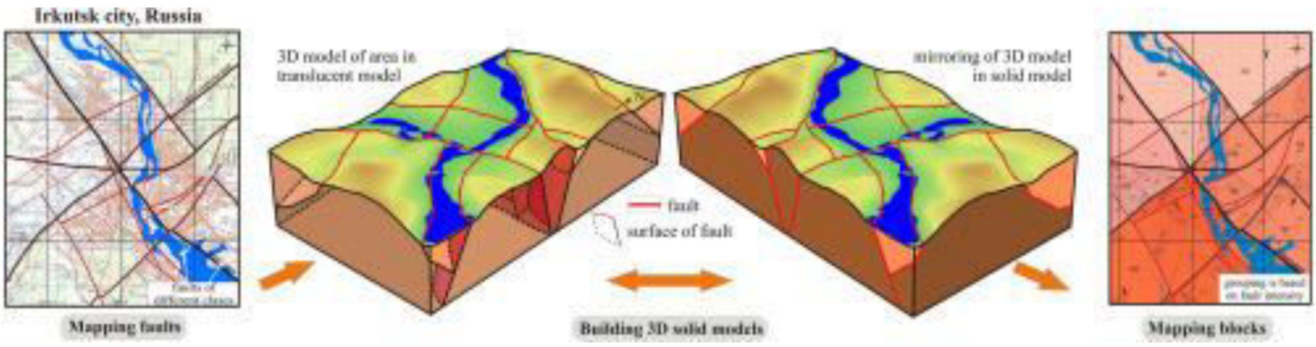


Figure 5.22: Earthquake Vulnerability Assessment by Integrated Modelling

Faults

Fault start from a single point, the slip movement along its whole length may be hundreds or thousands of kilometers. Seismic waves are generated at the initial break point. The energy is very high near the break point. Here it has greater potential for destruction. The Break point is called the earthquake focus. Epicenter is directly above the break point. Earthquake has different characteristics such as Surface faulting, Aftershocks, Tsunamis, Tremors, vibrations, Liquefaction, Landslides. It has different adverse effects e.g. Physical damage, Casualties, Public health, water supply.



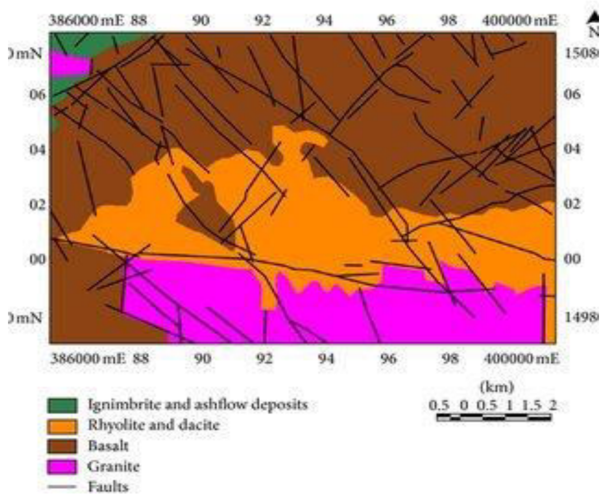


Figure 5.23: GIS Based analysis of Faults Pattern and Mapping

LANDSLIDE

Landslide is one of the natural disasters that involves the sudden movement of rock/soil mass. Natural conditions and human activities both play a vital role in causing landslides. It is a natural phenomenon but is triggered by a number of geological, atmospheric, and human-made factors. In India, landslide hazards occur every year in many regions in different states, particularly hilly areas, and pose challenges to the scientists, engineers, and planners. Landslides damaging the wealth of the country as well as human resources are one of the major obstacles for development in areas affected by these phenomena. A landslide occurs when stability conditions of the slope is disturbed either by the increase of stress imposed on the slope and / or by the decrease in strength of the earth material building up the slope and it involves mass downward movement of earth material under the influence of gravity. It is important to determine the causes of the landslides, as this will help in formulating effective remedial measures. Determination of causative factors of landslide in any given area will also help in demarcating the landslide prone zones.

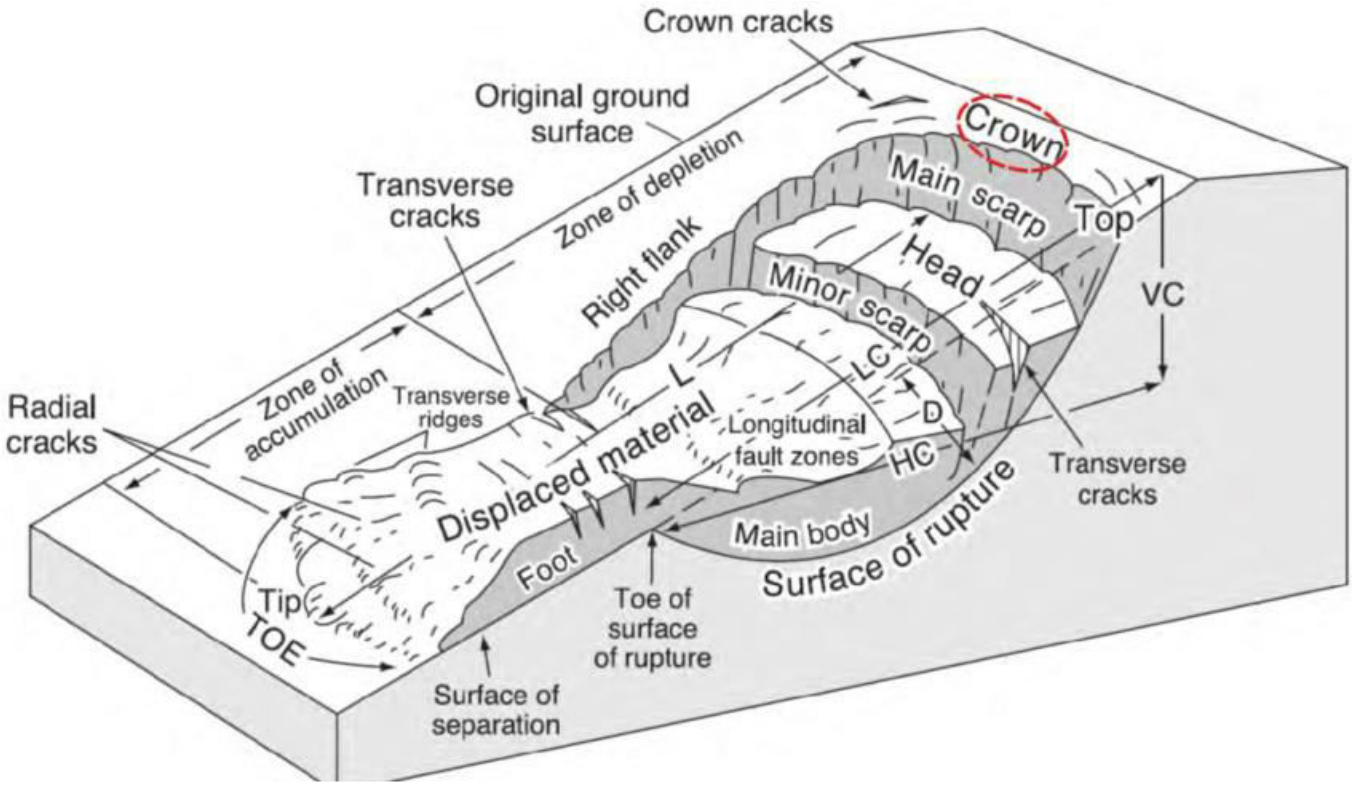


Figure 5.24: Landslide Process and Geomorphic Anatomy

CAUSES OF LANDSLIDES

Many of the landslides are natural phenomenon that occurs independently of any human actions. There are also landslides that have been induced by the very actions taken to make land suitable for some human purposes. Landslides can be triggered due to external causes or internal causes.

External Causes

1. Undercutting of the foot of the hill slope due to river erosion, quarrying, excavation for canals and roads, etc.
2. External loads such as buildings, reservoirs, highway traffic, stockpiles of rocks, accumulation of alluvium on slopes, etc.
3. Increase in unit weight of slope material due to increased water content.
4. Vibrations due to earthquakes, blasting, traffic, etc., causing increase in shearing stresses.
5. Authropic changes caused by deforestation.
6. Undermining caused by tunneling, collapse of underground caverns, seepage erosion, etc.

Internal Causes

1. Increase in pore water pressure.
2. Reduction in cohesive strength caused by progressive laterization.
3. Hair cracks due to alternate swelling and shrinkage from tension.
4. Presence of faults, joints, bedding planes, cleavage etc., and their orientation.
5. Freezing and thawing of rocks and soils.
6. Material properties such as compressive strength, shearing strength, etc., of earth material.

- **Effect of Increase in Water Content:** There is clear correlation between landslide activity and stroms, as the saturation of earth material increases the pore water pressure. The addition of water to clay-bearing materials decreases cohesion and the angle of internal friction as well, leading to a decrease in shear strength (resisting force) and decrease in weight (driving force). Recurring landsides usually occurs in the years of high rainfall. Studies have shown that single short periods of heavy rainfall can trigger small landslides such as soil slips and debrie flows, which affect only the near surface material. Deeper slides in unconsolidated materials will be triggered only by the cumulative effects of a series of storms. Bedrock slides appear to depend on the accumulation of precipitation over a long period of time during which precipitation consistently exceeds the average precipitation level for the region. A temporary rise in water pressure due to heavy rainfall in the material lying on the bedrock on a slope is sufficient to account for a decrease in strength, leading to debris slips and then debris flows.
- **Increase in Slope Gradient:** Steeper the slope, greater is the chances of its failure. An increase in the steepness or gradient, of a slope leads to an increase in shear stress on the potential rupture plane and to a decrease in normal stress. Such increase in slope gradient may be due to undermining of the foot of the slope by stream erosion or by excavation. Exceptionally, the change of slope gradient may be produced by subsidence and upliftment of the earth’s surface. When the slope is designed, a factor

of safety has to be computed and efforts are to be made to construct the slope in such a way as to maintain a factor of safety greater than 1.

- **Earthquake Vibrations:** Vibration due to earthquakes not only triggers devastating landslides but also rock falls and the like. Earthquake shocks, particularly those of shorter duration, acceleration of ground motion, tilt of the slope, modifies the system of forces in a manner that driving forces get the upper hand. The vibrations generated by the vehicular traffic create oscillation of different frequency in rocks and they change the stress pattern, reducing shear strength and inducing mass movement. Loosely deposited, fully saturated sand (void ratio larger than critical void ratio) may be compacted by seismic tremors (contractant deformation) so that the increased pore water pressure practically balances the effective stress and the soil liquefies, causing grave damages to the construction, pipelines, etc.
- **Excess Load on the Slope:** The addition of weight on the slopes like dumping of debris or wastes and the construction of dams, reservoirs, buildings, etc., increases the intensity of the driving force and reduces the slope stability.
- **Changes in Vegetation Cover**: Vegetation helps in retaining the soil cover firmly. Trees with strong and long roots increase the cohesive strength and effectively hold the formations in to relatively weaker foundations increasing thereby the tensile and cohesive strength. However, surface growths of bushy plants promote greater seepage, which may lead to increasing pore pressure. The degree of effectiveness of the vegetation depends upon the condition of the soil, thickness of the overburden, slope, type of vegetation and climate.

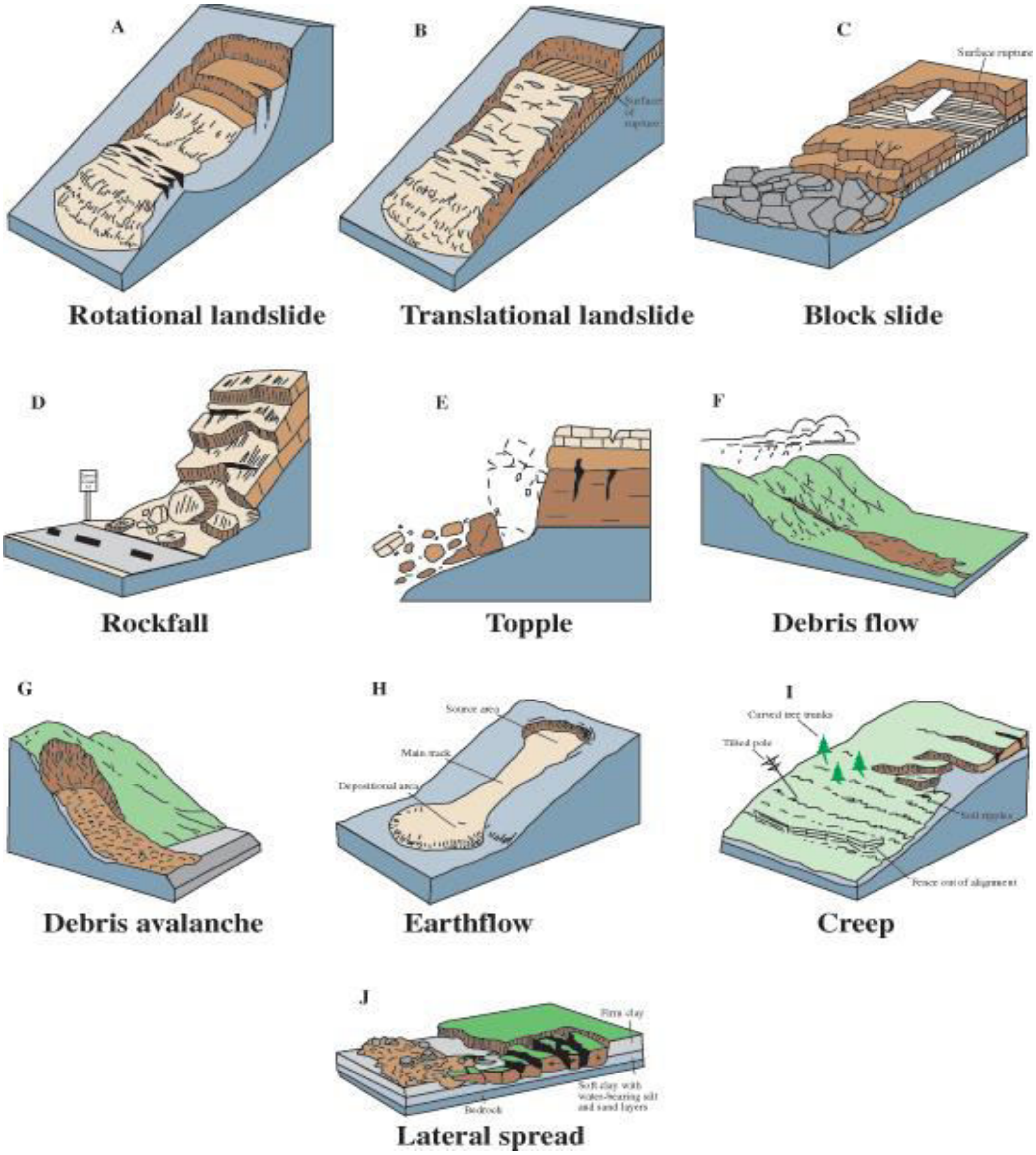


Figure 5.25: Types and Process of Landslide

TYPES OF LANDSLIDES AND SLOPE FAILURE

As a result, four main types of landslides (figure 5.25) can be described as follows:

1. **Earth Fall:** Occurs in steep or overhanging slopes from the detachment of soil along a surface on which little shear displacement takes place. This typically occurs where artificial cuts have been made and along eroded or undercut riverbanks.
2. **Earth Topple:** Occurs in vertical slopes with cohesive materials. Vertical joints or cracks develop behind the edge of the slope, resulting in a forward rotation of a compartment or column of soil. Field observations typically reveal mixed features associated to both fall and topple, making it difficult to clearly distinguish between the two types.

3. **Earth Slide:** Occurs in moderate to steep slopes and often consists of shallow weathered soil sliding onto a stronger or impermeable substrate (e.g. interbedded clay layers). Rotational slides (also referred to as slumps) involve sliding of the materials along a curved surface. Their occurrence is usually limited to an initial movement that evolves into compound slides or flows.

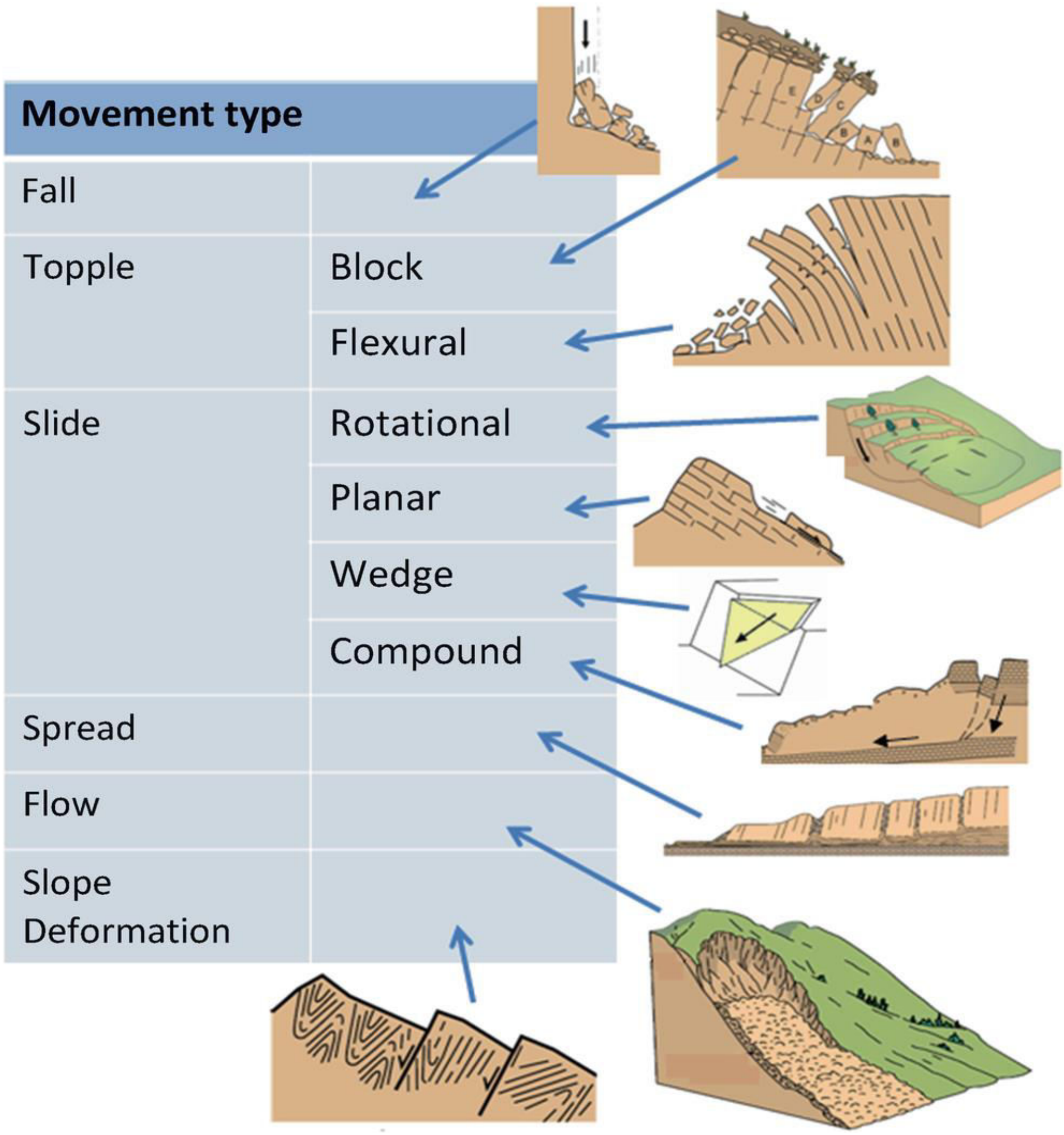


Figure 5.26: Landslide Movement and Material

4. **Earth Flow (or mudflow):** Occurs in moderate slopes during or after heavy rain events and involves excess pore pressure or liquefaction of the sliding materials. It forms characteristic bowl- or balloon-shaped scars on the hill flanks, with the mobilized material spreading out onto the valley floor and being subsequently rapidly washed Background Landslide Classification away, only leaving the main scar visible

over time. Earth flows often initiate as compound slides. Small-scale surface erosion may also be reported as landslides, though they occur mostly in artificial fills.

5. **Slump:** Type of slope failure in which a downward and outward rotational movement of rock or soil occurs along a curved concave up surface.
6. **Rock Fall:** Free falling of detached bodies of bedrock (boulders) from a cliff or steep slope.
7. **Rock Slide:** Sudden down slope movement of detached masses of bedrock is called a rockslide.
8. **Debris Fall:** Free falling is not only rock but also overlying sediments and vegetation is known as debris fall.
9. **Creep:** Imperceptibly slow down slope movement of earth cove or regolith. Utility poles, fence posts and gravestones etc. appear tilted or deformed on the surfaces were affected by creep.
10. **Debris Flow:** Down slope movement of collapsed, unconsolidated material typically along a stream channel.

IMPACTS OF LANDSLIDE

DIRECT IMPACT: Physical Damage- anything on top of or in the path of a landslide will suffer damage. Debris may block roads, supply lines (telecommunication, electricity, water, etc.) and waterways. Causalities- deaths and injuries to people and animals. Indirect loss of productivity of agricultural and forests land, reduced property values, erosion, flooding in downstream area, etc

INDIRECT IMPACT: The safety of a dam can be severely compromised by land sliding in the upstream area of the dam or on the slopes bordering the reservoir. Possible impacts include: Flood surges caused by movements of large masses of soil into the reservoir. The wave formed by those failures can overtop the dam causing downstream flooding and possibly failures to the dam. Increased sedimentation in the reservoir, resulting in loss of water storage and increased likelihood that the dam will be overtopped during periods of excessive runoff.

Landslides and Flooding: Landslides and flooding are closely associated because both are related to intense rainfall, runoff and ground saturation. Debris flow can cause flooding by blocking valleys and stream channels, forcing large amounts of water to backup. This causes backwater flooding in the upstream area and if the blockage gives away, quick downstream flooding too. In turn, flooding can cause landslides, due to rapidly moving floodwaters, which often undercut slopes or abutments. Once support is removed from the base of saturated slopes, land sliding often takes place.

Landslides and Seismic Activity: The occurrence of earthquake in steep landslide- prone areas greatly increases the likelihood of devastating mudflows and reactivation of mass movements on slopes. Large fills can become unstable due to moderate seismic activity if proper lateral support is not provided. Damage to electrical wires may also start fires.

LOSSES DUE TO LANDSLIDE

Landslides result in both direct and indirect losses in several ways.

Direct losses Loss of life

Landslides can result in death and injury of people and animals. The moving mass can bury people and animals under debris.

- **Loss of property and assets:** The force and speed of debris, mud or earth mass generated due to mass movement may destroy houses, buildings and other properties on its way.
- **Loss of infrastructure and lifeline facilities:** Earth mass can block or damage infrastructures such as roads, railway, bridges, telecommunication, electrical supply lines, etc. Loss of Resources Earth mass can affect water recourses in the area by blocking rivers, diverting water ways, blocking irrigation channels, reducing storage capacity of tanks, reservoirs, ponds, etc. it can cause production losses to open cast mines, rock quarries, etc.
- **Loss of farmland:** Productive land area may be covered with debris or blocked from access. Loss of places of cultural importance.

Indirect Losses of Life

- **Loss in productivity of agricultural or forest lands:** Due to being buried by debris, lack of access or being under flood. Reduced property values Due to unwillingness of people to purchase disaster prone land.
- **Loss of revenue:** Due to loss of productivity, transport breakdown, etc.
- **Increased cost:** Due to investments in preventing or mitigating future landslide damage.
- **Adverse effect on water quality:** Occur in water storage facilities such as streams, reservoirs, storage tanks etc.
- **Secondary physical effects:** Such as flooding which in turn generates both direct and indirect costs.
- **Loss of human productivity:** Due to death and injury.
- **Reduction in quality of life:** Due to the deaths of family members and the destruction of personal belongings, which may also have great sentimental value.
- **Impact on emotional wellbeing:** Any disaster can have a profound impact on people's emotional wellbeing affecting their feelings, thoughts, actions, and relationships. The sudden overwhelming disruption and danger to life and property can put tremendous psychological pressure on a person, often even affecting the ability to function at the time of the crisis. The impact a disaster can have on a person also depends on his/her past experiences of crises, how well he/she has been prepared for such events both physically and mentally and his/her attitude or level of resilience.

LANDSLIDE AND GEOSPATIAL TECHNOLOGY

Landslide susceptibility depends on the local terrain, land use, and climatic conditions, which require spatial information. A landslide susceptibility zone includes information of past landslide inventory with an evaluation of future landslide-prone areas, but it does not include assessment of the frequency of landslide occurrence. Also, the temporal probability of a landslide is not included in susceptibility models. High-quality landslide inventory maps can be developed using in situ measurements and field surveying. However, in situ measurements and field surveying are time consuming, expensive, and difficult for local to global scales. On the other hand, landslide susceptibility and inventory maps, as well as landslide hazard analysis, can be possible using remote sensing techniques and data, such as aerial surveys, unmanned aerial vehicles (UAV), light detection and ranging (LiDAR), and satellite imagery.

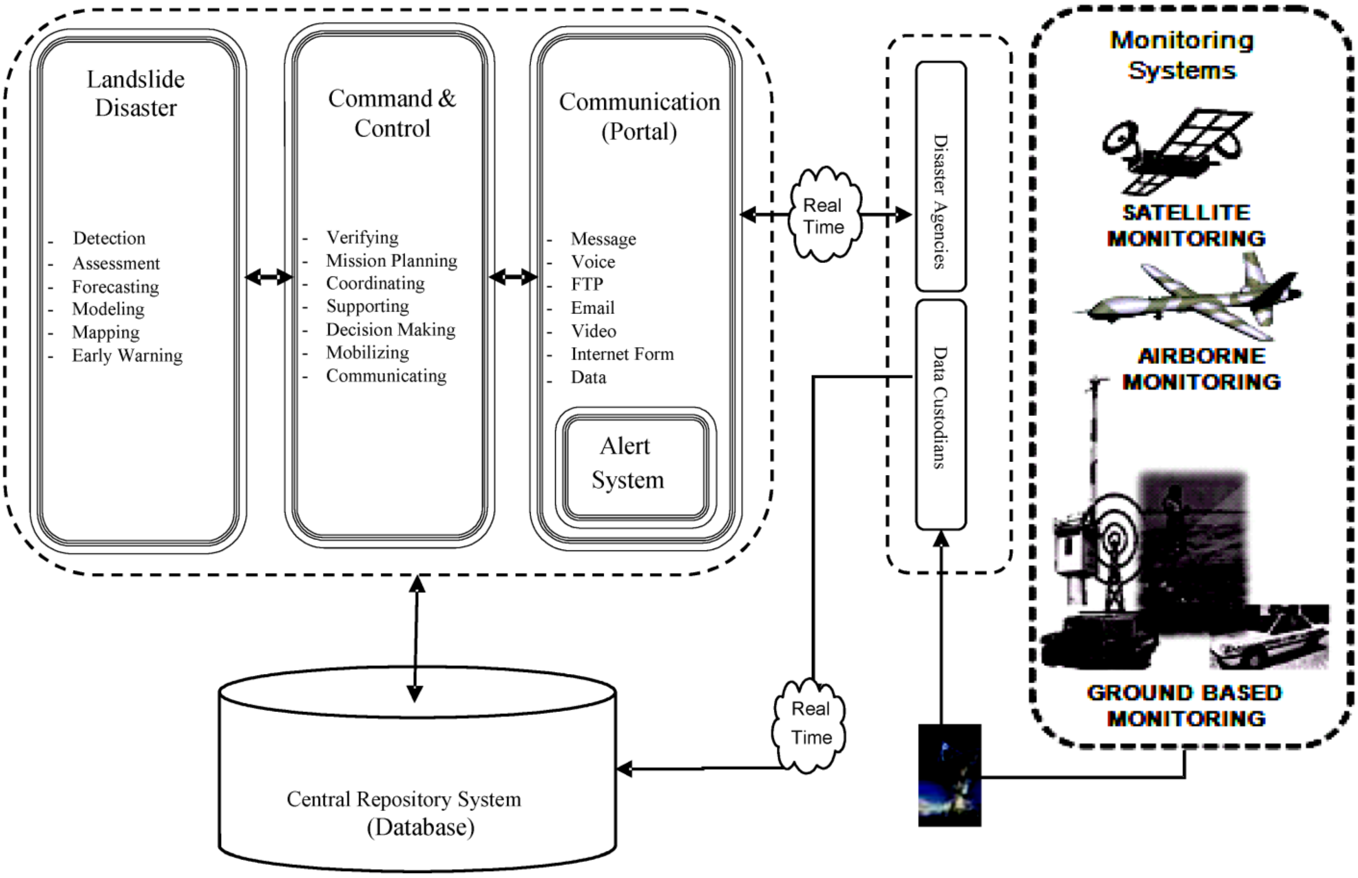


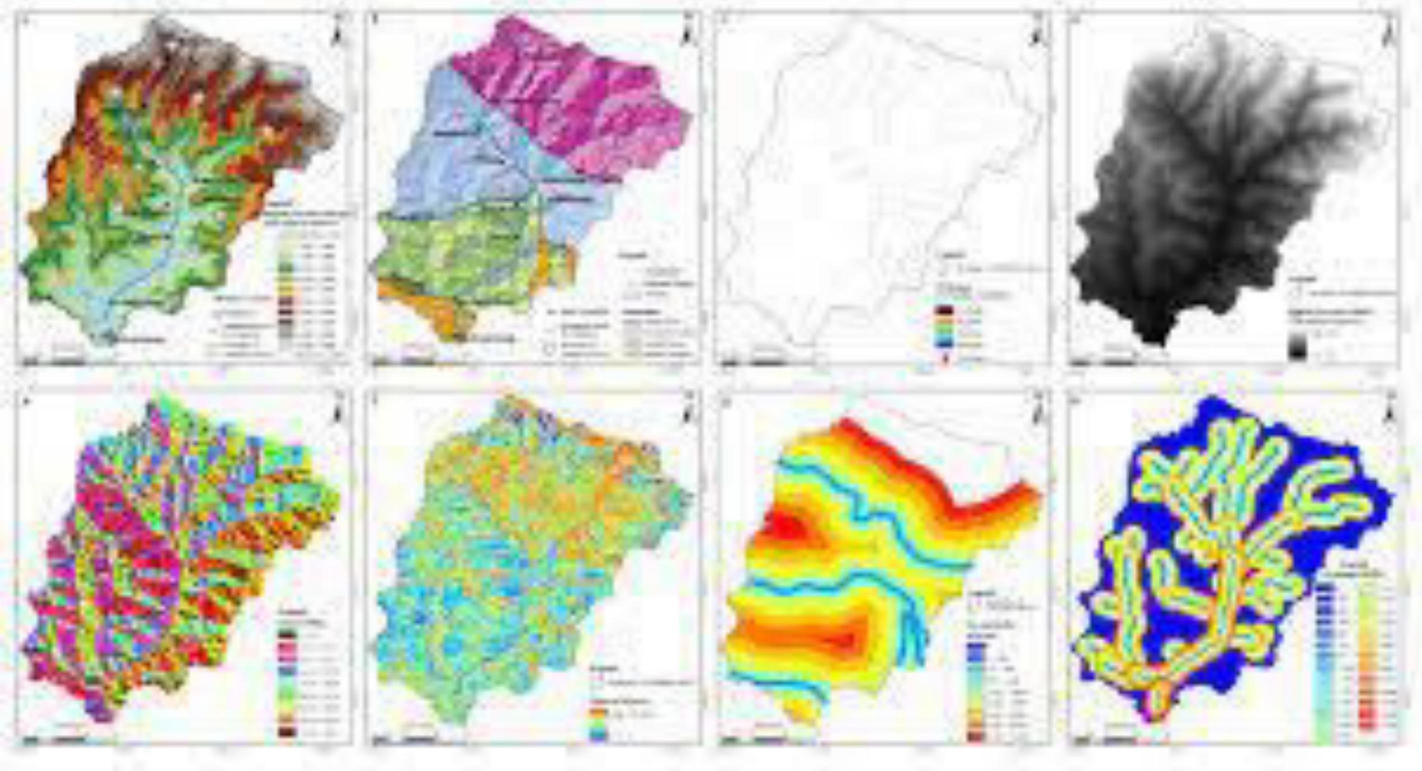
Figure 5.27: Landslide and Geospatial Technology

Although remote sensing is continuously used for landslide detection/mapping and monitoring, it is generally considered to have a medium effectiveness/reliability for landslide studies because satellite data are available relatively at coarse resolutions. On the other hand, hazard assessment requires high resolution data to define the spatial distribution of landslides and their state of activity both on a local scale and from studies from regional/global scales. In addition, remotely sensed data are cost-effective because most of the global satellite products are freely available and can cover rugged/complex terrains, which is otherwise not possible to assess with in situ measurements. Even in the late 1990s, stereoscopic air-photo interpretation was the most used remote sensing tool applied to the mapping and monitoring of landslides. Many studies have been carried out on landslide hazard evaluation using geographic information systems (GIS) and geoinformation-related techniques. Recently, GIS and remote sensing tools have become powerful tools for integrating spatial data to conduct landslide studies.

Remotely sensed data and techniques are widely used in landslide studies, including landslide inventory/detection, monitoring, and mapping, and hazard analysis. Timely and high-quality information derived from space-borne observations helps in managing natural and human-made disasters. Accordingly, landslide risk mapping and management can help reduce disaster risk. Similarly, early landslide predictions and warnings are important in curtailing landslide hazards. Landslide vulnerability assessment is used in identifying what elements are at risk and why; such information helps in landslide disaster mitigation measures.

The use of remote sensing data for landslide studies, whether air, satellite, or ground-based measurements, is mainly classified into three main categories: (a) detection and identification, (b) monitoring, and (c) spatial analysis and hazard prediction.

Figure 5.28: Geospatial Technology for Landslide Hazard Zonation and Prediction



LANDSLIDE HAZARD ZONATION

Landslides are complex natural phenomena that are hard to model and simulate. Predicting hazardous events like landslides are particularly difficult because no laboratory exists that can preliminarily measure important variables, refine the techniques, and apply the results. Mitigation of disasters on account of landslides can be successful only with detailed knowledge about the expected frequency, character and magnitude of mass movements in an area. For forecasting occurrence of landslides in near future in an area, comprehensive knowledge of causative factors of land sliding is necessary. Hence, the identification of landslide-prone regions is essential for carrying out quicker and safer mitigation programs, as well as future strategic planning for an area. Therefore, the Landslide Hazard Zonation (LHZ) of an area becomes significant whereby the area is classified into different LHZ ranging from very low hazard zone to very high hazard zone. Landslide susceptibility mapping is of great value for landslide hazard mitigation efforts. Landslide hazard analysis focuses mainly on the spatial zoning of the hazard (Beek and Asch, 2004). Remotely sensed data are used in solving various environmental tasks. This technology can be used as an effective aid in natural hazard investigation, as well as for the purpose of environmental planning. Terrain information, such as, land cover, geology, geomorphology and drainage could also be derived from it and existing thematic information can be updated to enable the quantification of human interference on the earth's surface. Geographic Information System (GIS), as a computer-based system for data capture, input, manipulation, transformation, visualization, combination, querry, analysis, modeling and output, with its excellent spatial data processing capacity, has attracted sincere attention in natural disaster assessment. The wet tropical and sub-tropical climate accompanied with humid condition favour disintegration of the top layer of soil through influence of several hydrological factors, soil conditions, topographic condition, which prevails in the most part of the eastern Himalaya region especially in Arunachal Pradesh, Meghalaya, Mizorum. With prevalent jhum cultivation practices, north-eastern Himalaya is more prone to soil erosion and degradation, which calls for sustainable management practices. Landform development in the Himalayan terrain is entirely different while comparing with Peninsular India of Pre-cambrian era. High relief, loose lithology, monsoon precipitation and intensive tectonic forces are highly influential for landform development in the Himalayan region. Within Himalayan ranges age of rocks differs from north to south, because of its episodic upliftment at different time interval vis-àvis its origin. The Himalaya is undergoing rapid uplift at a rate between 0.5 and 4 mm per year and consequently experiencing rapid erosion causing deposition of thick pile of terrigeneous sequences.

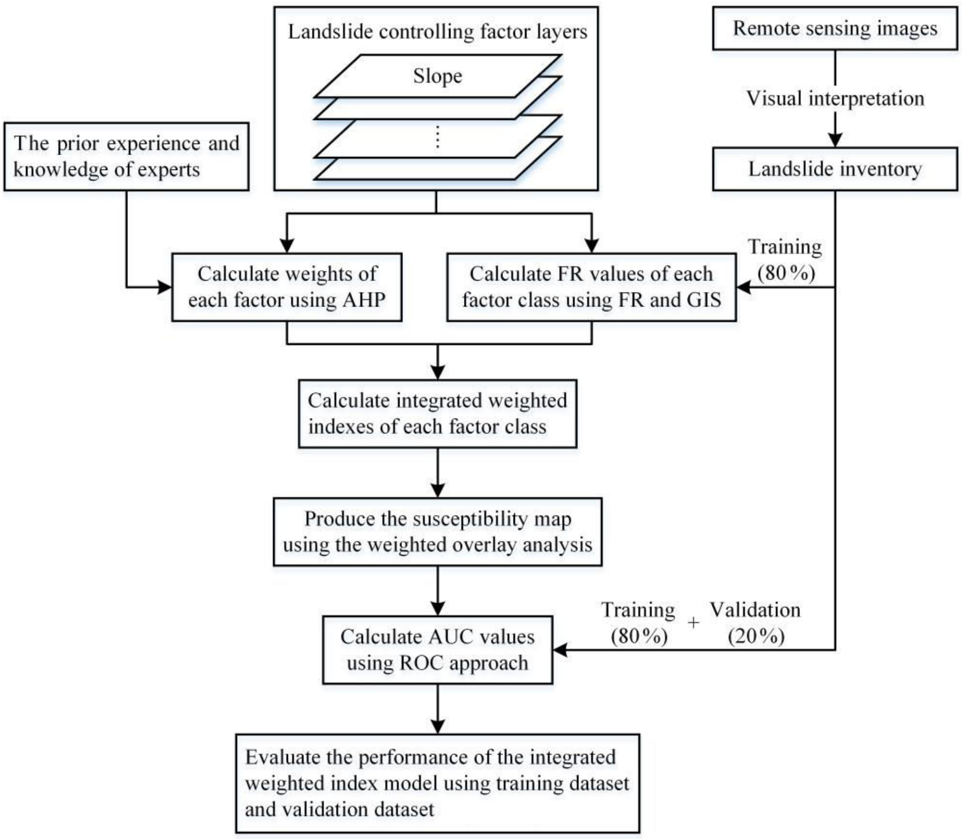


Figure 5.29: Geospatial Technology for Susceptibility and Zonation Mapping

Spatial and temporal thematic information derived from remote sensing, thematic maps and ground-based information needs to be integrated. Several researchers have envisaged remote sensing and GIS technologies for LHZ studies. Specifically, GIS has the potential of performing Landslide Zonation using various thematic layers. A study has also been carried out (in a part of Garhwal Himalaya (Tehri environ) to know the spatio temporal dynamics of landslide using multi temporal remote sensing data. To study temporal dynamics of landslides, satellite images of LISS-III and LISS-IV sensors for the year 1995 and 2005 were used (Plate 1). The total area effected from landslides hazard has been mapped in year 2005 with LISS III data and estimated to 2.93 sq. km which is greater than 1.3 sq. km of landslide area, mapped in the year 1995 with LISS-III data. In terms of landslide incidence, the number of landslides in area increased from 134 during 1995 to 725 in 2005 indicating 81.51 percent of increase in landslide incidence area. The number of landslides occurred during 1995 and 2005 were analyzed with reference to mapped terrain parameters to throw light on their genetic distribution in space and time. The decadal percent increase in landslides incidences have been calculated to understand the gravity of landslides incidence over various landslide inducing terrain parameters. Majority of the land use/landcover classes have witnessed a decadal percent increase in landslide incidence by less than 50 percent. It is interesting to note that no increase has been noticed over degraded forests whereas the highest increase is observed over agricultural land (86.7%). High increase in agricultural areas could be attributed to anthropogenic activities, low vegetation cover during no crop periods and high sheet erosion during heavy rainfall periods. In the assessment of risk associated with landslide movement, the likelihood of slope failure is of prime interest. Over the past two decades, many scientists have attempted to assess landslide hazards and produced susceptibility maps portraying their spatial distribution. However, there has been no general agreement on the methods or even on the scope of these investigations. The key issue in forecasting landslide or other geological hazards is the identification and collection of the relevant predictors whose nature, character and role vary depending on the type of disaster and geological, geomorphological and climatic setting of the region affected by the extreme event (Carrara et al., 1999). According to Van Westen et al. (1999), LHZ can be broadly divided into two categories; (1) direct hazard mapping, in which the degree of hazard is determined by the mapping by geomorphologist, based on his experience and knowledge of the terrain conditions, and (2) Indirect hazard mapping, in which either statistical models or deterministic models are used to predict landslide prone areas, based on information obtained from the interrelation between landscape factors and the landslide distribution. A comprehensive understanding of the geomorphological evolution of an area, combined with a thorough and detailed mapping by geomorphologists is essential in order to derive a reliable hazard map. Whether it is decided to use a direct or indirect method, the geomorphological expertise of the person collecting the data is crucial. The various causative factors in the form of thematic layers were integrated and analyzed in a GIS environment to derive LHZ map. Various methods of data integration for LHZ have been reviewed by Van Westen (1994). Some of the important methods are: (1) landslide spatial distribution analysis providing information on the occurrences of landslides, (2) the ordinal scale (quantitative) approach using weighting-rating system of terrain parameters (ground-based knowledge) and (3) the statistical method, which finds suitability for small areas with detailed information. On account of limited availability of field data, the quantitative approach can be adopted for LHZ in the Himalaya region.

According to Onagh et. al. land use is also one of the key factors responsible for the occurrence of landslides, since, barren slopes are more prone to landslides. In contrast, vegetative areas tend to reduce the action of climatic agents such as rain, temperature etc., thereby preventing erosion due to the natural anchorage provided by the tree roots and, thus, are less prone to landslides. The main goal of this study was assessment and appraisal of the Multiple Linear Regression modelling method in landslide susceptibility zonation and validation of landslide susceptibility map with inventory map of study area. In this study, it is found that multiple linear regression model hazard map is able to predict 76.2 percent of all the landslides occurred in the study area. Thus, it could be concluded that Multiple Linear Regression approach could also be useful in relatively moderate and small areas. This study also concludes that the approach of GIS based modelling can give good results in the analysis of field-oriented data. The validation results showed satisfactory agreement between the susceptibility map and the existing data on landslide locations. As a result, the success rate of the model (76.2%) shows high accuracy in prediction. Landslide susceptibility index map of study area has been classified into four categories of landslide susceptibility: low, moderate, high and very high, on the basis of distribution of landslide inventory of the area. It shows the validity of the system adopted to divide the landslide susceptibility index map. Moreover, planning of any project at a local level requires large scale and more accurate landslide susceptibility mapping. Landslide susceptibility mapping at a small catchment scale covers a lot of information that is necessary for micro level planning. On the basis of landslides susceptibility, use of land for different purposes may also be decided.

LANDSLIDE INVENTORY AND DETECTION

Landslides, influenced by several preparatory and triggering factors, are naturally hazardous events causing loss of lives and properties and environmental degradation. Landslide-triggering factors such as intense or prolonged rainfall or rapid snowmelt, earthquakes, or volcanic eruptions are enhanced by human-induced triggering factors such as deforestation, mining, and cutting slopes for road development. Landslides include various movements like flowing, sliding, toppling, or falling, and many landslides combine two or more of these movements at the same time or during the lifetime of a landslide. Traditionally, landslide inventory maps can be retrieved from historical sources, archives documents, and newspapers, which are important but not detailed enough, making quantitative risk assessment challenging. Historical landslide events offer a good opportunity to evaluate landslide detection techniques to develop landslide inventory, which can also be used in developing or validating landslide susceptibility and hazard mappings models.

An inventory map identifies landslides in a study area to establish the spatial correlation between landslides and environmental factors. A landslide inventory map is required to quantify landslide occurrence effectively. Landslide inventories generally include the size of landslides, its locations, and volume (preferred). Inventory maps, which provide information on the location of landslide distributions, help implement necessary mitigation measures. The first step in evaluating landslide hazards is a comprehensive landslide inventory map.

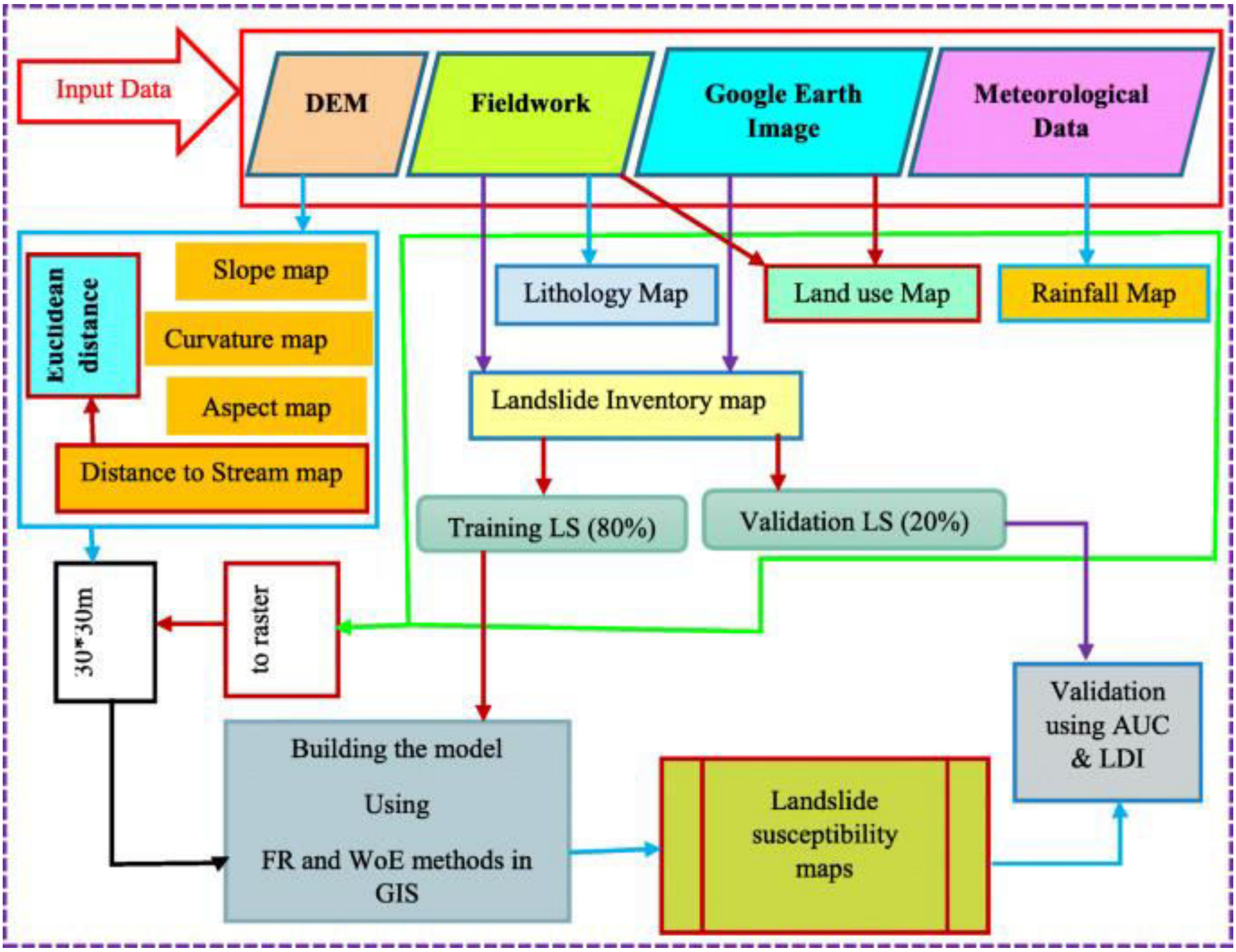


Figure 5.30: Landslide Detection and Susceptibility Mapping

Although landslide inventory mapping is a crucial requirement for a thorough hazard and risk analysis, the usefulness of these maps for land management and planning is rather limited due to their inhomogeneous spatial distribution and the use of different mapping and classification criteria and methods. However, large-scale landslide inventory maps, developed using remotely sensed data, can overcome these problems and limitations, thus making susceptibility hazard and risk assessment more efficacious. Since it is time consuming and expensive to develop landslide inventories using in situ measurements, remote sensing data, and tools can be an effective way to develop landslide inventory maps. High-resolution satellite image and advanced remote sensing and spatial analysis techniques allow developing more reliable landslide inventory maps. Methods involved in generating landslide inventories include visual interpretation of multi-temporal aerial photographs and remotely sensed images and geomorphological field mapping, expert knowledge on the geological setting in combination GIS tool can be used to develop a spatial map for statistical analysis in relation to other spatial variables; and the entire population of landslides triggered by the external forces or natural and anthropogenic causes must be mapped and plotted so that a complete landslide distribution can be obtained. However, detailed inventories are rarely available because evidence could have been lost due to various degrees of modification in the past. On the other hand, an inventory map/data can be developed using high-resolution historical remote sensing data, especially if morphological indicators for past landslide activities are present According to Guzzetti et al. and Malamud et al., landslide inventory maps are categorized into archive inventory (based on records in archives, newspapers, and so on). Similarly, in Guzzetti et al. landslide inventory maps are categorized as geomorphological inventory which can further be classified as follows:

- historical inventory (showing the cumulative effect of landslide over a long period without further temporal differentiation),
- event-based inventory (landslides caused by a single triggering event, such as a strong earthquake),
- seasonal inventory (landslides triggered within one active season) and multi-temporal inventory (continuous monitoring of landslide activity over longer periods independent of particular triggering events), and
- the multi-temporal inventory is the most labour-intensive inventory type and the only one with the potential for spatial-temporal completeness, and it generally requires the use of remote sensing.

A historical inventory is the most popular approach developing landslide inventories using past landslide events. High spatial resolution and long-term remotely sensed data help rapid mapping and monitoring, especially during an emergency. Based on the available in situ information and remotely sensed data, various landslide inventories can be produced and detailed at different scales covering the entire area affected by landslides, including, wherever possible, all sizes of landslides, and mapping landslides as polygons to depict their exact shapes. In addition, landslide inventory maps are prepared for multiple scopes, including:

- documenting the extent of landslide phenomena in areas ranging from small to large watersheds and from regions to states or nations,
- taking a preliminary step toward landslide susceptibility, hazard, and risk assessment,

- investigating distribution, types, and patterns of landslides in relation to morphological and geological characteristics, and distribution of slope failure processes,
- studying the evolution of landscapes dominated by mass-wasting processes,
- investigating the recent and historical relationships between mass movement processes, settlements, and high cultural value areas, and
- extracting thresholds of rainfall-induced landslides.

Landslide inventory and detection are technically very close and often used interchangeably. An inventory must be carried out through direct visual inspections (or field surveys) and/or in situ measurements (when possible), which, altogether, identify "detection." In other words, there is no good and effective inventory without detection. A complete and accurate landslide inventory is crucial for landslide predictions; therefore, the accuracy of landslide inventory can be maintained by analysing high-resolution satellite images. Identification of landslide's boundaries, terrestrial and topography verification, and third-party review are the procedures in interpreting the accuracy of landslide inventory.

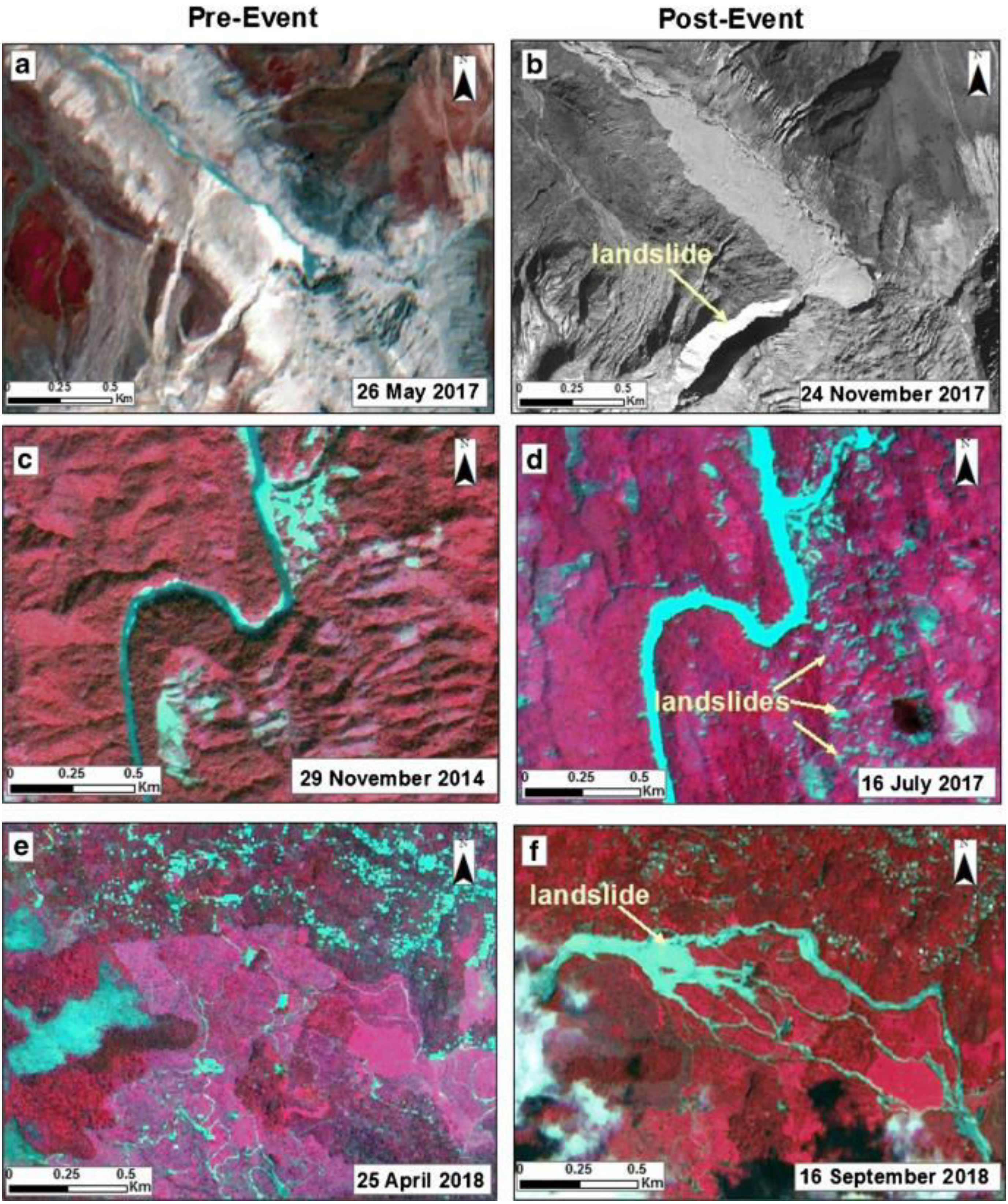


Figure 5.31: Landslide Inventory and Detection Mapping

The systematic information on the type, abundance, and distribution of landslide is still lacking, which helps document essential details on landslide types, patterns, recurrence, and statistics of slope failures. These pieces of information are helpful to identify landslide susceptible zones and determine potential hazards and landslide risk assessment. Multi-temporal inventories are needed, especially in regions of frequently occurring landslide. These regions require high spatial-temporal resolution data and efficient methods for landslide mapping and analysis. An inventory map which contains landslide type, state of activity, depth, volume, date, and place of occurrence, can be used for the calculation of predisposing factors for performance and reliability analysis. In addition to analyze and understand the causes of past landslides, landslide detection is equally useful for monitoring and predicting future hazards.

Landslide inventory/detection maps can be developed using the consolidated procedure of photo-interpretation of different sets of stereoscopic aerial photos, that can be integrated with an extensive field control of each recognized landslide. The field control process includes acquiring additional information about the main geomorphic elements and topographic signatures related to mass movement processes and their interpretation in terms of pattern, distribution, state of activity, and evolution of slope processes. In particular, the geomorphological field survey focuses on:

1. the validation of the information acquired by aerial photo-interpretation,
2. recognition of landslide types and state of activity,
3. analysis of deposits involved in slope failures, and
4. evaluation of damages to infrastructures.

Landslides of different sizes and types also offer to detect landslides, which can be used to develop a landslide inventory map. A landslide can be detected or identified using visual interpretation techniques combined with field investigations as a ground control to develop the most reliable form of inventory maps for scientific studies.

LANDSLIDE SESCEBTIBILITY MAPPING

Landslide prediction is vital to prevent possible damages and save human lives. Landslide susceptibility map is important in predicting landslides because it helps to identify potential landslide areas and any area susceptible to landslides. The local topography and hydrological conditions play a significant role in landslide susceptibility. Although a proper landslide inventory may provide both spatial and temporal information on previous landslides over an area, landslide susceptibility map gives information about potential future landslides over an area. However, detailed information on the historical records of previous landslides, rainfall, or earthquake is vital in determining triggering thresholds.

Landslide susceptibility can be quantified from stable to highly susceptible. Many researchers categorize slopes into four landslide susceptibility classes; highly susceptible, moderately susceptible, slightly susceptible, and stable. Some researchers used slightly different susceptible classes to develop landslide susceptibility maps such as unstable, quasi-stable, moderately stable, and stable. Some studies also used susceptibility indices: very high, high, moderate, low, and very low. For disaster prevention, a landslide susceptibility map can be used in land-use planning and decision making. A detailed susceptibility map for land-use mapping helps local authorities manage these landscapes for urban or industrial planning and development. However, developing an effective landslide susceptibility map is always a challenge because it requires multiple spatial information of soil, geology, vegetation, and hydrology. For example, Stanley and Kirschbaum identified four major issues that are important to be addressed for developing landslide susceptibility maps:

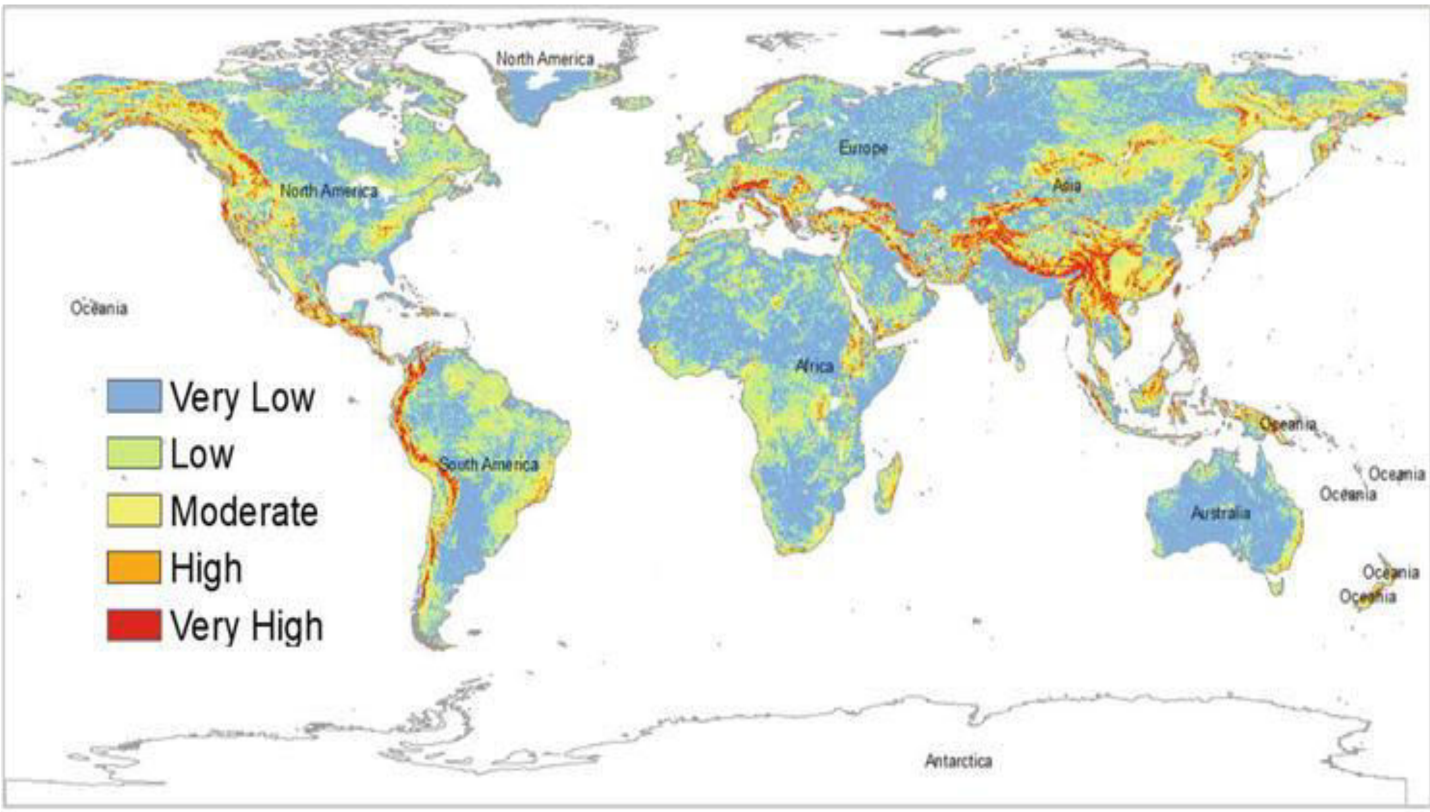
1. lack of detailed inventories,
2. minimum available input data,
3. regional differences in the importance of causative factors, and
4. the dearth of expertise on landscape processes across large regions.

Numerous methods exist in literature developing landslide susceptibility map using in situ measurements, models, remotely sensed data either stand-alone or in combination. For example, landslide inventories and causative factors, along with the statistical approach, are used in developing landslide susceptibility model for predicting potential landslide. In addition, many studies used statistical approaches, physically based models, and deterministic approaches in developing landslide susceptibility maps.

Besides the different existing methods for landslide susceptibility analysis and mapping, it is also essential to have advanced tools and detailed spatial information to develop an effective landslide susceptibility map. Digital tools such as GIS and global positioning system (GPS) are mostly used to analyze spatial data and developing landslide susceptibility and hazard maps. Moreover, remotely sensed data and technologies are widely used for effective landslide susceptibility mapping, hazard assessment, and risk assessment, which further helps in awareness, mitigation, and management of potential landslide threats.

Many researchers have used remotely sensed data to develop landslide susceptibility maps from local to global scale. For example, Ray and Jacobs and Kirschbaum et al. used remotely sensed precipitation data [TRMM and global precipitation measurement (GPM)] combined with slope, geology, road networks, fault zones, and forest loss to develop landslide susceptibility map at the global. Ray et al. used remotely sensed soil moisture (AMSR-E) combined with slope, soil, and vegetation characteristics to develop dynamic landslide susceptibility maps at a regional scale.

Figure 5.32: Landslide Susceptibility Mapping at Global Level



LANDSLIDE HAZARDS ANALLYSIS

Landslide is a major natural hazard that leads to a significant loss to human lives and properties. Landslide hazard requires systematic and objective assessment of the multi-landslide hazard, which includes different characteristics and casual factors of hazard along with their spatial, temporal, and size probabilities. Effective planning and management reduce social and economic losses caused by landslides. A landslide susceptibility map combined with temporal information can be converted into a landslide hazard map for estimating potential losses due to landslides. Landslide risk can be estimated using landslide hazard maps. A useful hazard map should include local geology, geomorphology, lithology, hydrology, vegetation, and climatic factors. These factors affect landslide events, needed for proper hazard analysis.

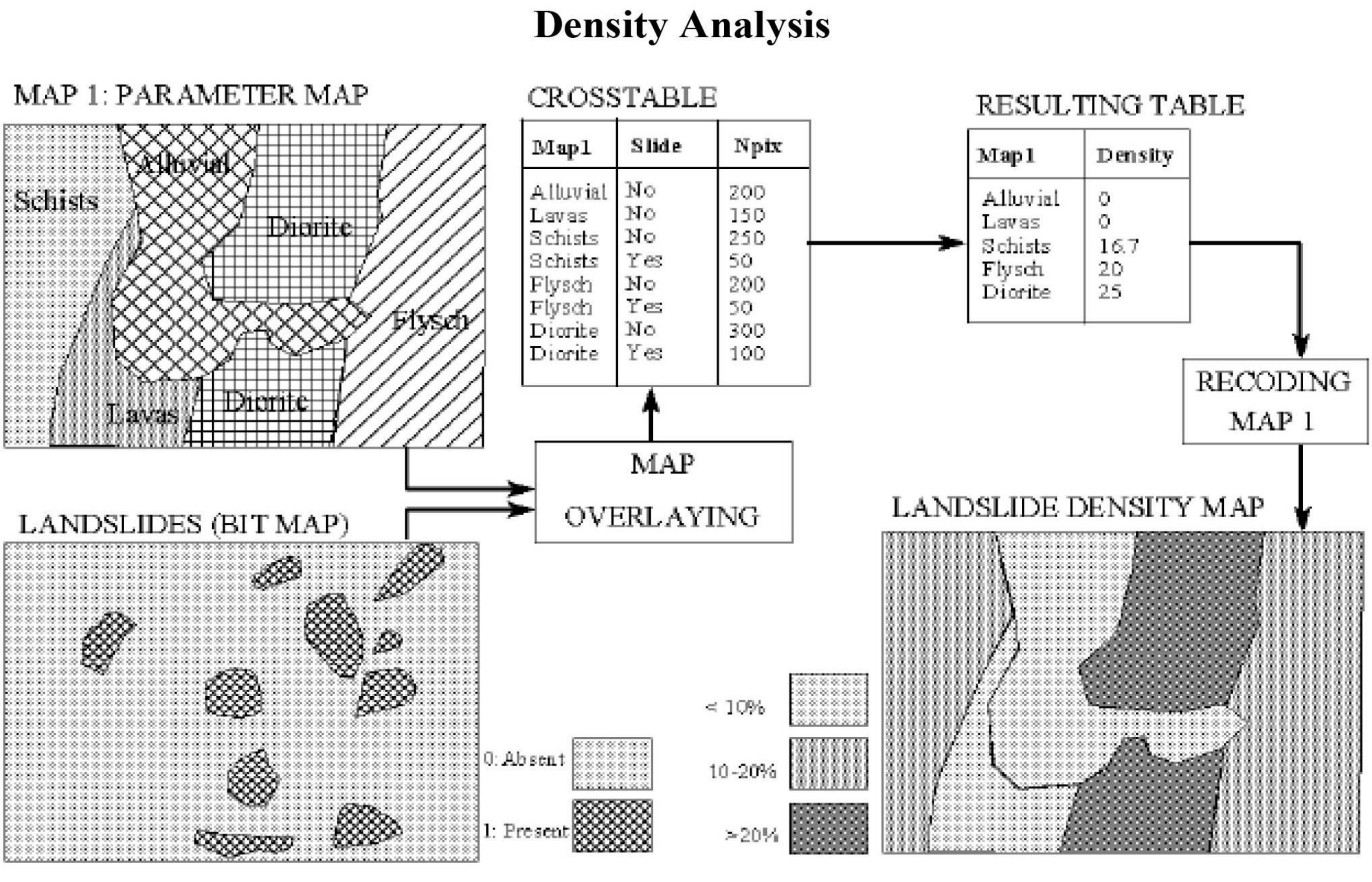


Figure 5.33: Landslide Hazard Analysis

A vital part of hazard assessment is the quantitative estimate of the pre-failure and failure stages of the susceptibility of the slope. Landslide hazard assessment determines slope failure probability. Over the last 30 years, numerous studies have been conducted on landslide hazard zonation as a result of the demand for slope instability hazard for planning purposes. Despite that susceptible slopes triggers or reactivate slope failures, hazard analysis must consider the speed of landslide movement along the slope. Huabin et al. suggested two important aspects of landslide hazard zonation, which are assessing the susceptibility of the terrain for slope failure, and determining the probability of a specific triggering event occurring. Nadim and Kjekstad used a landslide hazard index (Hlandslide) to classify landslide hazard levels from negligible to very high. The Hlandslide was obtained by multiplying a series of factors such as slope factor (Sr), lithology factor (Sl), soil moisture factor (Sh), precipitation trigger factor (Tp), and seismic trigger factor (Ts); the following equation was used to develop Hlandslide. Remotely sensed data provide several essential factors used in the equation to develop landslide hazard zones on the range of scales. It is often difficult to obtain the multi-spatio-temporal information on landslide occurrences needed for landslide hazard analysis. Chau et al. suggested that landslide analysis should include landslide-dynamics-based numerical simulations to prevent subjectivity and bias; incorporation with GIS should result in an adequate hazard map to work for better planning.

Susceptible areas can be assessed and predicted, thereby reducing damage caused by landslides through proper preparation and mitigation because landslide prevention is a severe challenge. Generally, landslide hazard analysis is conducted using aerial photographs, and/or remotely sensed images; therefore, it might contain a large degree of uncertainty, the degree of uncertainty is related to many factors, such as topography, soil, vegetation, and hydrology. On the other hand, the level of uncertainty is strongly related to the degree of susceptibility of a map. Also, the probability of landslide hazard depends on both the intrinsic and extrinsic variables. Intrinsic variables include geological conditions and slope structures, whereas extrinsic variables include rainfall and human activities. Chau et al. explained that a reliable landslide hazard map should include historical landslide events, geomorphological analysis, and mechanical analysis of slides, falls, and flows of earth mass. Since all three aspects of hazard analysis involve handling and interpreting a large amount of data, spatial analysis tools such as GIS is essential for such analysis.

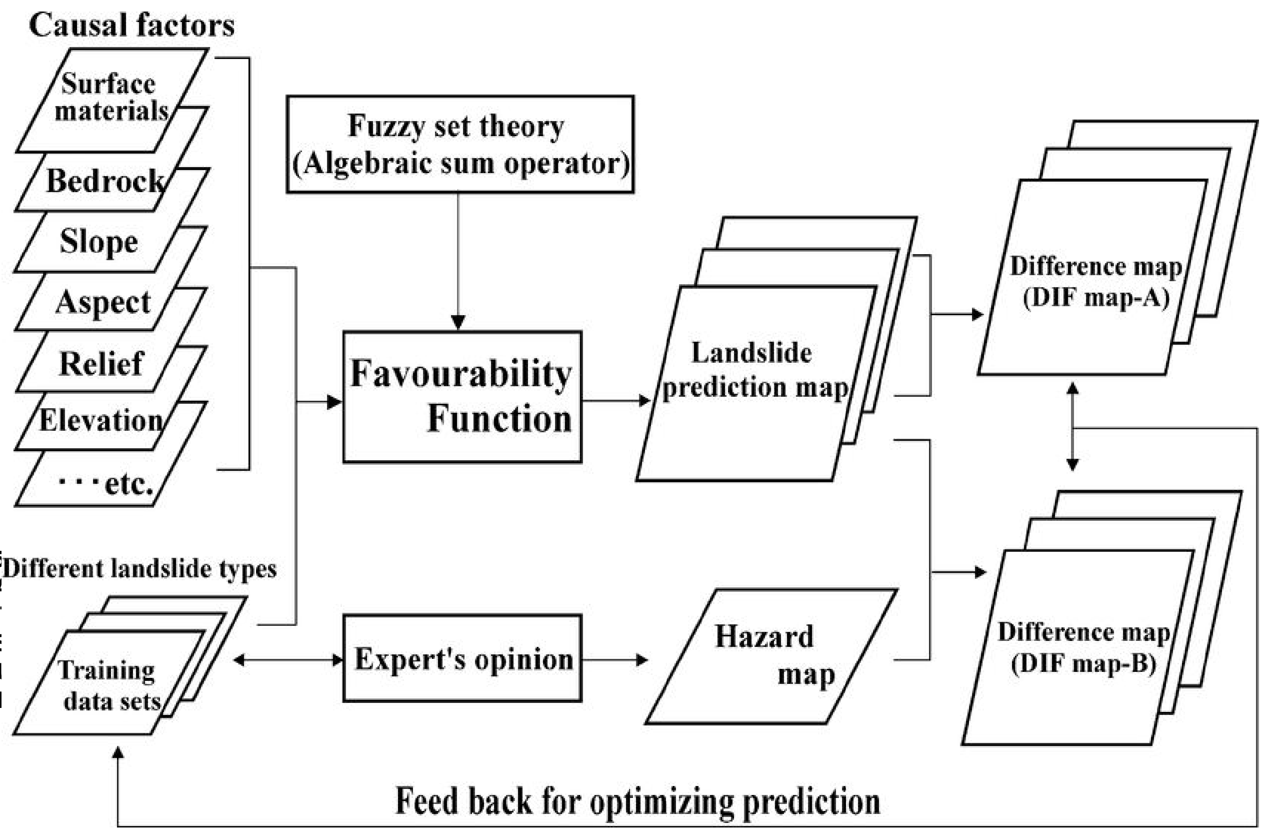


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Figure 5.34: Geospatial Technology for Landslide Prediction

Spatial information from previous landslide events is needed for landslide analysis and evaluating the probability of future landslide occurrence. Therefore, high-resolution spatial information (satellite data) for factors associate in landslide hazards is essential for effective hazard analysis. Recently, GIS tools and remotely sensed data have proven a vital approach for comparing and analyzing landslide, whereby a probabilistic landslide hazard analysis for the affected region is produced. Multiple layers of information are incorporated into the GIS system for a more accurate and reliable landslide hazard and risk analysis [86]. Geotechnical and safety factor-based models are also recommended for an effective landslide hazard analysis. Various scenarios with different volumes or sliding surfaces should be integrated for hazard analysis of potential unknown landslides. Golovko et al. used multiple satellite data (e.g., Landsat, Spot, Aster, IRS-1C, LISS III, and RapidEye) and automated detection techniques to develop landslide susceptibility map and landslide hazard index. They summarized that their presented approach was based on the extensive use of remote sensing data and geospatial tools (e.g., GIS) to characterize landslide susceptibility and hazard. Ray et al. used satellite soil moisture and hydrologic model in combination to develop landslide susceptibility maps at active Cleveland Corral landslide area in California, U.S. Ray et al. used an integrated approach to combine satellite soil moisture and a hydrologic model to develop susceptibility maps at Dhading, Nepal.

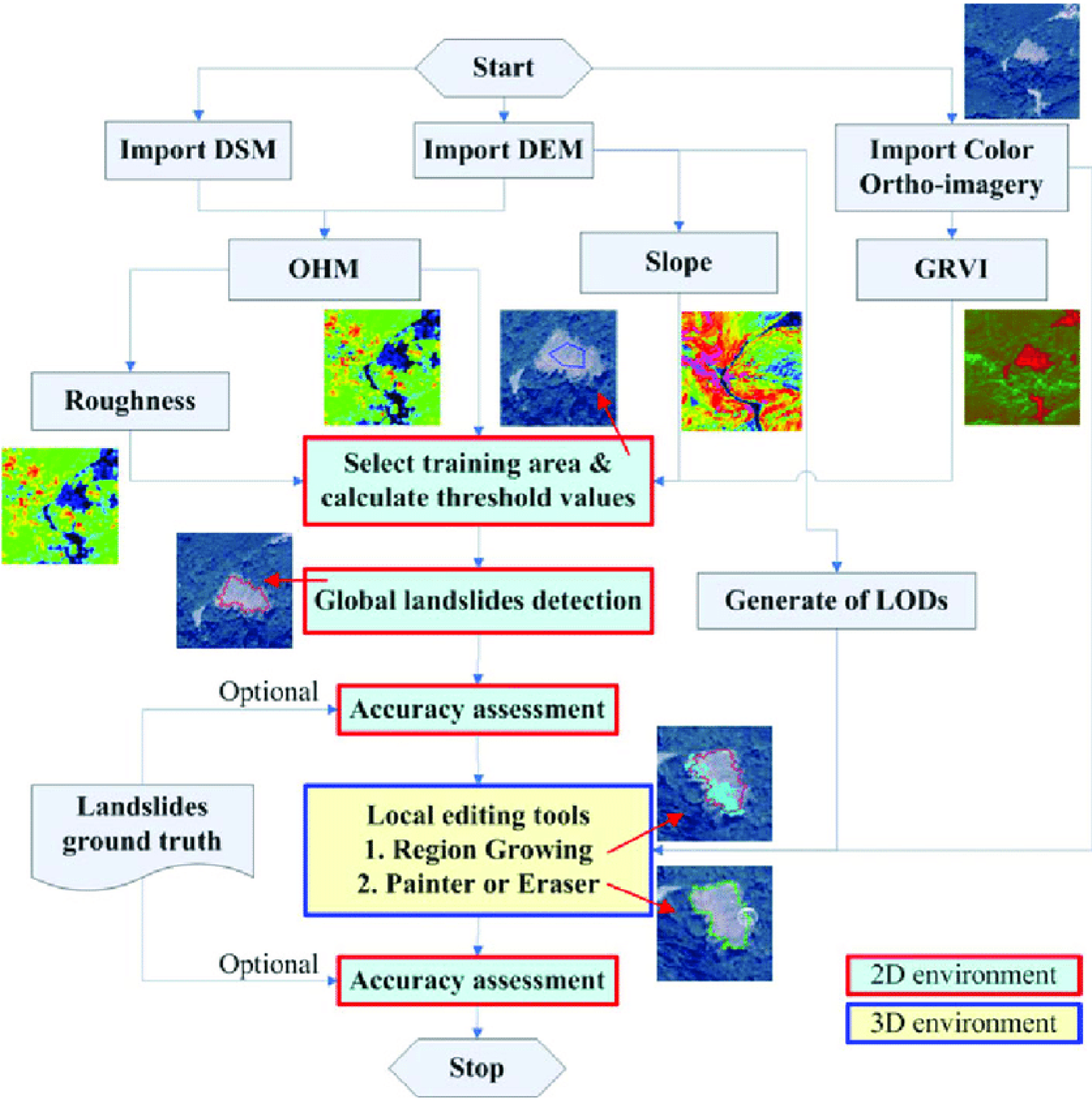
LANDSLIDE MONITORING

Landslide monitoring includes all of the activities discussed earlier, such as developing landslide inventory/detection, landslide susceptibility maps, and conducting a landslide hazard analysis. The easiest way to provide geological information to decision-makers and the public is through maps or visualization, which show locations of the landslide events, or where it might occur, thereby providing information on landslide hazard zones. The most effective way to minimize and reduce the impact of landslide hazards and improve risk management is through landslide monitoring and planning. Landslides occur due to the combined effect, such as intense rainfall, topography, and antecedent soil moisture. However, landslides can also be triggered due to external driving forces, such as earthquake, volcano, and excessive surcharge load on the slopes. Landslide hazard causes enormous infrastructural damages and human casualties in mountainous regions, and environmental degradation. The combined effect of surface and sub-surface saturation is critical because landslide trigger is not due to only surface layer saturation. Landslide monitoring technique depends on the type and size of the landslide, and the risks involved; it also differs between countries because of their available technology and expertise in landslide monitoring, past experiences with a landslide, and other factors. For example, monitoring the surface displacements of a slope provides essential data for landslide dynamics.

Landslide hazard mitigation measures include hazard mapping and assessment, real-time monitoring systems of active and complex landslides, and emergency planning. Landslide monitoring includes a comparison of the areal extent, speed of debris movement, rate of slope movement, surface topography, etc., concerning landslide conditions from different landslide occurrences to assess the activity of a landslide. Timely and high-quality information received from spatial observations is crucial for managers of natural and human-made disasters, particularly in response to emergencies. Landslide monitoring has improved over the years, with better monitoring equipment, automatic measurements done by machines, and less expensive tools.

Figure 5.35: Landslide Monitoring, Accuracy Assessment and Mapping

Remote sensing data and techniques can be used for in-depth hazard mapping and monitoring because of their extensive coverage and frequency of observations, especially in high



mountainous regions. Stereoscopic air-photo interpretation as far back as the late 1990s has been the most consistent remote sensing tool for landslide monitoring. Combining aerial photography and infrared imagery gives a better result of terrain conditions rather than from either system separately. Coupled with pre-existing landslide inventory maps and synthetic aperture radar (SAR) imagery and interferometric synthetic aperture radar (InSAR) through the integration of auxiliary data (e.g., detailed geological information) can be an effective method to update landslide inventory. Ground-based optical systems (video cameras) limits monitoring movement of active landslides, in case of fog, rain, and darkness. InSAR is useful to monitor prolonged slope movements. Also, InSAR has been widely used in research because of its broad coverage, high spatial resolution, and ability to operate under all weather conditions. Landslide monitoring includes detailed information on topography, geology, groundwater levels, material properties, possible mass movements. Several types of instruments, such as extensometers, inclinometers, piezometers, strainmeters, pressure cells, geophones, tiltmeters, and crack meters, have been used to monitor slope movements and deformation. Recently, the landslide monitoring system has been improved with the development of less expensive computerized equipment. According to Savvaidis, and Macek et al., landslide monitoring systems and techniques include:

1. Remote sensing techniques with space-derived information. They are of importance for seismic hazards, landslide hazards, and management of earthquake disasters. Also, remote sensing tools provide surface soil moisture data up to 1–5 cm deep, which has been used to develop landslide susceptibility maps.
2. Global positioning system (GPS) technique. It is a flexible and easy operation that uses a series of satellites to determine accuracy in the order of centimeters. A handled GPS provides accurate differential positioning over several kilometers .
3. Photogrammetric technique, combined with digital imaging sensors data. It allows early identification of landslide hazard. A photogrammetric technique, which includes interpretation of aerial photography, is a useful technique to identify and map landslides for an extended period. It is also a valuable technique for identifying and describing the 3D overview of the terrain in determining surface information.
4. Ground-based conventional surveying techniques measure for absolute displacement computations with the use of different instruments, usually employed in an episodic `monitoring program.
5. Geotechnical methods make use of sensors permanently working on or in the region under consideration, and can also use a telemetric system for real-time transmission of data to a control center .

TYPES OF GEOSPATIAL TECHNOLOGY IN DISASTER MANAGEMENT AND MONITORING

Several remote sensing data have been used to study landslide processes, including space-borne synthetic aperture radar (SAR) and optical remote sensing, airborne light detection and ranging (LiDAR), ground-based SAR and terrestrial LiDAR, incorporating in situ measurements and observations of environmental factors. In particular:

- SAR data have been widely used in landslide research because of their broad coverage and high spatial resolution and the ability to operate under all weather conditions. Satellite SAR data used include archived ERS and Envisat ASAR, ALOS/PALSAR, COSMO-SkyMed constellation, TerraSAR-X, TerraSAR-X/TanDEM-X and Sentinel-1 and Envisat 2010+ data (22 October 2010–8 April 2012).
- Optical remote sensing images were mainly applied to generate landslide inventory, considering long time-series of Landsat TM/ETM, SPOT 1–5, ASTER, IRS-1C LISS III, and RapidEye between 1986 and 2016. The ZY-3, and GF-1 high spatial resolution satellite images were used to investigate the landslide cinematics with an image correlation algorithm to SPOT-5 images.
- Multi-temporal LiDAR images and ortho-photos can be compared to quantify landscape changes caused by an active landslide. The ground-based terrestrial laser scanner (TLS) LiDAR can produce highly detailed three-dimensional (3D) images within minutes, allowing the study of 3D surface changes of landslides.
- Among the most useful applications derived from the analysis of remote sensing images is the development of digital terrain models (DEMs), such as those generated from Indian remote sensing satellite (IRS) P5 images and TerraSAR-X/TanDEM-X images by InSAR. DEM can then be used to assess erosion, landslide, and topographic multi-temporal differences.
- Lu et al. used Quickbird remotely sensed data for landslide detection and mapping. They summarized that traditional mapping techniques for landslide detection and mapping, which rely on manual interpretation of aerial photographs and intensive field surveys, are time consuming and not efficient for generating such event-based maps. Guzzetti et al. used aerial photographs, high-resolution DEM (LiDAR), and satellite images (e.g., Landsat-7, IRS, IKONOS-2, Quickbird-2, WorldView-2, and GeoEye-1/2) to develop multi-temporal landslide inventory maps. Holbling et al. used SPOT-5 remotely sensed data for landslide change detection, whereas used ALOS/PALSAR imageries and InSAR techniques for landslide detection. On the other hand, Desrues et al. used LiDAR DEM and satellite images for landslide detection and mapping.
- These approaches are very useful mainly in very large geographical areas where landslides are the most common yet highly devastating disasters, such as in Nepal, U.S., Philippines, and in many other countries. In the U.S., landslides caused 25 to 50 deaths each year, whereas extreme rainfall is the most common cause of landslides in the Philippines. Ray and Jacobs studied landslides in California, U.S., Leyte, Philippines and, Dhading, Nepal. They established the relationship between landslides, satellite soil moisture (Advanced Microwave Scanning Radiometer (AMSR-E)), and satellite precipitation (Tropical Rainfall Measuring Mission (TRMM)). In Nepal, Amatya et al. used high resolution optical data for landslide mapping and susceptibility analysis along the Karnali Highway in Nepal.

- Light detection and ranging (LiDAR) data open unprecedented possibilities for landslide mapping, with potential opportunities for hazard and risk zonation and landscape evolution modeling. Gorsevki et al. used LiDAR data to detect landslides in the Cuyahoga Valley National Park, Ohio, U.S, to generate a susceptibility map using the artificial neural network (ANN). Martha et al. used a semiautomatic approach to develop landslide inventories from post-event satellite images, which they used for landslide susceptibility, hazard, and risk in the High Himalayan terrain in India. Following the 2004 Typhoon Aere, the object-based image analysis approach (OBIA) was adopted to develop landslide inventory in Xiulan, Taiwan.

FLOOD DISASTER

Flooding is arguably the weather-related hazard that is most widespread around the globe. It can occur virtually anywhere. A flood is defined as water overflowing onto land that usually is dry. Flooding is often thought of as a result of heavy rainfall, but floods can arise in a number of ways that are not directly related to ongoing weather events. Thus, a complete description of flooding must include processes that may have little or nothing to do with meteorological events. Nevertheless, it is clear that in some ultimate sense, the water that is involved in flooding has fallen as precipitation at some time, perhaps long ago. The origins of flooding, therefore, ultimately lie in atmospheric processes creating precipitation, no matter what specific event causes the flooding. Floods produce damage through the immense power of moving water and through the deposition of dirt and debris when floodwaters finally recede. People who have not experienced a flood may have little or no appreciation for the dangers of moving water. The energy of that moving water goes up as the square of its speed; when the speed doubles, the energy associated with it increases by a factor of four. Flooding is typically coupled to water moving faster than normal, in part because of the weight of an increased amount of water upstream, leading to an increase in the pressure gradient that drives the flow. In most cases, the damage potential of the flood is magnified by the debris that the waters carry: trees, vehicles, boulders, buildings, etc. When the waters move fast enough, they can sweep away all before them, leaving behind scenes of terrible destruction.

Figure 5.36: Aerial View of Flood Disaster of Bihar, India

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Figure 5.37: Types of Floods

TYPES OF FLOODS

Over recent years, floods have hit the headlines on several occasions. At the beginning of 2014, parts of England experienced the **wettest January on record**. Who can forget the striking pictures; coastal towns thwarted by high tides and stormy seas; entire streets submerged in meters of flood water; roads and buildings left battered and damaged? But not all floods are equal and there are in fact many different types. Here's a helpful overview.

1. **Coastal Flooding:** Coastal areas often bear the brunt of severe storms, especially if these have gathered pace over the oceans. Extreme weather and high tides can cause a rise in sea levels, sometimes resulting in coastal flooding. Low-lying seaside areas usually have defences against the water - whether that's man-made defences or natural barriers such as sand dunes. As global warming develops, coastal flooding is expected to be a recurring and increasingly severe problem. Coastal flooding is the inundation of land areas along the coast by seawater. Common causes of coastal flooding are intense windstorm events occurring at the same time as high tide (storm surge), and tsunamis. Storm surge is created when high winds from a windstorm force water onshore — this is the leading cause of coastal flooding and often the greatest threat associated with a windstorm. The effects increase depending on the tide - windstorms that occur during high tide result in devastating storm surge floods. In this type of flood, water overwhelms low-lying land and often causes devastating loss of life and property. The severity of a coastal flood is determined by several other factors, including the strength, size, speed, and direction of the windstorm. The onshore and offshore topography also plays an important role. To determine the probability and magnitude of a storm surge, coastal flood models consider this information in addition to data from historical storms that have affected the area.
2. **Pluvial Flooding:** A pluvial flood occurs when an extreme rainfall event creates a flood independent of an overflowing water body. A common misconception about flood is that you must be located near a body of water to be at risk. Yet pluvial flooding can happen in any location, urban or rural; even in areas with no water bodies in the vicinity. There are two common types of pluvial flooding:
    - Surface water floods occur when an urban drainage system is overwhelmed and water flows out into streets and nearby structures. It occurs gradually, which provides people time to move to safe locations, and the level of water is usually shallow (rarely more than 1 meter deep). It creates no immediate threat to lives but may cause significant economic damage.
    - Flash floods are characterized by an intense, high velocity torrent of water triggered by torrential rain falling within a short amount of time within the vicinity or on nearby elevated terrain. They can also occur via sudden

release of water from an upstream levee or a dam. Flash floods are very dangerous and destructive not only because of the force of the water, but also the hurtling debris that is often swept up in the flow.

3. **River Flooding:** River flooding is one of the most common types of inland flood; occurring when a body of water exceeds its capacity. **When a river 'bursts its banks'** - typically due to high rainfall over a prolonged period of time - localised flooding can cause considerable damage to surrounding properties, as well as posing a significant safety threat. To prevent flooding, rivers needs good defences, especially in flat or populous areas.
4. **Flash Flooding:** Caused by heavy and sudden rainfall, flash flooding happens when the ground cannot absorb the water as quickly as it falls. This type of flood usually subsides quickly, but while it lasts can be fast-moving and dangerous. Flash flooding can be prevented by good drainage systems and by avoiding over-development on floodplains.
5. **Groundwater Flood:** As opposed to flash floods, groundwater flooding takes time to occur. As rain falls over an extended period, the ground becomes saturated with water until it cannot absorb any more. When this happens, water rises above the ground's surface and causes flooding. This type of flooding can last for weeks or sometimes even months.
6. **Drain and Sewer Flooding:** Sewer floods are not always attributed to the weather. As well as rainfall, they could occur as a result of a blockage or similar failure within the drainage system. Drain and sewer flooding may be internal (within a building) or external. While there may be many different types of floods, they all share one common attribute: the potential to wreak havoc. Understanding the risks and taking steps to mitigate them is key. In the UK, there is a national move away from flood defence to flood risk management and enabling communities to take reasonable responsibility to protect their homes, work places, businesses and communities.

CAUSES OF FLOOD

Common causes of flood can be divided into the factors triggering it. These factors include -

- Meteorological factors
- Physical factors
- Human factors

Let's discuss the factors causing floods in India.

1. Meteorological Factors

The natural causes of flood are discussed below -

- **Heavy Rainfall**: The season of monsoon enter India in mid-July and stays till the end of September. During this time, rainwater flows and is collected in dams. When this tired or collected water reaches beyond the storage capacity limit, it ends up in flood. Floods caused by rainfall usually occur at the sub-Himalayan plains of West Bengal, Indo-Gangetic, West coast region of West Ghat and Assam.

- **Cloud Burst**: Cloud Burst occurs due to intense precipitation in a short duration which can sometimes be accompanied by hail and storm and can cause a flood. These natural incidents occur at the mountain slopes, and water runs down towards the plains, causing a flood.
- **Cyclone**: Cyclones occur in a low-pressure zone where winds rotate inwardly. Cyclones can be accompanied by a massive storm and lead to extreme weather conditions. Four eastern coastal states in India, such as Tamil Nadu, West Bengal, Odisha, Andhra Pradesh, mostly suffer from cyclonic floods.
- **Global Warming**: Due to the increased rise in global temperature, glaciers of the Himalayan range start to melt. As a result, the seawater level also rises, causing floods in surrounding years.

2. Physical Factors

Those wondering about what physical factors act as flood causes can get a clear idea from the following section.

- **Insufficient Drainage Management**: Improper planning of the drainage system of an area can cause excess water due to heavy rainfall to get stuck and lead to a flood.
- **Catchment Area**: Catchment area is an area from where the rainfall water flows into a river. This can be a lake or reservoir. During monsoon, when excess water exceeds the limit of holding capacity of the catchment area, it leads to floods.

3. Human Factor

Following is a list of human causes of flood -

- **Siltation**: Siltation refers to the flow of silt and sediments in the riverbed. As particles remain suspended in the river and accumulated in the riverbed, it disrupts the flow of the river, causing a flood.
- **Improper Agricultural Practices**: If farmers are not cautious of the effects of farming practices meaning if they leave the waste material into the river or cannot handle water management properly, it can lead to a flood.
- **Deforestation**: Deforestation is one of the major human causes of floods. Trees act like a sponge that helps to hold soil and water and prevent flooding. As trees are being cut down at a fast pace to make way for urbanization to grow, more water runs towards a river during heavy rainfall. As a result, a flood occurs.
- **Collapse of Dams**: Dams are built to store water and provide water to people. As dams are human-made, these can be worn out and subsequently collapse causing floods. Also, if heavy rainfall sustains for a long time, State Governments often declare to open dam gates which can lead to a dangerous flood.

The piece mentioned above clearly describes what the causes of floods are. Now let’s learn about the types of floods.

IMPACTS AND CONSEQUENCES OF FLOODS

The most damaging aspect of floods is the huge loss of human lives. In economic terms, the immediate effect of floods is seen in temporary loss of fertile lands (since most of the flood-affected area is also the most cultivable area). The sowing season, the rainy season and the monsoons coincide in India.

Although floods bring fertile silt along with them each time, they also cause extensive soil erosion resulting in loss of precious soil cover. The Brahmaputra is particularly notorious for erosion of its banks during the monsoons. Areas with poor drainage, like Punjab and Haryana, which are also intensively cultivated with a high level of assured irrigation and use of chemical fertilisers and pesticides, are vulnerable to salination once the flood waters evaporate during the warm season that follows the rains. Sometimes, river courses are permanently shifted because of floods. This has a long-term effect on land use along river courses. The indirect impact of floods is seen in disruption of rail and road communication, and of essential services.

The consequences of flood depend on the location, duration, and vulnerability of the area. The impacts of floods affect both individuals and communities and have social-environmental consequences. Below is a list of damage caused by floods.

- **Human Loss and Property Loss**: Every year, millions of people become homeless and washed away due to floods.
- **Spread of Communicable Diseases**: Waterborne diseases like cholera, typhoid fever, hepatitis, and leptospirosis spread in flood-affected areas. Floods also lead to vector-borne diseases, transmitted through parasites and pathogens such as a mosquito. As a result, the health of flood victims deteriorates.
- **Destruction of Crops**: Every year, floods destroy a large number of crops.
- **Loss of Livestock**: Like humans, livestock also get displaced during floods and die due to the loss of their habitats.
- **Disruption of Communication Link and Transportation**: Flood causes damage to transportation links such as bridges, rail, power plants etc., thus causing communication disruption in those areas.
- **Economic and Social Disruption**: The economy comes to a standstill as people are forced to move to another place, and revival of this situation takes time.

What flood events share in common, is their ability to cause widespread community disruption, displacement, economic loss, property damage, deaths, injury as well as profound emotional suffering. Infrastructure and property, agricultural endeavours as well as historical and cultural sites may also be affected in flood disasters. According to the United Nations Regional Coordinator in Dakar (October 2007) the worst flooding in 30 years that battered West Africa from July 2007 caused more than 210 death and affected more than 785,000 people. The aftermaths of flood disasters in Ghana are the large-scale destruction of infrastructure, displacement of people from their dwellings, the loss of human lives, outbreak of diseases and water-borne infections, chemical exposure due to toxic pollutants being released into flood waters, huge loss of investments among other things.

Africa, which is one of the poorest continents in the world (in terms of GDP growth and income) has seen an increase in flood disasters in recent times. For instance, torrential rains and flooding affected 600,000 people in 16 West African nations in September 2009.

Countries with most devastating impacts were Burkina Faso, Senegal, and Niger. Another instance include the 2007 floods that displaced more than a million people in Uganda, Ethiopia, Sudan, Burkina Faso, Togo, Mali, and Nigeria, which claimed over 500 lives, and the 2008 floods in Mozambique which killed seven people and displaced tens of thousands residence. Heavy seasonal rainfall starting in December 2014 also caused flooding in southern Africa. As of January 2015, 135,000 people were affected by flood hazard in Malawi, Mozambique, Madagascar and Zimbabwe.

The impact of flooding varies both spatially and temporally. It could also be direct or indirect. Rahman indicated that the direct impacts of floods are closely related to the depth of inundation of floods water. The extent of a flood has a direct relationship for the recovery time of crops, pastures and the social and economic dislocation impact to populations. The impact of floods is considered far reaching with the aftermath effects such as flood-induced disease epidemics. Disease outbreak is common, especially in less developed countries. Malaria, Typhoid and Cholera outbreaks after floods in tropical countries are also common. further stated that physical damage to property is one of the major causes for tangible loss in floods. This includes the cost of damage to goods and possessions, loss of income or services in the floods aftermath and clean-up costs. Some impacts of floods, on the other hand, are intangible and are hard to place a monetary figure on. Intangible losses also include increased levels of physical, emotional and psychological health problems suffered by flood-affected people.

According to the cumulative number of people affected by rains and floods in 2007 in Southern Africa was more than 194,103 persons. This included 60,995 in Malawi (Mostly damage to property and crops), 94,760 people in Mozambique (all were evacuated into resettlement camps); more than 16,680 in Zambia (1890 persons had temporary accommodation, the rest were taken in by host families); and 15,168 in Zimbabwe. An estimated additional 4000 people had been affected in Lesotho and another 2500 persons in Swaziland.

Extreme events affect both the formal and informal economies, making it difficult to assess impacts which include direct and indirect ones. Depending on how well they are constructed and the severity of the event, buildings may be partially or totally destroyed by flooding.

FLOOD MAGNITUDE AND SEVERITY IN INDIA

Floods of various magnitudes have been occurring in one or other parts of the country during the summer monsoon season. The highest observed peak flood discharges at different gauge and discharge sites on major Indian rivers have been exhibited in Fig. 5.2. These peak flood discharges range from about 1170m 3/s for a 133-km 2 area basin to about 98,600 m 3/s for a 580,000-km2 area basin. The highest ever flood of 98,600 m3/s has been recorded on the mighty Brahmaputra River in 1988 followed by Ganga River in 1998 (80,230 m 3/s). According to Kale (1999), the 1968 flood on the Tapi River at Ukai is the highest since 1849; the 1970 flood on the Narmada River is the highest for the last 107 years and the1982 floods on the Mahanadi River is the highest since 1834. It is remarkable to find that the highest floods of 9340 m3s−1for a 735-km2 area and 16,307 m3s−1for a 1930-km 2 area occurred in the arid region of the state of Gujarat. The most of the extreme floods have occurred in the northern and the central river basins; the area is most frequently impacted by the monsoon depressions from the Bay of Bengal. Interestingly, the peak flood discharges of the Indian rivers are remarkably comparable with the highest flood discharges recorded in the world with respect to drainage basin area (Rakhecha 2002). The frequency of floods is the highest during the months of monsoon (June to September) in India. The occurrence of severe and devastating floods at different gauging and dis-charge sites on Indian rivers from 1951 to 2003 has been demonstrated in Fig. 3. A flood is said to be severe and dev-astating when flood crosses the danger level at a gauging and discharge site by 5 and 10 m, respectively (Dhar and Nandargi 1993, 1994, 2003). As expected, majority of the severe and devastating floods occurred in the month of September (13) followed by August (9). It is primarily attributed to good Floods of various magnitudes have been occurring in one or other parts of the country during the summer monsoon season. The highest observed peak flood discharges at different gauge and discharge sites on major Indian rivers have been exhibited in Fig. 5.2. These peak flood discharges range from about 1170m 3 /s for a 133-km 2 area basin to about 98,600 m3 /s for a 580,000-km2 area basin. The highest ever flood of 98,600 m 3 /s has been recorded on the mighty Brahmaputra River in 1988 followed by Ganga River in 1998 (80,230 m 3/ s). According to Kale (1999), the 1968 flood on the Tapi River at Ukai is the highest since 1849; the 1970 flood on the Narmada River is the highest for the last 107 years and the 1982 floods on the Mahanadi River is the highest since 1834. It is remarkable to find that the highest floods of 9340 m 3s−1 for a 735-km 2 area and 16,307 m3s−1 for a 1930-km2 area occurred in the arid region of the state of Gujarat. The most of the extreme floods have occurred in the northern and the central river basins; the area is most frequently impacted by the monsoon depressions from the Bay of Bengal. Interestingly, the peak flood discharges of the Indian rivers are remarkably comparable with the highest flood discharges recorded in the world with respect to drainage basin area (Rakhecha 2002). The frequency of floods is the highest during the months of monsoon (June to September) in India. The occurrence of severe and devastating floods at different gauging and discharge sites on Indian rivers from 1951 to 2003 has been demonstrated in Fig. 5.3. A flood is said to be severe and devastating when flood crosses the danger level at a gauging and discharge site by 5 and 10 m, respectively (Dhar and Nandargi 1993, 1994, 2003). As expected, majority of the severe and devastating floods occurred in the month of September (13) followed by August (9). It is primarily attributed to good Floods of various magnitudes have been occurring in one or other parts of the country during the summer monsoon season. The highest observed peak flood discharges at different gauge and discharge sites on major Indian rivers have been exhibited in Fig. 5.2. These peak flood discharges range from about 1170m3/s for a 133-km2 area basin to about 98,600 m3/s for a 580,000-km2 area basin. The highest ever flood of 98,600 m 3/s has been recorded on the mighty Brahmaputra River in 1988 followed by Ganga River in 1998 (80,230 m3 s). According to Kale (1999), the 1968 flood on the Tapi River at Ukai is the highest since

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(1) Indiscriminate deforestation in catchment areas and upper reaches results in soil erosion and consequent silting of river courses, which, again reduces their capacity to

absorb more water. This factor is a major cause of worry as far as flooding in the Himalayan Rivers is concerned. The Brahmaputra is particularly affected by silting of its tributaries, the Dihang and Lohit.

(2) Overgrazing, especially in the foothills, leaves the soil without cover. The type of soil cover is easily dislodged by the surface run-off during heavy rains and becomes the cause of silting of river courses. Overgrazing in the hills of Himachal Pradesh, Punjab and Uttarakhand has made long stretches of the Himalayan Rivers in their lower reaches prone to flooding.

(3) Unscientific farming practices like shifting cultivation result in loss of vegetation cover and consequent soil erosion. This mode of silting of rivers is evident in north-eastern India where silting of tributaries of the Brahmaputra is a major cause of flooding of the Brahmaputra River.

Distribution of Flood-Prone Areas:

Among the severely affected areas of the country are the Brahmaputra valleys, north Bihar (Kosi River and north Gangetic plain) and lower West Bengal.

Apart from these, floods affect large areas in the following belts:

(i) The lower courses of rivers in the north Indian plains get silted and change their courses. These areas lie in the states of Punjab, Haryana, Himachal Pradesh, Delhi, Rajasthan, Uttar Pradesh, Bihar and West Bengal.

(ii) The tributaries of the Indus—the Jhelum, Satluj, Beas, Ravi and Chenab—cause floods in Jammu and Kashmir, Punjab, Haryana, western Uttar Pradesh and Himachal Pradesh. Inadequate drainage in parts of Haryana and Punjab is the main cause of inundation.

(iii) Certain areas in central India and the peninsula get flooded by the Narmada, Tapti, Chambal, Godavari, Krishna, Cauveri and Pennar.

(iv) Certain areas along the east coast get flooded due to cyclonic storms. The total area affected by floods in India is between 7.5 million hectares and 10 million hectares. Uttar Pradesh is the worst affected state.

FLOOD DISASTER AND GEOSPATIAL TECHNOLOGY

Space and Air based on observations of earth provide a unique vantage point for monitoring and assessing the floods and other disasters. The traditional floods mapping and studies were based on conventional surveys and historical flood records. In this regard, space technology has made substantial contribution in every aspect of flood disaster management such as preparedness, prevention and relief (Rao 1994, Rao et al 1998). The Indian and other global remote sensing satellite are being used for obtaining the information about floods inundation areas and flood damage assessment.

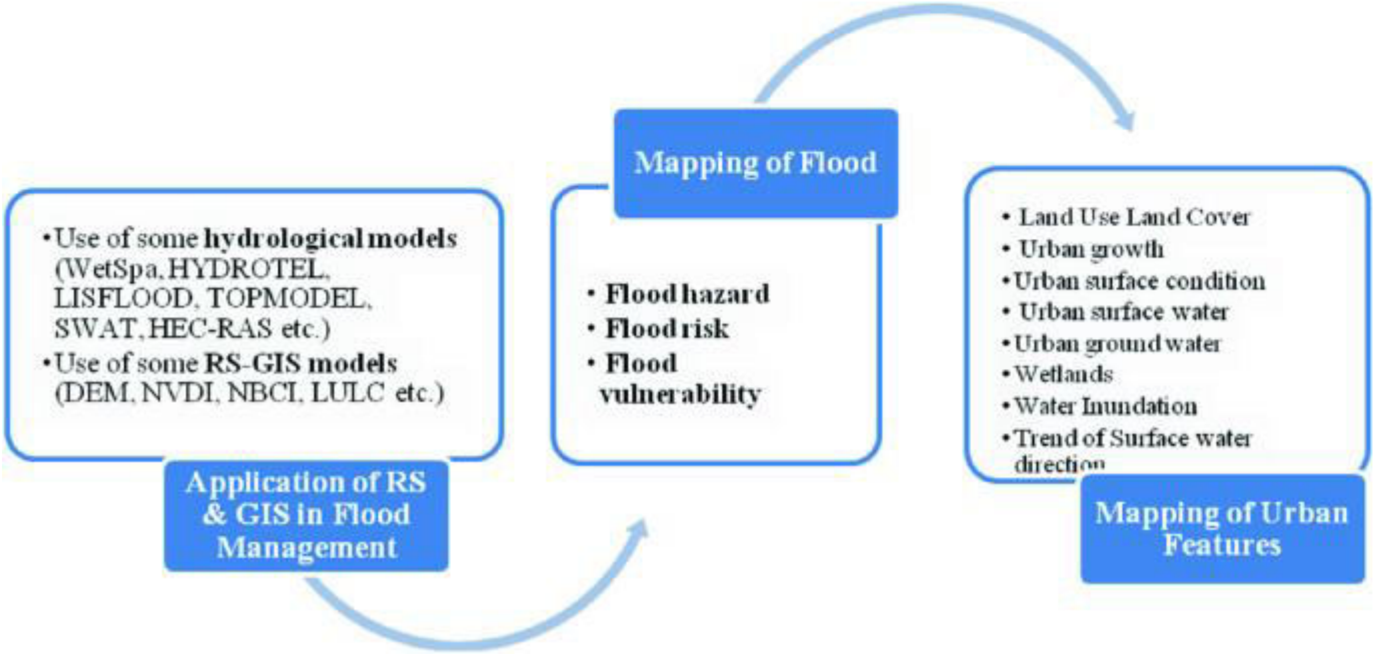


Figure 5.38: Application of Geospatial Technology in Flood Management

According to Merzet al., (2007), there have four typical types of flood map at the local scale where it briefly

described each type of definition of flood map. How GIS can be used in flood management? **By deploying sensors in particular locations, we can track inward and outward flow of rainwater in the city**. By using these sensors, the officials can map the situation during floods and can take decisions accordingly. This transformation of data into decision making is made possible by our 3D GIS platform. Remote sensing and GIS can **provide spatial information, which can be effectively used for flood monitoring, forecasting and analysis**. Flood modeling is also useful for flood management particularly to help solving flood inundation problem, which often occurs in the lower plain. Pivotal flood-response technologies include: **Surveillance Technology** – Drones or unmanned aerial vehicles (UAVs) provide ground crews with an "eye in the sky" that allows them to gain a full picture of the flooding, including which areas are most affected and where emergency responses may be required next. Remote sensing and GIS can **provide spatial information, which can be effectively used for flood monitoring, forecasting and analysis**. Flood modeling is also useful for flood management particularly to help solving flood inundation problem, which often occurs in the lower plain.

The prepared image was combined with GIS which consisted of spatial and attribute data. Such combination helped to study the damages caused by flood disaster such as the damages on transportation networks, agricultural and urban areas. The damages were examined and identified for each administrative unit such as subdistrict, district and province to facilitate proper allocation of relief funds. Flood disaster appearing on the satellite data could be the submerged areas in flood plain or flooded areas caused by overflow from the river or tributaries. Since the damage of flood disaster depended upon the duration of inundation, GISTDA planned to receive the satellite data in the same area consistently especially the data from RADARSAT 1 which was able to record the data in 7 modes leading to the availability of multi-temporal image. Floods cannot be controlled totally. However, flood damages can be minimized by proper flood control measures. Human activity tends to concentrate in flood-liable areas which are often convenient and attractive locations for settlement and other economic endeavours resulting in greater flood damages. Losses due to floods in terms of lives and property can be minimized by long- and short-range flood prediction, prevention, warning, monitoring and relief, along with floodplain regulation. This involves the interaction among different government and private agencies on one hand and the people of the country facing the disaster on the other hand, in making use of information and carrying out the above tasks. Geospatial technology along with integrated hydrologic-hydraulic modelling can be used for making the flood risk maps, flood forecasting as well as flood evacuation route identification.

- Flood risk maps are the essential tools for land use planning in flood-prone areas. The basic criteria for mapping are usually chosen according to flood return periods. Sometimes the expected water depth or dynamic considerations are used instead. These criteria are discussed on mapping examples from several countries. To draw a flood risk map, for phases are usually recognized: hydrologic, geomorphic, hydraulic and land use. Each of these phases poses different problems and requires relevant methodologies to accomplish them.
- Satellite remote sensing has an enormous potential in providing inputs to disaster management. Remote sensing provides a means of quickly visualizing the impact of a natural disaster like floods and make an assessment for prioritizing and taking necessary relief measures in time and space. In addition, space-based communications play vital role in disaster management. Earth observation satellites provide comprehensive, synoptic and multi temporal coverage of large areas in near real-time. The technology can be adopted to provide real-time information on major disasters like floods and cyclones in the following areas; - Near real-time flood mapping due to riverine and cyclonic floods - Damage assessment due to floods and cyclones - Flood progression, recession, and duration studies - River morphometric studies - Spatial flood early warning studies - Preparation of flood hazard maps - Embankment breach studies - River bank erosion studies and efficacy of anti-erosion measures taken up in the river banks. Considering the potential use of space technology in terms of satellite remote sensing and communication in disaster management, Indian Space Research Organization has embarked upon the Disaster Management Support Programme (DMSP) addressing all three disaster phases of preparedness, response and mitigation for Disaster Risk Reduction in the country by through space-based inputs.
- Spatial Flood Early Warning Development of spatial flood early warning models using very high-resolution Digital Terrain Models is gaining momentum for giving spatial flood alarm prior to the event. Space based inputs provide very vital information on topography and climate that can be used in developing long range flood early warning models. Considering the requirements at national level and its

importance, National Remote Sensing Centre has developed spatial flood forecast models for Godavari and Mahanadi Rivers in association with CWC using spacebased inputs. Web-enabled semi-automated Spatial flood early warning models for major floodplains of these two rivers have been developed using high resolution digital terrain models (ALTM DTM) and land use land cover and being run on experimental mode in real-time with other data support from CWC and IMD, and the results are being disseminated. The pilot studies led to the development of fully automated operational spatial flood early warning systems for Godavari and Tapi river basins under National Hydrology Project (NHP).

- Near Real-Time Monitoring and Mapping of Floods Space technology has been providing accurate and near real-time information on riverine and cyclonic flooding using its large area and frequent temporal coverage. This Report of information is an important input for near real-time relief and rescue operations and flood management on the ground. Duration of spatial flooding, flood progression and recession are the other products provided using temporal remote sensing data. Flood damage can be assessed using very high-resolution optical data acquired immediately after the flood events. NRSC works in close coordination with the concerned Central and State Disaster Management authorities including MHA, NDMA, SDMAs, etc and disseminates the satellite and aerial based disaster products for disaster risk reduction in the country.
- State Level Flood Hazard Atlases using Historic Satellite Data Preparing flood hazard maps is one of the best inputs for non-structural methods of flood damage risk reduction. These maps are useful in planning developmental activities in floodplains, construction of relief, rescue, and health centers, planning flood tolerant crops in floodplains. Satellites provide synoptic observations of the natural disasters at regular intervals that help in disaster risk reduction in the country. As part of disaster mitigation phase, NRSC has taken up major responsibility on the behest of NDMA in preparing State level Flood Hazard Atlases using historic satellite data coupled with ground validation. Flood Hazard Atlases of Assam, Bihar, and Odisha were prepared and released by the concerned States. Preparation of Flood Hazard Atlases of Andhra Pradesh, West Bengal, Uttar Pradesh, and updation of Bihar Atlas are taken up on top priority

Flood Mapping

Using SAR imagery, we can penetrate cloud cover and see the ground clearly during storms. This makes radar a powerful tool for monitoring flood events. This cloud penetration proved crucial for this work, as the post-flood images from optical satellites such as Landsat-8 and Sentinel-2 were all obscured by clouds. This work used data from the Sentinel-1 satellite constellation, operated by the European Space Agency (ESA).

We retrieved 4 Sentinel-1 GRD (ground range detected) images covering the Abbotsford area and the North-Western portion of Washington. Two of the images were taken before the flooding (November 04 and 13), and two were taken after (November 16 and 20). These images were grouped into two before/after image pairs for change detection – Nov 04/Nov 16, and Nov 13/Nov 20. After preprocessing the data, we created the flood detection layers using a change detection algorithm. The algorithm highlighted areas of surface water in the post-flood images which were not present in the pre-flood images to create a flood map.

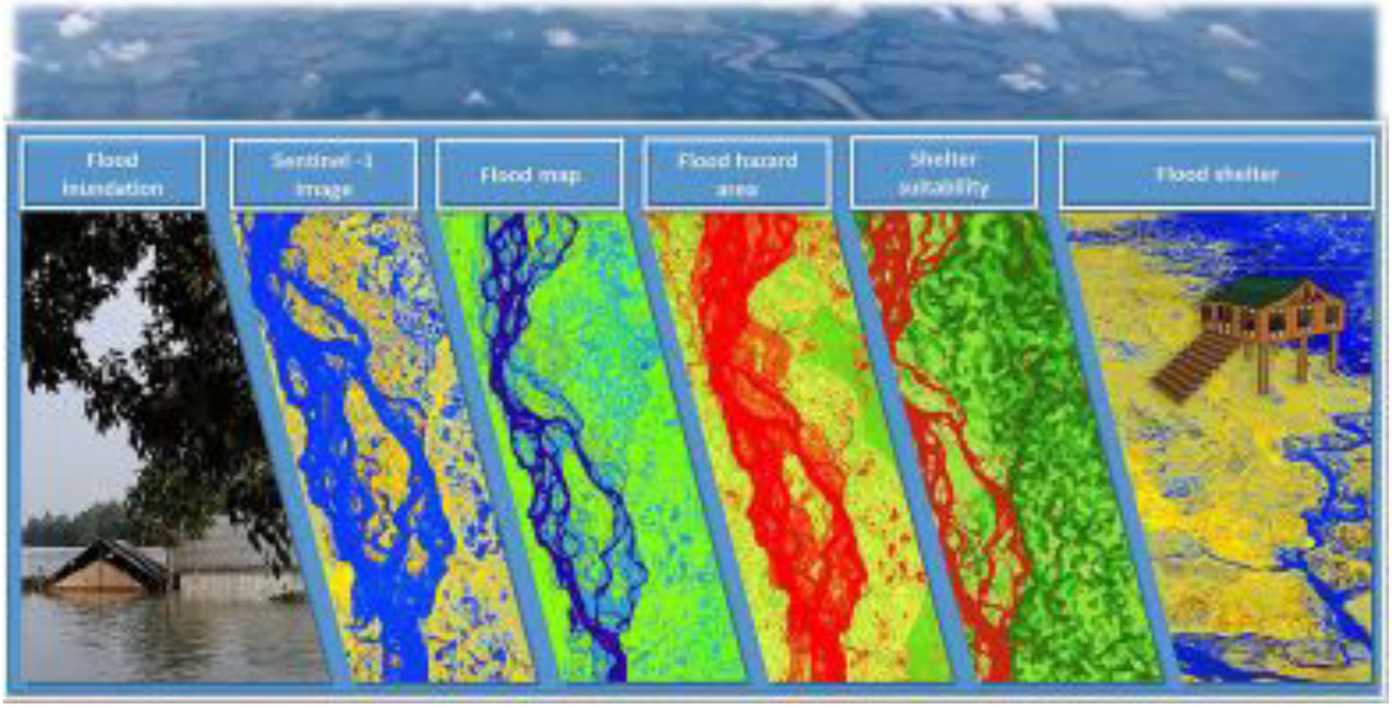


Figure 5.39: Potential Flood Hazards Zonation and Flood Shelter Suitability Mapping

The first natural colour image in the above gif is an optical satellite image from Sentinel-2 showing both the Abbotsford region as well as portions of Washington state around the Nooksack river. The SAR data in the second two images are symbolized using a gradient blue colour ramp: darker shades of blue indicate a weaker radar return signal, while brighter shades indicate a stronger return. Water appears dark in SAR imagery due to specular reflectance, with the water surface reflecting the majority of the radar pulse away from the sensor, resulting in a weak return signal.

We see a significant number of dark areas appear between the first and second SAR image. These are the standing water from the floods. Significant flooding can be seen around the Nooksack River and the Sumas Prairie South-east of Abbotsford. There is also a significant amount of water present in between the Nooksack river and the Sumas Prairie, reinforcing the conclusion that water from the Nooksack flowed North-east into the Sumas region. We can see there was also significant flooding north of the city, on the flood plain adjacent to the Fraser River. This flooding is unlikely to be related to the overland flows from the Nooksack river, and more likely was the result from either the Fraser River overtopping its banks, or from rain water flowing into the area from Abbotsford and the surrounding areas.

Satellite Imagery to predict the damage caused by Flood

Flood disaster in Thailand was mainly caused by high volume of runoff water during the rainy season especially in the watershed areas leading to overflow and then flooding along the riverbanks. The factors to slower or to obstacle the drainage system was consisted of the slope, shallow bed of the river and tributaries, and tide as well as man-made environment. According to Fig. 5.4, the satellite data recorded in 2002 showed the situation of flooding in various watersheds which was beneficial for co-analysis with hydrological and meteorological data and model leading to the prevention and mitigation strategies from flood disaster.

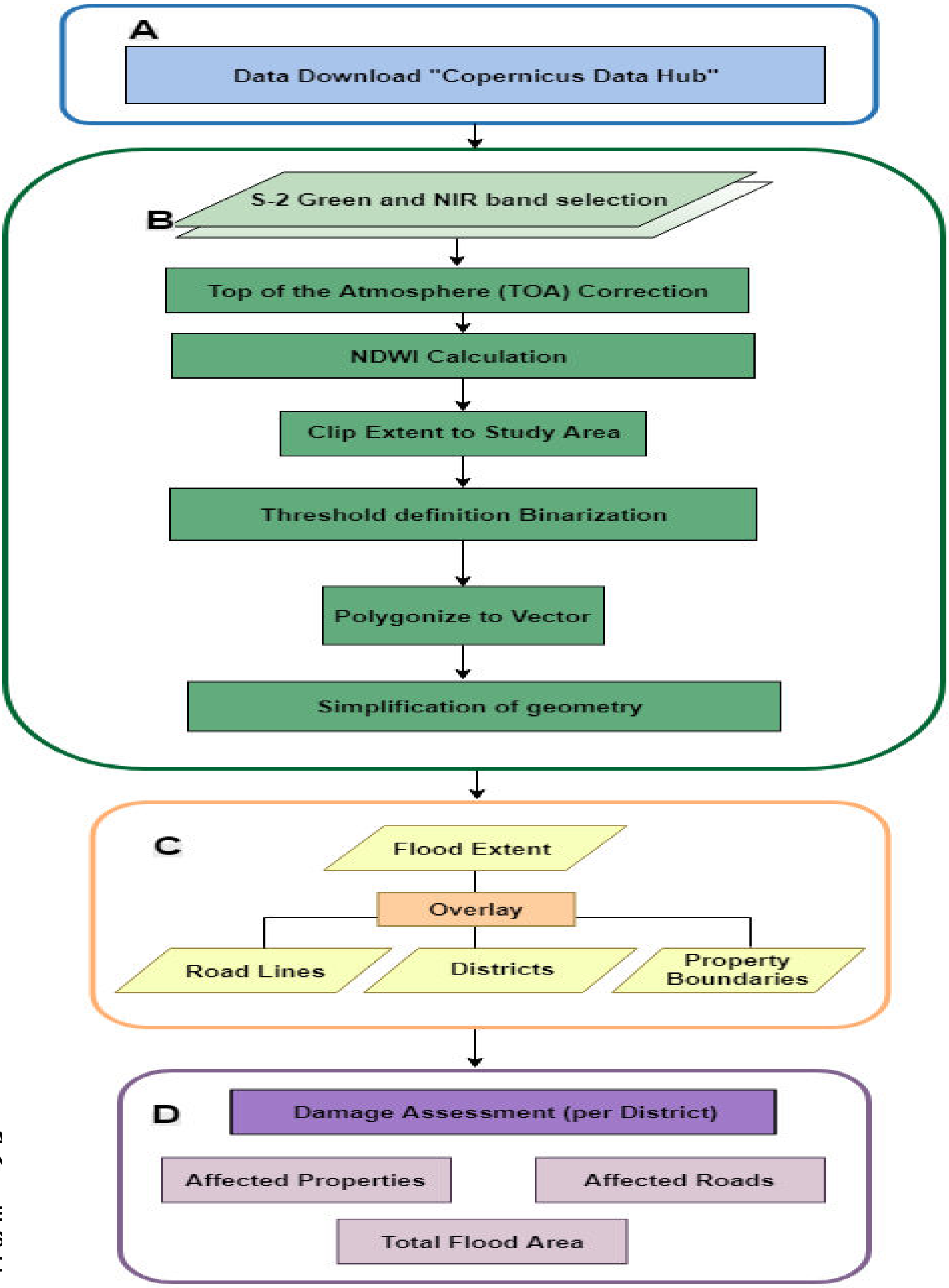


Figure 5.40: Flood Mapping and Damage Assessment

Flood Damage Assessment

The GIS data base created during preparedness phase contains agriculture, socio-economic, communication, population and infra structural data. This can be used, in conjunction with the flooding data to adopt an evacuation strategy, rehabilitation planning and damage assessment in case of a critical flood situation. During this phase integrated hydrologic-hydraulic modelling can be undertaken to reconstruct the flood event as well as generate the flood scenarios due to extreme precipitation, storm surge, cyclone, dam break or glacial lake outburst flood (GLOF). Bates et al (1997) used integrated remote sensing observations for flood hydrology and hydraulic modelling and Horritt and Bates (2002) has evaluated 1D and 2D numerical models for predicting river flood inundation. Thakur and Sumangala (2006) used geospatial technology to develop an integrated methodology for flood mapping using combination of RADARSAT, IRS LISS-III/LANDSAT satellites images and Geographic Information Systems (GIS), and Hydrodynamic modelling for September 2003 flood event of Puri District, Orissa, India. In this study flood inundation maps were generated using DEMs (ASTER), flood modeling was done using hydrodynamic models and comparison with the flood extent maps derived from RADARSAT SAR satellite images (4, 11, 13 September 2003). The flood inundation areas were extracted from RADARSAT images by visual and digital interpretation. Digital Elevation Models from ASTER was used to derive cross sections in flood plain and six cross sections were collected during field visit to Puri district, which were further adjusted from cross sections as derived from DEMs. The stage-discharge relationships were established using the observed flood gauge and discharge data at available cross sections. Hydrodynamic model HEC-RAS (Hydraulic Engineering Center-River Analysis System) is used to find the longitudinal profile, water level and routed discharge along Bhargavi, Kushabhadra rivers and flood mitigation canal at upstream of Kushabhadra river. This information was further used in Hec-GeoRAS GIS to find out the flood. The GIS is developed **using lumped statistics corresponding to administrative units and land cover information obtained from satellite image classification**. The method is applied to a recent flood in Chiba prefecture, Japan, and estimations compare well with post damage assessments.

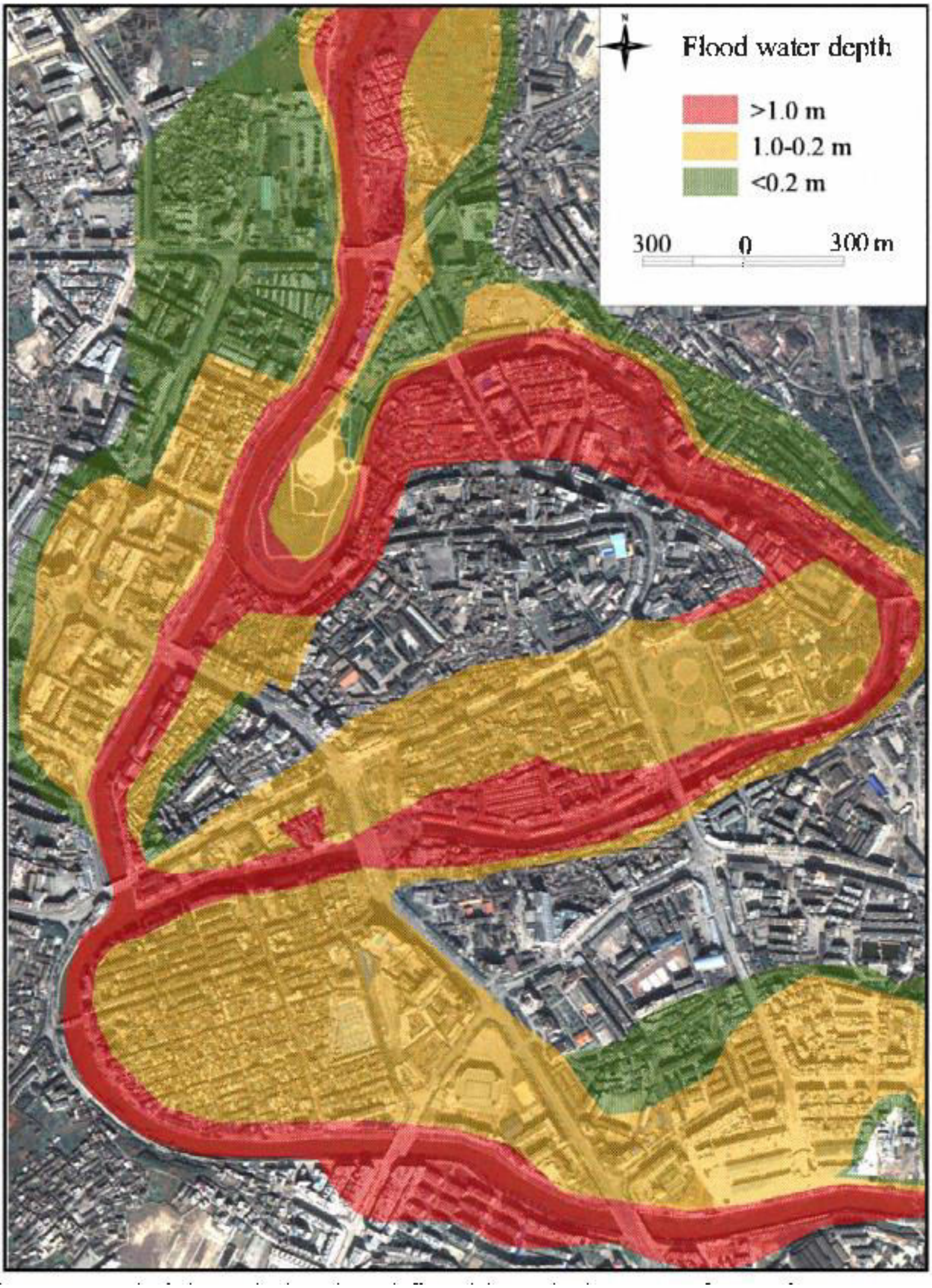
Urban Hydrology

The urban hydrology and flooding are different than that of natural landscape. Urban areas have more impervious areas such as parking lots, roads, driveways, roofs, built-up areas etc which prevents the infiltration and halts the interflow, this results in >55 % rainfall as surface runoff. This produces multi peaked hydrograph for urban areas for different rainfall intensities. The high discharge further cause channel erosion and flooding. The SAR system are ineffective for the urban floods as they have multiple/corner reflection form urban buildings etc, therefore delineation/monitoring of flooded streets/parkways/grounds is difficult to detect satellite images. The current state of art in flood studies with geospatial techniques are limited to mapping, monitoring and modeling of floods. But still research is required to find the flood depth and duration of inundated area for more realistic flood management and simulation studies. The temporal SAR/cloud free optical images can give the rough estimates of duration of flooding and pre flood terrain information form DEMs and flood extent maps can be utilized for the calculations of flood water depth and duration. This requires multi satellite/sensors/altimeters/ground-truth approach for flood studies.

Figure 5.41: Flood Inundation Mapping

Flood Discharge Management

Space based SAR systems have been extensively used for flood mapping and stream discharge measurements. The future sensors specific to flood discharge retrieval is Water



Elevation Recovery Mission. WatER is a swath-based altimetry mission designed to acquire elevations of inland water surfaces (and hence the capability to derive surface water storage and river discharge) at spatial and temporal scales necessary for answering key water cycle and water management questions of global importance. WatER is an international effort with participants from 14 countries (Rodriguez 2004). Maximum incidence angle is 4.3º, thus the instrument operates very near nadir where water surfaces are very bright. At Ka band, the interferometer will easily penetrate clouds and relies on subtle canopy openings to penetrate to any underlying water surfaces (openings of only 20% are sufficient. Height accuracies will be ±50 cm for individual pixels" thus centimetric accuracies are achieved through polynomial averaging schemes. Such altimeters can provide the discharge/ water level fluctuation to the flood simulation/forecasting models for near-real time flood management.

In this regard high resolution optical images (CARTOSAT, QUICKBIRD), high incidence/resolution SAR (TERRASAR-X/PALSAR/AIRSAR) and highresolution DEM from (CARTOSAT-1, LIDAR) should be used to find flood inundation areas and perform urban flood simulations.

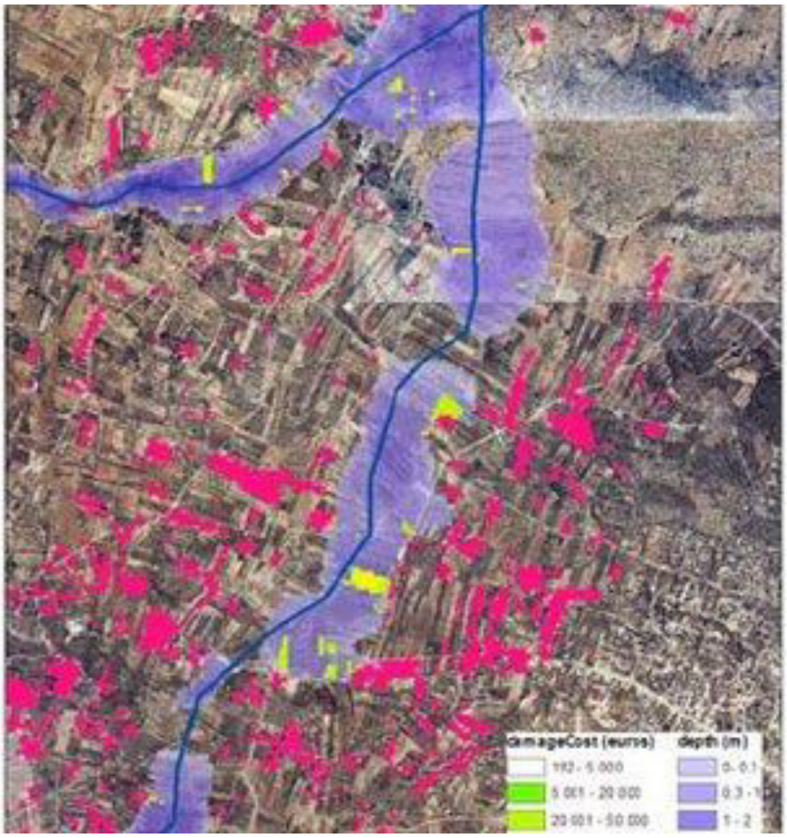


Figure 5.42: Flood Damage Mapping and Estimation

The inputs from remote sensing and conventional methods such as satellite/rain gauge based precipitation, land use land cover, soil texture, DEM, etc can be integrated in geospatial environment to simulate the rainfall-runoff process, which becomes an input to the flood fore-casting models. The hydrologic-hydraulic and flood forecasting models can be used for the flood peak estimation and simulating the past/future flood scenarios. The simulated flood events can be used for the flood-plain delineation, flood hazard zonation and creation of flood risk map with different return period floods. The flood risk maps can than be used for flood prevention/mitigation purpose, fixing of flood insurance rates.
the general flow chart of FMIS.
Remote sensing and GIS can **provide spatial information, which can be effectively used for flood monitoring, forecasting and analysis**. Flood modeling is also useful for flood management particularly to help solving flood inundation problem, which often occurs in the lower plain. Model decision trees and model prediction capabilities are strongly influenced by training data used at the start of the study. Moreover, training data is an example of historical data that is static. So if using different training data, decision trees and predicted results are likely to change. So the decision tree model is less powerful. This is one of the major disadvantages of Chaid's decision tree method. Due to this deficiency, this model is only suitable for making predictions according to current circumstances. Predictions of future floods with certain rainfall could be done, but it is feared the results are not accurate. The next thing is related to the decision making process. The decision tree making algorithm that applies to SPSS software states that flood or non-flood categorization depends on the percentage of most terminal nodes. Cutting categorization is greater than 50%. So if one category value is greater than 50% on the terminal node, then the category will be the flood status in each terminal node.

5.4 SUMMARY

The technology of Remote Sensing and Geographic Information System can provide an efficient and timely information for disaster monitoring and complements the conventional methods for damage assessment and mapping. The information derived from these technology could be applied in case of landuse planning and dis aster management. Then relevant organizations in public sectors can prepare strategic plans to protect and reduce the impact on life and the assets of government and local people in the downstream area. Natural disasters such as hurricanes, earthquakes, tsunami, and landslides have been on the rise, causing damage to property and human lives, especially in mountainous regions. Major causes of landslides are conditioning factors, such as lithology, relief, geological structure, geo-mechanical properties, weathering, and triggering factors such as precipitation, seismicity, temperature change, and static and dynamic loads. Conventional methods for landslide studies mainly rely on the visual interpretation of aerial photographs and field investigation in combination. However, these methods are time consuming and cost-ineffective. On the other hand, remotely sensed data at high spatial and temporal resolutions and advanced techniques could be used for landslide studies at a range of scales, which can reduce the time and resources required for the studies. Landslides, ground settlement and avalanche interfere greatly and persistently with mass activities. It occurs when hill side or valley side slopes falls using to specific geological, climatic and biotic factors. They are bringing about major disruptions of towns and cities, communication systems and large structure including dams and bridges. Slope plays a dominant role to create gravity force for wasting process like land sliding, soil creeping, slumping etc. Construction activities for development in Himalayan region have greatly enhanced the frequency of landslides. Mitigation of disasters due to landslides can be successful only with detailed knowledge about the expected frequency, character and magnitude of mass movements in an area. To forecast possibilities of the future landslides in an area, comprehensive knowledge of causative factors of land sliding is necessary. The wide applicability of geospatial technologies is using in solving various environmental tasks. This technology can be used as an effective aid in natural hazard investigation, as well as for the purpose of environmental planning. Drainage map, contour map, digital elevation model, slope angle map, land use / land cover map, relative relief map, thrust (buffer) map, photo lineament (buffer) map, geological map is basic requirement for landslide hazard zonation or for identification of landslide prone areas which can be delineated under GIS environment using remote sensing data. Geographic Information System (GIS), as a computer- based system for data capture, input, manipulation, transformation, visualization, combination, query, analysis, modeling and output, with its excellent spatial data processing capacity, has attracted great attention in natural disaster assessment.

5.5 GLOSSARY

- Flood frequency analysis- is a technique commonly used to relate the magnitude of extreme runoff or river flow events to their frequency of occurrence through the use of probability distribution functions.
- Geospatial Technology- is an emerging field of study that includes Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS).
- Disaster Mitigation- It's the ongoing effort to lessen the impact disasters have on people and property. Mitigation involves keeping homes away from floodplains, engineering bridges to withstand earthquakes, creating and enforcing effective building codes to protect property from hurricanes, and more.
- Flood Discharge- is the volume of water that passes through a given cross section per unit time, usually measured in cubic feet per second (cfs) or cubic meters per second (cms).
- Contour Maps- Earth's surface has many different kinds of landforms that vary widely in height and elevation. Contour maps show the elevations of these surface features, which allows you to look at a two-dimensional map to visualize the Earth in three dimensions.

- Digital Elevation Model- A Digital Elevation Model (DEM) is a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects.
- Drainage basin- is the topographic region from which a stream receives runoff, throughflow, and groundwater flow.

5.6 ANSWER TO CHECK YOUR PROGRESS

1- Define Flood frequency analysis?
2- Write a short note on Disaster mitigation?
3- Define Drainage basin?
4- Define Digital Elevation Model?
5- Define Contour Maps?

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5.8 TERMINAL QUESTIONS

(1) What do you understand by geospatial technology? Explain how it can help in disaster management with suitable examples.
(2) How can GIS help in flood analysis and management?
(3) Which remote sensing technology is useful in flood and earthquake management?
(4) How does remote sensing help in disaster mitigation and prediction?
(5) Explain the GIS Technology for Disaster and Emergency Management.?

UNIT 6 - RECENT TRENDS IN GEOINFORMATICS FOR DISASTER MANAGEMENT, THE ROLE OF MOBILE GIS AND SDI AS INTEGRATED FRAMEWORK IN EMERGENCY MANAGEMENT

6.1 OBJECTIVES
6.2 INTRODUCTION
6.3 RECENT TRENDS IN DISASTER MANAGEMENT, THE ROLE OF MOBILE GIS AND SDI AS INTEGRATED FRAME WORK IN EMERGENCY MANAGEMENT
6.4 SUMMARY
6.5 GLOSSARY
6.6 ANSWER TO CHECK YOUR PROGRESS
6.7 REFERENCES
6.8 TERMINAL QUESTIONS

6.1 OBJECTIVES

After reading this unit you should be able:

- To get a detailed knowledge of recent trends in geoinformatics.
- To understand the geoinformatics role in disaster management.
- To describe the role of mobile GIS for emergency management in disaster management.

6.2 INTRODUCTION

Present world is described with high speed and broad spatial range of changes, together with complex interdependences between running processes. This puts a lot of challenges for timeliness, accuracy and high quality about decisions and actions. Essential for implementation of these requirements must be Geographic information systems with incorporate Mobile technologies. To meet the challenges of complex crisis management situations, new interactive visualization tools are in development to deal with large, complex datasets and similarly large and complicated analytical tasks. These systems must help enable connections between response, mitigation, and recovery specialists in disaster situations. Recent crises have revealed the need for visualization tools to support time-sensitive collaboration, analytical reasoning, problem solving and decision making in analysis, planning and time-sensitive response activities. As almost all crisis management activity contains a geospatial component, these activities will necessarily include geospatial data. To create a comprehensive disaster management system, our society needs to rely on advanced geospatial technologies and services. Mobile GIS is one of the most vital technologies for the future development of disaster management systems. Mobile GIS and mobile Geographic Information Services extend the capability of traditional GIS to a higher level of portability, usability and flexibility. Mobile GIS are integrated software and hardware frameworks for access to geospatial data and services through mobile devices via wireline or wireless networks. The unique feature of mobile GIS is the ability to Dynamic and Mobile GIS: investigating changes in space and time incorporate Global Positioning Systems (GPS) and ground-truth measurement within GIS applications.

For example, mobile GI Services can combine GPS and satellite images to assist the local government and emergency response teams in identifying potential threat areas. So critical “hot zones” can be immediately created. Near real-time spatial analysis models supported by

GIS could be used to rapidly generate the most effective evacuation routes and emergency plans during natural hazard events, including wildfires, floods and tsunamis. Wireless Internet-based GIS could also assist public policy officials, firefighters and other first responders with identifying areas to which their forces and resources should be dispatched. To accomplish these goals, it is important to introduce these new mobile GIServices technologies to emergency management personnel and related organizations. Also, emergency managers and first responders need to realize both the advantages and the limitation of GIS technologies in disaster management.

6.3 RECENT TRENDS IN DISASTER MANAGEMENT, THE ROLE OF MOBILE GIS AND SDI AS INTEGRATED FRAME WORK IN EMERGENCY MANAGEMENT

RECENT TRENDS IN GEOINFORMATICS

Developments in remote sensing can broadly be categorised into technology and application domains. The technological developments can again be classified into the areas of data acquisition and data interpretation techniques. One good example is the acquisition of remote sensing data from space shuttles. USA based Johnson Space Centre maintains a database of large amount of data acquired during the manned space shuttle flights. Because of the developments in data acquisition technologies, remote sensing data are now available in volumes larger than what is actually being analysed by data analysts. Developments in computing technologies have enabled data accessibility and availability to a large number of researchers and users. This has also resulted in development of algorithms which are able to derive information from a variety of remote sensing data acquired from different data acquisition platforms without much human interaction and intervention. This information is also becoming more accurate. Increased number of parameters, which we can derive from remote sensing data has also enabled us to apply it in a variety of application areas.

In the initial years, there were satellites, the data from which were used for land, coastal areas and ocean. In the recent times, application specific missions are being launched. One of the examples is the GRACE (Gravity Recovery and Climate Experiment) gravity gradient sensor mission that measures minute changes in Earth’s gravity field to pinpoint localised variations in the planet’s density. The GRACE mission is being executed by NASA (National Aeronautics and Space Agency) of USA in collaboration with Germany. Another example is the Jason mission by NASA in partnership with France, which employs a radar altimeter to measure sea surface height to a global average of within 5 cm of its actual value.

Developments in remote sensing technologies have resulted in different kinds of data acquisition methodologies which are known as panchromatic remote sensing, multispectral remote sensing, hyperspectral remote sensing, etc. In the following sub-sections, we will discuss about the kinds of remote sensing and their related developments.

1. **OPTICAL REMOTE SENSING:** Panchromatic imaging systems: This sensor is a single channel detector sensitive to radiation within a broad wavelength range resulting into a black and white image. The physical quantity being measured is the apparent brightness of the targets. The spectral information of the target is lost.

   Examples of satellites carrying panchromatic imaging systems are as follows:
   - Cartosat
   - QuickBird
   - WorldView
   - GeoEye
2. **MULTI-SPECTRAL IMAGING SYSTEM:** This kind of sensor is a multi-channel detector with a more than one spectral band and generally 3 to 7 bands. The resulting image is a multi-layer image which contains both the brightness and spectral information of the targets observed (Fig. 6.2). Examples of multispectral systems are:
   - QuickBird MSS
   - GeoEye MSS
   - IKONOS MSS
3. **SUPERSPECTRAL IMAGING SYSTEM:** Super-spectral imaging sensor has many more spectral channels (typically >10) than a multi-spectral sensor. The bands have narrower bandwidths, enabling the finer spectral characteristics of the targets to be captured by the sensor. Examples of super-spectral systems are:
   - MODIS
   - MERIS
4. **HYPERSPECTRAL IMAGING SYSTEM:** A hyperspectral imaging system is also known as an “imaging spectrometer”. It acquires images in about a hundred or more contiguous spectral bands. The precise spectral information contained in a hyperspectral image enables better characterisation and identification of targets. Hyperspectral images have potential applications in fields such as precision agriculture (e.g., monitoring the types, health, moisture status and maturity of crops),

coastal management (e.g. monitoring of phyto-planktons, pollution, bathymetry changes).

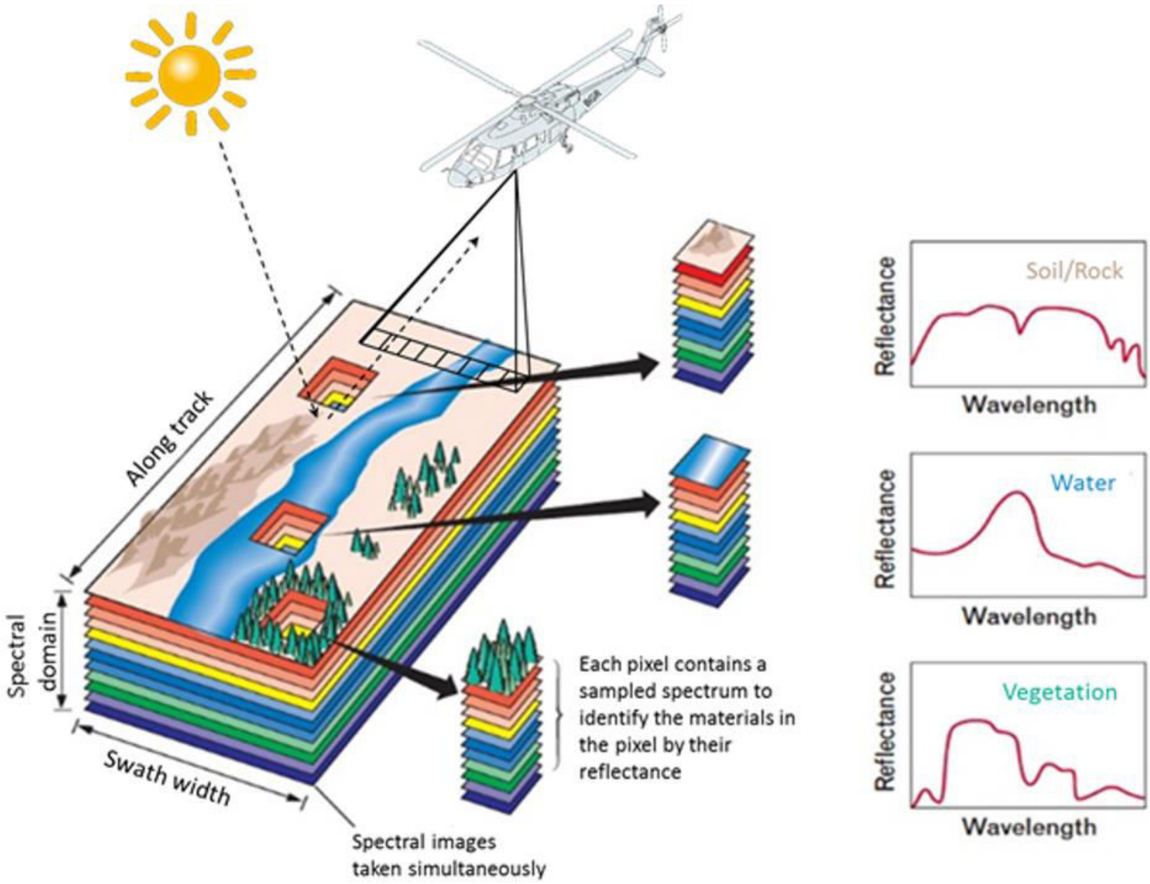

Figure 6.1: Hyper Spectral Remote Sensing

Source: Google

Hyperspectral remote sensing, also known as imaging spectroscopy, is relatively a new technology that is currently being investigated by researchers and scientists with regard to the detection and identification of minerals, terrestrial vegetation, and man-made materials and backgrounds. Imaging spectroscopy has been used in the laboratory by physicists and chemists for over 100 years for identification of materials and their composition. Recently, with advancing technology, imaging spectroscopy has begun to focus on the Earth. The concept of hyperspectral remote sensing began in mid-eighties and since then it has been used most widely by geologists for the mapping of minerals. Hyperspectral remote sensing combines imaging and spectroscopy in a single system which often includes large data sets and requires new processing methods (Fig. 6.1). There are many applications which can take advantage of increased spectral information provided by hyperspectral remote sensing.

• Atmosphere: water vapor, cloud properties, aerosols

- Ecology: chlorophyll, leaf water, cellulose, pigments, lignin
- Geology: mineral and soil types
- Coastal Waters: chlorophyll, phytoplankton, dissolved organic materials, suspended sediments
- Snow/Ice: snow cover fraction, grain size, melting
- Biomass Burning: sub pixel temperatures, smoke
- Commercial: mineral exploration, agriculture and forest production.

MICROWAVE REMOTE SENSING

You have already read that microwave portion of the spectrum i.e. 1cm to 1 m in wavelength is used to acquire the remote sensing information. Longer wavelength microwave radiation can penetrate through cloud cover, haze, dust, etc. This property allows detection of microwave energy under almost all weather and environmental conditions so that data can be collected at any time.

Passive microwave sensing is similar in concept to thermal remote sensing. A passive microwave sensor detects the naturally emitted microwave energy within its field of view. Applications of passive microwave remote sensing are used in the fields of meteorology, hydrology, and oceanography.

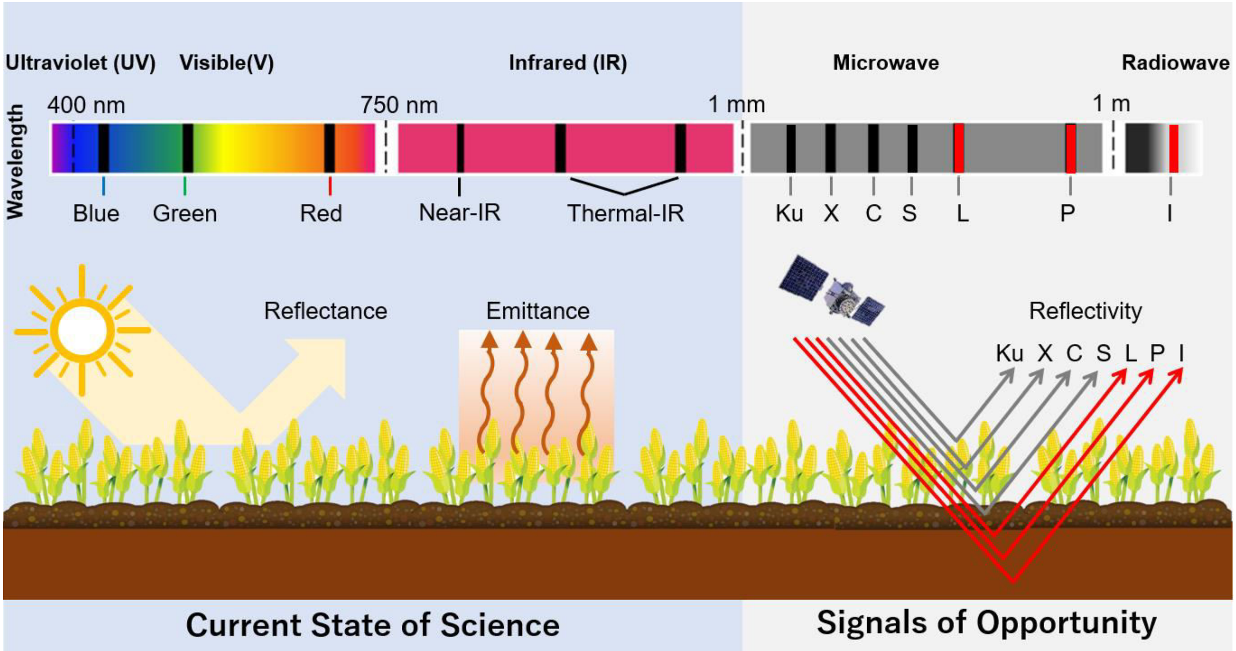

Figure 6.2: Remote Sensing and Electro Magnetic System

Source: Google

Active microwave sensors provide their own source of microwave radiation to illuminate the target. Active microwave sensors are generally divided into two distinct categories: imaging and non-imaging. The most common form of imaging active microwave sensors is RADAR. RADAR is an acronym for Radio Detection and Ranging, which essentially characterizes the function and operation of a radar sensor (Fig. 6.2). This image shows RADARSAT's ability to distinguish different types of bedrock. The light shades on this image (C) represent areas of limestone, while the darker regions (B) are composed of sedimentary siltstone. The very dark area marked A is Bracebridge Inlet which joins the Arctic Ocean.

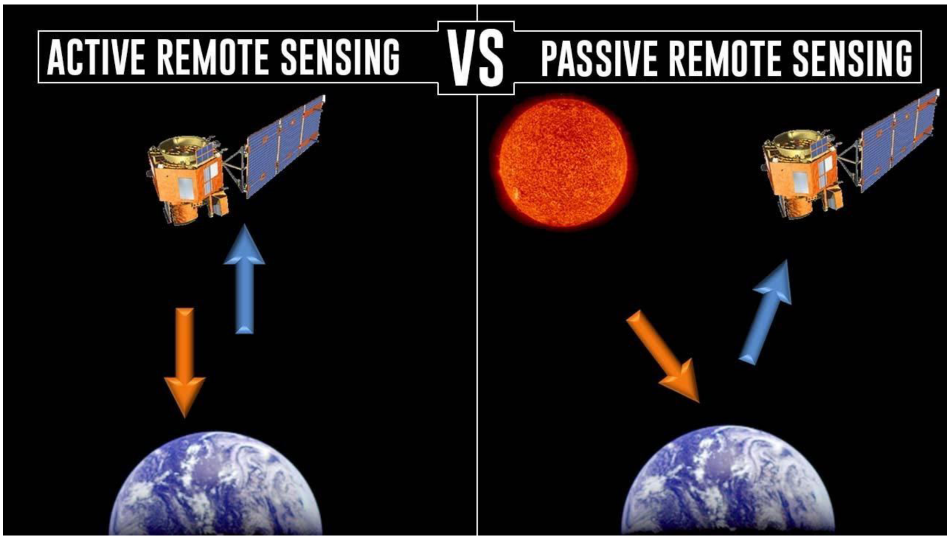

Figure 6.3: Active and Passive Remote Sensing

Source: Google

Non-imaging microwave sensors include altimeters and scatter meters. Generally, altimeters look straight down at nadir below the platform, and thus measure height or elevation. Scatterometers are used to make precise quantitative measurements of the amount of energy backscattered from targets. Seasat-1, ERS-1, ERS-2, ENVISAT-1, JERS-1, RADARSAT-1, etc. are the examples of satellites carrying microwave sensors. Another development is the Synthetic Aperture Radar (SAR) imaging, in which microwave pulses are transmitted by an antenna towards the Earth surface. The microwave energy scattered back to the spacecraft is measured (Fig. 6.4). The SAR makes use of the radar principle to form an image by utilising the time delay of the backscattered signals.

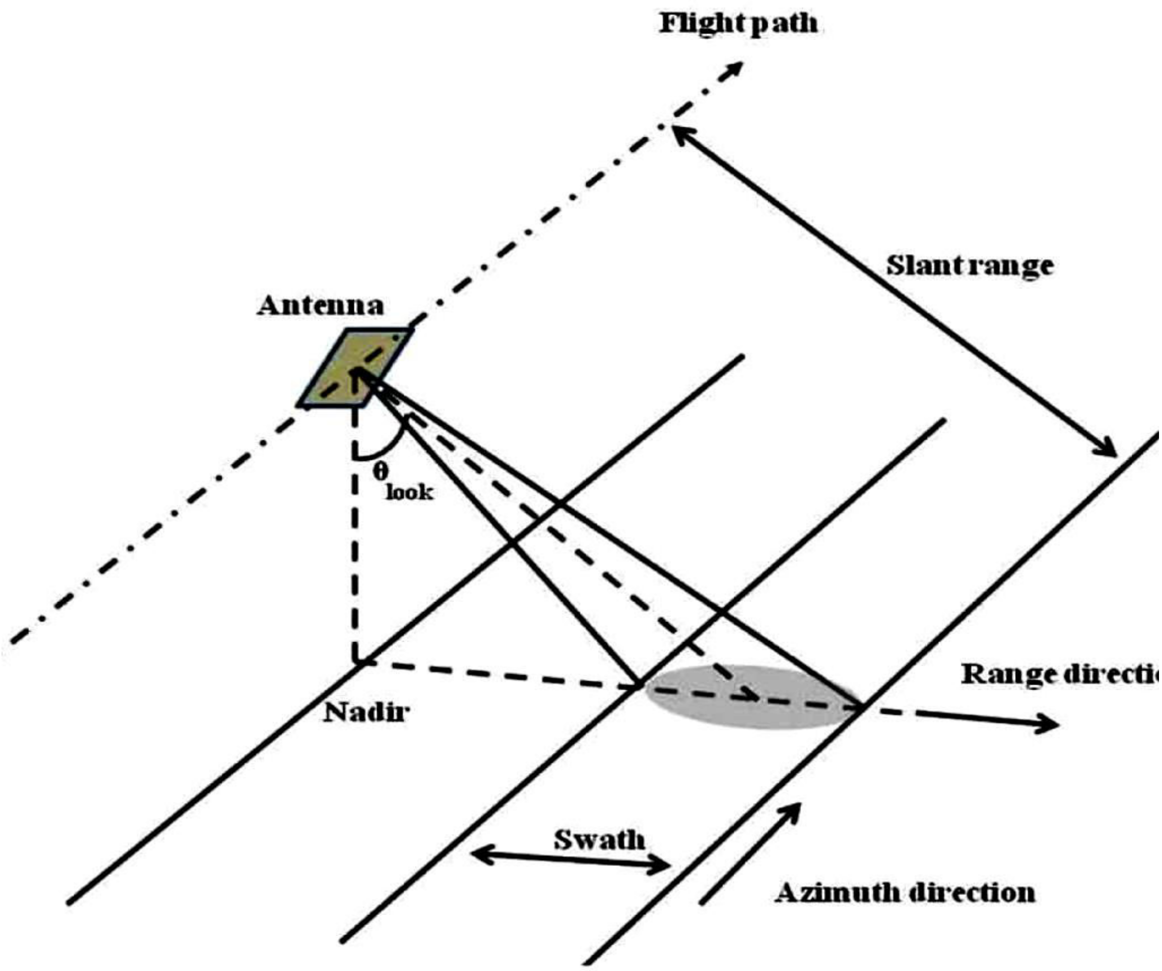

Figure 6.4: Synthetic Aperture Radar (SAR) imaging

Source: Google

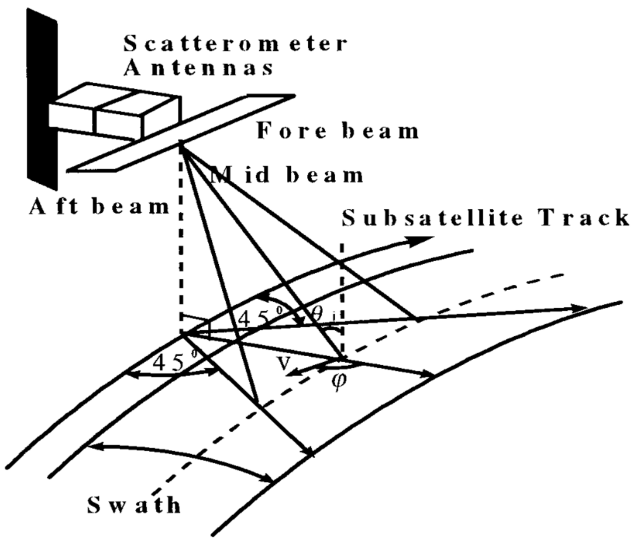

Figure 6.5: Scatterometer in Remote Sensing

Source: Google

THERMAL REMOTE SENSING

Thermal remote sensing is the branch of remote sensing that deals with the acquisition, processing and interpretation of data acquired primarily in the thermal infrared (TIR) region of the electromagnetic (EM) spectrum. In thermal remote sensing, we measure the radiations 'emitted' from the surface of the target, as opposed to optical remote sensing where we measure the radiations 'reflected' by the target under consideration. Thermal remote sensing, in principle, is different from remote sensing in the optical and microwave region. In practice, thermal data prove to be complementary to other remote sensing data. It is unique in helping to identify surface materials and features, such as rock types, soil moisture, geothermal anomalies, etc. The ability to record variations in infrared radiation has advantage in extending our observation of many types of phenomena in which minor temperature variations may be significant in understanding our environment.

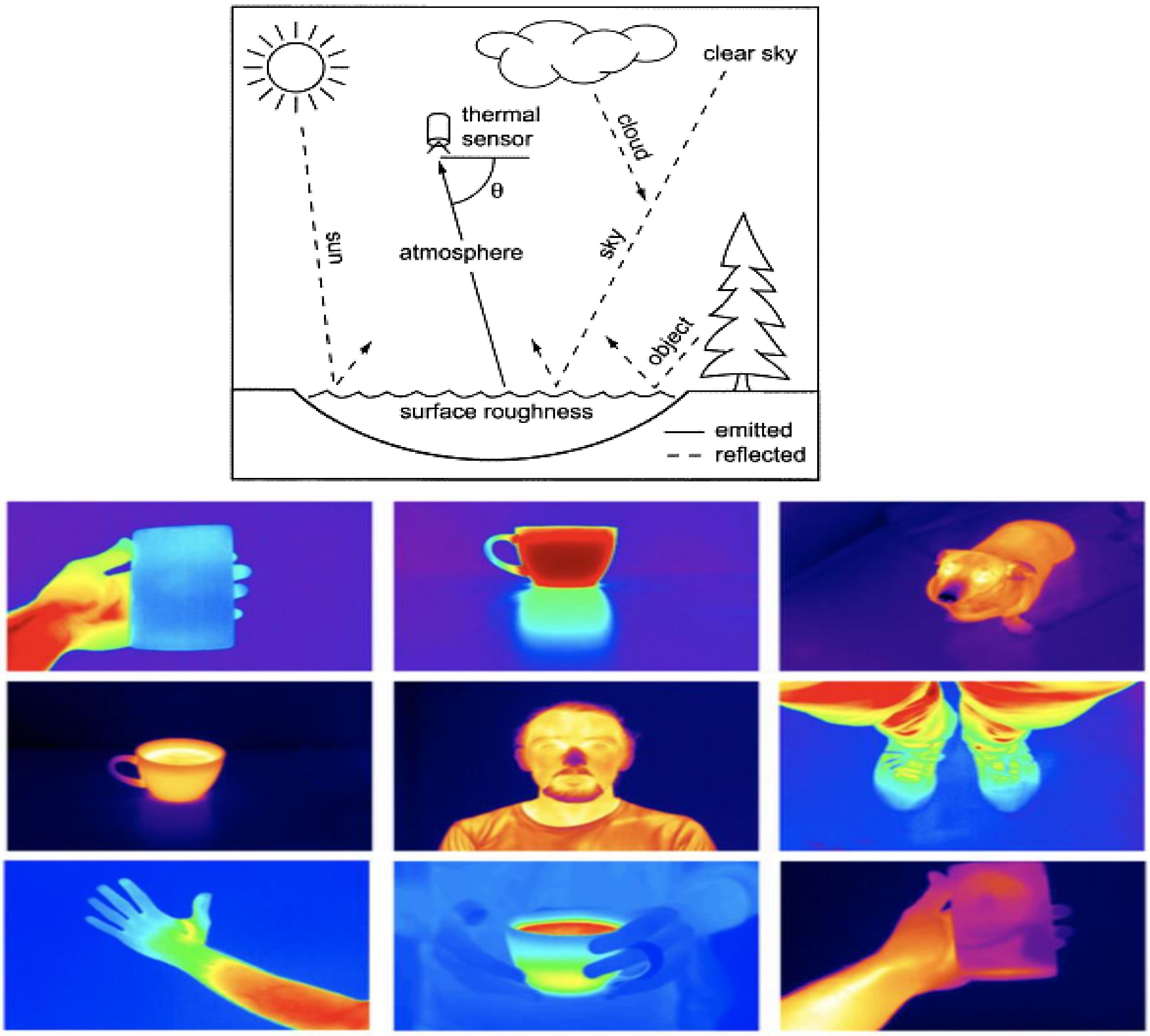

Figure 6.6: Thermal Remote Sensing

Source: Google

3D GIS

3D GIS The land surface has been the object of mapping for hundreds of years and the terrain with its undulating, continuous land surface is a familiar phenomenon to GIS users. Mapmakers have introduced various techniques for displaying 3- dimensional Earth into 2-dimensional maps and GIS outputs which has made it easier to incorporate terrain mapping and analysis into applications ranging from wildlife habitat analysis to hydrologic modelling. Use of 3D in GIS began around a decade back. Now most of the GIS software has the capability to create 3D visualisation complete with landscape objects such as buildings, trees, etc. Fig. 6.7 displays the capability of 3D GIS in visualisation of features. At present, the 3D research area is concerned with issues of 3D structuring and 3D topology.

Figure 6.7: 3D GIS

Source: Google

Web GIS

You have been introduced to Web GIS in various units earlier. The advent of web mapping can be regarded as a major new trend. Earlier, cartography was restricted as it required expensive and complex hardware and software, as well as skilled cartographers and geoinformatics engineers. With web mapping, freely available mapping technologies and geodata potentially allow every skilled person to produce web maps. Web mapping is the process of designing, implementing, generating and delivering maps on the World Wide Web and its products. While web mapping primarily deals with technological issues, web cartography additionally includes theoretic aspects: the use of web maps, the evaluation and optimisation of techniques and workflows, the usability of web maps, social aspects, and more. Web GIS is similar to web mapping but with an emphasis on analysis, processing of project specific geodata and exploratory aspects.

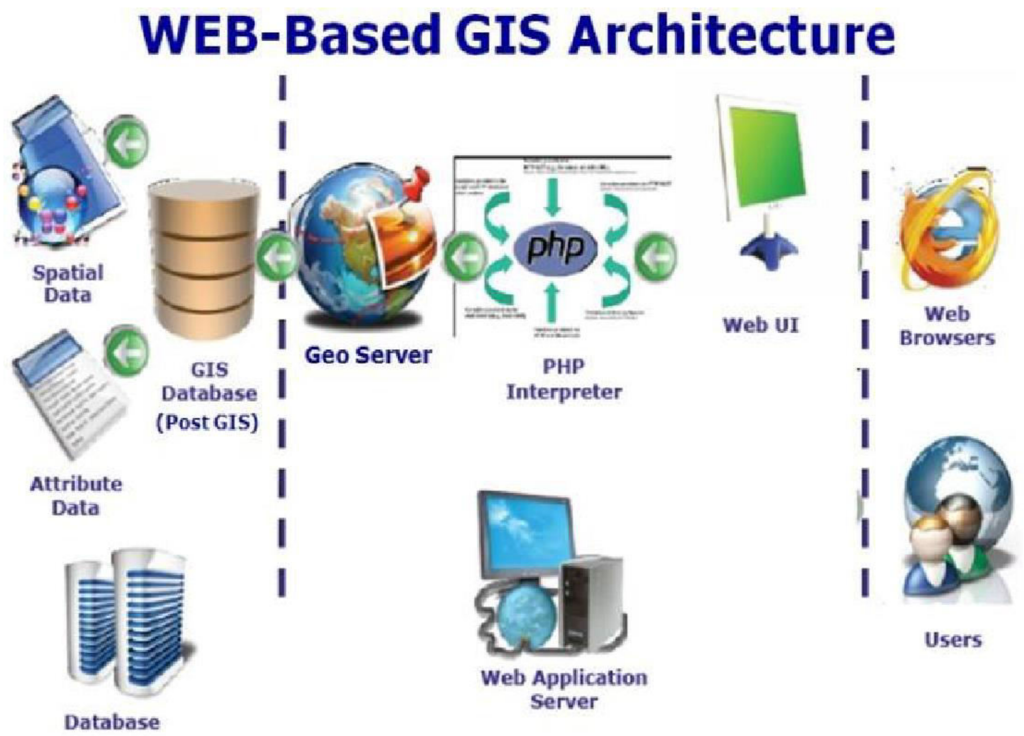

Figure 6.8: Web-GIS

Source: Google

There are various types of web maps, such as analytic, animated, collaborative, customised, distributed, hyper maps, interactive maps, etc. Out of which collaborative web map projects appear to be more popular, such as Google Map Maker, OpenStreetMap, WikiMapia, etc. There are several advantages of web maps. We will mention here about some of them:

- easy delivery of up-to-date information- when the maps are generated automatically from databases, they can display information in almost real-time for example, a map displaying the traffic situation near real-time by using traffic data collected by sensor networks or a map showing locations of vehicles
- availability of software and hardware infrastructure at low cost
- easy distribution of product updates
- web maps work across browsers and operating systems

- capability to combine distributed data sources
- web maps allow for personalisation
- web maps enable collaborative mapping
- web maps support hyperlinking to other information on the web
- easy to integrate multimedia with web maps.

LOCATION BASED SERVICE

Convergence of different technologies, such as wireless networks, internet, GIS and GPS have introduced a new type of information technology, called Location Based Services (LBS). It is developing rapidly in the mobile and IT fields. Advancement of LBS is governed by increased demand and interest in utilising geospatial information through wireless networks. LBS is an information or entertainment service, accessible with mobile devices through the mobile network utilising the ability to make use of the geographical position of the mobile device (Fig. 6.10). LBS can be used in a variety of contexts, such as health, indoor object search, entertainment, work, personal life, etc. LBS include services to identify a location of a person or object, such as discovering the nearest banking cash machine or the whereabouts of a friend or employee. LBS include parcel tracking and vehicle tracking services. LBS can include mobile commerce when taking the form of coupons or advertising directed at customers based on their current location. They include personalised weather services and even location-based games. They are an example of telecommunication convergence. LBS applications are useful for the following tasks: • recommending social events in a city • requesting the nearest business or service, such as an ATM or restaurant • turn by turn navigation to any address • locating people on a map displayed on the mobile phone • receiving alerts, such as notification of a sale on gas or warning of a traffic jam • location-based mobile advertising • games where your location is part of the game play, for example your movements during your day make your avatar move in the game or your position unlocks content. • real-time questions and answers revolving around restaurants, services, and other venues.

MOBILE GIS

The development of versatile computer hardware and software along with the successful implementation of Wireless Application Protocol (WAP) in communication network is a new concept of work on the move. It is easy to see that the integration of geo spatial information and mobile Internet is inevitable. The integrated system is designed to work on mobile intelligent terminals and brings new dimension and at any time and at any place to access geo spatial and attribute information in GIS, which is known as Mobile GIS.

Traditionally, GIS mainly focused its attention on static spatial entity (also known as static GIS or SGIS), the analysis is correlated to position and its attribute, but it does not consider the moving nature of the world, i.e., it cannot record the change of a piece of land in terms of its change in the boundary of the field or the ownershi8p of a field. In 1988, Langram and Chrisman introduced the concept of Temporal GIS (TGIS) where the attention is focused on to a moving spatial object/entity. TSDGIS adds a new dimension in its analysis space i.e., position, attribute, and time. Interestingly, both SGIS and TGIS consider a spatial entity that has a geographical aspect such as a road, mountain top, building, but does not consider a non-geographic entity such as a car, desk or a book. Mobile GIS is a kind of GIS where it considers a non-geographic moving object in geographic space. It identifies a relationship between moving object in geographic entity, or a moving object and another moving object. For example, by integrating GIS, GPS, wireless Internet to build a mobile GIS to monitor cars, the GIS analyst is interested in studying the moving car in geographic entity space, and the moving car is a non-geographic entity.

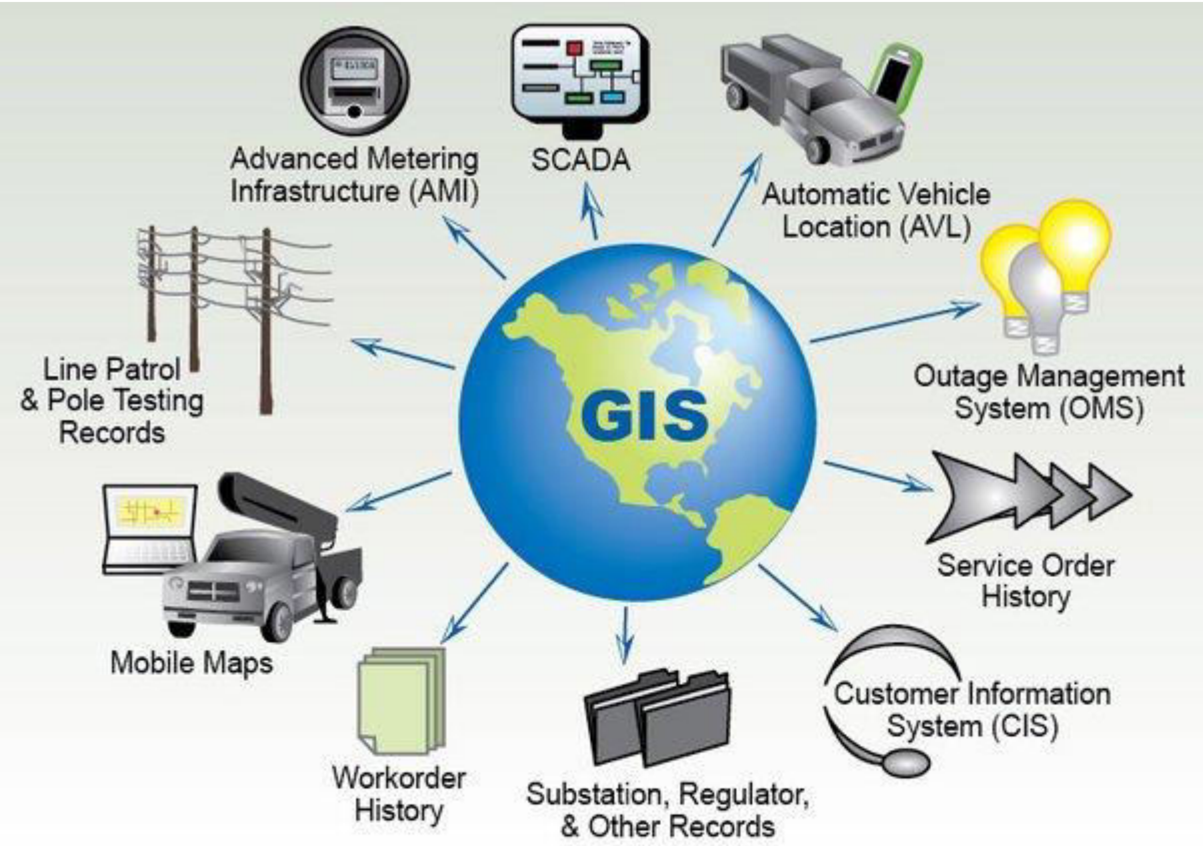

Figure 6.9: Mobile GIS

Source: Google

Mobile GIS is not a modified conventional GIS to operate on a smaller computer, but a system built using a fundamentally new paradigm. It extends unlimited information on the Internet and powerful service functions of GIS to mobile devices to provide mobile users practice and thousands of potential applications. The general architecture of a mobile GIS is an integrated system of mobile client, a server, a wireless network, a mobile client position recording system, such as a SGPS mobile client can be a moving car equipped with GPS that can send information regarding the geographic position to the server by SMS. Alternately, a PDA equipped with GPS can show a digital map, and communicate with the server through a wireless network having GSM. CDMA, CDPP, or GPRS that can support digital data transmission. Mobile GIS can be simply divided into two categories, depending upon the manner by which access to Mobile Internet is done. The one is based on Short Message Service (SMS)/Multimedia Message Service (MMS), while the other is based on Wireless Application Protocol (WAP).

Figure 6.10: Mobile GIS

Source: Google

Hence, WAP-based Mobile GIS has richer information presentation, friendlier GUI, more system functions, and more application files that the former. Moreover, it can work on la wide range of mobile devices with a WAP micro browser only, from Personal Digital Assistants (PDAs), mobile phones, and in-car computers to other small mobile devices. WAP-based Mobile GIS can be as mobile users (with a WAP mobile terminal only). It can perform almost the same functionality as of Internet GIS but in a mobile environment at any place and without the limitation of operating system and wired link. It is expected that because of the advantages of WAP, the WAP-based Mobile GIS will play a leading role immobile information services market.

Mobile GIS is a mapping technology for resource managers and other field workers to visualise and improve their field-based management and research tasks. With mobile GIS, field workers may capture spatial data directly in the field and, with access to a wireless communication network; the data can then be remotely transferred in real time to the central database back at the company office. Mobile GIS is especially important in emergency situations and natural disasters when emergency workers, such as fire-fighters (Fig. 6.11), need to have access to the most current and accurate information in order to make decisions about people's lives and the health of the environment.

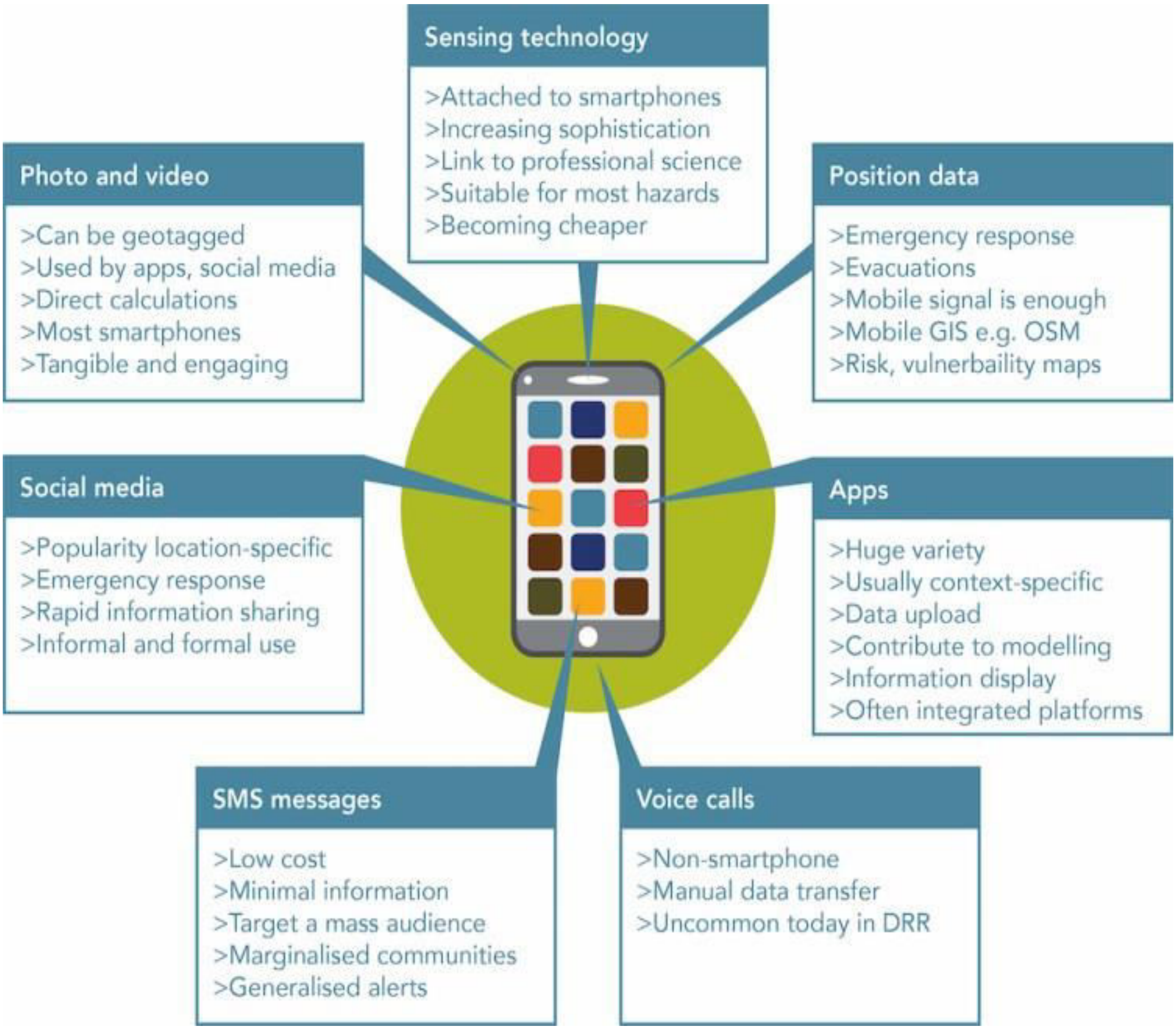

Figure 6.11: Application of Mobile GIS in Disaster Management

Source: Google

Disasters are events that cause misfortune, damages, and adverse effects on property and environment of human beings. Disaster is defined as an abnormal condition of the environment which can exert a serious and damaging effect on human, animal and plant life beyond a certain critical level of tolerance (Barrett and Curtis, 1982). However, it is difficult to define the critical level of tolerance since it involves considerable knowledge on various aspects including economic conditions and human psychology. Some of the disasters that occur world-wide on a regular basis are earthquake, floods, cyclones, avalanche, landslide, tsunami, drought, forest fire etc. Internet / Mobile GIS helps in disaster preparedness by providing repetitive and synoptic up to date information on the locally available resources and by facilitating the forecast of the event in time so that alternative arrangement could be provided. Disaster prevention measures can be improved through this technology in these ways (i) mapping the disaster-prone areas (ii) predicting / forecasting of impending disasters, and (iii) monitoring the phenomena to predict their onset and progress.

ENTERPRISE GIS

Enterprise GIS is a geographic information system that is integrated through an entire organisation so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs, including data creation, modification, visualisation, analysis, and dissemination. Enterprise GIS has evolved over a period of time and especially during last five-six years. Most of the leading GIS vendors have had components that constitute an Enterprise GIS for long time but the efforts to have them all packaged together and provide an end-to-end solution picked up fast pace in the recent times. To put it in simpler terms, an Enterprise GIS should be capable of: • supporting huge number of simultaneous transactions • integrating with other Enterprise Systems (such as SAP, Billing Systems) • comply with Open Geospatial Consortiums (OGC) Standards to enable easier integration with other systems • displaying data in the same way (styles/symbols) for Desktop, Web and Mobile users • preferred reusable functionality across Desktop, Web and Mobile platforms.

THE ROLE OF SDI AND WEBGIS IN DISASTER MANAGEMENT

Although a partnership model for spatial data collection and sharing can resolve the problem with collection, access and dissemination of required spatial data for disaster response, relevant research into collaborative efforts in spatial data production, sharing, and exchange shows that there are different technical (such as standards and interoperability models) and nontechnical (such as social, cultural, and institutional) issues that create barriers for such participation. SDI is a framework for resolving such problems. SDI is fundamentally about facilitation and coordination of the exchange and sharing of spatial data between stakeholders from different jurisdictional levels in the spatial data community. One of the fundamental applications of SDI can be in emergency management. SDI is an appropriate framework to facilitate the collaboration in spatial data collection and sharing among the parties involved in emergency management.

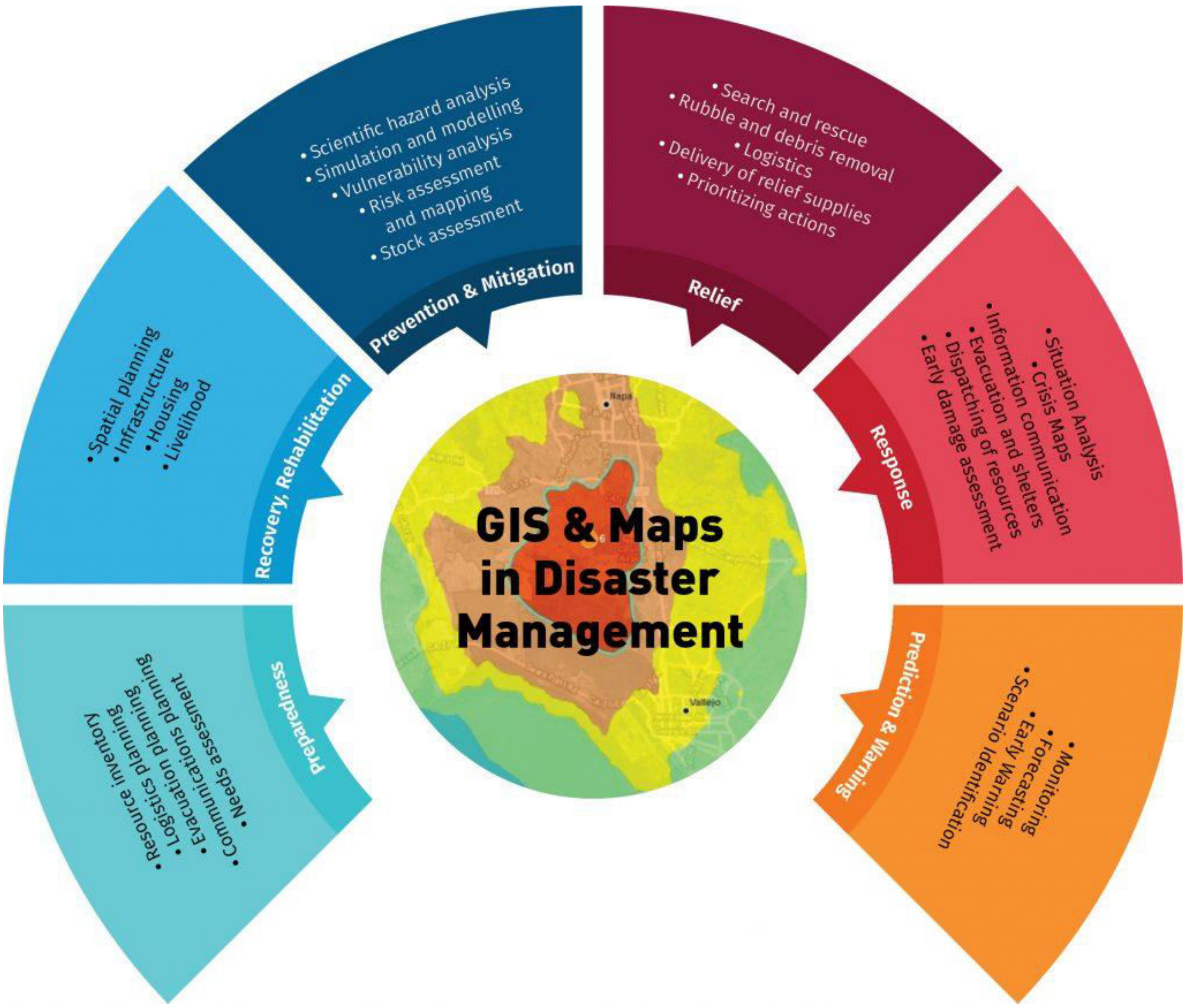

Figure 6.12: GIS and Disaster Management

Source: Google

Mansourian (2005) could improve emergency management by developing an SDI conceptual model and a web-based GIS as an integrated framework to facilitate spatial information management. On the basis of this developed model and system, each of the involved organizations in emergency management is in charge of collection and updating some part of required spatial data based on its responsibility during disaster response. The collected data is stored in the custodian's database. There is also a database in the EOC where representatives of involved organizations are gathered to coordinate disaster response operations and control the general emergency situation. Some parts of the general and base datasets are regularly copied from organizations' databases into EOC database after any data entry or updating through a replicate mechanism. In EOC, representatives of organizations have access to EOC database through a web-based GIS which can be based on a Local Area Network (LAN). Having access to EOC database, EOC is aware of the latest status of emergency situation for general planning, coordinating the response process and controlling the situation.

Figure 6.13: GIS and Disaster Management Process

Source: Google

At the same time, each organization has access to EOC database through a web-based GIS to use base information in EOC database besides their own specific information. This accessibility explains the concept of sharing spatial information. Emergency management organizations will have coordinated response operations while using spatial information in EOC database. In this way, SDI with related concepts and models, can be used as a framework for creating such an environment and consequently, facilitating disaster management. The SDI conceptual model developed for disaster management, appoints to a set of requirements (standards, policies, access network, people and data), while being supplied in emergency management, the concept of partnership and coordination will be provided during the emergencies. Based on the mentioned SDI conceptual model, similar to volunteer bodies that are trained for relief and rescue operations, specific staffs in each organization and volunteer bodies should be trained for spatial data collection during an emergency. Infield data collection while moving in the emergency area and the need to real time updating of EOC database brings mobile GIS as an appropriate data collection tool into front.

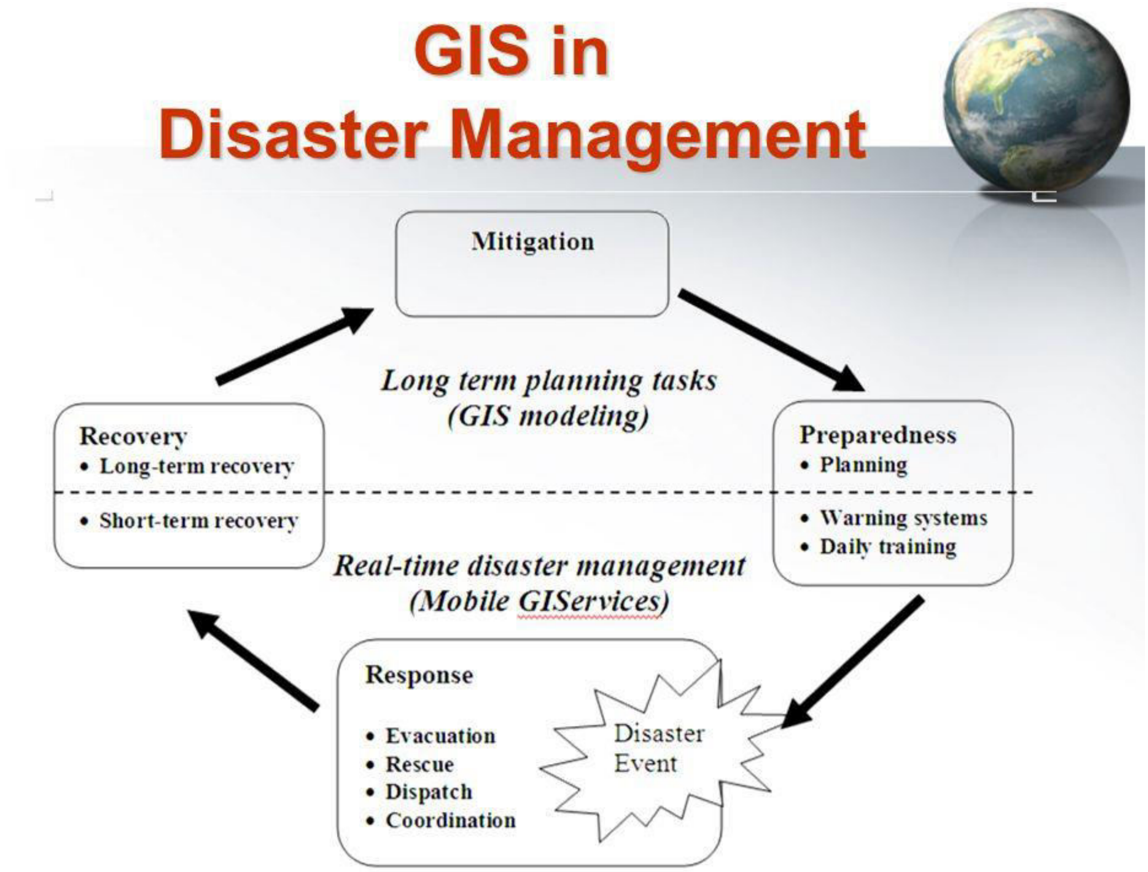

Figure 6.14: GIS in Disaster Management

Source: Google

THE ROLE OF MOBLIE GIS IN EMERGENCY MANAGEMENT

The Role of Mobile GIS in Emergency Management Mobile GIS is a movable GIS that makes spatial data acquisition, storage, sharing and analysis in every time and everywhere possible for users. In mobile GIS, not only data are movable but also hardware and software are. This characteristic makes mobile GIS an efficient technology in managing spatial data, particularly in emergency management. Mobile GIS has two fundamental applications in emergency management: · As mentioned earlier, mobile GIS facilitates infield data collection and real time updating of EOC database. Collected data can be about location of victims, burning buildings, closed routes, etc. Using mobile GIS emergency workers can access to EOC database which represents current status of emergency situation. Mobile GIS provides the capability of analysing these data to make the best infield decisions for emergency operations. Finding the best path to get into specific destinations and priorities emergency operations based on current situation are two examples of this analysis.

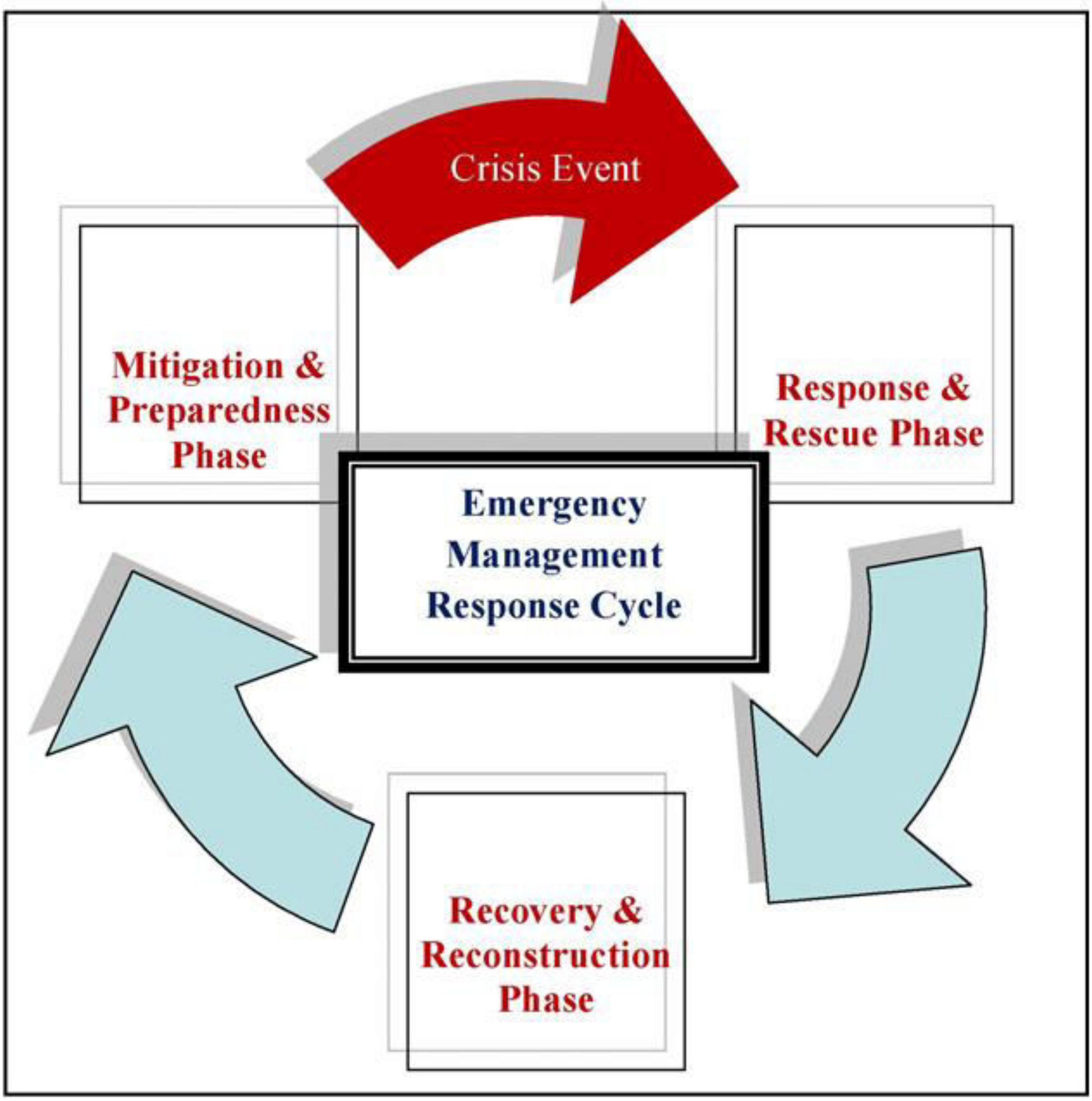

Figure 6.15: Emergency Management through GIS

Source: Google

Many parameters should be considered while designing a mobile GIS for a specific application especially for emergency management. One of them relates to the architecture of the system. Generally, there are 5 different architectures for mobile GISs.

- Stand Alone Client: This is the simplest mobile GIS architecture. In this architecture geodata, mobile GIS software and the customized application reside entirely on the client that is a mobile device.
- Client Server: Here the geodata is moved to a separate computer and served to the client by GIS server software through a wireless network. However, dependency of this system to the continuous connection between client and server reduces its flexibility. In other words, if the connection fails, the mobile GIS will no longer work.
- Distributed Client Server: Similar to previous architecture, geodata is stored in the server but some parts of information are also stored into mobile device. In this architecture, the mobile GIS (client) is usable even if being disconnected with the server. When the mobile device is connected to the server again, the data is synchronized with the server.
- Services: This architecture views the GIS server as a web service and allows for other web services to be part of the application as well. As long as these web services use the same communications protocol, the mobile device(s) can communicate with all of them. Furthermore, the web services can also communicate between themselves.
- PeertoPeer: In this scenario, a peertopeer architecture will allows for communication between mobile devices. Each mobile device will store a part of information so that the requirement to a server will be removed.

For the mobile GIS in emergency management one or a composition of these architectures should be chosen. Wireless network is another issue that should be examined in the context of mobile GIS. Nowadays wireless environment has been propounded as one of the most important human's inventions not only in GIS but also in many other sciences and technologies. Wireless network is the most important infrastructure that is required for implementation of mobile GIS in emergency management to provide online communication between emergency workers and EOC. Technical specifications of the network should be planned in accordance with the existing facilities in the country. Wireless networks have passed several generations in recent decades but still have some limitations compared to wired networks. These limitations consist of low bandwidth, inconsistent connectivity and transmission latency. In the context of emergency management, mobile environment should be considered from two aspects: the size of the network and the used protocol. The size of wireless networks can be personal (WPAN), local (WLAN) and wide (WWAN). Each of these has its specifications that should be considered under the emergency situation but generally the size of network has a direct relation to the extent of incident. Therefore, different network architectures should be considered with respect to extent and levels of emergencies. In addition, the efficiency of networks strongly depends on the used protocol. So, it should be considered which protocol has more compatibility with the emergency management specifications.

MOBILE GIS AND CRISIS MANAGEMENT

The ever-expanding role of emergency managers requires systems and solutions that help agencies provide quick response to frequent and systemic threats and hazards. emergency management operations solutions provide a set of real-time, configurable apps designed to support your mission-critical decision-making. Maintain situational and operational awareness, quickly analyse the incident impact, assess the damage, deploy resources, and engage the public with GIS maps built to scale. From a software architecture point of view, the system has two main groups of software packages: mobile GIS client applications and mobile GIS Web services. It is obvious that organizations involved in emergency response, may develop some mobile GIS Web services and some mobile GIS client applications, based on their own requirements. Since, there are several applications required for emergency management, in this research, a prototype system based on a predefined scenario and application was developed, that satisfied fire organization. Based on the scenario, fire organization as one of the participating organizations in emergency response is going to present following functionalities to its firefighters in the operation area:

- The ability to view a map that contains buildings, road network and important buildings such as gas stations, hospitals, schools, etc.
- The ability to determine a firefighter`s location and showing the location on the map to him/her.
- The ability to present up-to-date spatial data about the burning area to the firefighter in the field.
- The ability to update the database of fire organization after finishing an operation.
- The ability to use the municipality data about the closed roads.

- The ability to find optimum path from current location to the burning area, based on usable roads.

In order to develop a prototype system based on described functionalities the system was split into three distinct packages:

- Mobile GIS client application: Provides firefighter with an interface to interact with the system;
- Firefighting Web service: Is a web service, which is responsible for delivering information about burning area to firemen. Also, the service is responsible for receiving the information of firefighter about their finished operations and updating the database of fire organization by that information.
- Road network Web service: A web service, which is located at the municipality and is responsible to distribute the information about closed roads during an emergency. It also provides users with optimum path finding analysis.

In fact, many challenges exist for developing the mentioned packages: (i) the Web services have to provide information and functionalities for mobile devices over the wireless network and (ii) the mobile GIS client application have to be run over a restricted resource hand-held device. The first problem relates to the wireless network. As mentioned earlier, a variety of wireless networks are available now, each of which has unique characteristics that make it appropriate for specific applications. Meanwhile, mobile GIS system should address many issues with respect to wireless network characteristics including:

- Network coverage: Mobile devices do not have network connectivity everywhere at all times.
- Latency: Wireless network connections are slow and some are slower than others. Few wireless connections achieve their advertised bandwidth and also there are still errors in connections that increase the latency.
- Power: Wireless networks consume power at a voracious rate. For every bit of information transmitted or received, an amount of power is consumed.
- High costs: Wireless usage rates are expensive. Other than fixed costs of an enterprise WLAN, wireless network access involves a service provider who may charge by the minute, by the amount of bandwidth used, or through a flat rate.

Considering the mentioned issues, most mobile applications today adhere to one of the two distinct possibilities:

- Systems in which client applications require an always on network connectivity and
- Systems that function properly without the wireless network at all, but simply synchronize their data through a network-connected PC.

In general, both of these systems fail to satisfy the requirements of emergency worker in the defined scenario. Mobile GIS client applications, based only on offline synchronization capabilities, do not leverage wireless connectivity to provide real-time access to the most up-to-date information of the organizations. On the other hand, Mobile GIS client applications that heavily use the wireless network provides real-time access while decreasing application latency and increasing usage costs. Therefore, in this research an intermediate approach was adopted to develop the proper system for emergency management. This intermediate approach has following characteristic:

1. The mobile GIS client application is designed in the way that it can handle some of the requirements of the emergency workers, independent of Web service of fire organization. The client application has most of the important data about the operation area including buildings, road networks and important. The client application also is capable of showing the workers current position on the map using an intrinsic GPS receiver of the hand-held device. The application also has simple GIS functionalities such as zoom, pan, identify etc. The mobile client with these functionalities can provide emergency workers with some part of information in different situations without the need to a wireless connection to the firefighting or municipality services.
2. The mobile GIS client is capable of using firefighting Web service to retrieve the information about burning area and show this information on the map. Additionally, emergency workers can update the database of fire organization thorough the mobile GIS application and firefighting Web service. These functionalities are accessible only if the connection to wireless network is established and worked in a proper manner.

3. The mobile GIS client also is capable of using road network Web service of municipality to show the closed roads on the map. This functionality is accessible only if the connection to wireless network is established and worked in a proper manner as well.
4. The firefighting Web service uses transactions in order to update databases of fire organization. Therefore, if the connection between the server and the client is broken the database will not affect and the user should start over database updating; as there is no real means of saving information prior to a transaction completing.

Another problem for developing mobile GIS systems is that hand-held devices have limited resources dictated by their power and size constraints. Therefore, for developing the mobile GIS system, the simple functionalities are implemented at the mobile GIS client application and the more complex ones such as network analysis are implemented at the Web services. Mobile GIS can be exploited as a tool, which provides emergency workers with the ability to update required data for emergency management, particularly in response phase. Also, mobile GIS with the ability to access required spatial data can support in-field decision making of emergency worker.

Considering the specific characteristics of hand-held devices and wireless networks as well as requirements of emergency workers, in this study Web services was suggested as the appropriate technologies that can facilitate the development of suitable mobile GIS system for emergency management. Web services allow a part of mobile GIS system`s business logic to run on servers, independent of the mobile device`s computational resource limitations. Web services provide a variety of mobile devices with effectively access to the same functionality or business logic on remote servers. By implementing Web services on the servers of emergency management organizations, client applications on the hand-held devices of emergency workers can access the services of different organizations and therefore use different functionalities and data which are provided by other organizations.

In order to evaluate the usefulness of using Web services technologies for developing mobile GIS system for emergency management, a general architecture for mobile GIS system for emergency management was proposed and a prototype system based on the proposed architecture was developed. The prototype system was developed based on a defined scenario for firefighters in fire organization.

Using the developed system, firefighters can access to some basic functionalities and data of the area. Additionally, they can access up-to-date data about burning area from the Web service of fire organization. They can access to the most up-to-date data about closed roads using the Web service of municipality. The Web service of municipality also provides firefighters and emergency workers of other organizations with the ability to find the shortest path to a destination with respect to the open and closed roads during the emergency.

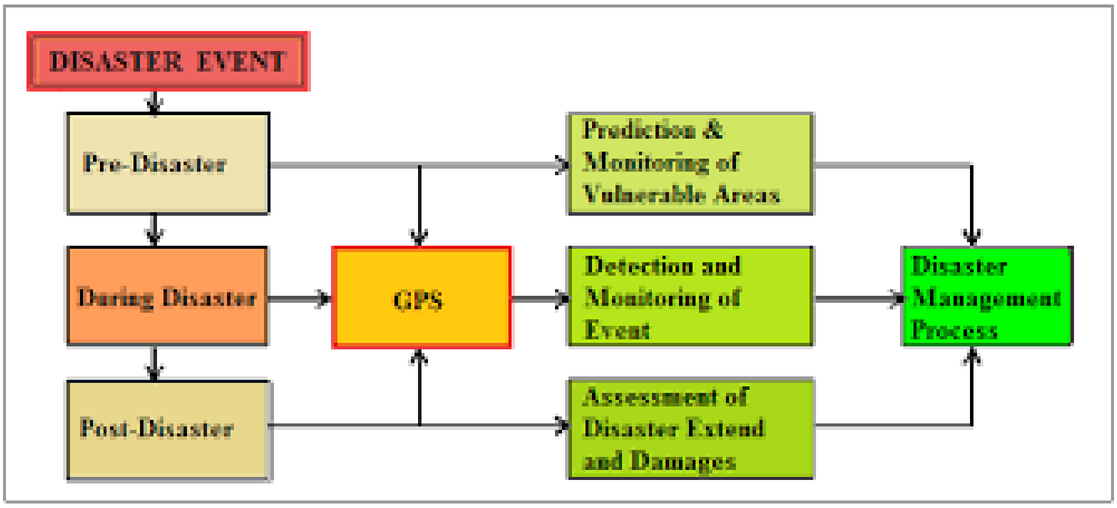

Figure 6.16: Application of GPS

Source: Google

ADVANCEMENT IN GPS

As per World GPS Market Forecast, the technology is fast gaining acceptance worldwide, as it is penetrating into previously untapped areas. Some of the notable trends and advancements in the field of GPS are listed below:

1. Introduction of GPS in civilian domain
2. Developments of methods and techniques to improve accuracy for civil applications, which has widened GPS applications in various land, water, air and space applications, including cellular telephony, geofencing, geotagging, etc.
3. The first handsets with integrated GPS were launched in the late 1990s. Disaster relief/emergency services depend upon GPS for location and timing capabilities.
4. In military, the GPS technology is utilised from reconnaissance to target tracking to missile and projectile guidance purposes. GPS satellites which carry a set of nuclear detonation detectors form a major portion of the United States Nuclear Detonation Detection System.

5. Enhancement in global coverage for GPS signals possibility of precise measurements with introduction of differential GPS.
6. Availability of wide range of GPS receivers with varying capabilities and processing speeds.
7. Availability of range of GPS receivers at reduced size and cost.
8. Greater real time applications.
9. Development and availability of improved user-friendly software for GPS receivers.

6.4 SUMMARY

Remote sensing sensors broadly cover optical, hyperspectral, microwave and thermal sensors. The data collected using the above-mentioned sensors become an input for various GIS mapping and customisation. Every sensor is unique in its application where they are put in to best use to most of the Earth resource applications. On the other hand, GIS in its advanced stage, and day-to-day utility, like 3D GIS, Web GIS, Mobile GIS, LBS, Enterprise GIS, and GIS customisation have been briefly elaborated to give the learner a flavour for the subject with some practical applications to try out as part of their on-going project. Global Positioning System (GPS) provides reliable positioning and navigation services on a worldwide basis at any point of time. GPS has undergone many notable developments in this field. There are many issues and challenges in the field of geoinformatics. It is high time that mankind should make use of sustainable space technologies to the very survival and to take it forward to our future generations. You have also learnt about potential applications of space technologies through integrated approach, such as GIS & RS in combination with GPS.

Some of the developments and trends observed currently at Indian and global levels are listed below:

- training and education in geoinformatics were earlier restricted to few selected disciplines and were later included in many other disciplines. It has now been realised that multidisciplinary education in information technologies, management, and space technology can increase employment opportunities.
- earlier, there were only few institutes and universities, which were offering educational and training programmes related to geoinformatics. Now many universities and institutes are offering such programmes.
- the range of programmes being offered vary from appreciation level (from few days to few weeks duration) to certificate levels (from few weeks to few months duration)

to diploma (of few months) to masters (from ~one year to ~three years) to doctoral levels • in comparison to the past, there are many choices one can make with regards to the level of programmes, depending upon the preference of learners with regard to location of institute, cost of programme, level and mode of programme, etc.

- focus has shifted from just developing professional and technical skills of learners to expose learners to modern tools and technologies and also to update their knowledge in specific application areas and domains.
- education and training is now also being imparted by adopting other modes, such as open and distance learning including e-Learning with interactive lecture/education materials and hands on exercises along with the use of internet medium to conduct online test and examinations. The use of e-Learning enables enrolment of working professionals as their time and possibility of attending courses are limited.
- due to the above efforts, geoinformatics technicians and professionals are comparatively more readily available in the market in comparison to the past

6.5 GLOSSARY

- 3D GIS-3D Geographic Information Systems (3D GIS) are systems for structuring and managing 3D spatial data and are capable of handling 3D geometry structures and performing onto them basic spatial analysis functionalities of a GIS.
- Web GIS- Is a technology that is used to display and analyse spatial data on the Internet. It combines the advantages of both the Internet and GIS.
- Mobile GIS - is taking Geographic Information Systems out of the office and into the field. A mobile GIS allows folks out in the field to capture, store, update, manipulate, analyse, and display geospatial data and information.
- Enterprise GIS- As a Noun, Enterprise GIS is "A geographic information system that is integrated through an entire organization so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs, including data creation, modification, visualization, analysis.

6.6 ANSWER TO CHECK YOUR PROGRESS

1) Digital photogrammetry is characterised with the use of digital images or scanned photographs as input data, correlation techniques, and availability of digital cameras, satellite imagery, and automation of some processes performed by operators.

2) Web GIS, Open GIS, 3D GIS.

3) Location Based Services (LBS) is an information or entertainment service, accessible with mobile devices through the mobile network utilising the ability to make use of the geographical position of the mobile device

ACTIVITIES FOR STUDENT

1) If you are living in a metro city then you know that traffic congestion is the biggest transportation issues facing cities. If you have won a project to use the high-resolution satellite imagery and GIS to identify the bottleneck areas and come out with a comprehensive traffic management plan. Here, you have a task to prepare entire road network, bridges, median, traffic island, signals, pedestrian crossing, accident spots, bus terminal, bus stops, etc. How do you plan to do this?
2) Government is on a massive drive against encroachment of settlements on lakes and rivers. In this connection, they are planning a demolition drive based on the individual house level details overlaid on high resolution satellite imagery. Here, how would you differentiate the buildings which are legal and illegal? Apply your real world knowledge and demonstrate.

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6.8 TERMINAL QUESTIONS

1) Discuss in brief some of the notable developments in remote sensing satellites.

2) What are the applications which can take advantage of hyperspectral remote sensing?

3) How Web Mapping is useful during natural disaster?

4) Discuss some of the notable trends and advancements in the field of GPS.

BLOCK 3 : APPLICATIONS OF GEOINFORMATICS IN URBAN AND INFRASTRUCTURE

UNIT 7 - CONCEPT OF URBAN AND REGIONAL PLANNING, URBAN LANDUSE PLANNING AND CLASSIFICATION SYSTEMS AND INFRASTRUCTURES

7.1 OBJECTIVES
7.2 INTRODUCTION
7.3 CONCEPT OF URBAN AND REGIONAL PLANNING, URBAN LANDUSE PLANNING AND CLASSIFICATION SYSTEMS AND INFRASTRUCTURES
7.4 SUMMARY
7.5 GLOSSARY
7.6 ANSWER TO CHECK YOUR PROGRESS
7.7 REFERENCES
7.8 TERMINAL QUESTIONS

7.1 OBJECTIVES

After reading this unit you should be able:

- To understand urban and regional planning.
- To explore land use and landcover mapping and planning using remote sensing and GIS.
- To discover and map urban 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 manifestation 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 URBAN AND REGIONAL PLANNING, URBAN LANDUSE PLANNING AND CLASSIFICATION SYSTEMS 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 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.

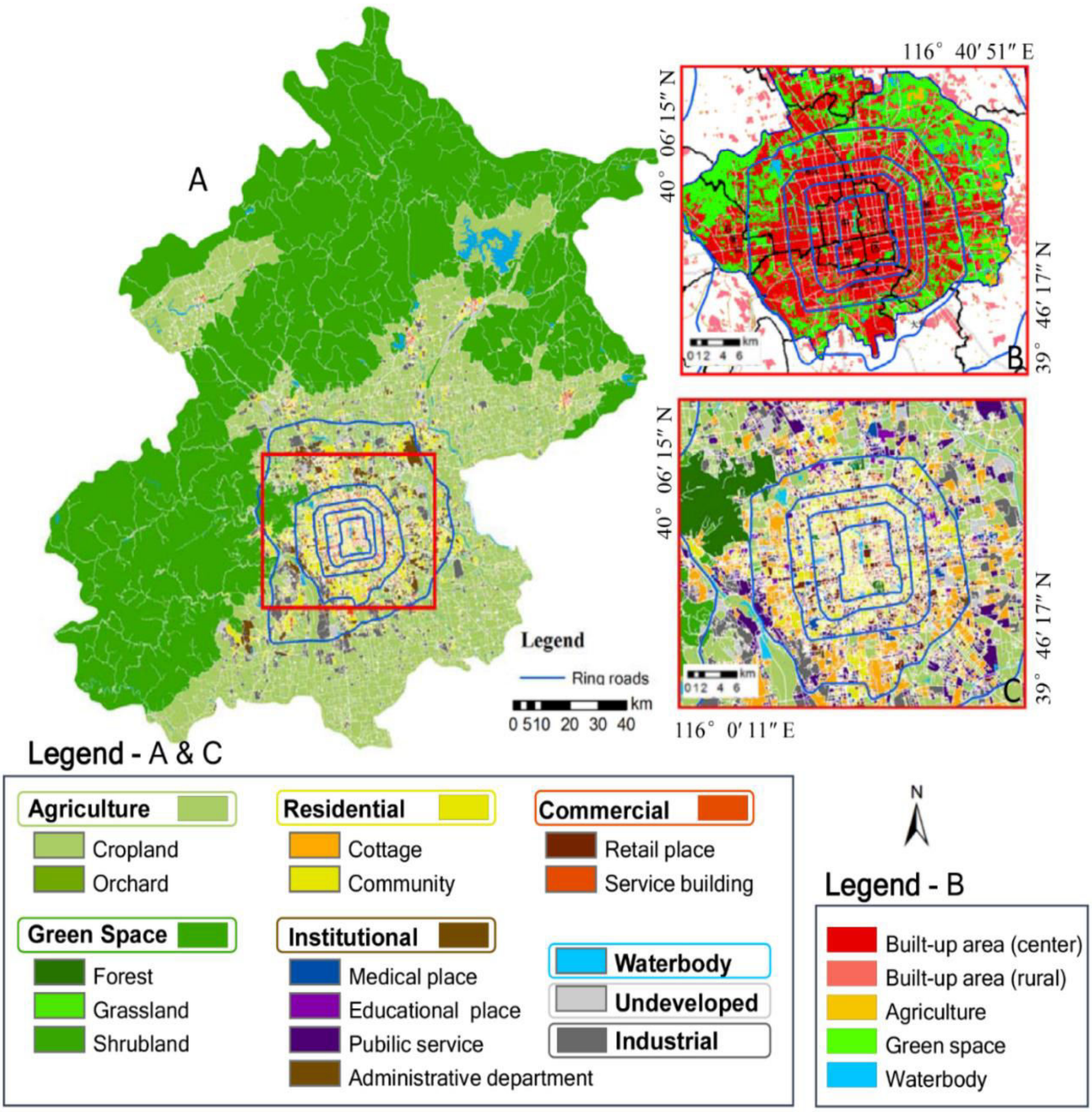


Figure 7.1: Mapping Urban Land Use using Remote Sensing Data

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 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.

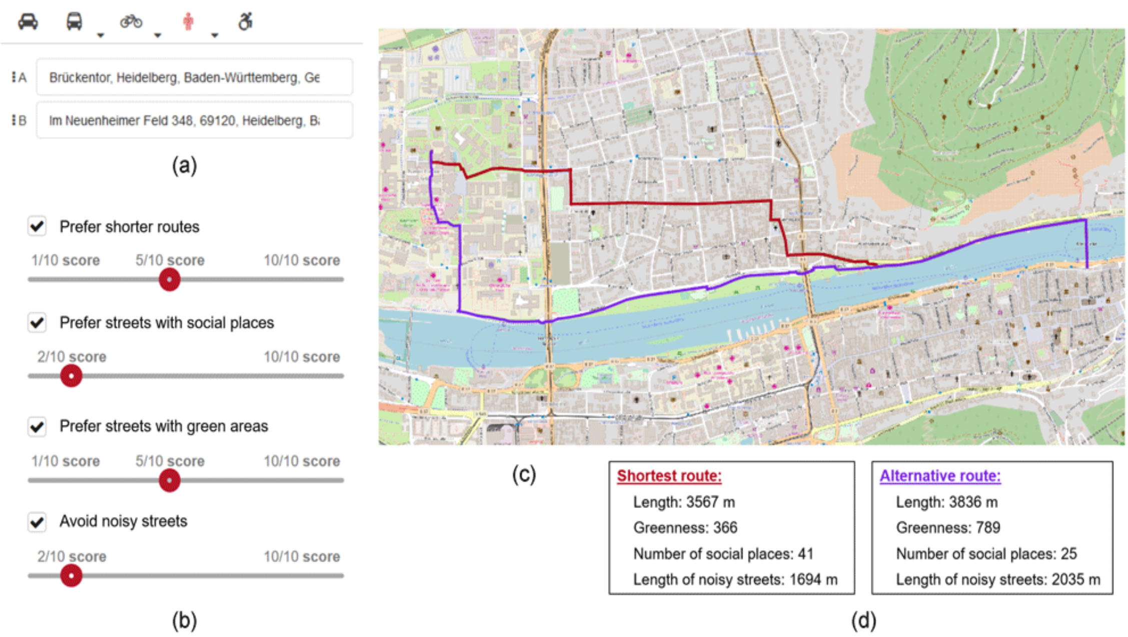


Figure 7.2: Travel Route Finding and Pleasant Route-Finding Using GIS

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.

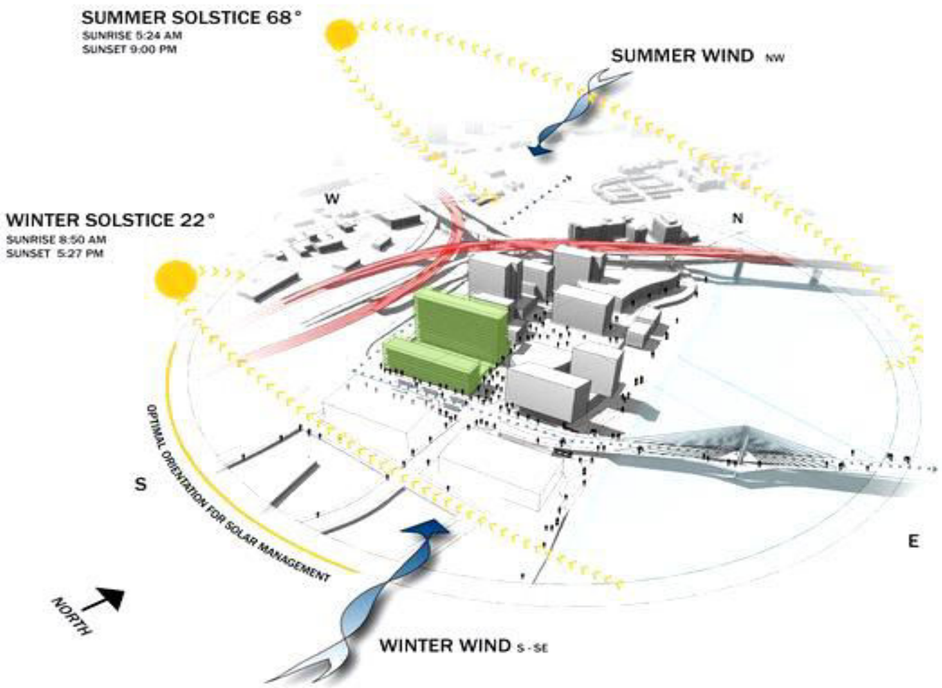


Figure 7.3: Urban Environmental Analysis using Geospatial Technologies

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".

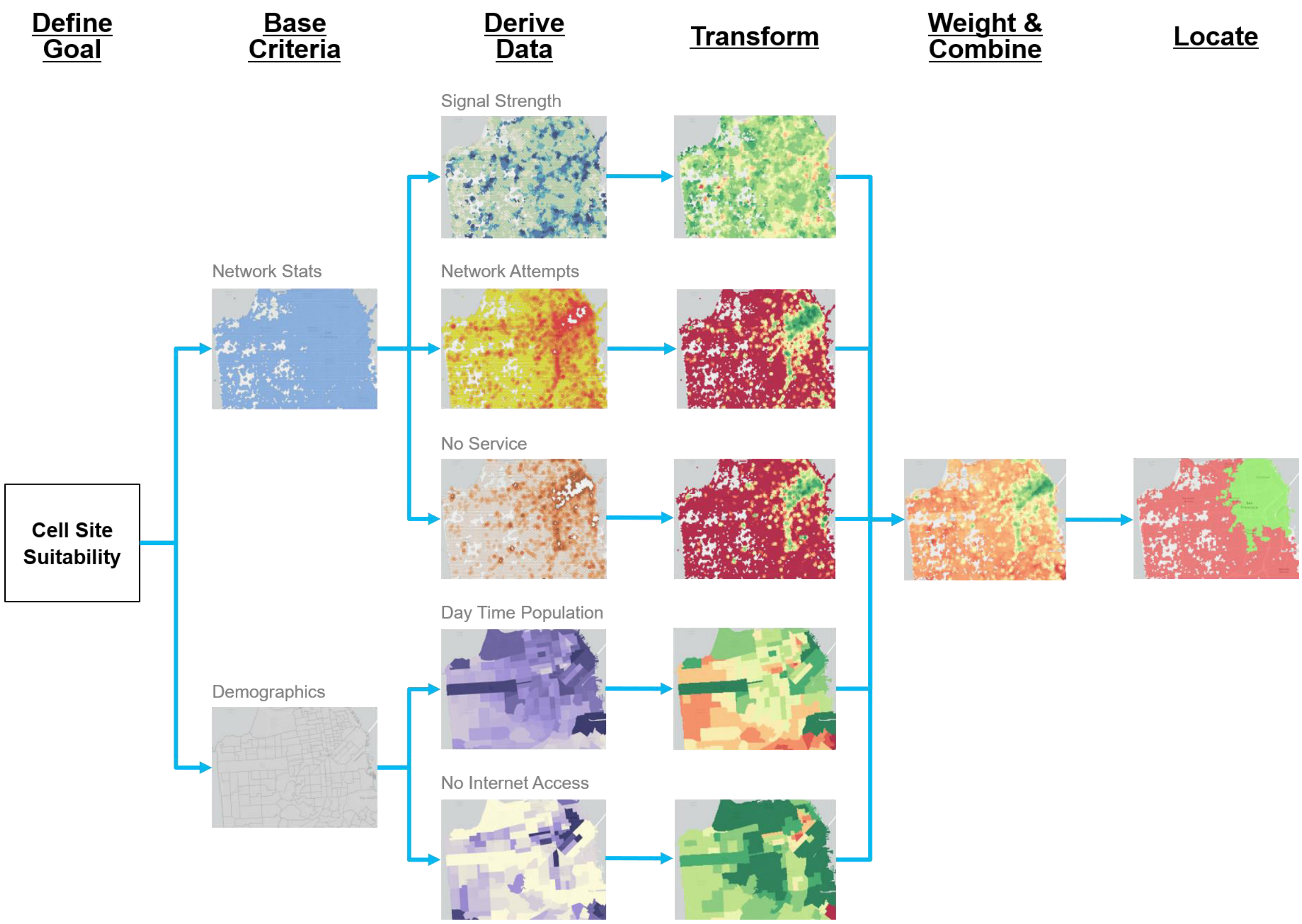


Figure 7.4: Site Suitability Analysis

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.

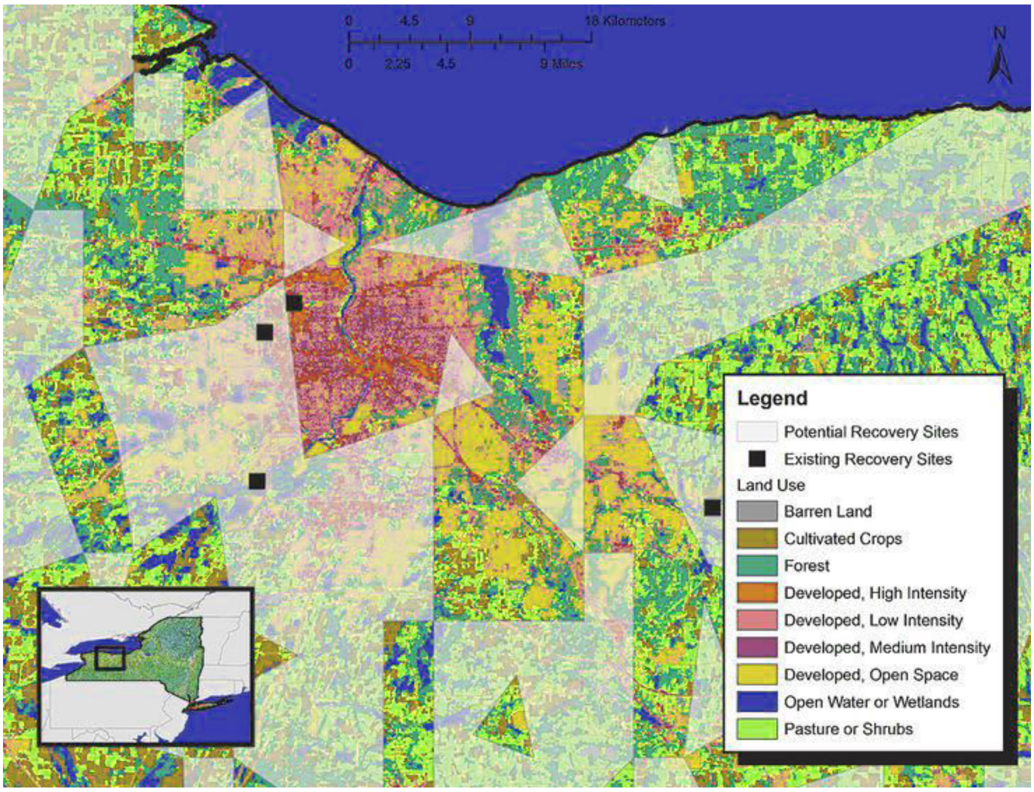
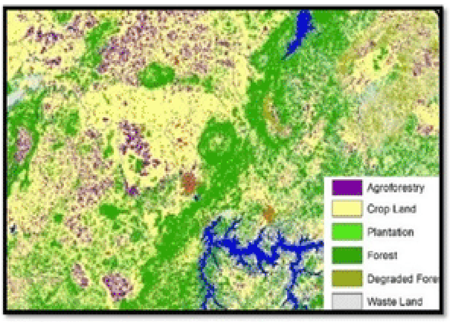


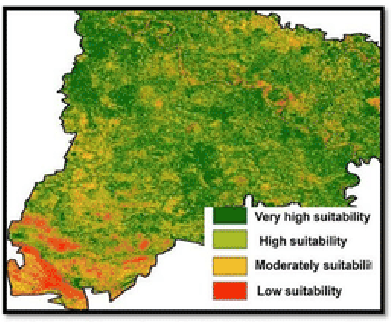
Figure 7.5: Urban Infrastructures and Geospatial Technologies

LAND COVER/BIOMASS MAPPING

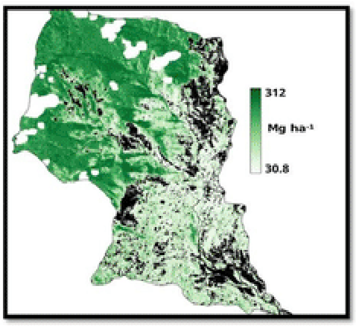
Land cover mapping serves as a basic inventory of land resources for all levels of government, environmental agencies, and private industry throughout the world. Whether regional or local in scope, remote sensing offers a means of acquiring and presenting land cover data in a timely manner. Land cover 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.



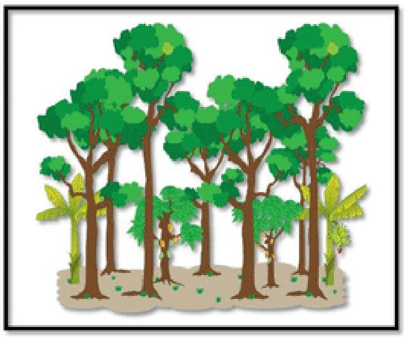
(a) Agroforestry mapping
Platform: *Satellite, Airborne (UAV)*
Dataset: *MS, MS+SAR, MS+HS, MS+ LiDAR, LiDAR + HS*



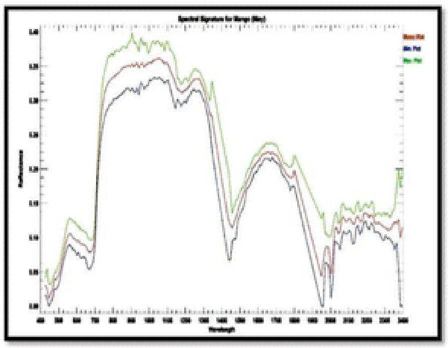
(b) Agroforestry Suitability mapping
Platform: *Satellite*
Dataset: *Raster*



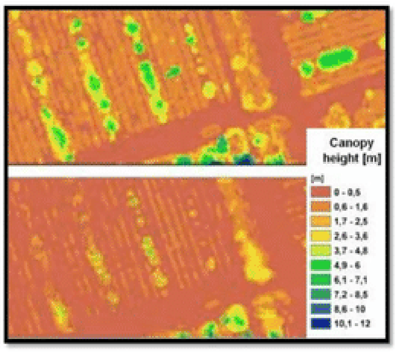
(c) Biomass & CS
Platform: *Satellite, Airborne (UAV)*
Dataset: *Raster, models, equations*



(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.**

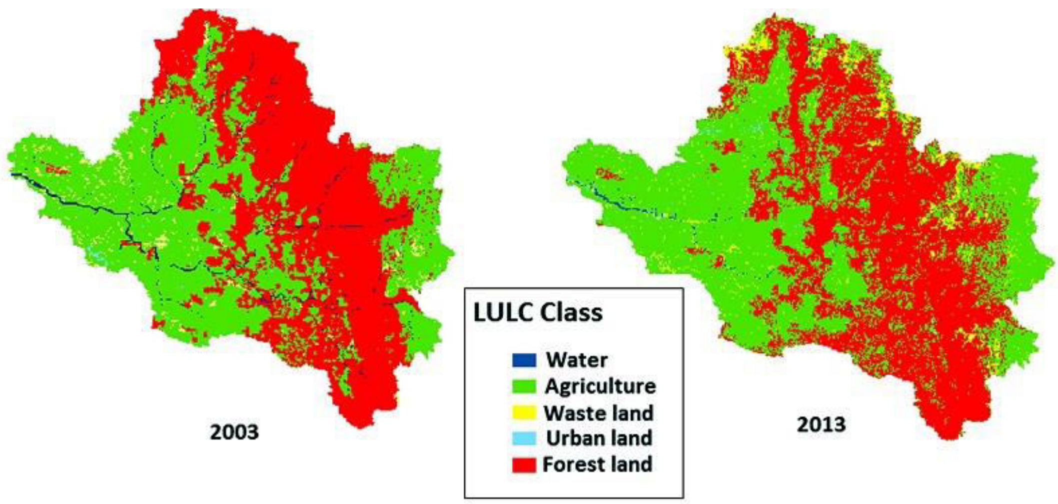


Figure 7.7: Land-use and Land Classification Mapping

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.).

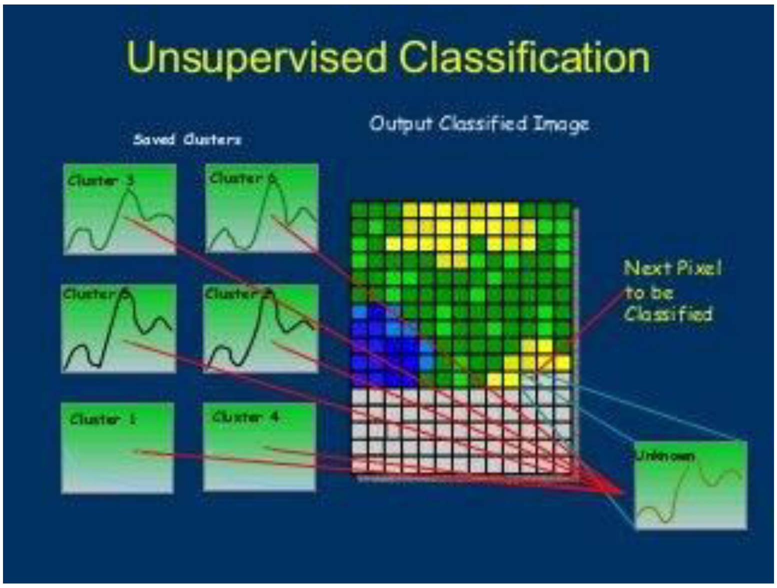


Figure 7.8: Unsupervised Classification

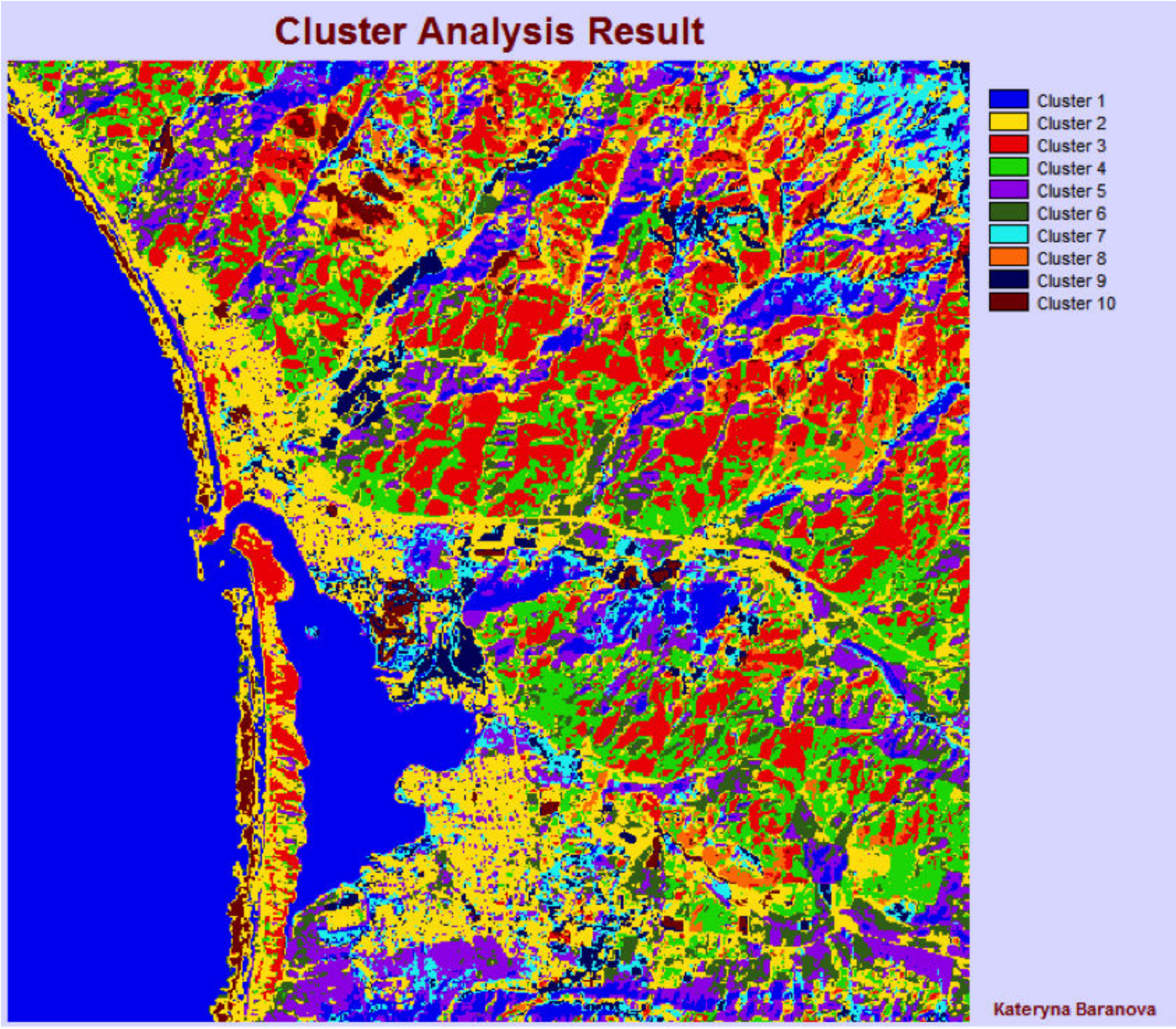
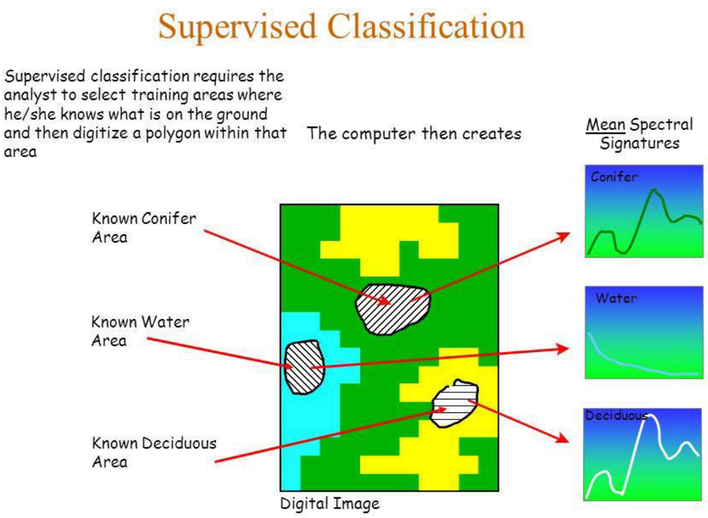


Figure 7.9: Unsupervised Classification in Remote Sensing

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.



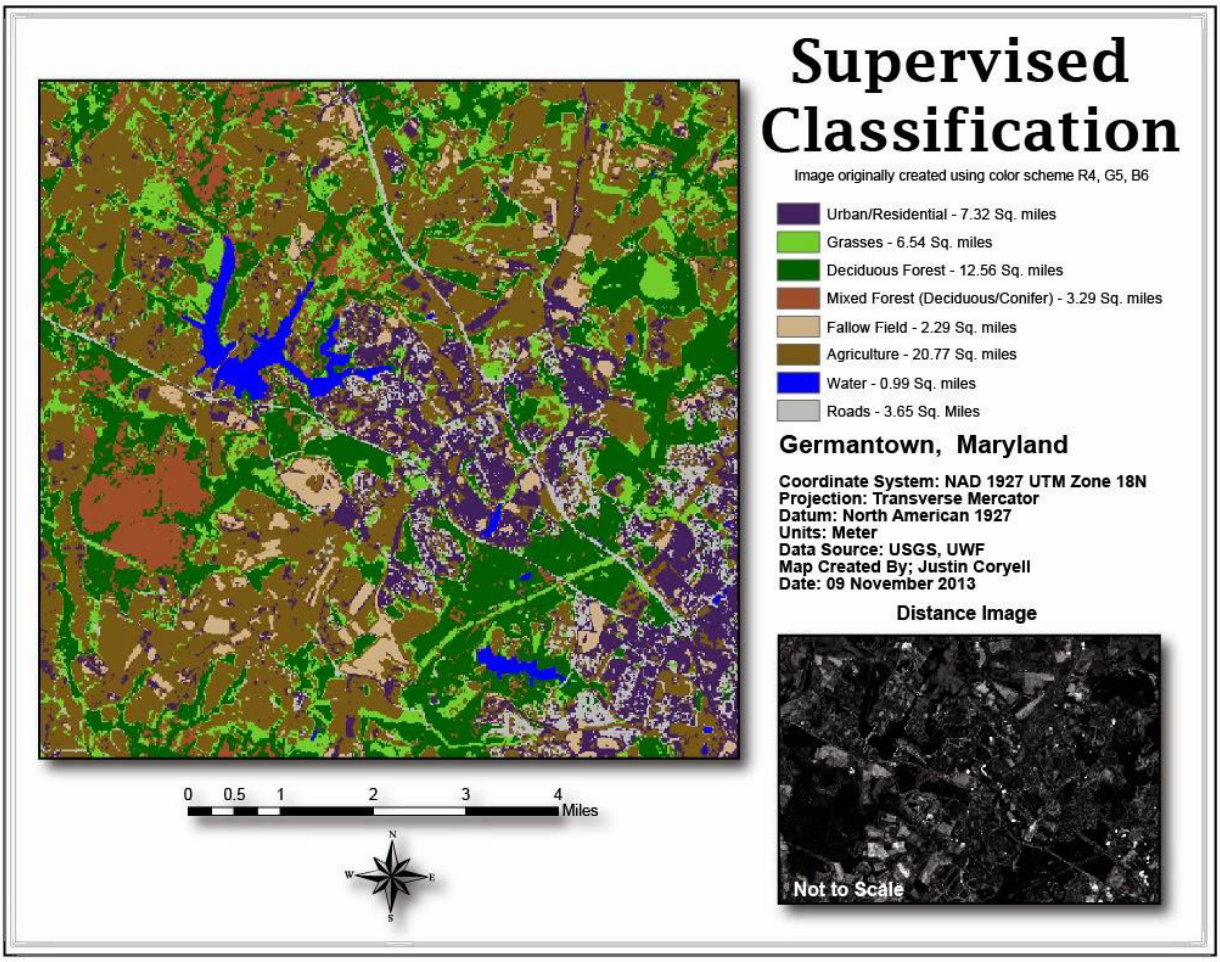


Figure 7.10: Supervised Classification

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.

URBAN 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.

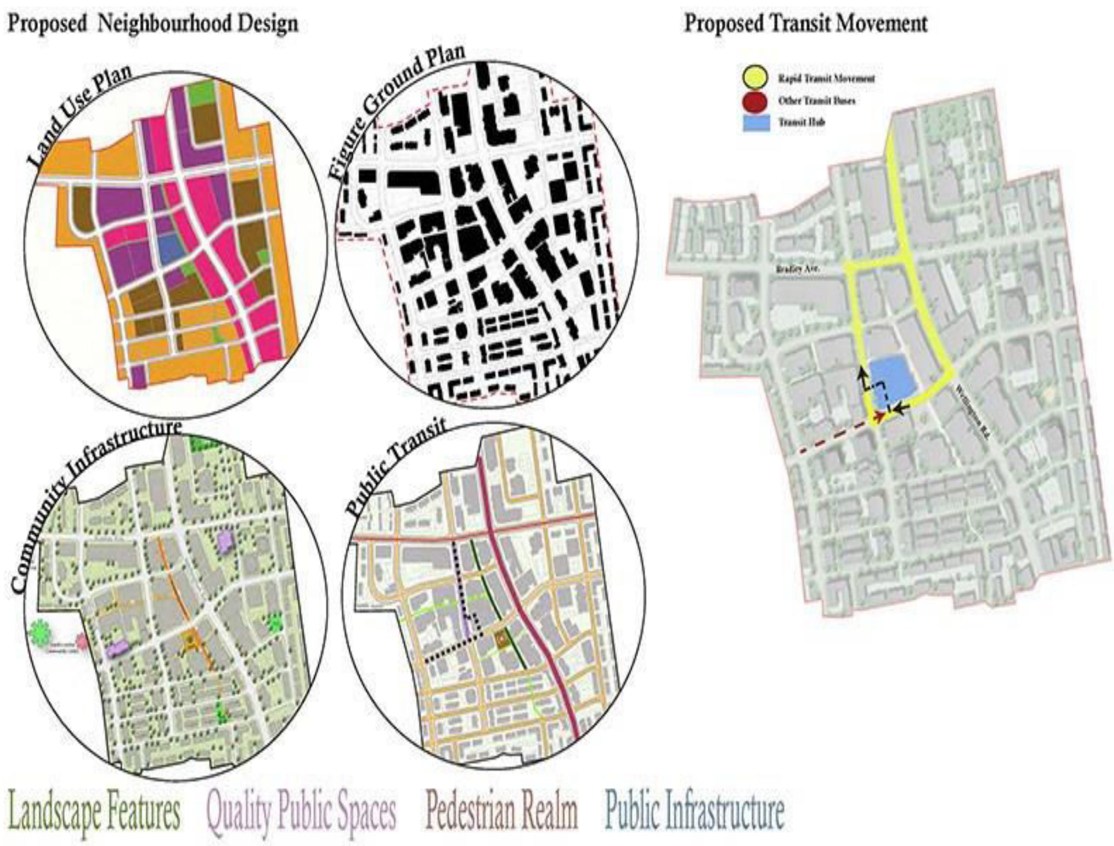


Figure 7.11: Urban Infrastructures and Solution Mapping

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.

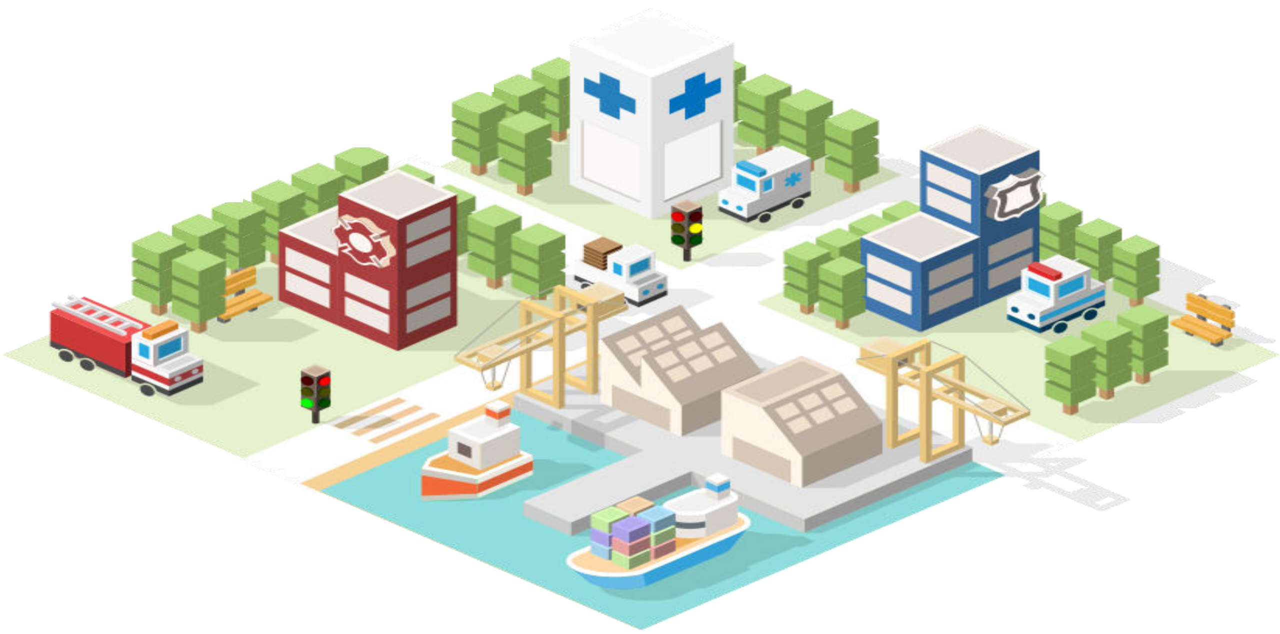


Figure 7.11: GIS in Utility Mapping

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. **Urban 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. **Urban 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. **Urban 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. **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. 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. Define Urban planning.
2. What do you mean by change detection?
3. Define Urban Biomass Mapping.
4. What do you understand by unsupervised classification?
5. What do you understand by supervised classification?
6. Define Site Suitability.
7. Define Land Classification.

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7.8 TERMINAL QUESTIONS

1. List major application of geoinformatics in Urban Studies.
2. Explain about the recently launched remote sensing satellite of India, its salient features and application potential.
3. What do you think are the challenges facing geoinformatics?
4. Discuss in brief two national agencies you think are impacting.
5. Explain how GIS can help in Urban Planning?

UNIT 8 - REMOTE SENSING DATA AND SCALE FOR URBAN AREA ANALYSIS, URBAN SPRAWL MONITORING, RESIDENTIAL AREA ANALYSIS

8.1 OBJECTIVES
8.2 INTRODUCTION
8.3 REMOTE SENSING DATA AND SCALES FOR URBAN AREA ANALYSIS, URBAN SPRAWL MAPPING AND MONITORING USING REMOTE SENSING, RESIDENTIAL AREA ANALYSIS
8.4 SUMMARY
8.5 GLOSSARY
8.6 ANSWER TO CHECK YOUR PROGRESS
8.7 REFERENCES
8.8 TERMINAL QUESTIONS

8.1 OBJECTIVES

After reading this unit you should be able:

1. To understand the remote sensing and urban analysis.
2. To know application of Geospatial technology in urban sprawl monitoring.
3. To describe residential area analysis and monitoring using Geospatial Technologies.

8.2 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.

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

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 Geo Pandas. Raster data can be worked with by using a program such as x array.

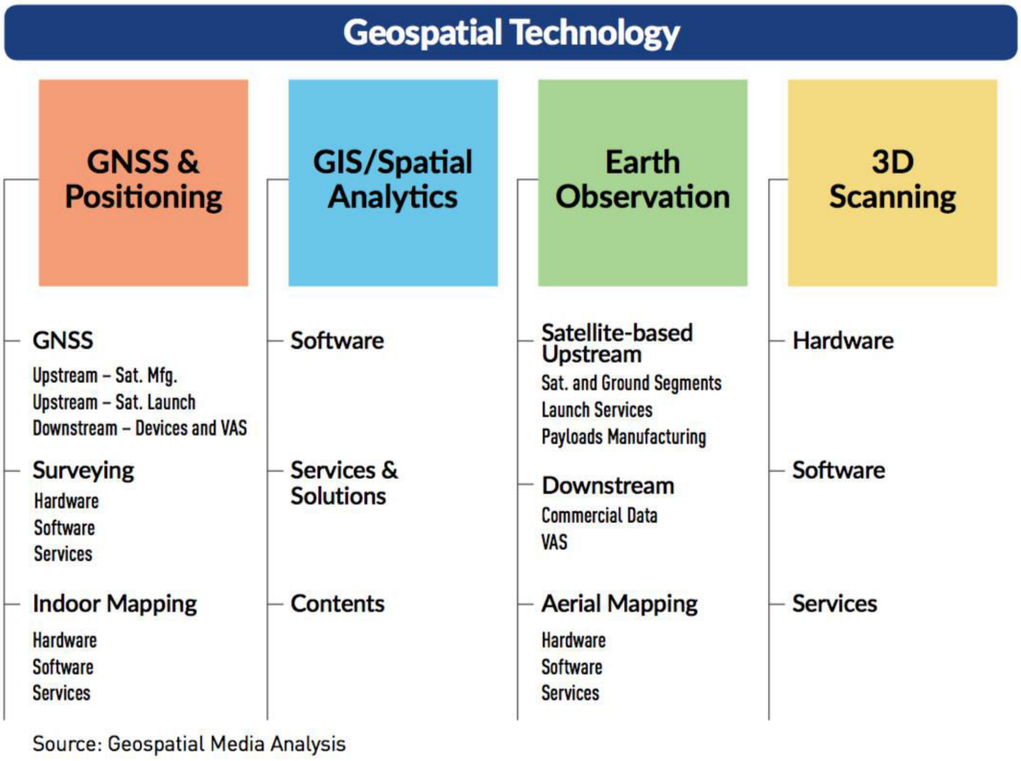

Figure 8.1: Geospatial Technology

REMOTE SENSING DATA AND URBAN 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 Resource sat 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, Quick bird 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 URBAN 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.

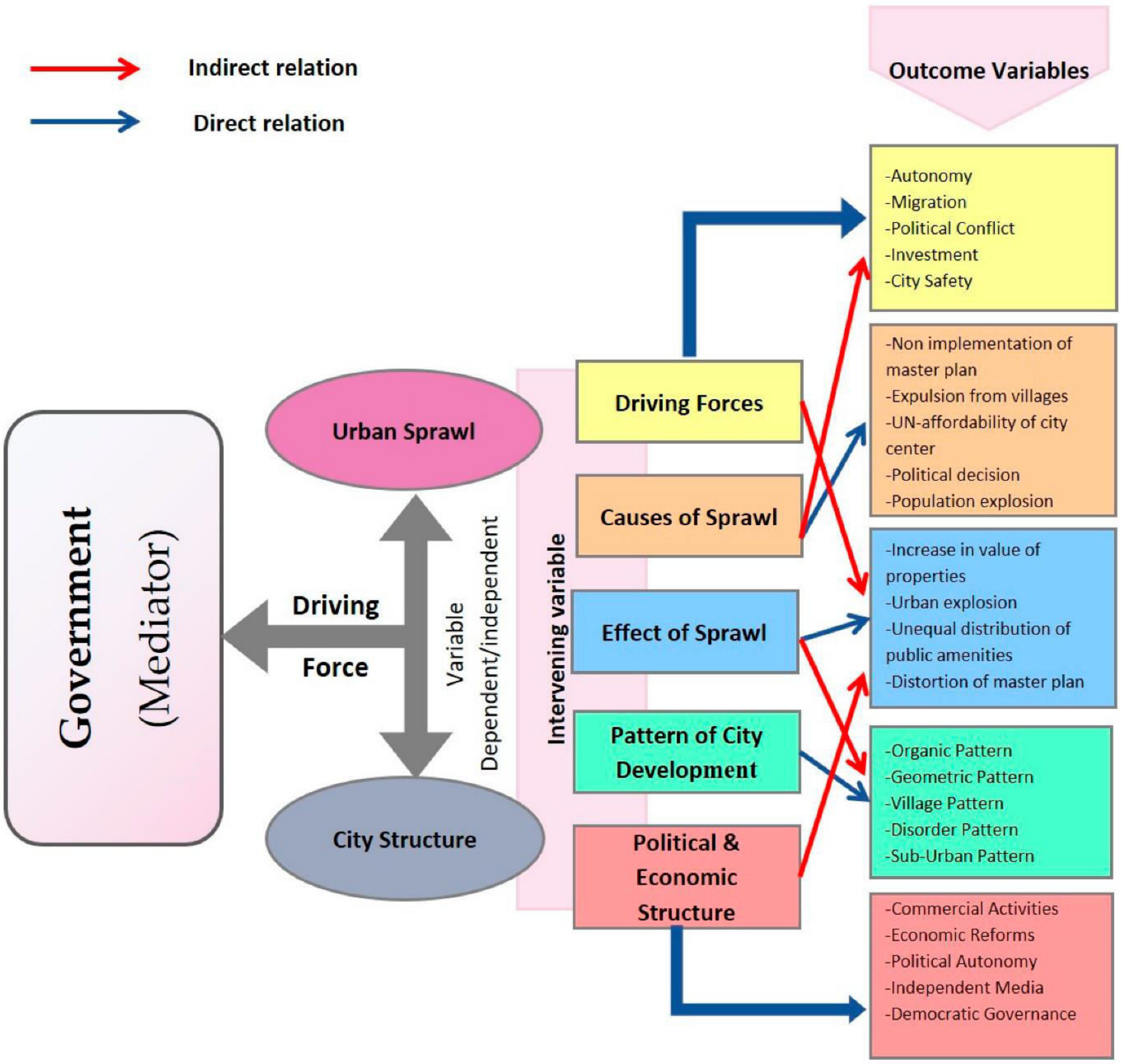

Figure 8.2: Urban Sprawl and Urbanization Monitoring

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, modelling 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.

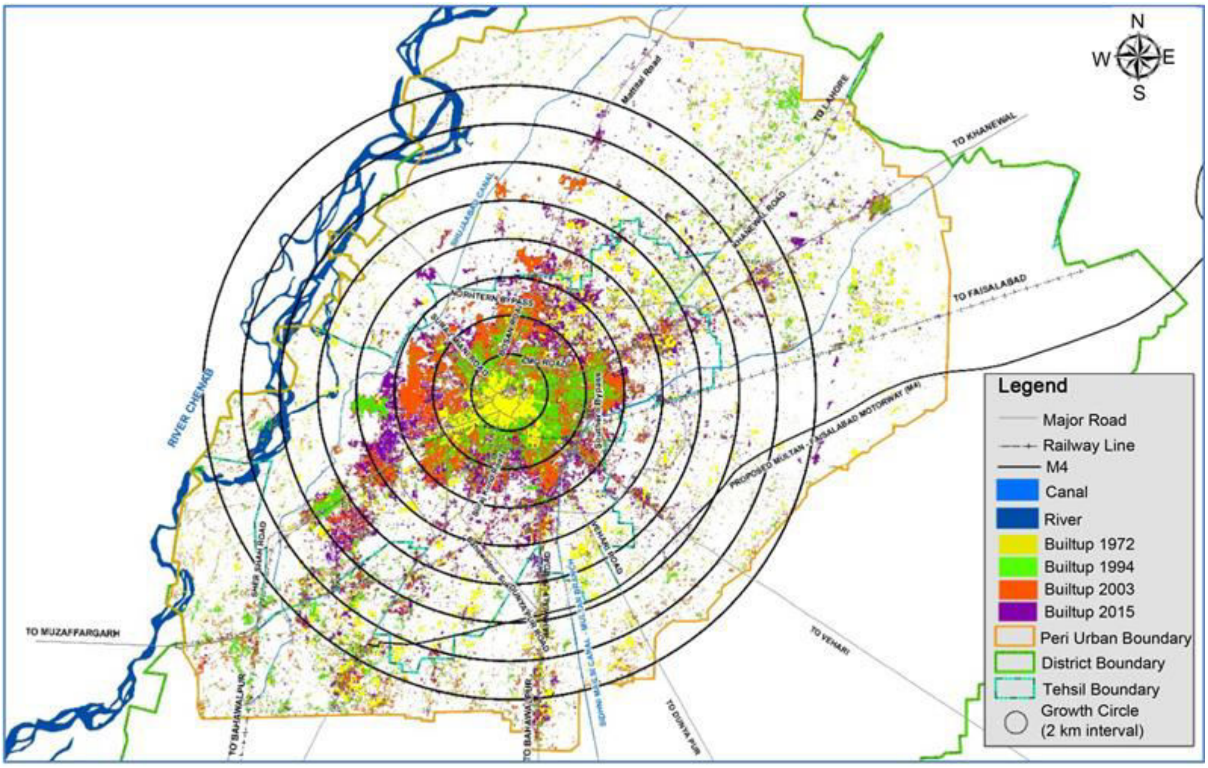

Figure 8.3: Geo-spatial Technology and Mapping Urban Growth

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 Urban 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.

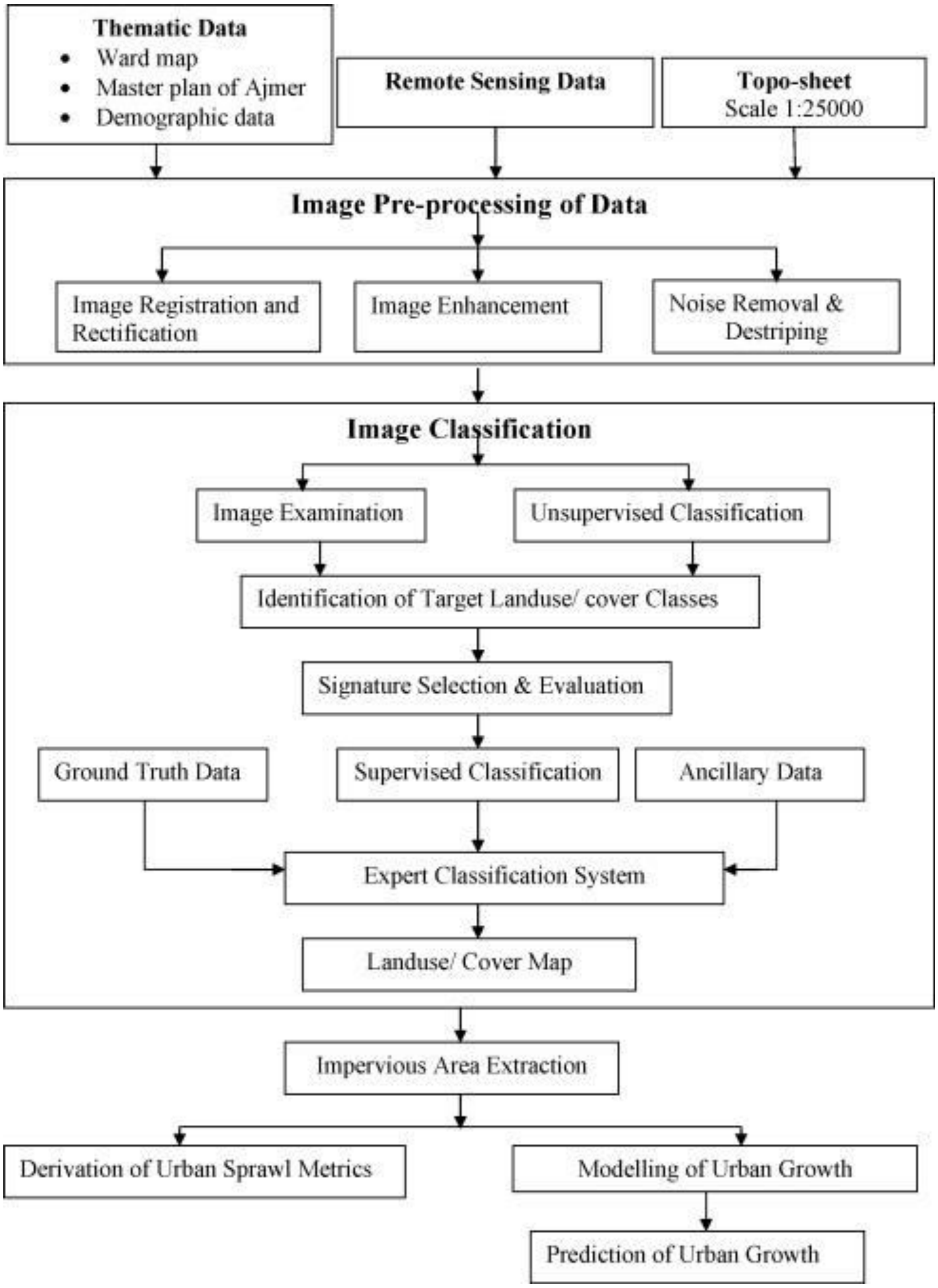

Figure 8.4: Monitoring and Measuring Urban Sprawl using Remote Sensing and GIS

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 analysed. 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.

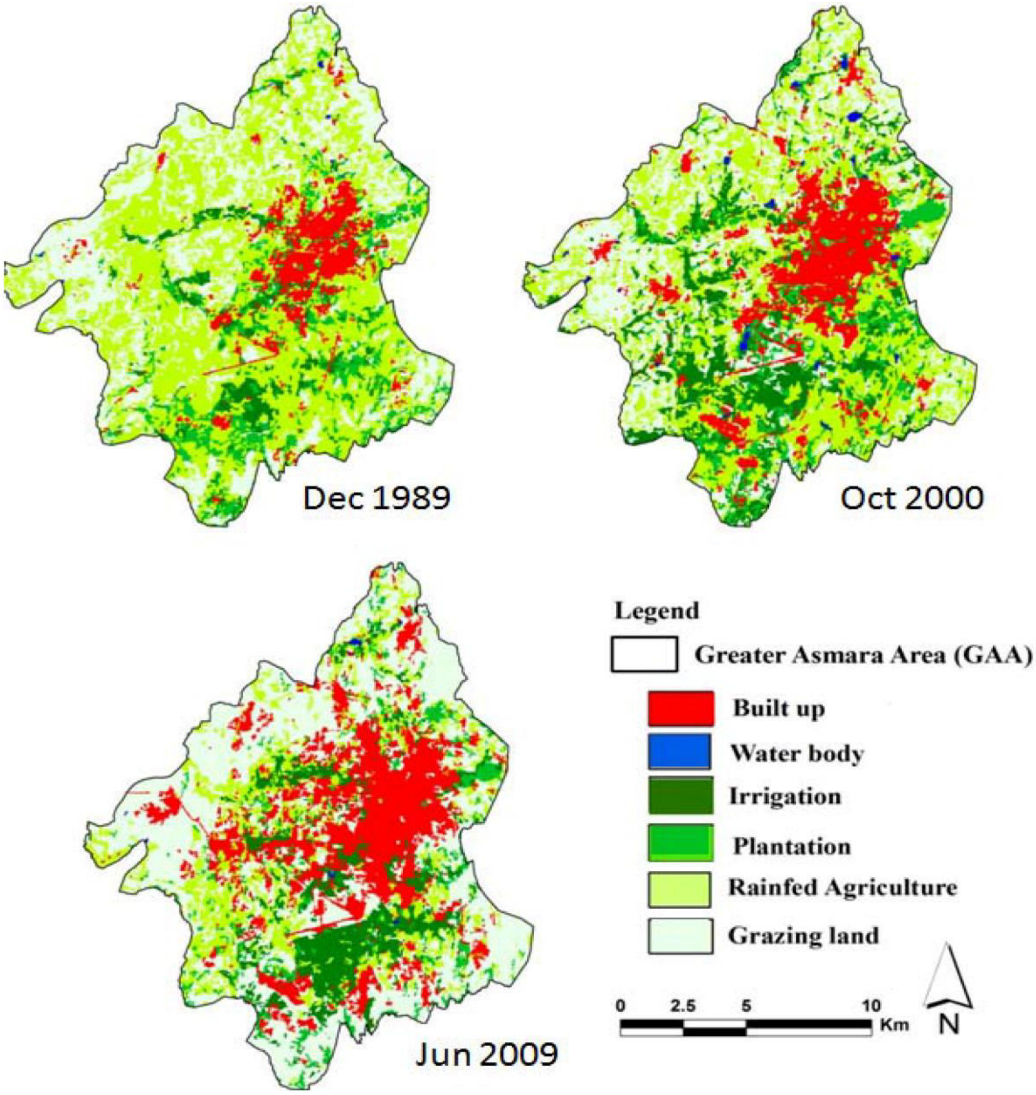

Figure 8.5: Urban Sprawl Analysis and Modelling

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 urban sprawl

The percentage of an area covered by impervious surfaces such as asphalt and concrete are 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 analysing 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 URBAN 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.

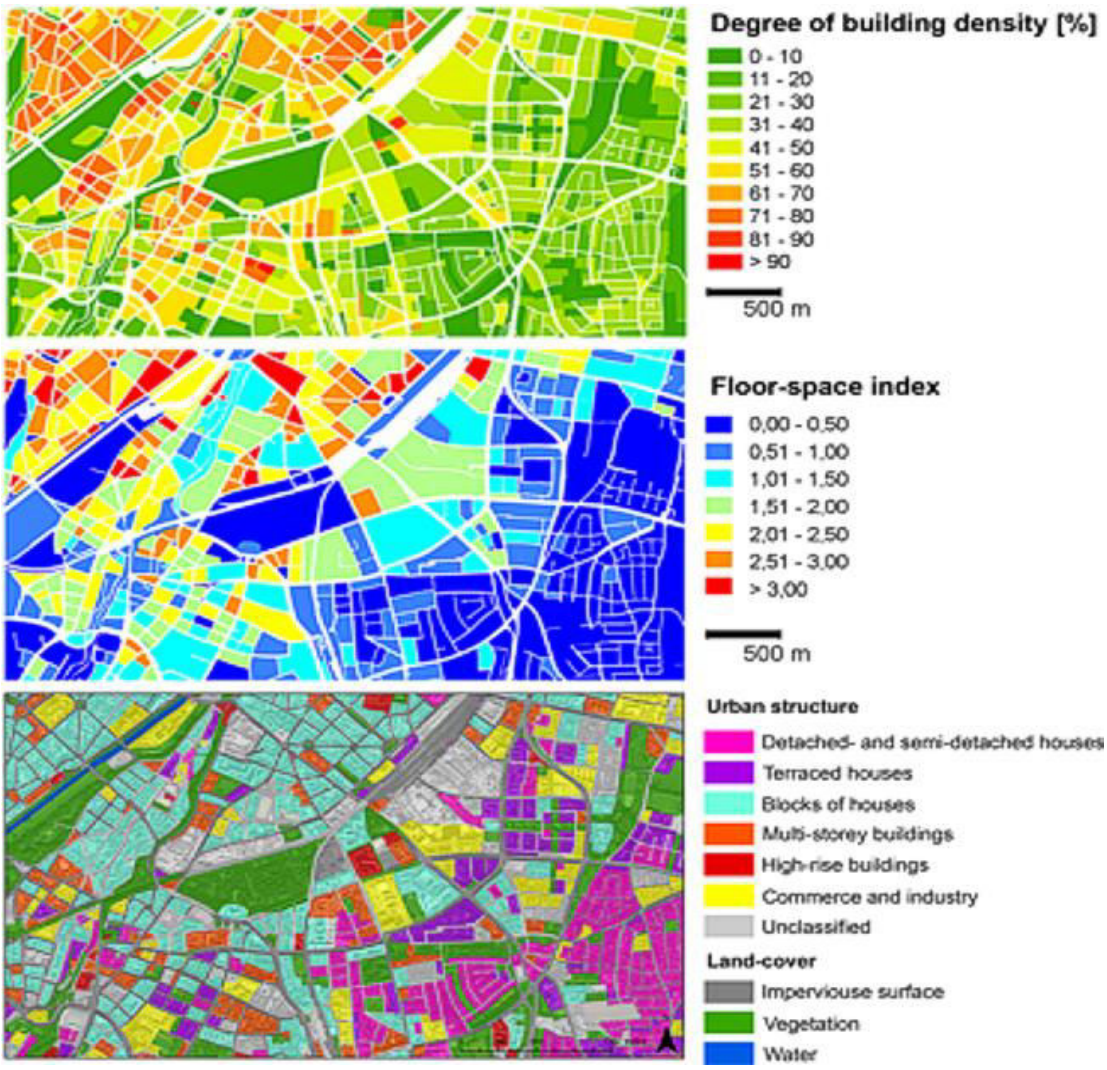

Figure 8.6: Remote Sensing and Urban Planning

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 analysed 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 8.4). 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.

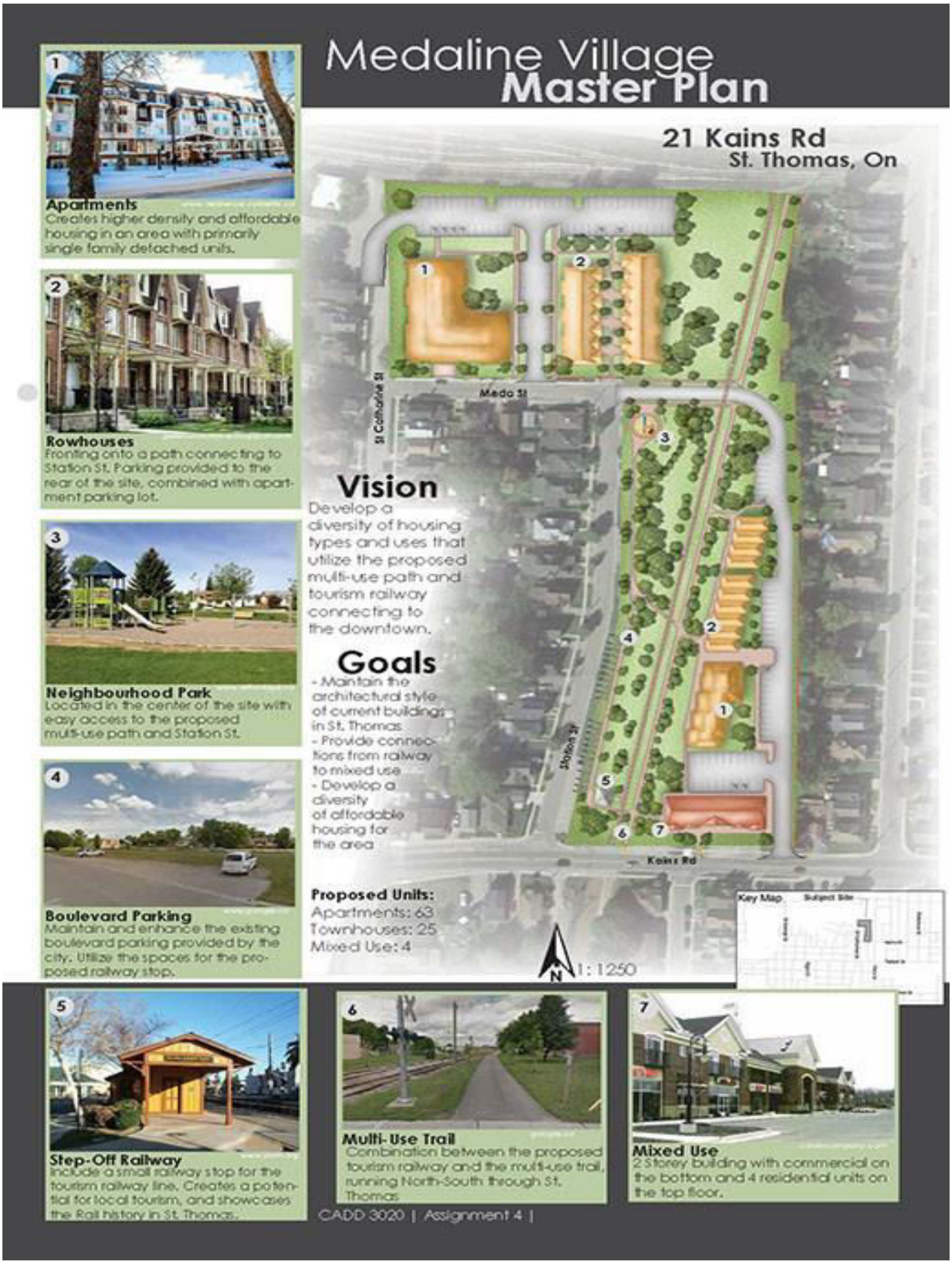

Figure 8.7: GIS and Urban Planning

URBAN 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.

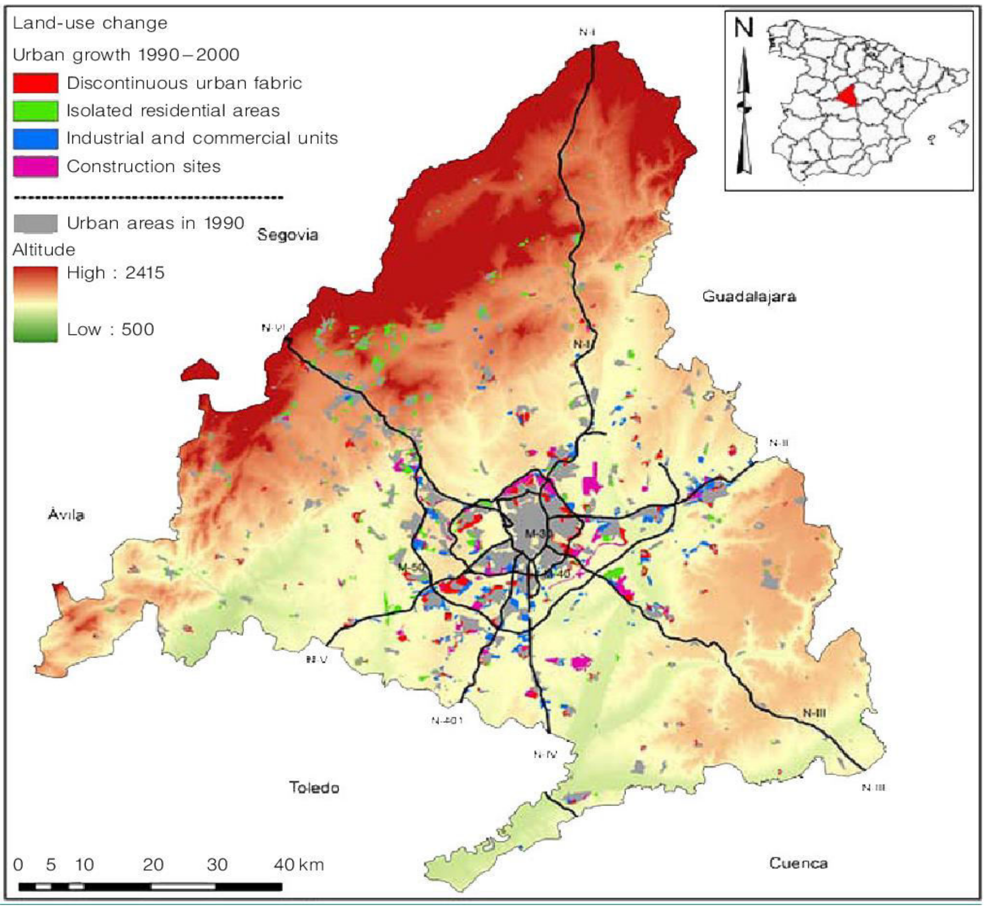

Figure 8.8: Urban Expansion and Mapping Using GIS

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 8.9: 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 base maps. Similarly, superimposition of revenue maps on base maps 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).

8.4 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 8.10: 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.

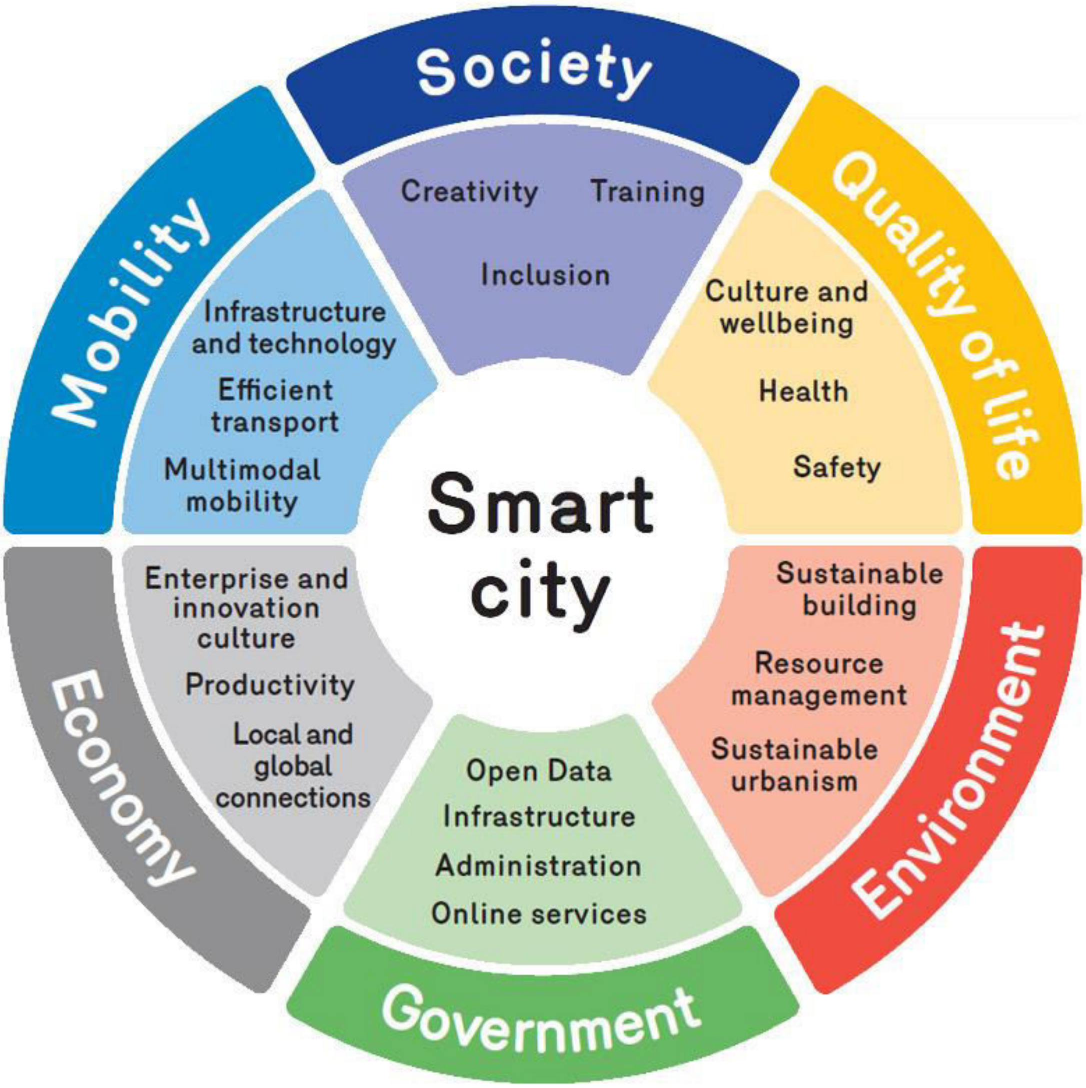

Figure 8.11: Smart City and Planning at Various Stages

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.

8.5 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.

8.6 ANSWER TO CHECK YOUR PROGRESS

1- Write a short note on smart cities?

2- Define Urban sprawl?

3- Define Urban planning?

4- Write a short note on Geospatial Technology?

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18. Google(For Images)

8.8 TERMINAL QUESTIONS

1. What do you understand by Geospatial Technology? Describe various types of geospatial data for urban planning.
2. Define urban expansion. Explain urban expansion using remote sensing.
3. Describe important application of geoinformatics in urban planning with suitable examples.
4. Why GIS is important in urban planning and how?

5. Define urban sprawl? How urban sprawling can be monitored by GIS.
6. Integration of geospatial technologies is necessary for urban planning and management. Evaluate?

UNIT 9 - OVERVIEW OF URBAN INFRASTRUCTURE, FACILITIES AND SERVICES, SLUM AND SQATTER SETTELEMENT AND THEIR IDENTIFICATION URBAN SERVICES AND FACILITIES ANALYSIS, LAND SUITABILITY ANALYSIS FOR URBAN AREA DEVELOPMENT

9.1 OBJECTIVES
9.2 INTRODUCTION
9.3 OVERVIEW OF URBAN INFRASTRUCTURE, FACILITIES AND SERVICES, SLUM AND SQUATTER SETTLEMENT AND THEIR IDENTIFICATION URBAN SERVICES AND FACILITIES ANALYSIS, LAND SUITABILITY ANALYSIS FOR URBAN AREA DEVELOPMENT
9.4 SUMMARY
9.5 GLOSSARY
9.6 ANSWER TO CHECK YOUR PROGRESS
9.7 REFERENCES
9.8 TERMINAL QUESTIONS

9.1 OBJECTIVES

After reading this unit you should be able:

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

9.2 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.

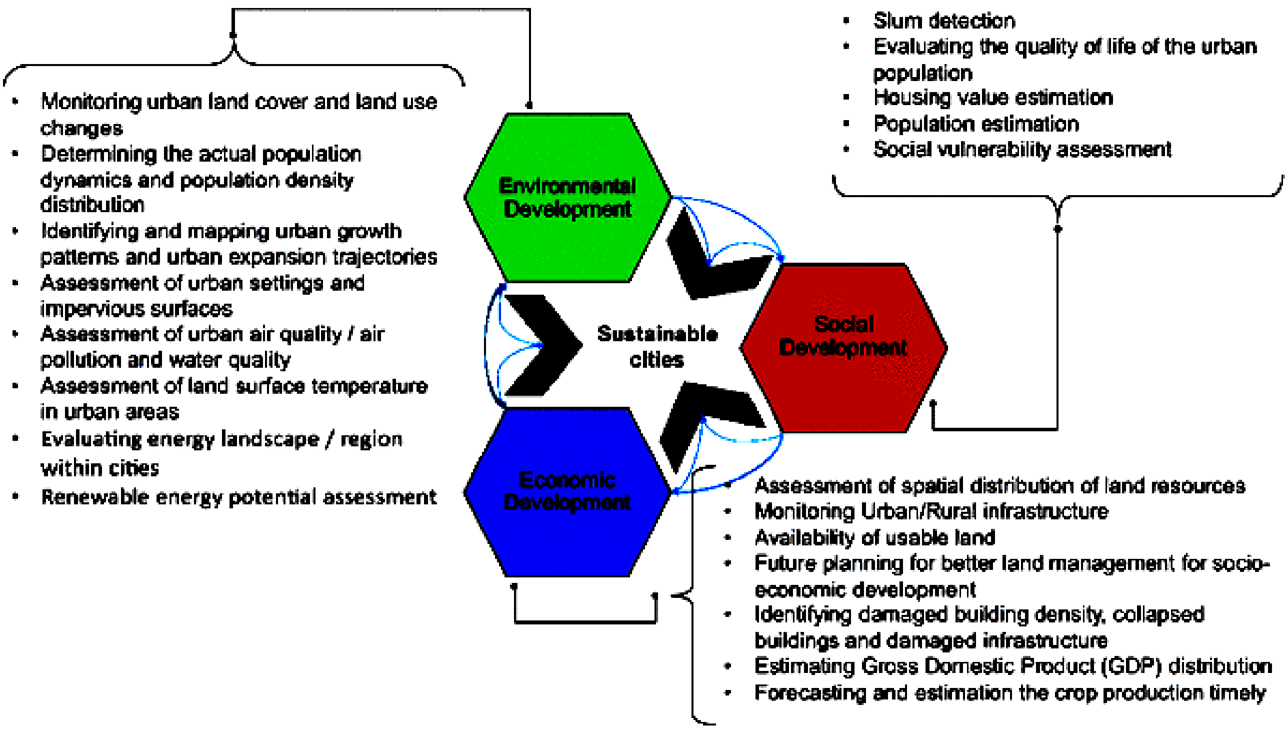

Figure 9.1: Urban Planning and Geographic Information System

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.

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

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.

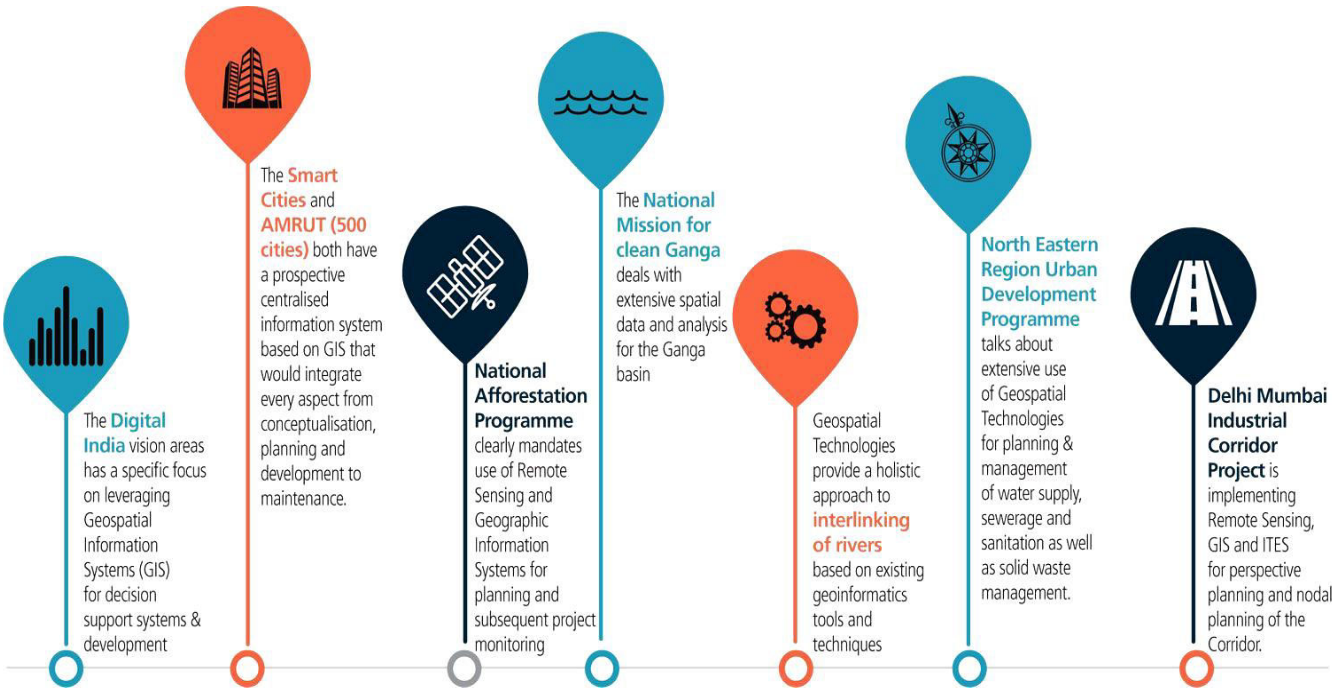

Figure 9.2: Smart Cities and Geospatial Technologies

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.

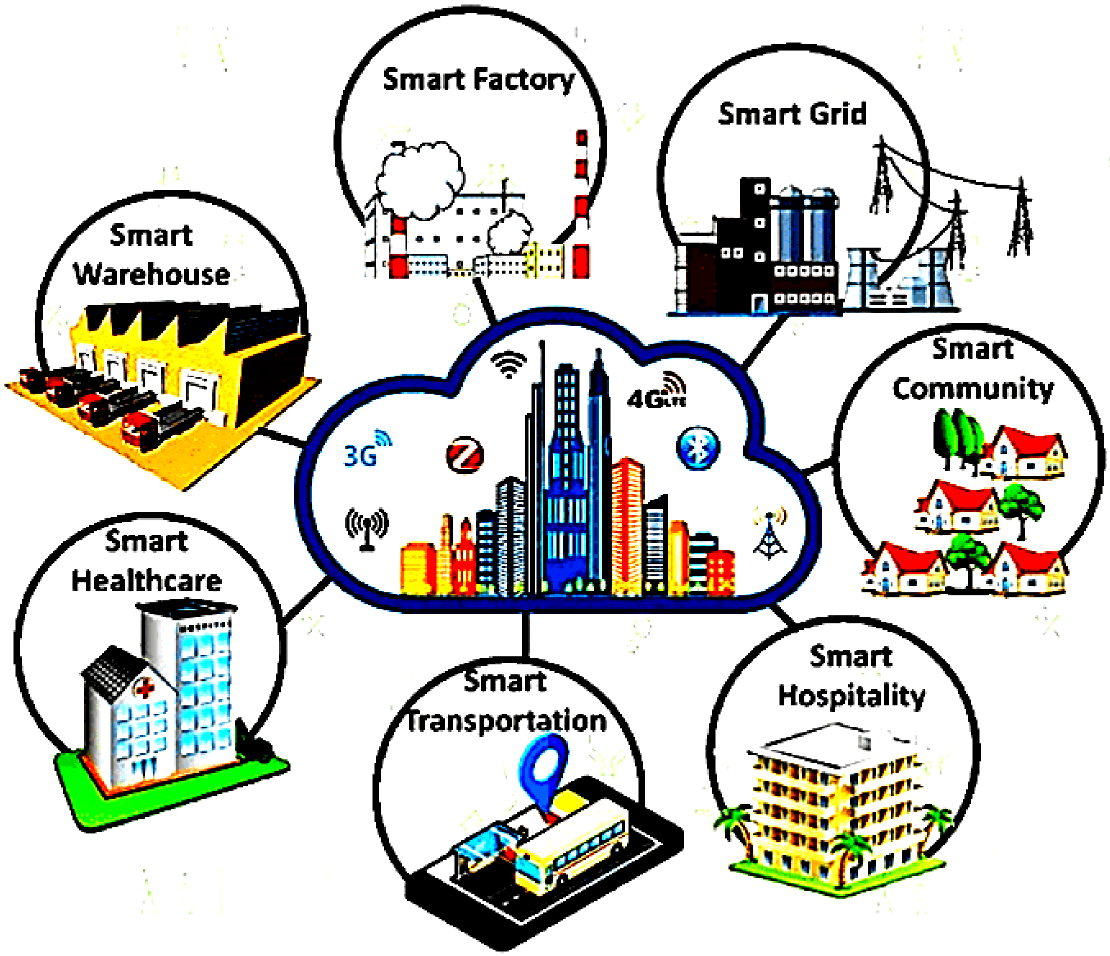

Figure 9.3: Urban Infrastructure and Service

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.

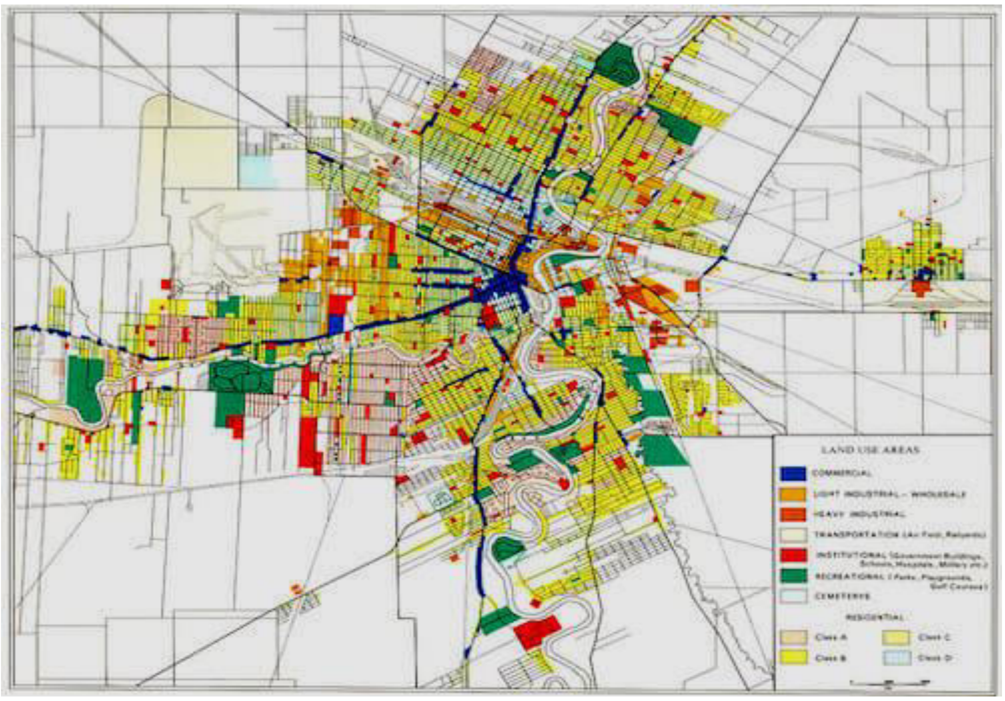

Figure 9.4: Mapping Resource Inventory for Urban Cities

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.

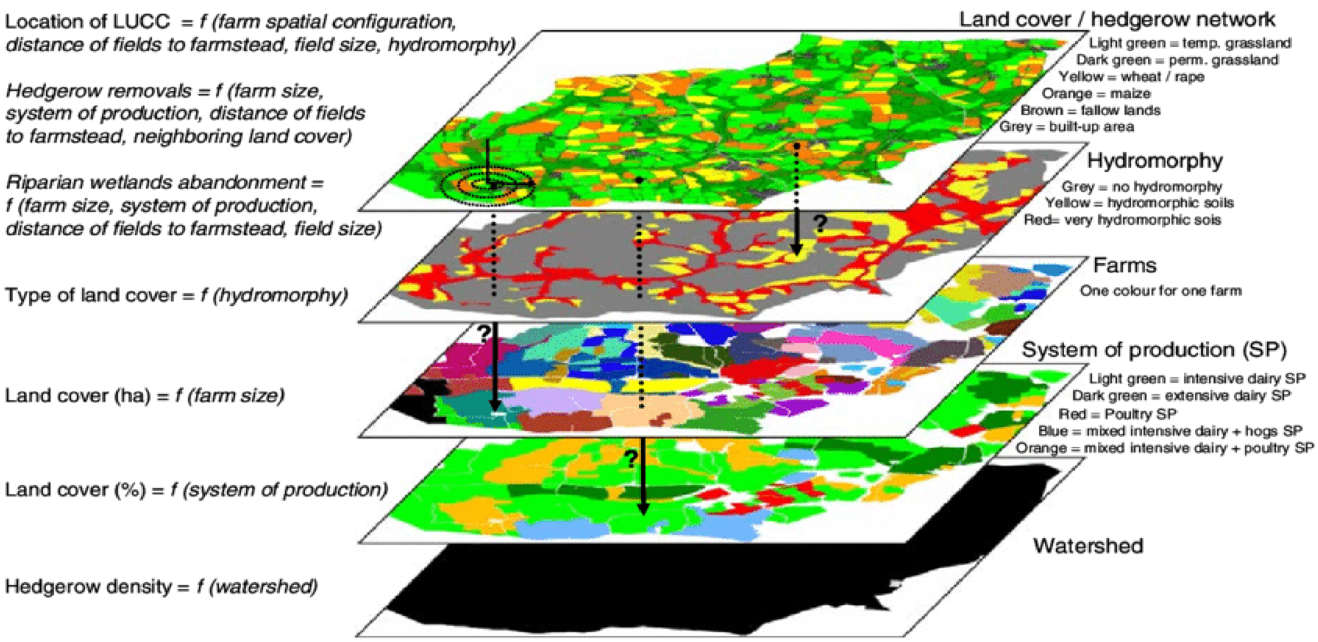

Figure 9.5: Land Use/Land Cover Mapping for Urban Planning

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.

URBAN 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 URBAN 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 9.6: 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.

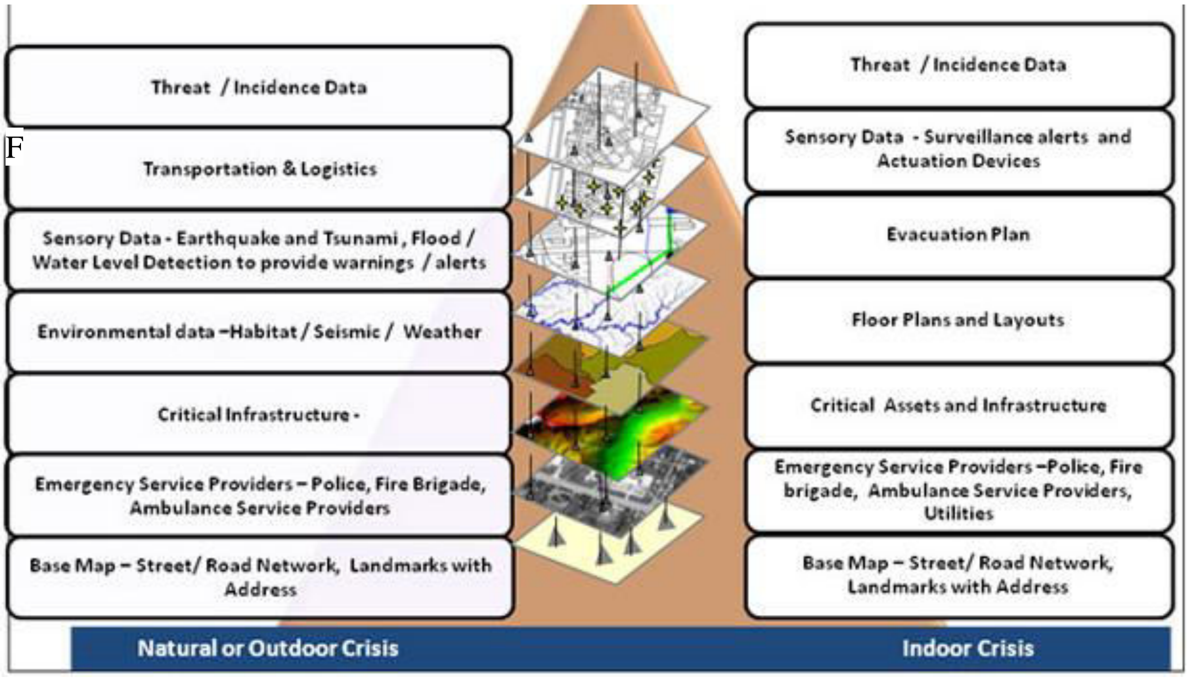

Figure: 9.7

- **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 analyse 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.

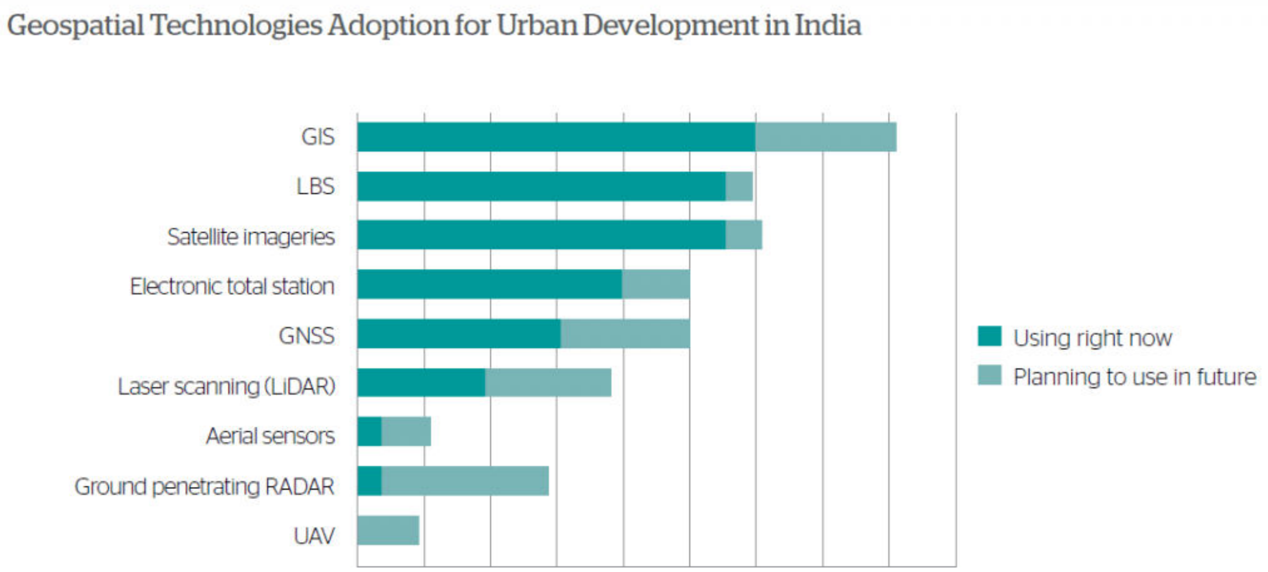

Figure 9.8: Geospatial Technologies for Urban Development

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 9.9: Airport Integrated Spatial Management System

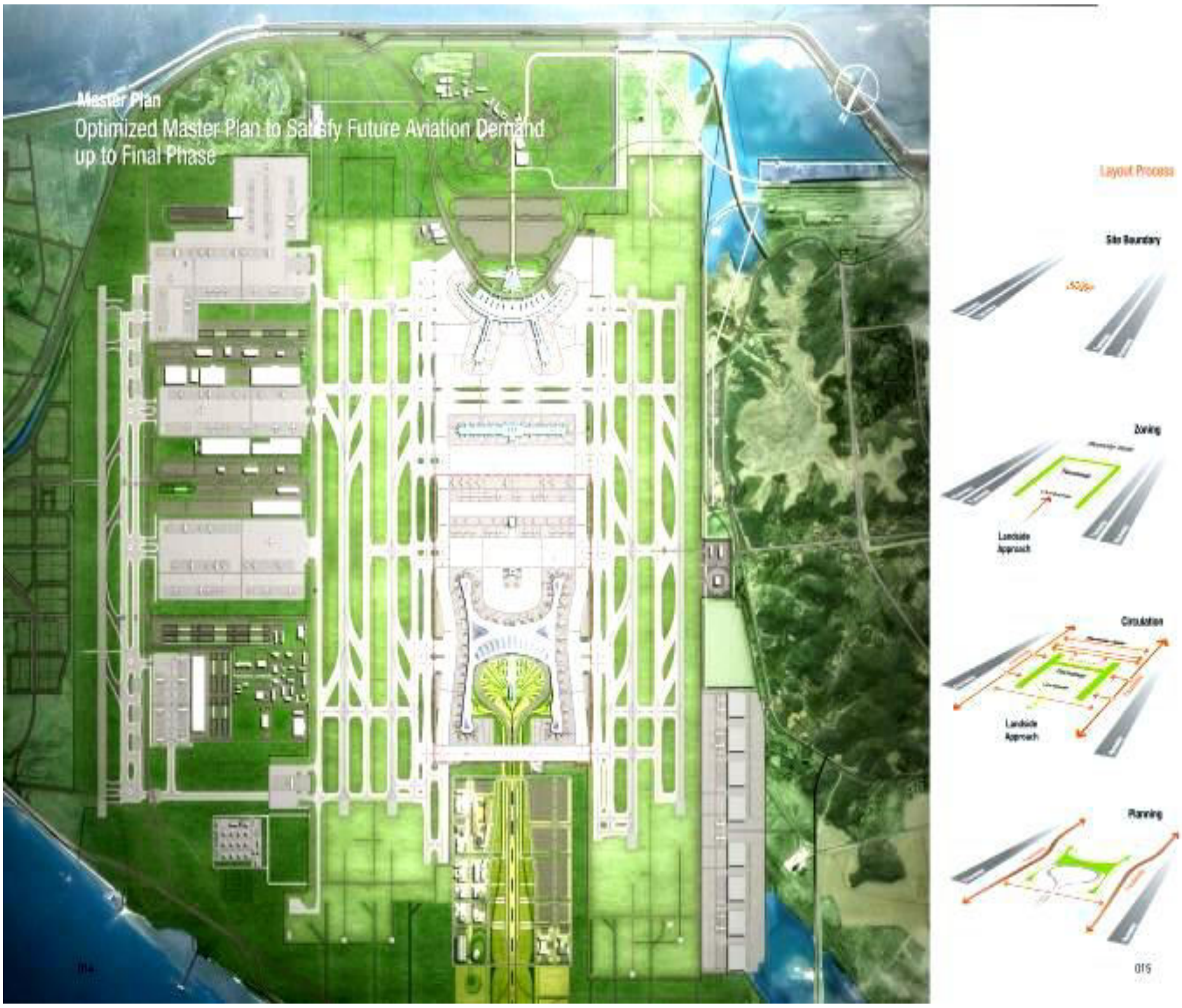

Figure 9.10: Airport Mapping and Master Plan Using Geospatial Technologies

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 9.11: 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 9.12: 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.

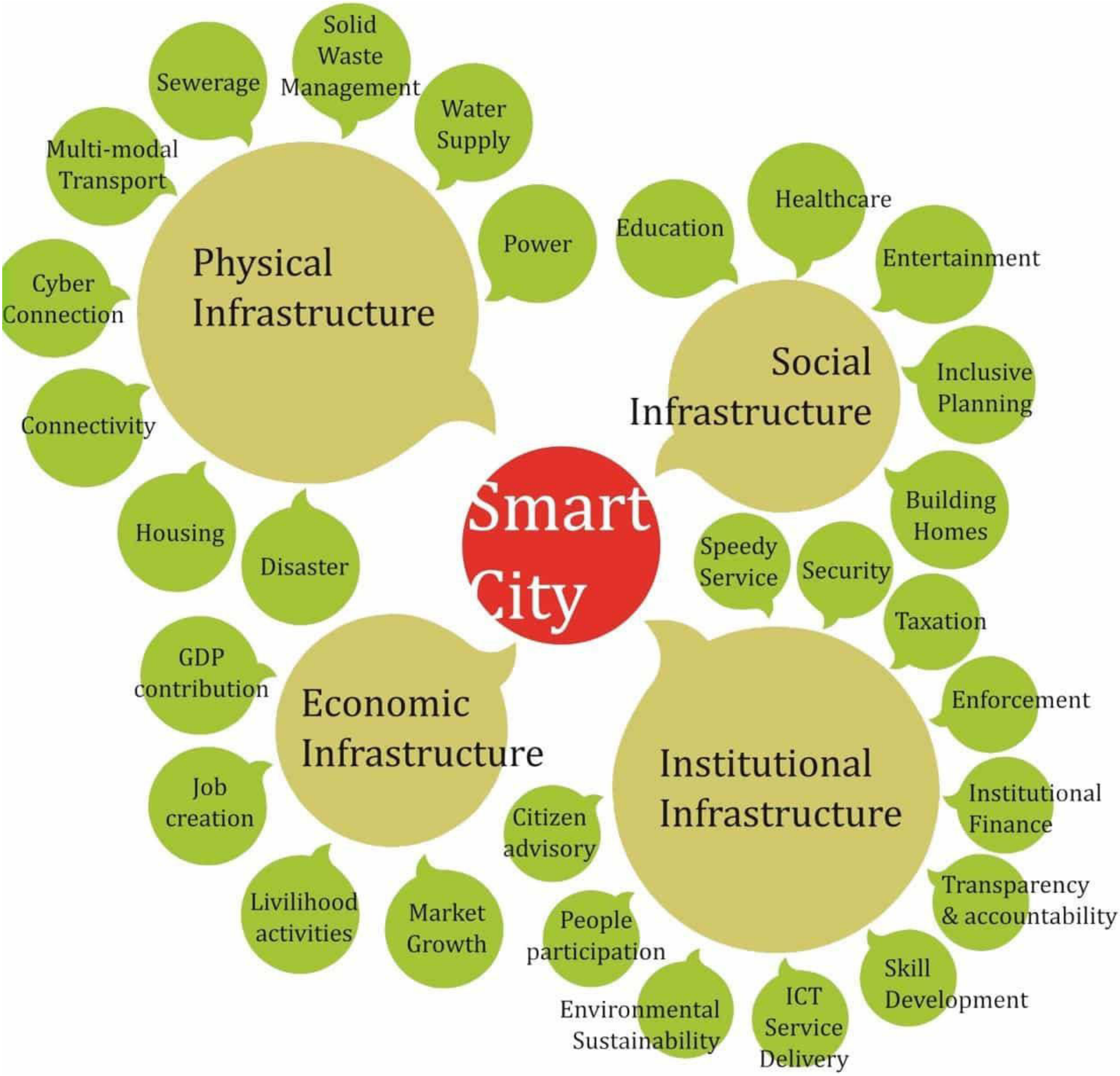

Figure 9.13: Smart City Planning using Geospatial Technology

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 9.14: 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 URBAN 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.

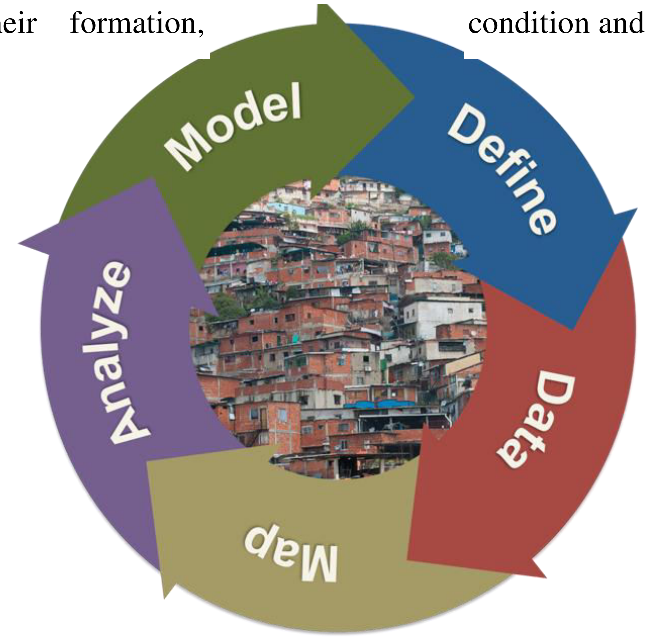

Figure 9.15: Mapping and Monitoring of Slum in Given 5 Steps

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.

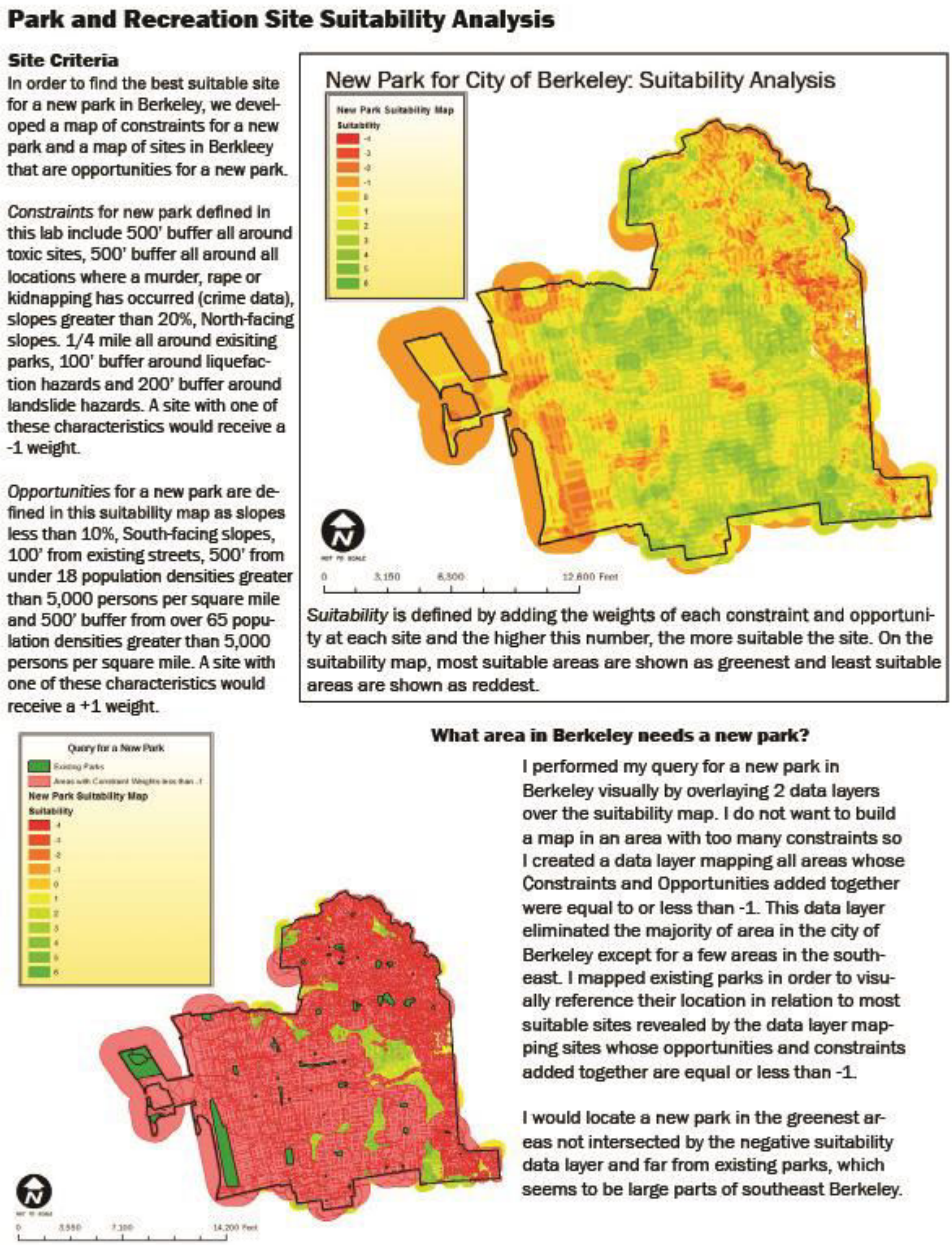

Figure 9.16: Site Suitability in Urban Planning

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 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. A wide range of specialist knowledge is needed to collect and analyze 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: 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.

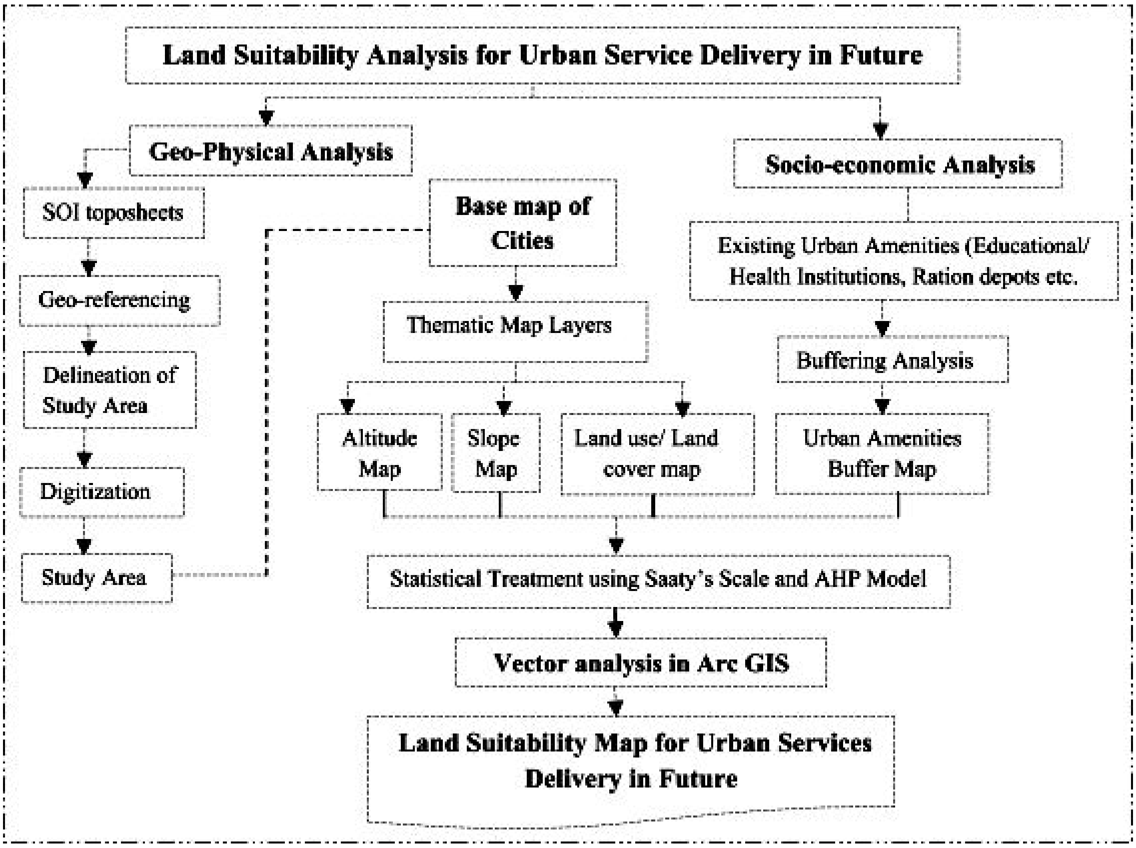

Figure 9.17: Land Suitability Analysis Model for Urban Development

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.

9.4 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.

9.5 GLOSSARY

- Slum- an area of a city where living conditions are extremely bad, and where the buildings are dirty and have not been repaired for a long time.
- Urban- connected with a town or city.
- Images- a visual representation of something.
- Photographs- a picture that is taken with a camera.
- Analytical- using careful examination in order to understand or explain something.

9.6 ANSWER TO CHECK YOUR PROGRESS

1-Write a short note on slum?

2- Define image?

3- Define photograph?

4- Write a short note on urban planning?

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9.8 TERMINAL QUESTIONS

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